U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-300 446

The Cost of Clean Air and Water Report to Congress

Battelle Columbus Labs, OH

Prepared for

Environmental Protection Agency, Washington, DC Office of Planning and Evaluation

Aug 79

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA 230/3-79-001	2.	3. Recipient's Accession No.
4. Title and Subtitle The Cost of Clean Air and Water Report to Congress			5. Report Date August, 1979
			6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Battelle Memorial Institute Columbus Laboratories 505 King Avenue Columbus, Ohio 43201			10. Project/Task/Work Unit No.
			11. Contract/Grant No. 68-01=4360
12. Sponsoring Organization Name and Address Economic Analysis Division (PM-220) Office of Planning and Management U.S. Environmental Protection Agency Washington, D.C. 20460			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

The Environmental Protection Agency is required by Congress to report on the cost of compliance with the Clean Air Act and the Federal Water Pollution Control Act. This report combines both of these requirements and aggregates costs by industries for both air and water. In 1977, it was estimated that industries spent 12.8 billion dollars in incremental annual costs (including capital charges and operating and maintenance expenses) to comply with Federal air and water legislation. Federal, State and local governments spent $4.6 billion and consumers spent $5.8 billion directly on mobile source emission control. The study projects future incremental investment costs for the period 1977-1986 to be $79.7 billion as a result of the Clean Air Act and $61.6 billion due to the Federal Water Pollution Control Act. Model plant analysis was used to generate most of the cost estimates in the report. This report is based on the regulatory framework in existence in mid-1978, and does not take into account regulations proposed or promulgated since that time.

17. Key Words and Document Analysis. 17a. Descriptors

Air Pollution Control Expenditures
Water Pollution Control Expenditures

17b. Identifiers/Open-Ended Terms

17c. COSATI Field Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21
	20. Security Class (This Page) UNCLASSIFIED	22. Price A15-A01

ADDENDUM

THE COST OF CLEAN AIR

REPORT TO CONGRESS

AUGUST, 1979

The following paragraph should be added to page 126, after the Section entitled, "Control Technology and Costs:"

The cost estimates in Table 10.1-1 reflect the cost of all sanitary landfills. In 1976, an estimated 235 million metric tons of solid waste were disposed of through sanitary landfills. Table 10-1 indicates that as of 1976, only 3.4 million metric tons of solid waste was reduced through open burning dumps.

ERRATA SHEET

THE COST OF CLEAN WATER

REPORT TO CONGRESS

AUGUST, 1979

1. On page 1, the word "annual" should be "biennial." The first paragraph should read:

   Section 516(b) of the Federal Water Pollution Control Act amendments (PL 92-500, hereafter FWPCA) of 1972 requires a biennial report on the costs of meeting the provisions of that act; this report is submitted in response to these requirements.

2. On page 11, the third paragraph indicates that on balance, BOD5 has increased. Since this report went to press, a more recent analysis by EPA suggests that there has been a small percentage decrease in BOD5.

3. On page 12, the following paragraphs should be inserted in place of the section entitled, "Categories of Need."

   Categories of Need

   The states' estimates of the cost of constructing publicly owned treatment works needed to meet the 1983 goals of the Act are divided into the five major categories used in the 1973 Survey, plus one new category for treatment and/or control of stormwaters; two of these categories were divided for the 1974 Survey and retained for the 1976 and 1978 Surveys. All six categories are briefly described below.

   Category 1. This includes the costs of facilities which would provide a legally required level of secondary treatment, or best practicable wastewater treatment technology (BPWTT). For the purpose of the Surveys, BPWTT and secondary treatment were considered synonymous.

   Category 2. Costs reported in this category are for treatment facilities that must achieve more stringent levels of treatment. This requirement exists where water quality standards require removal of such pollutants as phosphorous, ammonia, nitrates, or organic substances. Included in Category II are the costs necessary to raise the treatment level of Category II facilities to secondary levels, e.g., if the existing treatment level of a facility is primary then costs necessary to raise the

treatment level to secondary are reported in Category II together with the costs for treatment levels greater than secondary.

Category IIIA. These costs are for correction of sewer system infiltration/inflow problems. Costs could also be reported for a preliminary sewer system analysis and for the more detailed Sewer System Evaluation Survey.

Category IIIB. This category includes costs for replacement or major rehabilitation of existing collection systems necessary to the total integrity and performance of waste treatment works. Requirements for replacement and/or major rehabilitation of existing sewage collection systems are reported in this category. Costs were to be reported if the corrective actions were necessary to the total integrity of the system. Major rehabilitation is considered extensive repair of existing sewers beyond the scope of normal maintenance programs.

Category IVA. This category consists of costs of new collection systems in existing communities with sufficient existing or planned capacity to adequately treat collected sewage.

Category IVB. Included in this category are costs for new interceptor sewers and transmission pumping costs necessary for bulk transport of wastewaters.

Category V. Costs reported for this category are to prevent periodic bypassing of untreated wastes from combined sewers to an extent violating water quality standards or effluent limitations. It does not include treatment and/or control of stormwaters.

Category VI. States were also asked to make a rough cost estimate in a sixth category, "Treatment and/or Control of Stormwaters." This includes the costs of abating pollution from stormwater run-off channelled through sewers and other conveyances used only for such run-off. The costs of abating pollution from stormwaters channelled through combined sewers that also carry sewage are included in Category V. Category VI was added so the survey would provide an estimate of all eligible facility costs, as explicitly required by P.L. 93-243.

The estimates were to be reported in January 1978 dollars. Estimates were to be based on the projected 2000 population.

REPORT OF THE ADMINISTRATOR
OF THE
ENVIRONMENTAL PROTECTION AGENCY
TO THE
CONGRESS OF THE UNITED STATES
IN COMPLIANCE WITH

SECTION 312(c) OF THE CLEAN AIR ACT, AS AMENDED BY PUBLIC LAW 91-604, THE CLEAN AIR AMENDMENTS OF 1970

AND

SECTION 516(b) OF PUBLIC LAW 92-500, THE FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972.

EXECUTIVE SUMMARY

This report to Congress is mandated by the Clean Air and Water Acts. In both Acts, the Administrator of the Environmental Protection Agency is directed to make and report detailed estimates of the costs of carrying out the respective Acts. This report presents such estimates as two separate reports, one concerned with the control of air pollution, the other with the control of water pollution. This summary provides information on both reports and presents listings of "water costs", "air costs", and "combined costs".

The estimates reported here are limited to costs associated with Federal regulatory actions resulting from the Clean Air and Clean Water Acts, and do not account for costs voluntarily incurred by pollutors, required by State or local governments only, or mandated by other Federal laws. The estimates given here do not include costs incurred prior to the dates of the respective Acts (Air—1970, Water—1972), nor is any estimate given of the expenditures which would have taken place if the Acts had not been passed.

It should be noted that this document specifically does not dictate EPA policy with regard to the application of presently available or projected emissions-control technology to any industry or activity. Simplifying assumptions were required in order to estimate the cost of complying with EPA regulations on the source industries included herein. Thus, the control technologies assumed in providing these estimates are not to be regarded as specifically required by law nor by EPA. Moreover, the reader is cautioned that costs estimated in this study may differ from costs estimated in other studies because of differences in definition of the industries.

The costs reported for the control of air pollution are, for the most part, based on compliance with Federally-approved State Implementation Plans, Federal New Source Performance Standards, and Federal regulations for mobile sources. The costs reported for the control of water pollution are, for the most part, based on compliance with Federal Effluent Limitations Guidelines, New Source Performance Standards, and Pretreatment Standards. Regulations on hazardous and toxic pollutants are also taken into account.

This report was prepared in 1978, and reflects the regulatory framework in existence early in 1978. Projections beyond past expenditures are subject to change for both air and water. The Clean Air Act Amendments of 1977 contain significant changes that will affect future costs. The Clean Water Act of 1977, amending the Federal Water Pollution Control Act of 1972, also contains significant changes that will affect the future regulatory picture and the associated cost to industry.

In the case of air, some additional costs can be expected to comply with the revised State Implementation Plans and the provisions of Prevention of Significant Deterioration and Visibility Goals.

The reported projections for water pollution control costs are more difficult to assess. The Clean Water Act of 1977 will require less stringent controls for conventional pollutants. However, the 1976 Consent Agreement may result in more stringent guidelines for the 21 industries covered by the agreement.

The magnitude of these changes will vary considerably on an industry-by-industry basis. An extreme example is the Explosives industry. The Cost of Clean Water estimates show slightly over $2 billion of investment from 1977–1986. Preliminary estimates emanating from the current BAT-review process indicate that new investment will only be about $3–4 million for this industry. While this is not representative of the magnitude of the changes to be expected, it does indicate the degree of uncertainty in the present estimates. *Therefore, the reader should keep in mind that the costs presented here represent only what industries would have had to pay if the regulations in effect in early 1978 remained unchanged.*

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COST OF IMPLEMENTING THE ACTS

In the presentation of costs, 1977 is the base year; all costs are expressed in millions of 1977 dollars. Investment and annual costs are reported for two historical periods: 1970—77 (Air), 1972—77 (Water) and are projected for the period from 1977 through 1986.

The costs r ported include:

- Capital costs of equipment and installation
- Capital recovery (depreciation) and interest on unrecovered capital
- Direct operating and maintenance costs.

The methodology used to generate costs is discussed in the introduction of each report and in more detail in the specific chapters. The methodology involves the analysis of specific regulations, in terms of affected sectors of industry, and the costing of control equipment or methods characteristic to each sector.

The costs are the result of engineering estimates; they are not obtained from industry surveys. The estimates are based on the assumed application of existing technology, and are developed by various techniques such as the use of "model" plants, or actual data on an existing plant. Various other assumptions are used, such as the utilization of an "average" air-pollution regulation typical of all State Implementation Plans. The assumptions used are judged to result in an overstatement of costs, since no allowances are made for in-process changes or technological innovation, either of which might reduce the costs of pollution control.

The findings are presented in condensed form in the three following tables. Table 1 presents estimated total air and water pollution control costs, Table 2 shows estimated air pollution control costs, and Table 3 indicates estimated water pollution control costs. The tables show both investment costs and annualized costs.

Major industry groups are consistent in the tables; however, individual line items are presented only where costs have been developed. Some industries have only air or only water costs associated with them and so appear in only one of the last two tables. Table 1 is the sum of Tables #2 and 3. For example, the table entry for Mobile Sources appears in Tables 1 and 2 as an air pollution item. A key to accessing the way individual industry chapters were used to combine the two air and water reports is given as a note at the end of this Summary.

The costs to government shown in the tables are based on expenditures to run programs at the Federal, State, and local levels and the projected distribution of grants for construction of municipal water treatment plants. Program operating costs are shown for both air and water pollution control in terms of "Annual Costs" in both Table 2 and 3; the construction grants are shown as "Investment" in Table 3, with annualized capital costs of the grants included in the "Annual Costs" shown in Table 3.

Various major industries appear as single entries because of their significance in terms of pollution control costs, such as electric utilities, petroleum refining, iron and steel, primary aluminum and copper, and pulp and paper. The *Mobile Sources* category includes passenger cars, light and heavy-duty gasoline and diesel trucks, aircraft, and motorcycles. The category of *Other Food Processing* includes grain handling, feed mills, sugar processing, canning and preserving of fruits and vegetables and seafood, and processing of dairy products. The *Basic Inorganic Chemicals* group includes sulfuric acid and chlor-alkali production; the *Organic Chemicals* category includes production of petrochemicals, organic chemicals, plastics and synthetics, and vinyl chloride; the *Agricultural Chemicals* category includes production of fertilizers, pesticides, nitric acid, and other products based on phosphate rock and phosphorus; the *Formulated Chemicals* group includes the production of paints, inks, carbon black, soaps, detergents, explosives, gum and wood chemicals, and pharmaceuticals. The *Construction Materials* group includes activities such

TABLE 1. COST OF AIR AND WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	22.13	128.73	16.25	30.34
OIL & GAS EXTRACTION & PROCESSING	563.95	912.26	383.18	779.43
PETROLEUM REFINING	902.91	3321.15	1062.52	1326.76
ELECTRIC UTILITIES	3877.70	13127.70	11051.73	20913.55
COAL GASIFICATION	0.0	0.0	70.44	412.03
SUBTOTAL	5366.69	17489.84	12584.12	23462.11
MOBILE SOURCES	2912.00	12050.09	17234.55	49051.55
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	36.52	122.74	159.82	241.12
OTHER FOOD PROCESSING	689.60	4153.08	991.06	2116.23
SUBTOTAL	726.12	4275.82	1150.88	2357.35
CHEMICALS				
BASIC INORGANIC CHEMICALS	254.33	989.21	524.83	875.01
ORGANIC CHEMICALS	1009.65	2060.90	1449.64	2947.17
AGRICULTURAL CHEMICALS	125.24	270.10	152.87	276.04
FORMULATED CHEMICALS	258.38	711.21	1357.15	2129.50
SUBTOTAL	1647.61	4031.41	3484.49	6227.71
CONSTRUCTION MATERIALS	101.70	677.90	198.47	312.25
METALS				
ORE MINING & DRESSING	152.50	389.59	251.00	251.00
IRON & STEEL	981.22	2668.26	2337.60	3613.98
ALUMINUM	71.34	400.35	147.07	410.12
COPPER	90.00	1094.00	171.70	986.00
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	69.42	731.88	63.05	15091
SUBTOTAL	1364.49	5284.08	2970.42	5412.01
SOFTGOODS				
PULP & PAPER	964.00	3099.75	870.75	1953.05
TEXTILES	24.21	87.84	1030.21	1410.16
LEATHER & RUBBER	82.93	198.40	121.20	181.72
SUBTOTAL	1071.13	3385.99	2022.16	3544.92
MANUFACTURING				
ELECTROPLATING	49.79	264.74	81.55	81.55
SURFACE COATINGS	0.0	0.0	658.82	1707.64
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
SUBTOTAL	49.79	264.74	743.17	1793.99
SERVICES				
DRYCLEANING	10.04	141.75	6.75	13.27
HOSPITALS	24.50	69.77	25.65	69.56
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
SUBTOTAL	40.75	225.99	38.00	98.53
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE INCINERATION	4.29	27.11	11.31	24.72
SUBTOTAL	149.62	1771.23	729.93	2048.06
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	57.02	256.61	275.62	693.80
SUBTOTAL	295.13	2226.82	543.88	1158.92
TOTAL	18790.21	73276.93	61376.92	141349.24

TABLE 1. COST OF AIR AND WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	4588.00	12300.90	25130.00	71720.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	69.44	212.23	280.07	677.45
OIL & GAS EXTRACTION & PROCESSING	1453.15	3835.18	6289.13	15079.90
PETROLEUM REFINING	638.69	1643.40	3279.71	8268.68
ELECTRIC UTILITIES	4828.77	11372.57	31215.88	82319.19
COAL GASIFICATION	0.0	0.0	174.18	1919.48
SUBTOTAL	5945.70	13913.07	36783.56	97832.44
MOBILE SOURCES	5850.74	38203.01	33146.74	92068.00
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	39.08	98.90	293.18	947.35
OTHER FOOD PROCESSING	1453.15	3835.18	6289.13	15078.90
SUBTOTAL	1492.23	3934.08	6582.31	16027.25
CHEMICALS				
BASIC INORGANIC CHEMICALS	276.35	747.94	1469.03	3935.04
ORGANIC CHEMICALS	421.24	791.90	2589.27	7019.09
AGRICULTURAL CHEMICALS	117.50	223.86	601.37	1667.98
FORMULATED CHEMICALS	146.73	313.65	1070.45	3381.43
SUBTOTAL	961.82	2077.34	5730.12	16003.51
CONSTRUCTION MATERIALS	235.21	718.73	1094.42	2524.83
METALS				
ORE MINING & DRESSING	84.58	145.97	603.18	1340.06
IRON & STEEL	1075.86	3312.17	6595.23	18705.79
ALUMINUM	111.27	352.13	526.92	1236.31
COPPER	199.25	802.96	1011.18	2549.96
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	198.40	779.70	823.68	1820.02
SUBTOTAL	1669.37	5392.93	9569.18	25652.12
SOFTGOODS				
PULP & PAPER	659.01	1416.82	3014.37	8215.19
TEXTILES	27.42	64.01	1089.87	4499.59
LEATHER & RUBBER	47.68	95.93	254.54	707.69
SUBTOTAL	734.11	1576.76	4358.78	13422.47
MANUFACTURING				
ELECTROPLATING	141.74	316.31	751.27	1771.01
SURFACE COATINGS	0.0	0.0	374.38	1858.20
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
SUBTOTAL	141.74	316.31	1127.02	3641.80
SERVICES				
DRYCLEANING	23.07	86.06	95.58	156.53
HOSPITALS	16.37	34.69	79.65	219.62
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
SUBTOTAL	43.90	129.21	197.22	435.81
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE INCINERATION	6.05	24.19	30.57	75.14
SUBTOTAL	1118.27	4786.55	5449.80	15151.73
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	93.09	270.33	596.43	2013.17
SUBTOTAL	442.11	1459.90	2143.93	5647.71
TOTAL	23223.21	84808.80	131313.08	360127.75

TABLE 2. COST OF AIR POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	0.0	0.0	0.0	0.0
FUELS & ENERGY				
COAL MINING & COAL CLEANING	12.88	75.24	0.0	0.0
OIL & GAS EXTRACTION & PROCESSING	9.35	19.92	45.75	127.65
PETROLEUM REFINING	167.23	745.85	393.72	537.17
ELECTRIC UTILITIES	2850.92	11489.03	10174.58	18276.43
COAL GASIFICATION	0.0	0.0	70.44	412.03
SUBTOTAL	3040.38	12330.04	10684.48	19353.28
MOBILE SOURCES	2912.00	12050.09	17234.55	49051.55
FOOD PROCESSING				
OTHER FOOD PROCESSING	442.04	3323.80	769.95	1781.34
CHEMICALS				
BASIC INORGANIC CHEMICALS	74.55	517.56	145.45	327.10
ORGANIC CHEMICALS	83.86	115.10	190.39	257.63
AGRICULTURAL CHEMICALS	4.97	41.85	5.23	9.59
FORMULATED CHEMICALS	4.85	34.33	8.59	18.14
SUBTOTAL	168.23	708.84	349.66	612.46
CONSTRUCTION MATERIALS	55.78	501.37	96.31	160.46
METALS				
IRON & STEEL	320.28	1258.04	1281.12	1921.68
ALUMINUM	51.84	359.91	117.86	363.17
COPPER	90.00	1094.00	171.70	986.00
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	64.44	659.70	58.00	139.67
SUBTOTAL	526.56	3371.65	1628.61	3410.52
SOFTGOODS				
PULP & PAPER	264.00	921.00	429.50	442.00
MANUFACTURING				
SURFACE COATINGS	0.0	0.0	658.82	1707.64
SERVICES				
DRYCLEANING	10.04	141.75	6.75	13.27
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE INCINERATION	4.29	27.11	11.31	24.72
SUBTOTAL	149.62	1771.23	729.93	2048.06
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILER	238.11	1970.21	268.26	465.11
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	57.02	256.61	275.62	693.80
SUBTOTAL	295.13	2226.82	543.88	1158.92
TOTAL	7863.78	3734.59	33132.45	79739.49

TABLE 2. COST OF AIR POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	539.00	539.00	2787.00	5597.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	13.13	64.47	52.51	109.56
OIL & GAS EXTRACTION & PROCESSING	27.56	137.13	134.68	375.13
PETROLEUM REFINING	136.12	400.56	773.86	1981.58
ELECTRIC UTILITIES	4106.02	10076.90	28810.93	76395.50
COAL GASIFICATION	0.0	0.0	174.18	1919.48
SUBTOTAL	4282.83	10679.06	29946.16	80781.25
MOBILE SOURCES	5850.74	38203.01	33146.74	92068.00
FOOD PROCESSING				
OTHER FOOD PROCESSING	573.55	1903.77	2679.99	6769.09
CHEMICALS				
BASIC INORGANIC CHEMICALS	139.82	462.72	681.97	1657.49
ORGANIC CHEMICALS	56.64	124.71	438.78	1141.87
AGRICULTURAL CHEMICALS	14.55	50.07	63.72	137.39
FORMULATED CHEMICALS	11.11	36.55	52.33	117.96
SUBTOTAL	222.12	674.05	1236.80	3054.71
CONSTRUCTION MATERIALS	159.39	576.10	720.14	1562.65
METALS				
IRON & STEEL	519.20	1327.59	3473.60	9900.35
ALUMINUM	95.96	323.82	444.67	1007.86
COPPER	199.25	802.96	1011.18	2549.96
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	176.00	716.44	730.83	1571.24
SUBTOTAL	990.42	3170.78	5660.26	15029.38
SOFTGOODS				
PULP & PAPER	130.48	270.62	733.17	1736.53
MANUFACTURING				
SURFACE COATINGS	0.0	0.0	374.38	1858.20
SERVICES				
DRYCLEANING	23.07	86.06	95.58	156.53
WASTE DISPOSAL				
OPEN DUMPS & OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE INCINERATION	6.05	24.19	30.57	75.14
SUBTOTAL	1118.27	4786.55	5449.80	15151.73
OTHER INDUSTRIAL COSTS				
INDUSTRIAL & COMMERCIAL HEATING BOILER	349.02	1189.57	1547.50	3634.55
INDUSTRIAL, COMMERCIAL & BLDG. INCINERATORS	93.09	270.33	596.43	2013.17
SUBTOTAL	442.10	1459.90	2143.93	5647.71
TOTAL	14331.98	62348.90	84973.95	229412.79

TABLE 3. COST OF WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
	1977	1972–77	1977–81	1977–86
COSTS TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	9.24	53.50	16.25	30.34
OIL & GAS EXTRACTION & PROCESSING	554.61	892.33	337.42	651.78
PETROLEUM REFINING	735.68	2575.30	668.80	789.59
ELECTRIC UTILITIES	1026.78	1638.67	877.15	2637.12
SUBTOTAL	2326.31	5159.80	1899.62	4108.83
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	36.52	122.74	159.82	241.12
OTHER FOOD PROCESSING	247.56	829.28	221.11	392.71
SUBTOTAL	284.08	952.02	380.93	576.01
CHEMICALS				
BASIC INORGANIC CHEMICALS	179.78	471.65	379.38	547.91
ORGANIC CHEMICALS	925.79	1945.80	1259.25	2689.54
AGRICULTURAL CHEMICALS	120.27	228.25	147.64	266.45
FORMULATED CHEMICALS	253.53	676.89	1348.55	2111.37
SUBTOTAL	1479.37	3322.58	3134.82	5615.27
CONSTRUCTION MATERIALS	45.92	176.52	102.15	151.79
METALS				
ORE MINING & DRESSING	152.50	389.59	251.00	251.00
IRON & STEEL	660.94	1410.22	1056.48	1692.30
ALUMINUM	19.51	40.45	29.21	46.95
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	4.98	72.18	5.05	11.24
SUBTOTAL	837.93	1912.44	1341.74	2001.49
SOFTGOODS				
PULP & PAPER	700.00	2178.75	441.25	1511.05
TEXTILES	24.21	87.84	1030.21	1410.16
LEATHER & RUBBER	82.93	198.40	121.20	181.72
SUBTOTAL	807.13	2464.99	1592.66	3102.92
MANUFACTURING				
ELECTROPLATING	49.79	264.74	81.55	81.55
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
SUBTOTAL	49.79	264.74	84.35	86.35
SERVICES				
HOSPITALS	24.50	69.77	25.65	69.56
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
SUBTOTAL	30.71	84.23	31.24	85.26
TOTAL	10926.43	35930.34	28244.47	61609.75

TABLE 3. COST OF WATER POLLUTION CONTROL (IN MILLIONS OF 1977 DOLLARS) Continued

		ANNUAL COSTS		
	1977	1972–77	1977–81	1977–86
COSTS TO GOVERNMENT	4049.00	11761.90	22343.00	66123.00
FUELS & ENERGY				
COAL MINING & COAL CLEANING	56.31	147.75	227.56	567.89
OIL & GAS EXTRACTION & PROCESSING	381.24	547.74	1699.04	4272.51
PETROLEUM REFINING	502.57	1242.84	2505.84	6287.09
ELECTRIC UTILITIES	722.76	1295.68	2404.96	5923.74
SUBTOTAL	1662.88	3234.01	6837.40	17051.23
FOOD PROCESSING				
FEEDLOTS & MEAT PROCESSING	39.08	98.90	293.18	947.35
OTHER FOOD PROCESSING	879.60	1931.41	3609.14	8310.81
SUBTOTAL	918.68	2030.31	3902.32	9258.16
CHEMICALS				
BASIC INORGANIC CHEMICALS	136.53	285.22	787.06	2277.54
ORGANIC CHEMICALS	364.60	667.19	2150.49	5877.23
AGRICULTURAL CHEMICALS	102.95	173.79	537.65	1530.59
FORMULATED CHEMICALS	135.62	277.10	1018.12	3263.47
SUBTOTAL	739.70	1403.30	4493.33	12948.81
CONSTRUCTION MATERIALS	75.82	142.64	374.28	962.17
METALS				
ORE MINING & DRESSING	84.58	145.97	603.18	1340.06
IRON & STEEL	556.66	1984.58	3121.63	8805.44
ALUMINUM	15.31	28.31	82.26	228.45
NONFERROUS METALS, FERROALLOYS, & FOUNDRIES	22.40	63.29	101.85	248.79
SUBTOTAL	678.95	2222.15	3908.92	10622.74
SOFTGOODS				
PULP & PAPER	528.53	1146.20	2281.20	6478.66
TEXTILES	27.42	64.01	1089.87	4499.59
LEATHER & RUBBER	47.68	95.93	254.54	707.69
SUBTOTAL	603.63	1306.14	3625.61	11685.94
MANUFACTURING				
ELECTROPLATING	141.74	316.31	751.27	1771.01
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
SUBTOTAL	141.74	316.31	752.64	1783.60
SERVICES				
HOSPITALS	16.37	34.69	79.65	219.62
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
SUBTOTAL	20.83	43.15	101.64	279.28
TOTAL	8891.23	22459.90	46339.13	130714.96

as mineral mining, production of cement, lime, asphalt concrete, glass, structural clay products, asbestos, paving and roofing materials, timber products processing, and glass and fiberglass insulation. The *Nonferrous Metals* group includes the production of primary lead, zinc, magnesium, and other metals, and secondary aluminum, copper, lead, and zinc, as well as the production of ferroalloys and operations of iron and steel foundries. Further details on any group may be found via the key to aggregation given at the end of this summary, or the individual chapters of the report.

COMPARISON OF COSTS

In terms of the combined costs given in Table 1, the highest levels of expenditures are associated with the Energy Industries (largely electric power plants and petroleum refining) and Mobile Sources. The balance of the industry groups fall into either an intermediate range of expenditures, e.g., Food Processing, Chemical Industries, Metals, Softgoods, Waste Disposal, and Industrial Heating, or into a lower range of expenditures, e.g., the Construction Materials, Manufacturing, and Service groups.

The estimates reported allow a broad comparison of past and future expenditures. One observation is that investment to meet air pollution control regulations over the entire 1970–1986 period will be about 20 percent greater than investment to meet water pollution control regulations. A further observation is that, although the investments for air pollution control over the entire period are higher, sunk investment costs (i.e., before 1977) are roughly equal for air and water pollution control. This overall observation is, of course, subject to qualification in instances of individual industries.

The 1977 annualized cost of pollution control due to Federal Regulations was estimated to be $23 billion, or about one percent of 1977 GNP. The cumulative cost from 1970 to 1977 was $84.8 billion, and the projected cost over the period 1977 to 1986 is estimated at $360 billion.

In Table 2, (Air Pollution Control Costs) the groups showing the largest portions of investment costs include the Energy Industries (specifically, power plants), and Mobile Sources. The Mobile Sources costs include costs for lead phase-down and lead-free gasoline production; these elements of cost may be associated with the Petroleum Refining Industry in other studies. The next largest range of expenditures are those shown for the Metals and Food Processing groups.

Some of the individual features which may be noted in Table 2 (Air Pollution Control Costs) include the singularly high levels of expenditures for the control of Mobile Sources; these costs reflect the projected automobile populations that contain pollution control, as well as increasing stringency of regulations. The costs reported for electric utilities do not include any control costs stemming from the 1977 Amendments. The cost estimate for the electric utilities industry reflects the application of a mix of control technologies and fuel switching to achieve compliance.

The estimated costs for the metals industry group show the costs for the three major metals: steel, aluminum, and copper, with future investment costs for both the steel and copper industry estimated as more than the investment made up to 1977.

In Table 3 (Water Pollution Control Costs), the highest level of expenditure is that for the energy industry (largely for Petroleum Refining and, again, electric power plants) with the next highest levels of expenditures shown for the Chemical Industries (principally the organic chemicals industry), and for the so called "Softgoods" group; almost all the latter costs are associated with the pulp and paper industry.

The water pollution control costs in Table 3 include Federal grants for construction of municipal treatment plants as an investment expenditure. The cost of water pollution control for the electric utilities given in the table has, as a major component, the cost to meet thermal limits on discharge water and replacement of capacity lost to the operation of the required cooling towers. The Organic Chemicals and Formulated Chemicals categories reflect areas of high anticipated future costs, with the Organic Chemicals industry an area of complex control requirements for all components of a variegated industry. The "Softgoods"

group contains two noteworthy cost elements: the past and future cost for the pulp and paper industry and the estimated high future cost (related largely to compliance with the 1983-BAT regulations) for the textile industry.

Table 3 does *not* include an estimate for the control of nonpoint sources. EPA has not yet issued regulations controlling nonpoint sources; and the control technology and degree of control is still uncertain. The Water Report contains a discussion of nonpoint sources (agriculture, silviculture, urban runoff and new construction runoff control) in Chapter 10.1. Preliminary estimates indicate that future investment needs will be about $58 billion in the next five years. No estimate is available on what portion of this investment need will actually be spent.

BENEFITS

Historically, the benefits research program at the EPA has given primary attention to developing the capabilities to compute national estimates of the total damage from pollution, i.e., estimating the potential benefits of eliminating pollution entirely. Basically, the program has categorized the various types of economic damages from pollution (medical bills, property damage, etc.) by media and pollutant. Individual projects generally involved estimating the extent and value of the more important damages for which some data exist. At best, past studies have been used to defend overall EPA programs, though they may not have been all that useful for this purpose. There have been a few attempts to demonstrate the feasibility of evaluating the benefits of control of individual pollutants (e.g., EPA-sponsored analyses of nitrates, nonfluorinated halomethanes, chlorobenzilate, etc.) but these were not done in direct support of actual EPA regulatory decisions. The EPA has never applied comprehensive benefit estimation methodologies to a contemplated regulatory decision.

National Estimates

The national damage estimates have concentrated on air and water pollution control. Best EPA-generated estimates have been very crude, sometimes based on faulty or incomplete methodologies and always on inadequate data bases. The ranges defined by EPA and other estimates to date have been: air pollution damages from $2.0 billion to $35.4 billion and water pollution damages from $4.5 billion to $18.6 billion. These studies have been characterized as only providing crude, order-of-magnitude estimates of the damages.

The "Wyoming" Study

A recently completed EPA study done by a consortium of professors (primarily at the University of Wyoming) may provide significantly more reliable estimates of national morbidity and mortality damages from air pollution than the EPA has had before. The study also assesses potential benefits from air clean-up in the Los Angeles area. The results are:

- National mortality effects of $5 to $16 billion per year
- National morbidity effects of $36 billion per year
- Potential benefits of $0.65 to 0.95 billion per year from a 30 percent air clean up of the South Coast Basin of Southern California.

New Perspective on Damages

Besides suggesting that previous studies may have substantially underestimated both the health and other economic damages from air pollution, and thus the benefits of control, the new study and other recent work by many of the same environmental economists suggest a new perspective on air pollution damages and their measurement.

The new work indicates that the major air pollution damages are from increased chronic illness and from aesthetic effects like reduced visibility. This contrasts with earlier views that increased deaths were the major source of damage.

The economic damages attributable to increased air pollution-related deaths are roughly comparable to earlier studies, but this is largely accidental: although the new estimates of mortality effects are lower than earlier studies have indicated, these lower estimates are offset by higher estimates of the value society places on increased risk of death.

The study also concludes that many benefits, such as aesthetic ones, which are "traditionally viewed as intangible and thereby nonmeasurable can, in fact be measured" and can be made comparable to economic values expressed in the marketplace.

Derivation of New Health Estimates

The researchers derived their estimates of damage to health through two independent approaches. One approach examined data from the University of Michigan Survey Research Center on illnesses among a random selection of the U.S. population. This information was compared statistically with indicators of biological and social situation, life styles, income levels, physical environment, and air pollution levels in the county of residence. The analyses suggest the extent to which each indicator is associated with time lost from work because of illness.

The studies found statistically significant associations between lost work time because of chronic illness and ambient levels of both nitrogen dioxide and total suspended particulates. The researchers arrived at the $36 billion estimate for 60 percent control by projecting the relationship between lost time and particulate levels in their sample to the national urban population using the wage rates of the sample population to put a monetary value on the time lost from work. The authors emphasized, however, that their conclusions should be regarded as preliminary because of the short time they have worked with the data and the many combinations of explanatory hypotheses they will need to test.

In the second approach, the researchers concentrated on the death rates in 60 cities across the country, comparing them to air pollution levels and other factors that might influence those rates such as smoking, doctors per capita, and diet. The researchers found statistically significant associations between death from pneumonia and influenza and the level of sulfur dioxide. The study valued the benefits that would result from reduced mortality if there were a 60 percent improvement in air quality at $5 to $16 billion annually.

Los Angeles Benefits Also Large

In addition to studying health damages from air pollution, the same study also attempts to quantify air pollution damages in one air quality region—the Los Angeles Basin. It found that a 30 percent improvement in air quality would provide benefits of $650 to $950 million per year (or $350 to $500 per household) for this city alone.

This part of the study used interview surveys and analyses of property values to support its conclusions. In the interview survey people were first given a subjective understanding of the health effects and location of Los Angeles smog using maps of pollution levels (which varied from poor to quite good) throughout the Basin and later shown photographs of a view obscured by different levels of pollution. They were then asked how much they would be willing to pay for improved air quality. In the property value analyses, the researchers compared the selling prices of houses which were similar but which were located in areas experiencing different levels of pollution. The houses in the clean air areas had a substantially higher value than those in more polluted areas. The fact that the benefit estimates derived from the two approaches are similar lends credence to both.

In their interview survey, the researchers found that people living in the Los Angeles Basin believe aesthetic effects such as impairment of visibility account for 22 percent to 55 percent of the damages associated with air pollution. These findings are consistent with an earlier survey many of the same researchers undertook for the Electric Power Research Institute, which found that people living in the Four Corners area of the Southwest would pay an average of $90 a year to avoid having visibility reduced by 50 miles, i.e., from 75 to 25 miles.

Ongoing Pollutant-Specific Benefits Study

Since FY75, the EPA has contracted for 12 pollutant assessments from the National Academy of Science which were to include economic, and where possible, benefit-cost analyses. Of these assessments, two (halomethanes and nitrates) have been delivered, and three (chlorobenzilate, odors, and PCB's in the environment) are nearing completion and should be delivered in 1979. It appears that where adequate physical science data exist, benefit-cost analysis can contribute to Agency decision making (as applied to specific regulations proposed by the Agency).

Plans for a Benefits Study Program

To get reliable estimates, in the near future, of national or regional benefits, the EPA must push the state-of-the-art further and faster than has

been done so far. It will be necessary to devote significant resources to improving existing data bases.

Unfortunately, breakthroughs in benefits estimates are like those in other scientific fields, uncertain and expensive. In addition to continued "basic" research, there is a need to test the usefulness of a benefit-cost approach in analysing specific proposed EPA regulations on a prototype basis. The prototype basis, rather than the immediate application of benefit-cost analysis to all or most EPA regulations, is likely to be taken so that the Agency can first gain experience and find out if some of the carcinogen-related problems can be resolved. Whether additional research will be needed to assist the EPA in applying benefit-cost analysis to individual decisions is not yet clear, but may become more so as the proposed prototype effort is implemented in the next year.

THE ECONOMIC IMPACT OF EPA'S PROGRAM

This section is included to provide some perspective as to the economic effects of EPA programs. Widely disparate views on the economic impact of EPA's program have been expressed by some environmentalists — who say the program stimulates the economy and creates jobs — and by some businessmen — who say the program causes capital shortages and inflation in boom times and causes unemployment and stifles profitability in recessionary times.

The truth probably lies somewhere in between. While costs of pollution programs are high in absolute terms, the overall effects on prices, GNP, and employment are projected to be small and neither strongly positive nor negative in the long run.

Most concern about economic effects should be focused on a few heavily polluting industries which either are very capital-intensive materials producing industries or are characterized by many economically marginal operations. Of key importance for these industries are (a) concerns about limits on expansion due to capital shortfalls or siting constraints posed by environmental regulations and (2) the effects of these limits on growth in these and related industries.

This section does not discuss whether environmental programs (or various elements of them) have favorable benefit/cost ratios, since few credible benefits data have been generated which would allow such analysis. This section does briefly detail what is and is not known about the costs, macroeconomic and microeconomic impacts, energy impacts, and key economic impact issues associated with the environmental program.

Costs

The Federal pollution control program is projected to cost about *$360 billion in the period 1977–86* above expenditure levels which would have resulted without new Federal requirements since 1970. About $229 billion, or about 2/3 of these expenditures are the result of the Clean Air Act. Capital investment for Federally-required controls will be about $142 billion over the same period. About $81 billion of this total (57%) is as a result of the Clean Air Act.

The 1977 annualized cost of pollution control due to Federal Regulations was estimated to be $23.2 billion, or about one percent of 1977 GNP. Air pollution control costs were $14.3 billion in 1977, or about 62% of the combined air and water costs.

Total (air and water) pollution abatement investment by industry (excluding Mobile Sources and Cost to Governments) was $10.8 billion in 1977. This represents about 5.8% of 1977 fixed nonresidential private investment. Consumer investment for Mobile Source pollution control was slightly under $3 billion in 1977. This represents about 3.6% of 1977 consumer expenditures for motor vehicles and parts.

Macroeconomic Impacts

These costs can be put in perspective by looking at their macroeconomic effect on the economy. The magnitudes of these effects depend upon the general state of the economy. In a slack economy pollution control investment can stimulate growth and employment with little real effect on prices, while in a tight economy such investment can increase prices and tend to replace other capital spending plans with a relatively small effect on

employment. Macroeconomic forecasts can project these effects, but only with a wide band of uncertainty.

Price and Growth Effects — A Data Resources, Inc. (DRI) forecast prepared for EPA and CEQ in January 1979 shows that *the Consumer Price Index is currently about 2.7% higher* than it would have been without Federal pollution requirements and that by 1986 this difference will be about 3.6%, meaning that *consumer prices will increase between 0.2% and 0.3% per year more* than they would without these requirements over the period 1970–1986.

DRI estimates that GNP is currently very marginally higher than it would have been because Federal pollution requirements have caused use of capital and other resources that would not otherwise have been used. As the economy improves, environmental investment will increasingly be made instead of, rather than in addition to, other expenditures. DRI estimates that by 1986 *GNP will be almost 1.0% lower* than it would have been without Federal pollution requirements.

These estimated effects on prices and GNP use conventional measures for these variables. Since these measures do not take into account the benefits of *the environmental programs in terms of improved public health and welfare, these forecasts exaggerate the negative impacts on inflation and economic growth.*

Employment Effects — Employment is affected in a number of ways by environmental requirements. The program directly creates jobs in the construction (46,000 on-site jobs on EPA-funded sewage treatment projects in July 1976, with an equivalent number of off-site jobs) and the pollution control manufacturing industry (Arthur D. Little, Inc., estimates current employment to be nearly 36,000 and projects employment to grow to nearly 44,000 in this industry by 1983 as a result of the 1970 and 1972 air and water legislation), with many more indirect jobs stimulated by these expenditures.

On the other hand, when pollution control costs result in higher prices, lower demand and hence lower production and lower employment result. Furthermore, some transitional unemployment results from closing of marginal plants which cannot afford to comply with environmental requirements. Since January 1971, 132 closures involving nearly 24,500 jobs have occurred for which the firm has said that pollution requirements were a significant factor; 40 closures involved Federal action.

The combination of these factors according to the DRI macroeconomic projection will result in *increased employment through 1986 due to the stimulative effect of pollution control investment.* The jobs created in manufacturing, installing, and operating/maintaining pollution control equipment outweigh the dampening effect of higher prices on economic growth. DRI estimates the unemployment rate to be about 0.2% lower in 1979, 0.4% lower in both 1980 and 1981, and 0.2% lower in 1986 due to Federal pollution requirements.

OTHER METHODOLOGIES

This report is based primarily on a model plant analysis. A detailed description of the methodology used to generate these estimates can be found in the Introduction to the Air Report. Various other sources have estimated the cost of pollution control using other techniques. This section discusses some of these other sources and how they differ from this report.

Bureau of Economic Analysis

The Bureau of Economic Analysis (BEA), U.S. Department of Commerce, publishes the results of an annual survey of industries detailing capital expenditures for air, water and solid waste pollution abatement. The survey requests information on total plant and equipment expenditures for pollution abatement, not just that attributable to Federal legislation.

One of the major problems with the BEA survey, is that it samples company enterprises, not actual plants. A company is categorized by its major-product. For example, if a large petroleum company owns a textile mill, any pollution control

investment at the textile mill would be classified under petroleum refining. Thus, while the aggregate BEA estimates are quite useful, the individual industry-specific estimates reveal little about the cost to a specific industrial process.

Bureau of the Census

The Bureau of the Census, U.S. Department of Commerce, publishes the results of an annual survey of manufacturing establishments detailing both capital investment and operating costs for pollution abatement. The survey asks for total expenditures, not just that due to Federal legislation. Unlike BEA, the Census survey is based on a plant or establishment classification. However, it only includes manufacturing industries.

One of the main problems with the Census survey is that depreciation is included as a part of operating costs. Only total operating costs are reported by air, water or solid waste. The specific line items of operating costs (i.e., labor, materials and depreciation) are not broken out by media. Since the depreciable life of air and water pollution abatement equipment vary considerably, it is impossible to accurately subtract out depreciation. Furthermore, the depreciation expenses are likely to reflect changes in tax provisions that affect depreciation expenses for tax purposes. Thus, the inclusion of depreciation limits the reliability of this survey in estimating operating and maintenance costs.

McGraw-Hill Survey

The Economics Department of McGraw-Hill Publications Company issues the results of an annual survey of pollution control expenditures. The methodology used for this survey has never been revealed by the Company, and thus, it is difficult to compare with other estimates.

Business Roundtable

The Business Roundtable, a group representing large corporations, recently released a study of the cost of Federal regulation. The study covered 48 companies, mostly among the nation's largest. EPA regulations were one segment of the study, which is the first survey to request *incremental* expenditures, i.e. only those expenditures made as a result of Federal legislation. Since the survey was lengthy and detailed, such expenses as paperwork, meetings with government officials and other administrative expenses were included in the cost estimates. However, these costs were reported combined with operating costs. Thus, the usefulness of this information is somewhat limited.

Since the sample size was so small, not random, and did not reflect a cross-section of American business, no extrapolation of this survey's results can be made. It would be unrealistic to make any generalizations about the National costs of pollution abatement based on this study. Nevertheless, The Business Roundtable Study contains much useful information, especially in terms of cost accounting methodology.

KEY TO AGGREGATED COST TABLES IN EXECUTIVE SUMMARY

Table Entries	"Air" Report Chapter Numbers	"Water" Report Chapter Numbers
Cost to Government	2	2
Fuels & Energy		
Coal Mining & Coal Cleaning	3.5	3.1
Oil & Gas Extraction & Processing	3.3	3.2
Petroleum Refining	3.4	3.3
Electric Utilities	3.1	3.4
Coal Gasification	3.6	—
Mobile Sources		
Food Processing		
Feedlots & Meat Processing	—	8.6, 8.7
Other Food Processing	9.3, 9.4	8.1, 8.2, 8.3 8.4,8.5
Chemicals		
Basic Inorganic Chemicals	5.4, 5.7	4.2.1, 4.2.2
Agricultural Chemicals	5.3, 5.5, 5.6	4.8, 4.9, 4.10, 10.2
Formulated Chemicals	8.1	4.5, 4.6, 4.7, 4.11 4.12, 7.3, 9.1
Construction Materials	7.1, 7.2, 7.3, 7.4	6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 7.1
Metals		
Ore Mining & Dressing	—	5.1
Iron & Steel	6.1	5.2
Aluminum	6.5	5.5
Copper	6.6	—
Nonferrous Metals, Ferroalloys, & Foundries	6.2, 6.3, 6.4, 6.7 6.8, 6.9, 6.10, 6.11, 6.12	5.3, 5.4, 5.6, 5.7
Softgoods		
Pulp & Paper	9.1, 9.2	7.4
Textiles	—	4.14
Leather & Rubber	—	4.4, 8.8
Manufacturing		
Electroplating	—	5.8
Surface Coatings	8.2	—
Furniture Manufacture	—	7.2
Services		
Drycleaning	8.3	—
Hospitals	—	9.2
Photographic Processing	—	4.13
Waste Disposal		
Open Burning & Open Dumps	10.1	—
Municipal Incineration	10.2, 10.3	—
Other Industrial Costs		
Industrial & Commercial Heating Boilers	3.2	—
Industrial, Commercial, & Building Incinerators	10.5	—

THE COST OF CLEAN AIR

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1. INTRODUCTION AND SUMMARY

PURPOSE AND SCOPE

Section 312(a) of the Clean Air Act Amendments of 1970 (referred to as "Act" and "CAA") requires an annual report on the prospective costs and impacts of governmental and private efforts to carry out the provisions of the Act. This report is submitted in response to the Act.

National Cost estimates are presented for governmental programs as well as those for the control of the major sources of air pollution. For this purpose the sources of air pollution are broadly divided into several categories: energy industries, transportation sources, and other industrial sources. Coverage includes not only those criteria pollutants for which national ambient air quality standards have been promulgated, but also pollutants covered by accepted and proposed hazardous air-pollutant-emission standards and by new source performance standards.

Estimates of costs, benefits, and impacts reported herein are based, wherever possible, upon Federal regulations or those specified by the states in implementation plans submitted to EPA. All air-pollution control costs in this report are in July 1, 1977 dollars. Where costs were developed for earlier years, these were updated to 1977 dollars using the implicit price deflater of the gross national product (fixed non-residential investment part).

This report does not presume to include all costs of abating air pollution. Even before the Clean Air Act of 1970, costs were incurred in response to obvious pollution problems and to local legislation. Therefore, the costs herein are estimated incremental costs, over and above any cost of control incurred or the level of control practiced prior to the Act of 1970.

Fiscal year 1971 was judged as the appropriate baseline from which incremental costs are to be assessed. This is in keeping with the passage of the clearer and more specific Clean Air Amendments of 1970, and with the wording of Section 312(a) of that legislation.

Within this framework, the estimated direct costs of air-pollution control for industrial and other sources are detailed. Investments are projected through 1986. A large number of simplifying assumptions were necessary. Industry and motor-vehicle growth and technology trends were forecast and are described in their appropriate places in the text. Regulations which are pending under the Clean Air Act and which reasonably can be expected to become law were included in the calculations. The best available information on control technologies, associated control costs, and related information was employed. This information is being modified and updated continuously by the growing experience with applied emissions-control systems. The situation has been complicated further by recent uncertainty in the overall fuels/energy situation.

It should be noted that this document specifically does not dictate EPA policy with regard to the application of presently available or projected emissions-control technology to any industry or activity. Simplifying assumptions were required in order to estimate the effect of EPA regulations on the source industries included herein. The control technologies assumed in providing these estimates are neither specifically required by law nor by EPA; no interpretation of the contents of this document to the contrary should be made.

COSTS OF IMPLEMENTING THE ACT

The 1977 Amendments to the Clean Air Act were enacted by the Congress during the period in which these estimated costs were being generated. Further, there is a period of time between the issuance of direction by the Congress and the completion of specific actions by EPA which can be analyzed in terms of costs. Thus, any costs to industry involved in complying with the directions in the 1977 amendments cannot yet be expressed in the costs reported here. The Federal expenditures detailed in the amendments are reported here under Costs to Government.

A uniform costing methodology has been applied to the industrial sectors incurring air pollution abatement costs. Being free of the requirements of macroscopic input-output economic models, this

methodology permits an examination of each industrial sector at the most desirable level of disaggregation.

Estimates of the capital investments and annualized costs required for implementing the Act in 1977 and over the periods 1970–77, 1977–81 and 1977–1986, are summarized in Table 1–1. Each number in Table 1–1 is repeated in the appropriate chapter of this report, where the assumptions and background data are presented and discussed.

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

	1977	1970–77	1977–81	1977–86
TOTAL INVESTMENT	7863.78	37346.59	33132.45	79739.49
TOTAL ANNUAL COSTS	14331.98	62348.90	84973.95	229412.79

INVESTMENT

	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	0.0	0.0	0.0	0.0

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
COSTS TO GOVERNMENT	539.00	539.00	2787.00	5597.00

	1970	1970–77	1977–81	1977–86
MOBILE SOURCES				
INVESTMENT	2912.00	12050.09	17234.55	49051.55
ANNUAL COSTS	5850.74	38203.01	33146.74	92068.00
ENERGY INDUSTRIES				
FOSSIL FUEL POWER PLANTS	2850.92	11489.03	10174.58	18276.43
COMMERCIAL & INDUSTRIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
FUELS INDUSTRIES				
NATURAL GAS PROCESSING	9.35	19.92	45.75	127.65
PETROLEUM REFINING	167.23	745.85	393.72	537.17
COAL CLEANING	12.88	75.24	0.0	0.0
COAL GASIFICATION	0.0	0.0	70.44	412.03
TOTAL INVESTMENT	3278.49	14300.23	10952.74	19818.39

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
FOSSIL FUEL POWER PLANTS	4106.02	10076.90	28810.93	76395.50
COMMERCIAL & INDUSTRIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
FUELS INDUSTRIES				
NATURAL GAS PROCESSING	27.56	137.13	134.67	375.13
PETROLEUM REFINING	136.12	400.56	773.86	1981.58
COAL CLEANING	13.13	64.47	52.51	109.56
COAL GASIFICATION	0.0	0.0	174.18	1919.48
TOTAL ANNUAL COSTS	4631.83	11868.63	31493.64	84415.62

INVESTMENT

	1977	1970–77	1977–81	1977–86
CHEMICAL INDUSTRIES				
PETROCHEMICALS	4.47	27.63	9.37	22.06
VINYL CHLORIDE	79.39	87.47	181.02	235.57
NITRIC ACID	3.98	34.34	3.26	4.80
SULFURIC ACID	72.58	499.05	144.27	325.92
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.00	7.51	1.97	4.79
MERCURY-CELL CHLOR-ALKALI	1.97	18.52	1.18	1.18
TOTAL INVESTMENT	163.38	674.51	341.08	594.32

ANNUAL COSTS

	1977	1970–77	1977–81	1977–86
PETROCHEMICALS	29.21	94.74	142.72	376.15
VINYL CHLORIDE	27.44	29.97	296.05	765.72
NITRIC ACID	12.99	44.91	56.35	121.26
SULFURIC ACID	131.59	433.89	646.93	1586.17
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.56	5.17	7.37	16.12
MERCURY-CELL CHLOR-ALKALI	8.24	28.83	35.05	71.32
TOTAL ANNUAL COSTS	211.01	637.50	1184.47	2936.75

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

INDUSTRY	1977	1970–77	1977–81	1977–86
			INVESTMENT	
METALS INDUSTRIES				
IRON & STEEL	320.28	1258.04	1281.12	1921.68
IRON FOUNDRIES	6.03	46.67	8.04	28.02
STEEL FOUNDRIES	18.97	177.49	25.19	53.82
FERROALLOYS	24.63	328.79	0.0	0.0
PRIMARY ALUMINUM	51.84	359.91	117.86	363.17
PRIMARY COPPER	90.00	1094.00	171.70	986.00
PRIMARY LEAD	2.16	20.28	1.29	1.29
PRIMARY ZINC	6.56	42.13	13.21	30.20
SECONDARY ALUMINUM	2.44	15.64	5.28	12.41
SECONDARY BRASS	1.59	13.32	1.92	3.62
SECONDARY LEAD	1.75	12.42	2.88	6.02
SECONDARY ZINC	0.32	2.97	0.19	4.28
TOTAL INVESTMENT	526.56	3371.65	1628.67	3410.52
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
IRON & STEEL	519.20	1320.59	3473.60	9900.35
IRON FOUNDRIES	7.08	24.10	32.03	81.48
STEEL FOUNDRIES	47.78	170.26	208.19	494.37
FERROALLOYS	70.16	346.91	250.71	399.86
PRIMARY ALUMINUM	95.96	323.82	444.67	1007.86
PRIMARY COPPER	199.25	802.96	1011.18	2549.96
PRIMARY LEAD	4.02	14.14	17.11	30.24
PRIMARY ZINC	36.46	126.13	172.49	434.72
SECONDARY ALUMINUM	4.35	14.35	21.33	56.09
SECONDARY BRASS	2.77	9.31	12.66	30.56
SECONDARY LEAD	2.53	8.56	11.80	29.27
SECONDARY ZINC	0.86	2.65	4.51	14.66
TOTAL ANNUAL COSTS	990.42	3170.78	5660.26	15029.38
			INVESTMENT	
	1977	1970–77	1977–81	1977–86
QUARRYING & CONSTRUCTION INDUSTRIES				
CEMENT	4.44	14.58	18.04	41.24
CLAY CONSTRUCTION	11.04	96.06	10.24	15.66
LIME	14.67	137.94	8.80	8.80
ASPHALT	25.63	252.80	59.23	94.76
TOTAL INVESTMENT	55.78	501.37	96.31	160.46
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
CEMENT	3.29	7.48	24.22	79.18
CLAY CONSTRUCTION	37.32	128.59	162.81	337.42
LIME	25.05	87.68	106.61	230.90
ASPHALT	93.72	352.33	426.51	915.16
TOTAL ANNUAL COSTS	159.39	576.10	720.14	1562.65

TABLE 1.-1. AIR POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

INDUSTRY	1977	1970–77	1977–81	1977–86
			INVESTMENT	
OTHER MANUFACTURING SERVICES				
PAINT MANUFACTURING	4.85	34.33	8.59	18.14
SURFACE COATING	0.0	0.0	658.82	1707.64
DRY CLEANING	10.04	141.75	6.75	13.27
TOTAL INVESTMENT	14.89	176.08	674.16	1739.06
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
PAINT MANUFACTURING	11.11	36.55	52.33	117.96
SURFACE COATING	0.0	0.0	374.38	1858.20
DRY CLEANING	23.07	86.06	95.58	156.53
TOTAL ANNUAL COSTS	34.18	122.61	522.30	2132.70
			INVESTMENT	
	1977	1970–77	1977–81	1977–86
FOREST PRODUCTS & AGRICULTURE				
KRAFT PAPER	250.00	862.50	412.50	425.00
NSSC PAPER	14.00	58.50	17.00	17.00
FEED MILLS	212.66	1700.61	323.81	812.97
GRAIN HANDLING	229.38	1623.20	446.14	968.38
TOTAL INVESTMENT	706.04	4244.80	1199.45	2223.34
			ANNUAL COSTS	
	1977	1970–77	1977–81	1977–86
KRAFT PAPER	120.80	247.75	678.20	1606.81
NSSC PAPER	9.68	22.87	54.97	129.72
FEED MILLS	301.52	1023.07	1370.31	3409.44
GRAIN HANDLING	272.03	880.71	1309.69	3359.65
TOTAL ANNUAL COSTS	704.03	2174.40	3413.17	8505.62

1.1 BASIS FOR COSTS

The costs reported here are developed and aggregated according to a self-consistent method. The comparison of these costs with costs for pollution control developed by other sources should be done with allowance for the constraints and conditions discussed below.

This report presents the costs of controlling air pollution as associated with the actions of the United States Environmental Protection Agency under the directions of Congress as given in the Clean Air Act and subsequent amendments. The specific regulations issued by the U.S. EPA may be identified in terms of the following classes of emissions or limitations:

- New Source Performance Standards
- Criteria Pollutant Limitations
- Hazardous Pollutant Standards
- National Ambient Air Quality Standards
- State Implementation Plans.

The Environmental Protection Agency has promulgated and is scheduled to continue promulgating specific regulations limiting the emissions of selected pollutants from various types of industrial plants to be built in the future; the development of these New Source Performance Standards (NSPS) thrusts upon the Agency the responsibility for the strategic selection of categories of industries and pollutants to be controlled under these regulations.

This report makes no attempt to analyze several new concepts to air pollution regulation, as follows:

- Reasonably Available Control Technology (RACT)
- Best Available Control Technology (BACT)
- Lowest Available Emission Rates (LAER).

These topics will be addressed in the future Cost of Clean Air reports.

Many of the pollutants controlled under the provisions of NSPS's correspond to the "criteria" pollutants that the Agency is called upon to control, namely

Sulfur Oxides (SO_x)
Nitrogen Oxides (NO_x)
Hydrocarbons (HC)
Particulates
Carbon Monoxide (CO).

Because the Agency has just recently added lead (Pb) to this listing, there has not been enough time to integrate the costs associated with proper control of lead.

The Agency is given a third approach to controlling specific air pollutants by classing them as "hazardous" pollutants; so far, pollutants regulated under this strategy include:

- asbestos
- beryllium
- mercury
- vinyl chloride.

However the Agency has also been called upon to issue National Ambient Air Quality Standards (NAAQS) specifying levels of "criteria pollutants" in ambient air which will protect human health (primary air quality standard), or, as a further development, the total environment (secondary air quality standard). These basic tasks of the Environmental Protection Agency have been expanded in manifold ways through both amendments to the law and interpretive rulings. The ramifications are discussed in part later in this Introduction and in part in Chapter 2. In connection with National Ambient Air Quality Standards, the EPA is further required to approve (or disapprove) the methods by which states propose to achieve the NAAQS's, those methods being formalized as State Implementation Plans (SIP's). Thus, costs imposed upon industry in the course of compliance with SIP's are reported here as resulting from an extension of Federal authority. This report, written in 1977 and 1978, does not include cost effects of the new SIPs to be submitted to EPA in 1979.

The costs reported here are those associated with compliance with the above array of regulations, and thus exclude money spent on air pollution control under various other motivations, such as:

- money spent prior to 1970, the date of the Clean Air Act
- money spent in voluntary clean-up
- money spent to comply with local or state regulations that are not motivated by the Clean Air Act (e.g. nuisance laws to control odors)
- money spent for air-pollution control devices which are installed for reasons of business economics (e.g. materials recovery).

The industries covered in this report are those identified as contributing significant amounts of pollutants to the air and therefore being the subjects of specific regulations. Such coverage of industry categories is the best possible depending on the available information. With the available resources, industry categories are added, updated, or treated in expanded detail according to the best judgement of those responsible for the conduct of the program, and with due regard for other cognizant and interested parties.

Definitions and Procedures

All costs are expressed in constant dollar values, specifically in "July 1, 1977 dollars." No inflation factor is included in the projection of costs into the future.

Unless otherwise specifically noted, all tabulations are in millions of 1977 dollars.

All physical quantities have been stated in metric tons or other metric units, usually with common "engineering usage" units stated in parentheses. It is recognized that "metric tons" is not a unit in the System Internationale and should most strictly be expressed as a "megagram." However, in recognition of the current stages of transition toward "metrification", and in the anticipation of a readership not totally technical, the "common" metric units have been used.

The time periods used for the aggregation of costs are based upon certain milestones:

1970—passage of the Clean Air Act
1977—base year of this report
1986—selected year for projection of costs.

The "cost year" used in this report is taken from July 1 to June 30. This type of year was chosen on the basis that many regulations require compliance by July 1 of a given year. (This is especially true in the companion effort on the cost of water pollution control.) Further, during the period of preparation of this report, the fiscal year was in a state of transition, being a period of more than twelve months. Government expenditures are reported in terms of fiscal years.

1.2 METHODOLOGY

The approach used to develop the costs reported here consists (in most cases) of a sequence which starts with a detailed description of an industry segment and progresses to an aggregated cost reported for an overall industry. This methodology involves the work of a specialist who is familiar with many of the technical and economic aspects of a specific industrial activity.

A typical pattern of cost development by a specialist/chapter-author involves the detailed identification of processes, emissions, regulations, control technology, and control costs specific to an identifiable group of industrial activities or plants. This group of plants is then, on the judgement of the specialist, expressed in terms of a number of model plants of various sizes which represent a close approach to the actual numbers and sizes of plants and the total capacity of that group of plants. A hypothetical example of such a listing might appear as:

Number of Plants	Average Capacity tons/day
80	4.0
40	15.5
12	27.0

An expression of cost is then developed for a given control technology which takes the form:

$$\text{Cost} = A(\text{Capacity})^B$$

where A is a coefficient
and B is an exponent.

This expression relates the cost of control to the size of the plant (larger plants usually benefit from economies of scale). The cost equation is developed from existing cost data in that industry group. The cost of control can be calculated for the above example list of plants by calculating the cost for each size and multiplying by the number of plants of that size and adding the three size categories together.

This approach may be broken down into groups of plants determined by all combinations of:

- regulations (e.g., SIP's and NSPS's)
- control technologies (e.g., scrubbers and baghouses)
- new and existing plants
- other specific conditions.

Each set of special conditions may be costed separately and summed into the aggregate industry cost. Also, the growth rate of the industry is expressed in terms of the model plants. For example, a common trend is for smaller plants to close and be replaced by larger plants. This is significant in pollution control costs in that the control costs would, in this example, benefit from the economies of larger-scale operations. The use of projected growth rates in production output expressed as percentage increases (compared to specific predictions of plant construction) was selected for this methodology because of the requirement for projections, which are beyond the plant construction plans of industry.

A special case of this methodology is occasionally encountered in industries with very few plants. In these cases, the "model" plants are actually the real plants and control costs are based on estimates for each individual plant.

In some cases, cost data are obtained from special economic studies of the impact of the cost of pollution control on a specific industry. These economic impact studies, usually commissioned by the Environmental Protection Agency, are used as the basis for costs in this report when appropriate. The use of these documents improves the consistency and coherency of this report with other EPA publications. In some of these economic reports, the plant sizes, specific costs, etc., are not presented in detail corresponding to the above procedure. In these cases, cost data from the economic study are transferred empirically (i.e., exogenously) to the computer and reported in a form consistent with the findings of the base document. In these cases, the reported costs do not necessarily conform to the standard format, e.g., new plant costs may not be identifiable as such (relative to costs for existing plants), although costs projected into the future include costs to both types of plants. Similarly the base document may not use the same breakdown of annual costs or the same interest rate as is normally used in the existing computer program. Nevertheless, the overall costs and timing of the costs are reported as developed in the designated source document.

In this connection, the timing of capital investment and the associated rate of accrual of the annual

costs reflect both historical data (i.e., from 1970 to the most recent available data) as well as projected rates of investment by the particular industry segment. Projected rates of spending are largely based on the compliance date specified in the pertinent regulation with allowance for lead time required for fabrication, construction, and installation of the control technology involved. Also applied are investment schedules developed by other programs of the Environmental Protection Agency.

Thus, the information utilized in developing the costs reported here includes:

- a "model plant" description of the industry which includes a statement of industry capacity
- a statement of industry growth rate related to the model plant structure
- the identification of standards and dates of compliance
- the identification of costs of control for various plant sizes and regulations
- where appropriate the identification of money spent before the date of the Clean Air Act (1970) and in some cases, the timing of capital investment over the time period of interest
- the estimated life of the control equipment.

With these types of input, the computer program performs calculations, for each year in the period 1970 through 1986, of capacity based on each size class of model plant, and the cost of control for that class under the regulations pertinent for that year. At the year of compliance for New Source Performance Standards, all new expansion of capacity is costed according to the cost equation for new plants (usually different than for existing plants complying with the requirements of State Implementation Plans). The program thus generates a statement of capital investment, operating and maintenance costs, and annual costs for capital investment for each class of plants. These costs may be aggregated by industry segment, industry, or groups of industries for any year or span of years depending on the report desired.

For the calculation of the annual cost of capital, the computer program uses straight-line depreciation over the stated life of the control equipment and an interest rate of ten percent. It is understood that other systems of depreciation are used, that other interest rates are sometimes applicable, that "opportunity costs" for other uses of capital are not taken into account, and that tax write-offs are commonly applied to control equipment. The ten percent interest rate is used to signify the "social cost" of capital; likewise tax write-offs are excluded, since society ultimately bears the cost of pollution abatement. Thus, the costs reported show a total cost to society, which may not be borne directly by the industry.

The above methodology is applied to develop the costs for the larger portion of industry costs. Exceptions where exogenous cost data from economic studies have been accommodated have been mentioned before.

Two other areas of costs are reported here which are developed on different bases. Costs to government are reported based on expenditures as scheduled in legislation. The costs of control of mobile sources (automobiles, aircraft, etc.) are not subject to the above methodology; their development is described within the text of Chapter 4.

1.3 FUTURE COSTS

The following paragraphs contain a discussion of the major areas of direction contained in the 1977 Amendments and indicate the types of costs that can be expected to be incurred in each case.

SIP REVISIONS - ATTAINMENT AND MAINTENANCE

Introduction

The Clean Air Act of 1970 provided for the establishment of National Ambient Air Quality Standards (NAAQS), including primary standards to protect public health and secondary standards to protect public welfare. Each state was required to submit for EPA's approval a State Implementation Plan (SIP), detailing the state's strategy for attaining and maintaining the NAAQS. Under the 1970 legislation, all states were to have attained primary standards by July 1, 1975, with a few exceptions where extensions were granted to mid-1977. Secondary standards were to be attained within a "reasonable time", usually the same time period as the primary standards.

The Clean Air Act Amendments of 1977 specify that in areas not attaining NAAQS, (nonattainment areas) the SIP's must now be revised and submitted to EPA for approval by July 1979. The revised plans are required to impose measures representing reasonably available control measures (RACM) on existing stationary sources and transportation strategies for mobile sources (such as inspection and maintenance programs) which levels of control take cost and other factors into account. For major new or modified sources, the revised plans must require lowest achievable emission rates (LAER). Other specific requirements are described below.

Nonattainment Areas

The 1977 Clean Air Act Amendments extended the statutory attainment dates to December 1982 for all pollutants. In the case of photochemical oxidants (ozone) and carbon monoxide, Congress recognized the difficulty that areas with problems dominated by automobile emissions would have in demonstrating attainment by the earlier date. In such cases, an additional five years, to 1987, may be permitted. If the additional five-year extension is needed, the state must submit a revised SIP in 1979 which demonstrates that attainment is not possible by 1982 despite the application of all reasonably available control measures. Extensions of attainment dates beyond 1982 require the implementation of an inspection/maintenance (I/M) program.

Where an extension has been granted, the state must adopt by 1982, the remaining enforceable measures necessary to attain standards for photochemical oxidants and/or carbon monoxide.

If a state is unable to submit an SIP that can demonstrate attainment of national standards and which can be approved by EPA, specific sanctions are invoked under the Act including no major source construction after July 1979 and restrictions on federal funds for highways and wastewater treatment facilities. A major source is defined as one which has the potential of emitting at least 100 tons of pollutants per year before controls.

Prior to attainment of standards, the Clean Air Act Amendments call for interim progress in emission reductions on an annual basis, which will provide for attainment by the statutory dates. There is an explicit requirement that to the extent possible these reductions should be realized in early years. Growth must take place within the framework of a plan which will achieve health-based standards:

Prior to July 1979, the EPA offset ruling is in effect. There are four key conditions to the offset ruling:

- For every ton of emissions from a new source, there must be an offsetting emission reduction for existing sources of greater than one ton;
- The new source must meet the lowest achievable emission rate (LAER) which is the lowest rate achieved in practice or the lowest emission limitation set forth by a SIP for that same class or category of sources;
- All existing major sources owned and operated in the same state by the firm operating the new source must be in compliance with the applicable emission limitations and standards, or be meeting the target dates of a compliance schedule; and

- These offsets must provide a positive net air quality benefit in the nonattainment area.

After July 1979, states are given a choice of two options as to how to handle new growth. The state can either:

- Create a quantitative margin for growth within the state implementation plan by imposing emission limitations on existing sources to a greater degree than minimally necessary to meet standards; or
- Continue some form of case-by-case emission offset approach.

In many cases the states will provide for a combination of both approaches. With either option new major sources must meet the lowest achievable emission rate.

Transportation Control Plans

The 1977 amendments to the Clean Air Act permitted a five-year extension of the 1982 deadline for achieving carbon monoxide and photochemical oxidant standards. This extension is contingent on a state demonstrating in its 1979 State Implementation Plan (SIP) that attainment is not possible by 1982 despite the implementation of all reasonable stationary and transportation control measures.

Most major urban areas with carbon monoxide and photochemical oxidant problems will be unable to meet the air quality health standards by 1982 through reliance on stationary source controls and federal new car standards alone. These areas therefore will be required to develop and implement such transportation strategies as mass transit improvements, preferential bus and carpool treatment, areawide carpool programs, parking management, pricing, auto-restricted zones, etc. — which are all designed to reduce auto emissions.

In order to achieve reasonable progress toward these standards, EPA is requiring the 1979 SIPs to demonstrate a commitment to (1) accelerated implementation of specific strategies (e.g., transportation improvements contained in the current or recent plans); (2) the incremental phase-in of additional strategies; and (3) a schedule of activities leading to implementation of an inspection/maintenance program by 1981 (decentralized system) or 1982 (centralized system).

Congress authorized $75 million in planning funds in the 1977 CAA Amendments. $50 million was appropriated in fiscal year 1979 to support the first year of the local planning process. The Department of Transportation also contributes funding for these grants to local governments. These funds are discussed further in the Cost to Governments Chapter.

Prevention of Significant Deterioration (PSD)

In 1972, the Sierra Club and other environmental groups filed suit against EPA for failure to promulgate regulations under the Clean Air Act to prevent the significant deterioration of air quality. Both the District Court of the District of Columbia and the U.S. Court of Appeals for the District of Columbia Circuit granted the Sierra Club's motion and required EPA to promulgate significant deterioration regulations. In June 1973, the Supreme Court, by a four-to-four vote, affirmed the judgement of the Court of Appeals.

After extensive public participation and technical and economic analyses, EPA published final regulations in December 1974, which are based on allowable increments of pollutant concentrations for specific categories of new major industrial sources under an area-classification procedure. Subsequently, the Administration, as part of the Energy Independence Act of 1975, requested Congress to consider legislation which would clarify Congressional intent on the prevention of significant deterioration of air quality. The Administration requested that Congress carefully examine the potential effects of a significant deterioration policy, including the consideration of its complete elimination as well as other alternative approaches. In addition, Congress was asked to provide guidance that would allow a balancing of environmental, economic, and energy concerns in any legislative determination of the significant deterioration issue.

The Clean Air Act Amendments

The 1977 Amendments adopted EPA's basic approach to PSD standards. Significant deterioration is prevented by establishing area classifications designed to correspond to the overall air quality intended for the area, and to reflect the amount of energy or industrial growth desired. Three "classes" were established as follows:

- Class I — Applies to areas in which practically any air quality deterioration would be considered significant, thus allowing little or no energy or industrial development.
- Class II — Applies to areas in which deterioration that would normally accompany moderate, well-controlled growth would not be considered significant.

- Class III — Applies to areas in which deterioration would be permitted to allow concentrated or very large-scale energy or industrial development.

All existing international parks, national wilderness areas, memorial parks larger than 5,000 acres, and national parks larger than 6,000 acres are designated Class I. These lands may not be redesignated into a different class. All other regions are initially designated as Class II. They may be redesignated by a state into either Class I or Class III, subject to various public hearing and analysis requirements.

Each class has maximum specified allowable increments of air quality deterioration. Major new and modified sources are subject to preconstruction review, and must meet New Source Performance Standards (NSPS). These sources must conform to Best Available Control Technology (BACT) requirements. Under EPA's proposed regulations, all new major stationary sources and modified sources commencing construction or modification after December 1, 1978, must conform to these standards.

New Source Performance Standards

The Amendments also clarify certain aspects of New Source Performance Standards which had previously been evolved by the Agency (e.g., clarification of the term "modification"), but most significantly set rather stringent rules regarding fossil-fueled sources. The Amendments essentially require the use of either coal cleaning or flue-gas desulfurization for all new sources. This limits the preferential use of low-sulfur coal, and should avoid any disruption of the potential supply of coal from various sources. The Amendments also specify that emission control strategies must be based on continuous control equipment rather than tall stacks or intermittent controls such as production cutbacks.

Visibility Goals

The 1977 Amendments speak to a new aspect of air pollution in that they call for the Agency to develop appropriate analyses, methods, and regulations to protect the condition of visibility from degradation by man-made air pollutants. This direction is applicable to Class I areas, e.g., national parks, etc.

Cost Implications

The discussion herein concerns the cost of implementing the policies and regulations for nonattainment areas and for PSD regulations. The discussion in general is qualitative in that specific cost figures are not presented. Cost data were not available for this study. Few if any of the respective state agencies have entered the cost-analysis phase. The task is complex and will require significant resources.

The cost of air quality attainment and maintenance measures can be divided into direct and indirect costs. Direct cost can be estimated with considerable accuracy.

The direct costs include all expenditures required of a source, such as investment and operating costs for control equipment, incremental costs of fuel switching, costs of production process changes, emissions monitoring costs, administrative costs for accounting and reporting, costs of supervision of operating personnel, and costs required of the governmental unit for implementing a measure, such as operating costs for permit review programs, monitoring of air quality, reviews of source emission reports, and source surveillance. Indirect costs include the effects on sectors of the economy that are not required to respond to a particular maintenance measure, such as price changes for materials or products, costs associated with changes in behavioral patterns, and costs of increased solid waste and water pollution control.

The following potential cost implications are noted:

1. For existing stationary sources, RACM requirements will vary from state-to-state, from region-to-region, and even from source-to-source. The requirements will allow for the retrofitting of existing processes, taking technological feasibility and cost into account.

2. For mobile sources, inspection and maintenance programs may be instituted in certain areas. This will involve additional costs to automobile owners (for maintenance) and to the municipal or state governments (for inspection). Such costs are expected to be minimal to the consumer.

3. Major new sources in nonattainment areas may have increased costs over NSPS or BACT costs in order to comply with the LAER requirements. Finally, depending on how the state allows for new growth, there may be additional costs associated with an offset market or other state-adopted growth programs.

4. "Major sources" as defined by the Clean Air Act Amendments is broadened to include all sources which "potentially" emit 100 tons per year or more of any pollutant. EPA has interpreted this to include sources whosa emissions before controls would have been 100 tons. However, sources whose "allowable" emissions (after application of LAER) would be below 50 tons per year are not considered major sources. The effect of this change is to increase the number of sources covered by nonattainment and PSD regulations.

5. Under the PSD requirements, major new or modified sources may incur additional costs complying with BACT. The standards and associated costs will vary depending on the class designation of the region where the new source is locating.

2. COSTS TO GOVERNMENT

GOVERNMENT EXPENDITURES FOR AIR-POLLUTION CONTROL

The Clean Air Act Amendments of 1970 (P.L. 91-604) impose somewhat different requirements on governmental agencies than on others affected by the legislation. Although there will be some expenditures for abatement of pollution from government-owned facilities, the principal purposes of expenditures in the government sector are for research, monitoring, administration, and enforcement. Research is supported mainly by Federal funds, while state and local funds, supplemented by Federal grants, are used primarily to implement, operate, and maintain monitoring and enforcement programs.

Detailed analyses are not presented here since the main purpose of this effort is to determine the magnitude of this category of expenditures relative to other expenditures estimated in the report.

Table 2-1 shows projected governmental expenditures broken down into EPA, non-EPA, and state and local categories. A stable rate of expenditure after FY 1978 is assumed due to governmental revenue constraints and competing social needs.

Total expenditures by government for air-pollution control are expected to be about 5.6 billion dollars during the period 1977 to 1986. Excluding grants to state and local governments, EPA and non-EPA (other Federal) expenditures are estimated to be about 18 and 41 percent, respectively. This assumes stable outlays for air-pollution control starting with FY 1978. EPA grants to state and local governments are expected to be between 60 and 80 million dollars per year throughout the decade. Total expenditures by state and local governments are estimated to be from 2.2 to 2.8 billion dollars.

Table 2-1
Projected State and Local and Federal Air Quality Program Costs
(by fiscal year in million dollars)[1]

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
EPA[2]	99	103	103	103	103	103	103	103	103	103	1026
Non-EPA (Federal)	229	229	229	229	229	229	229	229	229	229	2290
Total Federal	328	332	332	332	332	332	332	332	332	332	3316
State and Local	211	230	230	230	230	230	230	230	230	230	2281
Total	539	562	562	562	562	562	562	562	562	562	5597

[1] Costs have been adjusted to reflect July 1, 1977 dollars.
[2] Excluding grants to state, interstate, and local governments which are included in the state and local category.

Source: Special Analyses, Budget of the U.S. Government, Fiscal Year 1978, pp. 312-330. GPO.

FEDERAL, STATE, AND LOCAL PROGRAM COSTS

The Clean Air Act authorizes a national program of air-pollution research, regulation, and enforcement activities. Under the Act, primary responsibility for the prevention and control of air pollution rests with state and local governments, with the program directed at the Federal level by EPA. EPA's role is to conduct research and development programs, set national environmental goals, ensure that adequate standards and regulations are established to meet these goals, assist the states, and ensure that the standards and regulations are enforced effectively.

One of the set of environmental standards is the National Ambient Air Quality Standards (NAAQS). These standards set forth the allowable concentra-

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tion in air of pollutants which affect human health and public welfare. The health and other effects of pollutants are delineated in criteria documents which are the basis for the standards. NAAQS standards have been set for total suspended particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide, photochemical oxidants, and hydrocarbons, and more recently—lead. Two types of standards are set: primary standards to protect human health, and secondary standards to protect the public welfare (prevent damage to property, animals, vegetation, crops, visibility, etc.). Controlling emissions to meet standards is handled through two major types of activities: (1) states carry out State Implementation Plans (SIPs) which control pollution primarily by prescribing specific emission limitations or control actions for types of polluters and (2) EPA controls emissions from new motor vehicles and selected stationary sources.

Program emphasis will continue to be on attaining and maintaining the NAAQS standards. Because the implementing of control actions is basically the responsibility of the state and local governments, it will be required that they take on increased responsibilities for air-pollution control if the standards are to be attained, particularly if automotive vehicle-related pollutants are to be controlled. The state control plans incorporate controls for automotive vehicle-related pollutants since reductions achieved as a result of the Federal motor vehicle control program are not sufficient to attain the standards for such pollutants in many areas. The Federal program places primary emphasis on increasing state and local control agencies' ability to control air pollution.

To attain the standards, efforts are to concentrate on the generation of State Implementation Plans, their reassessment, and revision if indicated. For maintaining the standards, many SIPs will have to be revised to include the controls required to assure that the ambient-air-quality standards are not violated in the future. The governors of 45 states have been formally notified by EPA Regional Administrators that the SIPs for their states must be revised in order to attain and maintain the NAAQS. Plan revisions are necessary in 34 states for particulate matter; 14 states for sulfur dioxide; 24 states for carbon monoxide; 27 states for photochemical oxidants; and 4 states for nitrogen dioxide.

The nature and magnitude of the problems associated with attainment and maintenance of the NAAQS varies with the specific pollutant involved. Federal programs will be aimed at formulating methodologies for developing control strategies, developing control systems, and supporting state and local programs. Maintaining the standards in the long term will also be facilitated by Federal programs that lead to minimizing emissions from new sources (i.e., new motor vehicle emission standards and standards of performance for new stationary sources) and assuring continued low emissions performance for these sources during their useful lives.

Program expenditures by the EPA are expected to remain level for the next several years, with the states gradually assuming greater responsibility for implementation of the various provisions of the Act. Table 2-2. shows projections of expenditures for the three major appropriations categories.

Table 2.-2.
Projection of EPA Program Expenditures by Category
(by fiscal year in millions of 1977 dollars)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
Abatement and Control	99	103	103	103	103	103	103	103	103	103	1026
Enforcement	16	20	20	20	20	20	20	20	20	20	196
Research and Development	48	44	44	44	44	44	44	44	44	44	444
Total	163	167	167	167	167	167	167	167	167	167	1666

Includes grants to state, interstate, and local government.

EXPENDITURES BY OTHER FEDERAL AGENCIES

Although covering a wide range of activities, Federal environmental programs are classified in three broad categories: pollution control and abatement; understanding, describing, and predicting the environment; and environmental protection and enhancement activities. It is difficult to attribute non-EPA Federal expenditures to specific pollution-control legislation in many cases, but an approximation of P.L. 91-604-related expenditures is given by the air-quality expenditures in the Pollution Control and Abatement category. Principal activities in this category include actions necessary to reduce pollution from Federal facilities; establishing and enforcing standards; research and development; and identifying pollutants, their sources, and their impact on health. Non-EPA air quality expenditures by the Federal government are estimated to be about 229 million dollars per year.

Since Federal spending is strongly influenced by policy and competing social needs, forecasting is always difficult. The best estimate currently is that such expenditures will remain stable over the next several years, with only minor growth or decline. If non-EPA Federal outlays in this category were to be held constant at the FY 1977 level, total decade expenditures would be about 2.3 billion dollars. While this is a large amount on an absolute basis, it is relatively small compared to total expenses in the nation in response to P.L. 91-604.

It is important to note that the environmental activities proposed in the 1977 Clean Air Act Amendments have not been considered in projecting government expenditures from the period 1977 to 1986. Because of this, the cost projections presented in this chapter maybe on the low side. The activities that may result in higher governmental expenditures include: accelerations of development of new source performance standards, promulgations of possibly three or four additional national emissions standards for hazardous air pollutants, and possible revisions and additions to the National Ambient Air Quality Standards.

The impact of the 1977 Amendments to the Clean air Act on government expenditures has yet to be determined specifically. The Amendments contain authorizations of amounts for various activities and periods of time but these are not necessarily identical with the appropriations or outlays which actually occur. The authorizations in the Amendments may be summarized as follows:

Amount	Activity
$75,000,000	One-time grants in support of State planning activities including traffic control plans under Section 175
$10,000,000	In support of the National Commission on Air Quality under Section 323
$16,000,000	Grants in support of Public Notification activities under Section 127; $4,000,000 in each of fiscal years 1978, 1979, 1980, and 1981
$30,000,000	Authorized in terms of $7,500,000 in each of fiscal years 1978, 1979, 1980, and 1981 in support of manpower training under Section 103 (a)(5)
$157,000,000	Authorized for EPA for fiscal year 1978
$120,000,000	Authorized for research, development, and demonstration under Sections 103 and 104; for fiscal year 1978.

As stated above, such authorizations are difficult to interpret in terms of actual outlays by various agencies. However it would appear that the above authorizations, in combination with the directions for increased efforts towards air-pollution control, will result in expenditures greater than those given in the preceding tables.

3. ENERGY INDUSTRIES

For the purpose of this report, the broad category "Energy Industries" was defined to include those industries which gather, transfer, process, and deliver energy to the consumer. These include: Fossil Fuel-Fired Electric Power Plants, and, because of the similarities with other industries included in this category with respect to technology, Commercial and Industrial Heating Boilers. Also included are a group of industries which process and deliver fuels to various consumers. These include:

- Natural Gas Processing
- Petroleum Refining and Storage
- Coal Cleaning
- Coal Gasification.

One important and relevent subject not included here appears in another Chapter.

- Producing and using gasoline with little or no lead is discussed in Chapter 4, "Mobile Source Emission Control".

Air pollution abatement costs are summarized in Table 3–1.

TABLE 3.-1. AIR POLLUTION ABATEMENT COSTS FOR THE ENERGY INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1970–77	1977–81	1977–86
FOSSIL FUEL POWER PLANTS	2850.92	11489.03	10174.58	18276.43
COMMERCIAL & INDUSTRIAL HEATING BOILERS	238.11	1970.21	268.26	465.11
NATURAL GAS PROCESSING	9.35	19.92	45.75	127.65
PETROLEUM REFINING	167.23	745.85	393.72	537.17
COAL CLEANING	12.88	75.24	0.0	0.0
COAL GASIFICATION	0.0	0.0	70.44	412.03
TOTAL INVESTMENT	3278.49	14300.23	10952.74	19818.39
		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
FOSSIL FUEL POWER PLANTS	4106.02	10076.90	28810.93	76395.50
COMMERCIAL & INDUSTRIAL HEATING BOILERS	349.02	1189.57	1547.50	3634.55
NATURAL GAS PROCESSING	27.56	137.13	134.67	375.13
PETROLEUM REFINING	136.12	400.56	773.86	1981.58
COAL CLEANING	13.13	64.47	52.51	109.56
COAL GASIFICATION	0.0	0.0	174.18	1919.48
TOTAL ANNUAL COSTS	4631.83	11868.63	31493.64	84415.62

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3.1 FOSSIL FUEL-FIRED ELECTRIC PLANTS

Operating Characteristics

Among the largest stationary sources of air pollution are the coal-, oil-, and natural gas-fired steam electric plants. Of the three fuels, coal results in the most air pollution, and natural gas in the least and gas is the most convenient to use. In 1975, more than 65 percent of the steam coal (on the basis of energy content) consumed in the USA was used for power generation. About 16 percent of all fuel oil consumed and 10 percent of natural gas consumed were used for the same purpose. The oil consumption by this industry is primarily residual oil which has a higher potential for air pollution than the lighter fractions, i.e., higher sulfur and ash content. It is apparent from these estimates that utility power plants have a major air pollution control problem, because they burn the most polluting fuels in the largest quantities.

Emission Sources and Pollutants

The emissions resulting from the use of each fuel in a typical uncontrolled 1,000 megawatt power plant are given in Table 3.1-1.

Table 3.1-1.
Emissions For a Typical Uncontrolled 1000 Megawatt Power Plant By Fuel Type
(in kilograms per hour, pounds per hour in parentheses)

Fuel	Particulates	SO_x	NO_x
Coal	69,000 (152,000)	41,000 (90,000)	13,000 (27,000)
Oil	600 (1,300)	12,500 (27,500)	8,600 (19,000)
Gas	170 (375)	7 (15)	6,800 (15,000)

Natural gas is the preferred fuel from an emissions standpoint. Gas provided 21 percent of the heat for generating electricity produced in 1975 from fossil fuels. The use of gas for power generation is being strongly discouraged by Federal policy and is expected to decline drastically. The growing fossil fuel demand will be supplied by coal and to a lessened degree by residual oil.

For utility power burners, despite the potential switch from oil to coal in many power plants, residual fuel oil will continue to supply a significant fraction of the energy required in 1980. Fuel oils for utility burners contain sulfur (typical sulfur contents average about 0.7 percent for United States crude oils and about 2.2 percent for imported crude oils), much of which is removed from the final product before burning. Alaskan crude contains a higher percentage of sulfur. The ash from fuel oil combustion is low, about 0.5 percent.

The most abundant fossil fuel in this country is coal. In 1975, about 364 million metric tons (400 million short tons) of coal were burned to produce about 45 percent of the electrical power. The resources of coal are widespread throughout the United States, but coal has not been used in proportion to its availability in comparison with the other fuels.

Coal typically has an ash content of 9 percent, although it varies widely. Most large utility boilers burn the coal in pulverized form, thus releasing most of the residual ash suspended in the combustion products, while only a small amount is retained in the boiler. About 85 percent would be emitted from a dry-bottom boiler, and 65 percent from a wet-bottom boiler. Resulting uncontrolled particulate emissions into the atmosphere would be orders of magnitude higher than those from the other fossil fuels, and would exceed allowable emissions. Particulate controls of varying efficiencies are found on all but the smallest coal-fired power plants, the most prevalent being electrostatic precipitators.

Sulfur dioxide emissions from coal burning are also serious and more difficult to control. In current commercial practice, all the sulfur in the coal is emitted from the boiler as gaseous oxides, the bulk of which is sulfur dioxide with a small fraction emitted as sulfur trioxide (usually less than 5 percent). To reduce the initial emission of sulfur oxides, a coal of low-sulfur content might be chosen. However, much of the Eastern low-sulfur coal is reserved for use as coke by the metals industries. In only a small percentage of current coal production is the sulfur content low enough to meet New Source Performance Standards. The Western low-sulfur coals are attractive insofar as they have permitted some plants to meet Federal and local SO_x emission regulations.

The use of coal to supply increasing amounts of electric power in the near future seems unavoidable, considering the domestic supply of oil and gas, and the international balance-of-payments problems associated with imported gas and oil.

Table 3.1–2 is a 1976 projection by the Electric Power Research Institute (EPRI) of the use of coal in the generation of electricity:

Table 3.1–2.
Projected Use of Coal For the Generation of Electric Power (in percentage of energy generated) by year

1975	45.2%	1981	48.7%
1976	46.9%	1982	48.5%
1977	47.0%	1983	47.3%
1978	48.1%	1984	47.0%
1979	48.3%	1985	46.7%
1980	48.9%		

Although the percentages are expected to remain relatively constant, it must be remembered that the total production is expected to increase by 87 percent during this period. Therefore, the amount of coal burned to generate electricity will nearly double in this period on a tonnage basis, and stringent sulfur oxide emission controls must be maintained. In addition to burning inherently low-sulfur coal, other strategies are possible, such as removal of sulfur from flue gases, removal of sulfur from high-sulfur fuels before burning, and burning high-sulfur coal in a manner to contain the sulfur largely as a solid residue (ash), as is accomplished in fluidized-bed combustion systems now being developed.

NO_x emissions result from both the combustion of nitrogen compounds contained in the fuel, and from thermal fixation of atmospheric nitrogen at very high combustion temperatures. In general, coals contain more nitrogen compounds than other fossil fuels and combustion control techniques to attain low NO_x emissions are currently being developed.

The uncontrolled and controlled emissions from utility fossil-fuel burners may be estimated from known (measured) emission factors, for the first case, and from the capability of the various control techniques in the second.

Emission Standards

The EPA has established emission standards for new fossil-fuel-fired power plants as follows.

Pollutants	Type of fuel burned	Maximum allowed emissions in micrograms per joule fired, with lb per million Btu fired in parentheses
Particulates	all	0.043 (0.1)
SO_x	liquid	0.34 (0.8)
	solid	0.52 (1.2)
NO_x	gas	0.086 (0.2)
	liquid	0.13 (0.3)
	solid	0.30 (0.7)

The separate states, however, have established emission standards for existing sources, usually depending on the size of the boiler. For the larger sizes, greater than 10.6 tera-joules/hr (greater than 10.0 billion Btu/hr), the ranges of state standards are as follows.

Pollutants	Type of fuel burned	Maximum allowed emissions in micrograms per joule fired with lb per million Btu fired in parentheses
Particulates	all	0.008 (0.02) to 0.34 (0.8)
SO_x	liquid	0.13 (0.3) to NR
	solid	0.15 (0.34) to NR
NO_x	gas	0.86 (0.2) to NR
	liquid	0.13 (0.3) to NR
	solid	0.13 (0.3) to NR

NR – No regulation.

The Federal standards are likely to be made appreciably more stringent in the future, as the total national emissions increase and control technology is improved. The standards shown here have been used in this report, however. Should new, more stringent standards be adopted, the costs of meeting the standards will be correspondingly increased.

Control Technologies and Costs

The following paragraphs analyze the different technologies presently employed to control sulfur oxides, nitrogen oxides, particulates, and the related costs.

Sulfur Oxides

Considering the present economic and regulatory environment, there are several options open for utilities in their choice of a control strategy for application. Changes in Federal regulations, taxes, and costs can alter these choices drastically. When controls are needed to meet State or Federal standards, three immediately available strategies are:

- Burn low-sulfur coal as a substitute fuel, possibly involving long hauls and expensive charges
- Utilize washing and blending of coals to reduce sulfur content of the fuel fired to meet immediate local or national requirements
- Install and operate flue gas desulfurization scrubbers.

Under the recent regulatory system it was estimated that the following strategies will be adopted:

Table 3.1–3.
SO_x Compliance Methods by 1985
(million kw)

	Pre-1974 Units	1974–1976 Units	1977–1985 Units	Total 1985 Capacity
No Additional Control Needed	70.2	4.6	—	74.9
Washing/Blending	37.2	—	—	37.2
Medium—Sulfur Coal	21.8	11.4	—	33.2
Low—Sulfur Coal	1.4	2.2	66.2	69.8
Scrubbers	42.9	11.5	63.5	117.9
Coal Capacity	173.5	29.7	129.7	332.9

The capital and operating costs vary depending on whether a new plant or a retrofit is involved. Federal regulatory actions may result in an increase in the use of scrubbers above these estimates, permitting the burning of more high-sulfur coal while reducing SO_x emissions.

Other techniques for utilization of high-sulfur coal while reducing sulfur emissions are being developed, but are not expected to have significant impact on the utility industry before 1985. These include:

- Fluidized-bed combustion
- Coal-derived liquid fuels with low sulfur cintent
- Chemical desulfurization of coal
- Coal gasification and desulfurization
- Alternative non-fossil fuels co-fired with coal.

Particulate

The choice of SO_x control in many instances affects the requirements for particulate control, so these strategies often must be considered together. The two principal techniques used by the power utilities are electrostatic precipitators and venturi scrubbers. The substitution of low-sulfur and/or high-ash coal often requires substantial upgrading of the precipitators. The decision to use flue gas desulfurization scrubbers is usually accompanied by the use of venturi scrubbers for particulate control. Only 40 percent of existing plants have been estimated by EPA as being able to meet regulations with current equipment.

The following table presents the options for particulate control, their expected applications to meet compliance, and the associated costs.

Table 3.1–4.
Particulate Compliance Methods by 1985
(million kw)

	Pre-1974 Units	1974–1976 Units	1977–1985 Units	Total 1985 Capacity
Total kw requiring no additional controls	71.1	—	—	71.1
Precipitators	81.3	18.2	66.2	165.7
Particulate scrubbers	21.1	11.5	63.5	96.1
Total Coal capacity	173.5	29.7	129.7	332.9

Nitrogen Oxides

Emissions of these pollutants can be reduced by applying staged combustion and off-stoichiometric firing. The unit costs for a 500 megawatt plant burning coal, oil, and gas were used in assessing the total cost of control. Emissions of nitrogen oxides are being abated by the above techniques now in some locations. While it is recognized that this may not necessarily be universal, the costs obtained by this assumption will represent an upper limit for the period 1975–80. Variances and exemptions issued in Air Quality Control Regions (AQCR) where the ambient levels of this pollutant are not critical will of course lower the overall costs of control.

It appears that only AQCR's 24 and 67, (the boundaries of which encompass the cities of Los Angeles and Chicago, respectively,) will restrict nitrogen oxide emissions from utility burners. in Los Angeles, the 1975 total oil- and gas-fired capacity to be controlled amounts to 11,770 megawatts of coal-, oil-, and gas-burning facilities. An additional 2,000 megawatts of coal-burning capacity is estimated to be on-stream by 1978. Estimates of control costs in these two AQCR's were made and added to the national estimates for SO_x and particulate controls.

Total control costs for the control of air pollution from Fossil Fuel-fired Electric Plants are summarized in Table 3.1–5. Due to the nature of the available cost data, costs for new plants are included in the same category as existing plants.

TABLE 3.1–5. FOSSIL FUELED ELECTRIC POWER PLANT AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	2850.92	11489.03	10174.58	18276.43
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	2850.92	11489.03	10174.58	18276.43
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1510.51	4178.14	9628.12	27066.36
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	1510.51	4178.14	9628.12	27066.36
O&M				
EXISTING PLANTS	2595.51	5898.75	19182.80	49329.14
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	2595.51	5898.75	19182.80	49329.14
ALL ANNUAL COSTS	4106.02	10076.90	28810.93	76395.50

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.2 INDUSTRIAL AND COMMERCIAL HEATING

Operating Characteristics and Capacities

The majority of commerical and industrial heat is supplied by hot water and steam boilers. Although hot-air furnaces are utilized for space heating, these units are fired with gas or distillate oil and they generally do not contribute significantly to regional air pollution.

Commercial equipment normally is defined as having a capacity in the range of 0.05 to 2.11 million kcal per hour (0.2 to 8.37 million Btu per hour). Industrial equipment normally is defined as equipment having a capacity in the range 2.11 to 169 million kcal per hour (8.37 to 671 million Btu per hour). These ranges are loosely defined and in practice they often overlap; the equipment size distribution by location and fuel type is not available.

The estimated 1974 installed capacity of commercial and industrial boilers is 10×10^{15} kcal per year (40×10^{15} Btu) based upon a 1967 inventory and assumed growth rates of 4.5 percent per year for commercial units and 4 percent per year for industrial units.

Emission Sources and Pollutants

Pollutants emitted by fossil-fuel combustion are a function of fuel composition, efficiency of combustion, and the specific combustion equipment being used. Particulate levels are related to the ash content of the fuel. Sulfur oxide levels are related to the sulfur content of the fuel. Emissions of nitrogen oxides result not only from the high-temperature reaction of atmospheric nitrogen and oxygen in the combustion zone, but also from partial combustion of the nitrogenous compounds contained in the fuel. Thus nitrogen levels are dependent both on combustion equipment design and upon nitrogen in the fuel. Carbon monoxide, hydrocarbon, and particulate levels are dependent on the efficiency of combustion as it is affected by combustion equipment design and operation. Accordingly, natural gas and distillate oil are considered clean fuels because of their low ash and sulfur contents, and also because they are relatively easy to burn with high efficiency. In contrast, coal (and some residual oils) contain significant amounts of sulfur and ash, require more sophisticated combustion equipment, and are more difficult to burn at high efficiencies.

The estimated uncontrolled emission factors and average emission factors, as required by most State Implementation Plans (SIP) for commercial and industrial boilers, are listed in Table 3.2–1; these values are based on the following assumptions and conditions:

- The sulfur contents of coal, residual oil, and distillate oil are assumed to be 3, 2, and 0.2 percent by weight, respectively.
- The ash content of coal is assumed to be 12 percent by weight.
- The difference in particulate emissions factors for commercial and industrial coal-burning installations probably is related to differences in equipment design.

In Table 3.2–1 the emissions factors within parentheses indicate those required or allowed by SIP where applicable.

Table 3–2–1.
Emission Factors (in kg per million kcal)
Figures in Parentheses Indicate the Allowed Emission Factors Under SIP

Commercial	Particulates	Sulfur Oxides
Coal	1.8 (1.08)	8.6 (5.8)
Residual Oil	0.29 (1.08)	4.0 (2.0)
Distillate Oil	0.18 (1.08)	0.36 (0.43)
Gas	0.032 (1.08)	0.0011 —
Industrial		
Coal	11.7 (0.63)	8.6 (5.7)
Residual Oil	0.29 (0.63)	4.0 (2.0)
Distillate Oil	0.18 (0.63)	0.36 (0.43)
Gas	0.031 (0.63)	0.0011 —

Control Technology and Costs

It is apparent that equipment fired with gas and distillate oil essentially meets all of the air pollution regulations. The most cost-effective control technology has been switching from coal and high-sulfur residual oil to the less-polluting fuels. The current shortages and projected price rises for

natural gas and distillate oils, and the proposed disincentive on switching to these fuels, will require implementation of other control technologies in many cases.

Estimates of control costs are based on the assumption that, for commercial boilers, fuel switching from coal and high-sulfur residual oil to low-sulfur coal and oil respectively is possible, and that for industrial boilers, fuel switching from high-sulfur residual oil to low-sulfur residual oil is possible. An alternative control method for coal-fired industrial boilers is assumed to be dual-alkaline scrubbers for sulfur oxides and electrostatic precipitation for particulate control. For the coal-fired boilers, flue gas desulfurization appears plausible for the larger units, while fuel switching appears realistic for the smaller ones. However, because no boiler size distribution was available at this time, all industrial coal-fired boilers were assumed to be using flue gas desulfurization and electrostatic precipitators as the preferred control technologies; these assumptions will overstate the control costs.

Because of the present instability and future uncertainty of fuel prices, no attempt was made to account for the cost differential among fuels. On a heating value basis, there might be little difference in costs. Although it appears that the cost of coal coal and high-sulfur residual oil would be lower than the cost of the clean fuels prior to firing in a boiler, the higher costs of handling the coal and high-sulfur residual oil, as well as the higher equipment maintenance costs, are judged to offset any price differential. The net effect of these considerations should produce virtually equivalent fuel costs on a consistent basis. Thus, the costs reported here reflect the cost in equipment changes associated with fuel switching.

The estimated control costs for all industrial and commercial boilers are given in Table 3.2-2.

TABLE 3.2-2. INDUSTRIAL AND COMMERCIAL HEATING AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	222.71	1924.77	142.21	142.21
NEW PLANTS	15.40	45.44	126.06	322.91
TOTAL	238.11	1970.21	268.26	465.11
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	204.18	702.96	877.05	1973.37
NEW PLANTS	4.82	9.59	49.22	202.12
TOTAL	209.00	712.55	926.27	2175.49
O&M				
EXISTING PLANTS	139.74	476.48	604.13	1359.29
NEW PLANTS	0.28	0.55	17.10	99.77
TOTAL	140.02	477.03	621.23	1459.06
ALL ANNUAL COSTS	349.02	1189.57	1547.50	3634.55

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.3 NATURAL GAS PROCESSING INDUSTRY

Industry Characteristics and Capacities

The natural gas industry may be viewed as having three major sectors: exploration, production, and transmission-distribution. Natural gas is processed by the production sector. The production sector is dominated by large firms, many of them primarily petroleum producers, but a large number of smaller firms contribute a sizable share of the total output. The transportation/distribution sector is primarily organized as public utility companies which operate under Federal and/or State regulations. Although many gas-transmission companies are now integrating back into production, the basic structure of the industry remains as described here.

As of January 1, 1976, the 754 natural gas processing plants in the United States had a total capacity of 2.06 billion cubic meters per day (72.7 billion cubic feet per day). The actual through-put rate of these plants in 1975 was 1.40 billion cubic meters per day (49.4 billion cubic feet per day) about 90 percent of all gas produced. Since 1971 the amount of gas processed has decreased an average of 4 percent per year. Total production, including untreated gas, has declined since 1972 and is expected to continue to drop until some way is found to market North Slope production.

The production of petroleum (crude oil) is usually associated with the production of substantial quantities of natural gas. The distinction between "oil wells" and "gas wells" is arbitrary — based on the ratio of oil to gas produced. Natural gas is primarily methane, but the raw gas contains varying amounts of heavier hydrocarbons and other gases such as carbon dioxide, nitrogen, helium, and hydrogen sulfide. To obtain a natural gas of pipeline quality, much of the content of these undesired components must be removed. The gas is normally purified at or near the well site. The heavier hydrocarbons, which can be conveniently condensed, are combined with the liquid (oil) production and sent to refineries for further processing.

Emission Sources and Pollutants

Hydrogen sulfide is the air-pollution impurity of concern. Because of the corrosive, poisonous, and odorous nature of hydrogen sulfide, only very low concentrations are permitted in the natural gas product. Approximately 5 percent of the natural gas produced in the United States is treated to remove hydrogen sulfide. The hydrogen sulfide content of raw natural gas varies from trace quantities to over 50 percent by volume. The high-concentration wells are operated more as sulfur sources than as natural gas wells.

Although removal of the hydrogen sulfide from natural gas is universally practiced, recovery of the corresponding sulfur in elemental form to avoid air pollution is not universally practiced. In the large operations, Claus plants have been installed for this purpose, but in many small plants the hydrogen sulfide is merely flared, resulting in emissions of sulfur oxides.

For the natural gas plants which have Claus plants, the source of the sulfur oxides emitted is the Claus plant tail-gas, which is incinerated. The sulfur content of this emission corresponds to 4–6 percent of the sulfur originally fed to the Claus plant associated with the natural gas plant. For the natural gas plants without Claus plants, the sources of the sulfur oxides emitted are the flares in which the hydrogen sulfide that was removed from the gas is burned.

Regulations

As of January, 1979, no NSPS has been adopted, although proposed regulations are in tentative draft form.

The principal states producing sour gas have a wide variety of regulations in their SIP's. Most have requirements that are the equivalent to requiring 2- or 3-stage Claus plants on gas plants over a given size. This size varies from about 5 to about 15 metric tons per day (about 5.5 to about 16.5 short tons per day) total sulfur input, depending on the state, county, and location (rural versus urban). Achievement of desired ambient SO_x levels is the main consideration in some states; others are more specific about plant emission factors. Florida has the most stringent rules, requiring tail-gas cleanup since 1975 and forbidding any flaring of hydrogen sulfide. Oklahoma requires tail-gas cleanup for all new plants. New Mexico requires it for new plants of 51 metric tons per day (56 short tons per day) total sulfur input. In other states tail-

gas cleanup for large sulfur plants (51 metric tons or 56 short tons and over) may be unofficially required for new permits, although this is not spelled out in the regulations. For old plants, some 2-stage Claus units were upgraded to 3-stage units to meet ambient or general emission standards.

Control Technology and Costs

Because of the severe limitations on the hydrogen sulfide content of pipeline gas, all natural gas processing plants that handle sour gas already have amine-type scrubbing facilities or the equivalent to remove it from the raw gas. The technology needed to prevent hydrogen sulfide from causing air pollution consists of:

- A Claus sulfur plant in which the hydrogen sulfide is converted to elemental sulfur
- Treatment facilities to remove sulfur compounds from the Claus plant tail-gas.

The cost data developed by EPA for refinery sulfur plants[1] was modified by changing the capital recovery figure and correcting for inflation. Since Claus plants larger than about 20 metric tons per day (22 short tons per day) produced (in 1974) a net credit when sulfur was valued at $30 per metric ton ($27 per short ton) only Claus units smaller than this are considered a cost. January, 1979 prices for crude sulfur ranged from $25 to $65 per metric ton ($23 to $59 per short ton), depending on location and other factors. All tail-gas cleanup units are a cost because the incremental cost exceeds the incremental revenue whether the unit is added to a new or to an existing Claus plant.

Only one plant now has tail-gas cleanup. It was assumed that all new plants over 45 metric tons per day (50 short tons per day) and half of those in the range of 9.1–45 metric tons per day (10–50 short tons per day) would have this equipment.

Industry growth is hard to estimate in view of the decreasing capacity and increasing output of existing sulfur units. It was assumed that new plants would be built annually amounting to 8 percent of existing capacity, i.e., the replacement of old with new as they wear out over a 16-year life plus an extra 2 percent for new fields and reservoirs remote from old plants. (This is the historic rate of addition of new reservoirs and fields.) The increment was distributed in various size plants in the same proportion as existing operating sulfur plants, ignoring the largest two. The upgrading of Claus units from 2 to 3 stages probably involved 20–30 percent extra cost in constant dollars but was ignored because of a lack of quantitative data and because much of this upgrading was done in the 1970–1972 period, before the SIP's were formalized.

In 1976, the 68 operating Claus plants in the natural gas processing industry had a total sulfur capacity of 5,883 metric tons per day (6,485 short tons per day), and an actual production rate of 3,943 metric tons per day (4,346 short tons per day). Although the number of plants has declined from 84 in 1973 and capacity from 6,249 metric tons per day (6,888 short tons per day), sulfur production is up from 2,443 metric tons per day (2,693 short tons per day), a 17 percent per year increase. Apparently the existing plants are extending their coverage to gas plant output that was formerly flared.

Control costs are detailed in Table 3.3–1.

REFERENCE

1. Economic Impact of EPA's Regulations on the Petroleum Refining Industry, Part Two, Environmental Protection Agency, 1976.

TABLE 3.3–1. NATURAL GAS PROCESSING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.0	10.58	0.0	0.0
NEW PLANTS	9.35	9.35	45.75	127.65
TOTAL	9.35	19.92	45.75	127.65
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1.39	7.37	5.56	12.52
NEW PLANTS	1.19	1.19	18.82	83.78
TOTAL	2.59	8.57	24.38	96.30
O&M				
EXISTING PLANTS	24.09	127.68	96.36	216.81
NEW PLANTS	0.88	0.88	13.93	62.02
TOTAL	24.97	128.56	110.29	278.83
ALL ANNUAL COSTS	27.56	137.13	134.68	375.13

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.4 PETROLEUM REFINING INDUSTRY

Production Characteristics and Capacities

The petroleum industry can be divided into four operating areas:

- **Exploration and production,** which includes the search for new oil supplies, drilling oil fields, removing oil from the ground, and pretreatment at the well site. (Natural gas is frequently found in the search for oil. It is collected and sold by oil companies).
- **Refining,** which includes the operations necessary to convert the crude oil into salable products such as gasoline, jet fuel, kerosene, distillate and residual fuel oils, lubricants, asphalt, specialty products, and chemical raw materials such as ethylene and benzene.
- **Transportation,** which involves the movement of crude oil to the refinery and refined products to market areas.
- **Marketing,** which involves the distribution and sale of the finished products.

This chapter covers the airborne emissions from only the refining sector.

Integration and diversification prevail within the industry. Most of the firms involved in refining are also involved in production of oil and gas and/or marketing. All the large and medium-sized firms are involved in the manufacture of petrochemicals. Some firms are involved in the production aspects of energy sources other than crude oil and natural gas, i.e., coal or Canadian tar sands.

As of January 1, 1976, the 277 refineries in the United States (excluding Puerto Rico and the Virgin Islands) had a total crude oil capacity of 2.09 million metric tons per day (15.3 million barrels per day), according to the Bureau of Mines. A distribution of these refineries by size and percent of total capacity is shown in Table 3.4–1.

Table 3.4–1.
Refinery Distribution by Size
(in thousands of metric tons per calendar day with thousands of barrels per calendar day in parentheses)

Capacity Range	Number of Refineries	Total Capacity	Total Industry Capacity (%)	Average Capacity
(Up to 5) Up to 0.08	56	(171) 23.4	1.12	(3) 0.42
(5 to 10) 0.08 to 1.4	36	(277) 37.9	1.81	(8) 1.1
(10 to 15) 1.4 to 2.1	19	(241) 33.0	1.58	(13) 1.7
(15 to 25) 2.1 to 3.4	24	(504) 68.9	3.29	(21) 2.9
(25 to 50) 3.4 to 6.8	53	(2,043) 279.5	13.36	(39) 5.3
(50 to 75) 6.8 to 10.3	27	(1,671) 228.6	10.92	(62) 8.5
(75 to 100) 10.3 to 13.7	20	(1,792) 245.1	11.72	(90) 12.3
(100 to 200) 13.7 to 27.4	27	(3,933) 538.0	25.71	(146) 19.9
(Over 200) Over 27.4	15	(4,664) 638.0	30.49	(311) 42.5
Totals	277	(15,296) 2,092.5	100.00	

During the period from 1970 to 1976, total crude processing capacity increased by 450 thousand metric tons per day (3.2 million barrels per day), almost all through expansion of existing refineries. Although about 130 firms operate refineries, over 75 percent of the total capacity is controlled by 17 major firms; each firm controls crude processing capacity in excess of 18 thousand metric tons per day (135 thousand barrels per day). A breakdown of capacity and number of plants operated by these firms in 1976 is shown in Table 3.4–2.

Table 3.4–2.
The Refinery Inventory in 1976
By Operator (capacity in thousands of metric tons per calendar day with thousands of barrels per calendar day in parentheses)

	Number of Refineries	Crude Capacity	Crude Capacity(%)	
Exxon	5	170.0	(1,243)	8.1
Shell	8	157.9	(1,154)	7.5
Amoco	10	152.8	(1,117)	7.3
Texaco	12	146.8	(1,073)	7.0
Standard (CA)	12	140.1	(1,024)	6.7
Mobil	7	122.3	(896)	5.9
Gulf	8	118	(866)	5.7
ARCO	5	110	(805)	5.3
Union Oil	5	66.9	(489)	3.2
Sun Oil	5	66.2	(484)	3.2
Sohio/BP	3	59.0	(431)	2.8
Phillips	6	55.8	(408)	2.7
Continental	8	53.2	(389)	2.5
Ashland	7	52.4	(383)	2.5
Marathon	3	44.3	(324)	2.1
Cities Service	1	30.7	(268)	1.8
Amer. Petrofina	3	18.5	(135)	.9
Subtotal	108	1,571.7	(11,489)	75.1
Remaining Firms	169	520.8	(3,807)	24.9
	277	2,092.5	(15,296)	100.0

Industry capacity has expanded at fluctuating rates in recent years in anticipation of market growth. The annual growth was 2.3–4.3 percent from 1970–73, 6.2 percent from 1973–74, 12.8 percent from 1974–76. Capacity in 1977 is expected to be about 7 percent larger than in 1976.

Very few new refineries have been built in the past 5 years; the growth has occurred primarily through the expansion of existing facilities. This is in part due to difficulty in securing approval for new sites. The Bureau of Mines in 1976 reported 158 thousand metric tons (1,155,000 barrels per day) of refinery construction underway, of which only 29.4 metric tons per day (215 thousand barrels per day) is in two new refineries.

Emission Sources and Pollutants

The three major sources of air pollution in the petroleum industry covered in this chapter are particulate and carbon monoxide emissions from the regeneration of catalysts used in catalytic cracking, sulfur oxide emissions from the burning of fuel gases from various refinery process operations, and volatile hydrocarbon emissions from handling and storage of petroleum products and crude oils.

A consolidated view of the type and extent of the emissions from refining and related operations is presented below.

Catalytic Cracking

Catalyst regeneration during the operation of catalytic cracking units has been identified as a major source of carbon monoxide. Particulates also are discharged from the fluid bed units which dominate this process. The coke deposited on the catalyst during the cracking operation must be removed continually to permit the catalyst to maintain a high activity. In a fluid bed catalytic cracker, the catalyst bed is continuously circulated between the reactor, where the coke is deposited on the catalyst, and the regenerator, where it is burned off with air. The amount of coke deposited on the catalyst per unit of feedstock is a function of the feedstock and operating conditions.

Fuel Gas Burning

Amine scrubbing units are widely used to remove hydrogen sulfide from the fuel gas generated within refineries. The hydrogen sulfide is thermally stripped from the scrubbing liquor and then is either sent to a sulfur recovery plant (usually a Claus plant) or is burned to sulfur dioxide, which is emitted to the atmosphere, through a flare. In 1973, about 70 percent of the sulfur which went into fuel gas was recovered as elemental sulfur, the other 30 percent was emitted as sulfur dioxide.

Petroleum Storage

The most significant hydrocarbon losses in the petroleum industry occur from storage facilities, in particular those used to store crude oil, gasoline, and naphtha-type jet fuel. The magnitude of hydrocarbon emissions from storage tanks depends on many factors in addition to the physical properties of the material being stored — climatic and meteorological conditions, and the type, size, color, and condition of the tank.

Control Technology and Costs

Control technology and costs for the three major emission sources in the petroleum industry are outlined in the following paragraphs.

Catalytic Cracking

Particulate matter (catalyst fines) can be removed from the regenerator gas with high-efficiency electrostatic precipitators. Carbon monoxide and unburned hydrocarbons can be reduced either by increasing the regeneration temperature or by installing carbon monoxide boilers.

In 1971, about 29 percent of the fluid catalytic cracking capacity was equipped with electrostatic precipitators and about 69 percent was equipped with carbon monoxide boilers. These boilers are often economically justified by the steam which they generate, especially for large catalytic cracking units. Increasing energy costs are making carbon monoxide boilers more attractive for this reason. In some existing refineries, the additional

steam generated by the addition of a carbon monoxide boiler cannot be used, but new refineries can be designed to take advantage of this means of reducing their total energy requirement. Because there is a net credit to the industry from installing carbon monoxide boilers, the costs (or credits) have not been included in the cost of pollution abatement.

Fuel Gas Burning

The control technology involves installing additional amine scrubbing facilities where required, installing Claus plants on the 30 percent of capacity now without them, and installing tail-gas treatment facilities on all the Claus plants. The tail-gas treatment facilities increase the overall sulfur recovery from about 94 to 99.8 percent.

The credit for the sulfur recovered in these processes is an important economic consideration and is also difficult to define. In the coming years, the reduction of allowable sulfur emissions from refineries, power plants, etc., plus the increasing sulfur content of the crude oil processed will combine to cause a very large increase in the production of sulfur. This will probably depress the price of sulfur, but the extent is open to considerable speculation. The price level used in this study was $30 per metric ton ($30 per long ton).

Petroleum Storage

The EPA new source pollution regulations require that petroleum products having vapor pressures of 78 to 570 mm of mercury be stored in floating-roof tanks or their equivalent. There is also a requirement for products with vapor pressure greater than 570 mm of mercury, but this will cause no additional expense since the control methods have long been used for these products. Most SIP's also require control of vapors from petroleum storage. This report is concerned only with the storage of crude oil, jet fuel, and gasoline.

Costs were obtained for converting existing fixed-roof tanks to floating-roof by retrofitting an internal floating cover. This conversion method is used since it costs only about half as much as removing the fixed roof and replacing it with a floating roof. The annual operating costs for the tanks, including maintenance, property taxes, and insurance, were taken at 6.0 percent of the investment.

Abatement of vapors from gasoline and crude oil storage involves no net cost since the vapors retained provide a credit larger than the capital charges and operating and maintenance costs. The facilities for crude oil storage at Valdez, Alaska, are an exception and are included here. The cost of abatement for naphtha-type jet fuel storage includes refinery, pipeline, and terminal storage tanks.

Air pollution control costs are summarized in Table 3.4–3. The costs shown are the summation of all those discussed above, including a zero O&M cost assigned to the control of emissions from storage tanks, which may actually result in a credit due to the reduction of product losses. The cost of lead-free gasoline and lead phase-down has not been included in this chapter. These costs appear in Chapter 4, Mobile Sources.

TABLE 3.4–3. PETROLEUM REFINING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	127.15	375.04	288.83	288.83
NEW PLANTS	40.08	370.81	104.89	248.35
TOTAL	167.23	745.85	393.72	537.17
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	47.82	119.15	299.40	727.02
NEW PLANTS	45.06	130.61	221.84	572.81
TOTAL	92.88	249.75	521.24	1299.83
O&M				
EXISTING PLANTS	10.85	33.29	110.96	307.21
NEW PLANTS	32.38	117.52	139.66	374.54
TOTAL	43.23	150.81	252.62	681.75
ALL ANNUAL COSTS	136.12	400.56	773.86	1981.58

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.5 COAL CLEANING INDUSTRY

Production Characteristics and Capacities

In 1975, which is the last year for which Bureau of Mines data were currently available, the total production of bituminous and lignite coal in the United States was 588 million metric tons (about 648 million short tons). The annual production rate has gone both up and down in recent years, but the net change from 1969 to 1975 was an increase of about 16 percent. The 1975 production came from 6,168 mines. About 45 percent of the production came from underground mines, 49 percent from surface mines, and 6 percent from auger mines. The trend over recent years has been toward more mines and toward a greater dependence on surface mining. The recent decline in the number of underground mines, largely because of the strict regulations of the 1969 Coal Mine Health and Safety Act, was reversed during 1975.

In coal mining, various inert materials and other impurities, such as pyritic sulfur, are recovered along with the coal. If these materials are present in sufficient quantity, they may be partially removed by coal cleaning. This mechanical cleaning process increases the heating value of the coal and reduces the amount of pollutants emitted when the coal is burned.

In surface mining where the coal seams are uncovered, the amount of impurities in the coal is relatively low, and only about 27 percent of the coal mined in this manner requires cleaning. In underground mining, the cutting and loading methods used lead to somewhat greater amounts of impurities, and about 61 percent of the coal mined in this manner requires cleaning. Overall, about 41 percent of the coal mined in this country is mechanically cleaned. In 1975, about 339 million metric tons (about 374 million short tons) of raw coal were cleaned, yielding about 242 million metric tons (267 million short tons) of cleaned coal. The amount of coal cleaned showed a net decrease of about 8 percent from 1973 to 1975; this decrease resulted from the increased use of surface mining (which requires less cleaning), and the increased shipments to electric utilities, which usually do not require cleaning.

Mechanical coal cleaning involves methods similar to those used in the ore-dressing industries. About 97 percent of coal cleaning is done by wet-processing methods, with pneumatic or air cleaning methods being used for the other 3 percent. The dust abatement regulations of the Occupational Health and Safety Act will eventually cause a phasing out of pneumatic cleaning over the next few years.

About 13 percent of the coal which is cleaned by wet-processing methods is thermally dried before being loaded. Drying is done to avoid freezing problems, to facilitate handling, to improve quality, or to decrease transportation costs. In 1975, there were 119 thermal drying plants in this country which processed about 32 million metric tons (36 million short tons) of coal. The amount of cleaned coal thermally dried decreased by about 1 percent from 1974 to 1975. In such drying plants, a significant source of pollution is the particulate emissions from the driers. To meet the new regulations on particulate emissions, venturi scrubbers (or the equivalent) must be installed.

The present turmoil in the related areas of energy supply, energy conservation, and environmental protection makes the prediction of future growth trends in the coal industry rather uncertain. The basic factor inhibiting the rapid growth of coal production is the high sulfur content and related pollution abatement costs of most readily available eastern coals. The western portion of the nation has large reserves of low-sulfur coal but the high cost of transporting this coal to the midwestern and eastern markets has, at least until recently, precluded large scale use of this source. The alternative to the use of low-sulfur coal is flue gas desulfurization technology. continue to be adhered to and electric utilities indicate a reluctance to apply flue gas desulfurization technology at new plants, a slowing in the growth rate of coal usage could result. On the other hand, the current emphasis on reducing our energy dependence on imported petroleum by increasing consumption of domestically available energy could accelerate the demand for coal.

The revised New Source Performance Standards for the utility industry (recently proposed) may provide an incentive to use deep-mined high-sulfur coal. This is so because the revised NSPS will likely require scrubbers universally on new

sources, thus lowering the incentive to use low-sulfur western coals in eastern markets. The move toward deep-mined coal would trigger growth in coal cleaning.

Therefore, the long run outlook for coal consumption in the U.S. is unsure. The need to protect our environment has placed the emphasis, when coal is consumed, on producing low-sulfur coal and finding acceptable means of removing sulfur from high-sulfur coal. Most of the low-sulfur coal, acquired from surface mines, has a lower incidence of cleaning and associated drying requirements.

Sulfur removal from high-sulfur coal is being accomplished by scrubbing the combustion flue gases or via precombustion cleaning. Sulfur removal (other than now accomplished in current coal cleaning processes) via precombustion cleaning currently has an unsure future (i.e., it is an unproved technology) and is not addressed in this report.

Therefore, the unsure future for coal production coupled with the shift toward increased surface mining leads to the conclusion that the quantity of thermally dried coal will remain at a relatively constant level during the foreseeable future.

Emission Sources and Pollutants

The emissions of primary concern from mechanical coal cleaning plants are the particulates resulting from drying operations. Data available in 1975 indicated that 74 percent of the coal drying capacity was equipped with devices capable of removing at least 99 percent of the particulate matter in the effluent gas. The remainder of the capacity was equipped with low-energy cyclones which remove only about 90 percent of the particulate matter. To meet environmental regulations, these cyclones will have to be replaced with the high-energy venturi scrubbers.

Control Technology and Costs

In most cases, the technology used for removing particulate matter will be venturi scrubbers. If other technology is used for some of the driers, its cost should be comparable to the cost of venturi scrubbers, thus a cost analysis based on venturi scrubbers should be valid.

A report for the EPA by the Industrial Gas Cleaning Institute (IGCI) gives some cost information on venturi scrubbers for coal driers. This information and some calculations based on it are summarized in Table 3.5–1. Control costs are given in Table 3.5–2.

Table 3.5–1
Investment And Operating Cost Data On Venturi Scrubbers For Coal Cleaning (1977 dollars)

	Model Plant A				Model Plant B			
Coal Drying Capacity (tons/hr)	250				750			
Particulate Removal (%)	99.64				99.84			
Investment (1000 $)	530				1,373			
Operating Cost Components	No. of Units	Cost (1000 $/yr)			No. of Units	Cost (1000 $/yr)		
		Low	Medium	High		Low	Medium	High
Operating labor	125 hr/yr	0.88	1.22	1.74	125 hr/yr	0.88	1.22	1.74
Maintenance materials		3.32	3.70	4.08		9.00	10.00	11.00
Power	2.45×10^6 kWh/yr	17.05	37.46	68.16	8.13×10^6 kwh/yr	56.54	124.49	226.32
Process water	64.4×10^6 liters/yr (17.0×10^6 gal/yr)	3.55	5.90	8.26	192.7×10^6 liters/yr (50.9×10^6 gal/yr)	10.63	17.71	24.80
TOTAL Operating and Maintenance cost		24.80	48.28	82.24		77.05	153.42	261.86

Basis: International Gas Cleaning Institute report on Contract No. 68–02–0301 for EPA, 9/30/72. Values for two units given were averaged. Costs were updated to 1977 dollars.

TABLE 3.5–2 COAL CLEANING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	12.88	75.24	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	12.88	75.24	0.0	0.0
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	13.03	63.99	52.12	108.66
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	13.03	63.99	52.12	108.66
O&M				
EXISTING PLANTS	0.10	0.49	0.40	0.89
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.10	0.49	0.40	0.89
ALL ANNUAL COSTS	13.13	64.47	52.51	109.56

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.6 COAL GASIFICATION

Production Characteristics and Capacities

Currently, no commercial coal gasification plants operate within the United States. Coal gasification is an emerging industry in which the first announced commercial plants will produce a high-Btu synthetic gas from coal to supplement domestic natural gas production.

Consumption of natural gas is constrained by the available supply. Dwindling reserves and the rising cost of natural gas are forcing consumers to seek alternative forms of energy such as coal, oil and electricity. Consumption of natural gas is expected to decline as a percent of total U.S. energy consumption.

Estimates of future aggregate supply for natural gas vary widely. The Federal Power Commission's National Gas Survey has estimated future supply under different scenarios. The Survey's base case assumes minimal technological innovation and projects a 1990 supply of 714 billion cubic meters (25.2 trillion standard cubic feet). A more optimistic estimate of future supply is contained in the Survey's "Case III", which assumes moderate technological innovation, accelerated development of offshore and Alaskan reserves, production of synthetic gas from coal, and increased imports from Canada. With these assumptions, 1990 supply is estimated at 968 billion cubic meters (34.2 trillion standard cubic feet), of which 24.6 percent is imported from Canada and 8.8 percent is synthetic gas produced from domestic coal. Synthetic gas from coal would represent about 11.6 percent of domestic total production in 1990. Finally, with an unconstrained supply of natural gas, the Future Requirements Committee, a body of industry and government observers, estimates that 1990 demand for gas would amount to 1.28 trillion cubic meters (45.3 trillion standard cubic feet). For the purpose of this report, the estimate of the National Gas Survey's Case III was used since it appears to be a moderate demand scenario.

Synthetic gas from coal is one alternative source of natural gas which is anticipated to supplement domestic natural gas production.

Coal gasification is the combination of coal and water to form carbon monoxide, hydrogen, and some methane. Both pressure and elevated temperatures are required to promote the gasification reactions, which are many and varied. Thus, the key requirements for coal gasification are coal (carbon), water (steam), and heat.

Commercial coal gasification processes in use today outside the United States include the Lurgi, Koppers-Totzek, and Winkler processes, all for the manufacture of synthesis and fuel gases. Practically all of the first-generation coal gasification projects – those being engineered for the United States in commercial sizes today – are based on use of the Lurgi process. Three types of coal gasification plants have been proposed – low-Btu gasifiers for industrial and utility boiler fuels; intermediate Btu gasifiers producing "synthesis" gas as feedstock for manufacture of liquid fuels, methanol, ammonia and possibly other valuable chemicals; high-Btu or substitute natural gas (SNG) to supplant declining natural gas supplies; and an intemediate Btu gas for local use. For the low-Btu case, no commercial-sized plants exist; however, pilot-scale and demonstration plants are planned. Intermediate-Btu gas projects in the United States are also under consideration at this time, with no announced commercial plants.

High-Btu gas is well advanced with at least 22 plants under study and as many as four plants may be under construction by 1980. With high-Btu gasification nearest commercial production and process and emission control schemes unclear for the other cases, this report is directed toward high-Btu gas (SNG).

As previously noted, the first-generation gasification processes are based on the Lurgi coal gasifier. In the Lurgi gasifier, gasification takes place in a countercurrent moving bed of coal at 2.07–2.76 x 10^6 N/m^2 (300–400 psig) and 540–760°C (1000–1400°F). A cyclic operation using a pressurized lock hopper is used to feed coal.

The pressurizing medium is a slip stream of raw gas which may later be repressurized and put back into the raw gas stream. The gasifier has a water jacket to protect the vessel and provide steam for gasification. Other features include blades to mechanically overcome caking, a moving grate on the bottom to remove dry ash, and a mechanism to

introduce steam and air or oxygen uniformly over the gasifier.

Several high-Btu gas projects using the Lurgi coal gasifier have been announced and are at various stages of engineering. In addition to the gasification process itself, other major components include a large, 250–500 megawatt power boiler and steam superheater to provide steam for the gasification process; an oxygen plant which supplies oxygen to the gasifier; coal receiving, handling, storage, and preparation facilities; byproduct recovery and storage, and waste-treating and -disposal facilities. The product gas has a typical heating value of 35–36 million joules per cubic meter (950–970 Btu per standard cubic foot) and consists of roughly 96 percent methane, 2 percent CO_2, 1 percent inert gas, and less than 1 percent mixture of hydrogen and carbon monoxide.

It is difficult to project the growth of the coal gasification industry through the year 2000. Uncertainties about world oil prices, coal and water availability, and FPC decisions concerning incremental or roll-in pricing have already delayed the construction of the first proposed coal gasification plants. Government incentives, including loan guarantees and/or subsidies, could encourage more rapid development of coal gasification.

A number of projections of high-BTU gas production from coal have been made by the Federal Power Commission (National Gas Survey), the Bureau of Mines, and the National Petroleum Council. Estimates of 1990 production vary widely, from 34 billion cubic meters (1.2 trillion standard cubic feet) to 140 billion cubic meters (5.1 trillion standard cubic feet) representing 14–61 plants assuming an average size of 7 million cubic meters (250 million standard cubic feet) per day. Current announcements propose 14 plants which could be operative by 1990 producing 34 billion cubic meters (250 trillion standard cubic feet). The intermediate value of 85 billion cubic meters (3.0 trillion standard cubic feet) estimated by the National Gas Survey Case though achievable, capacity for the year 1990. With this assumption, it is estimated that synthetic gas will grow from 1.6 percent to 11.6 percent of total domestic production between 1980 and 1990. Production of 37 billion cubic meters (1.3 trillion standard cubic feet) of synthetic gas in 1985 and 85 billion cubic meters (3.0 trillion standard cubic feet) in 1990 will require operation of 16 and 36 gasification plants in the respective years.

Emission Sources and Pollutants

Lurgi coal gasification plants emit particulate matter, sulfur dioxide, NO_x, nonmethane hydrocarbons, and carbon monoxide. Within a coal gasification plant, the primary point source which accounts for essentially all the NO_x emissions and most of the particulate matter emissions is the steam generating facilities. These facilities also account for the major portion of the sulfur dioxide emissions. The standards of performance promulgated for fossil-fuel-fired steam generators, however, will limit emissions of particulate matter, NO_x, and sulfur dioxide from these facilities in any new coal gasification plant.

The secondary point source which accounts for the remaining particulate matter emissions within a coal gasification plant is the coal handling facility. The standard of performance promulgated for coal preparation plants, however, will limit emissions of particulate matter from these facilities in any new coal gasification plant. Consequently, standards of performance limiting emissions of particulate matter, NO_x, and a major portion of the sulfur dioxide emissions from coal gasification plants already exist. Thus, uncontrolled emissions would be limited to nonmethane hydrocarbons, carbon monoxide, and the remaining emissions of sulfur dioxide.

Both nonmethane hydrocarbons and carbon monoxide emissions are controlled by the same technique—incineration—therefore consideration is given to limiting emissions of only nonmethane hydrocarbons and sulfur dioxide.

The primary point sources of nonmethane hydrocarbons and sulfur dioxide emissions within Lurgi coal gasification plants are the: coal gasifier lockhoppers; coal gas purification facilities; byproduct recovery gas/liquid separation facilities; and the sour water stripping facilities. These point sources together account for essentially all the nonmethane hydrocarbon emisssons and the remaining uncontrolled sulfur dioxide emissions.

Uncontrolled emissions of pollutants from a 260 x 10^{12} joule/day (250 x 10^9 Btu/day) Lurgi gasification plant are estimated as follows in kilograms per hour (with pounds per hour in parentheses): "C_2"-2640 (5820), CO-700 (1540), COS-194 (427), H_2S-6200 (13,700) and total sulfur-5940 (13,100) (based on coal feed stock of approximately 2 grams per million joules or 1.0 pound sulfur per million Btu).

Control Technology and Costs

As mentioned above, no commercial coal gasification plants have been constructed in the United States, although eight Lurgi coal gasification plants are currently operating in other countries. These plants, however, are not representative of those planned for the United States in terms of the emission characteristics of the off-gas streams.

The Lurgi coal gasification plants projected for construction in the United States by the domestic natural gas industry will employ the Lurgi Rectisol process to remove carbon dioxide and hydrogen sulfide from the coal gas. The Rectisol system is not considered an emission control system because sulfur removal is a process requirement of coal gasification. These new plants must comply with existing pollution standards as contained in NAAQS and PSD regulations.

Data and information developed by the domestic natural gas industry indicate that this process will discharge two waste gas streams. Depending on the properties of the coal gasified, the composition of one of the waste gas streams will be about 90–95 percent carbon dioxide, 0.5–1 percent nonmethane hydrocarbons, and 0.25–5 percent hydrogen sulfide; and the composition of the other waste gas stream will be about 55–95 percent carbon dioxide and 5–40 percent hydrogen sulfide.

Proposed standards of performance for these emissions can not be based on existing plants because none exist, therefore, emission control systems for these waste gas streams have been based on a "transfer-of-technology" from other industries.

The emission control technology demonstrated in the steel industry, the oil and natural gas production industry, the petroleum refining industry, and the carbon black manufacturing industry to control emissions of hydrogen sulfide and nonmethane hydrocarbons can be "transferred" to the coal gasification industry for application to Lurgi coal gasification plants. These control technologies include the use of Stretford and Claus sulfur recovery plants, tail-gas scrubbing to reduce sulfur emissions further, and incineration to reduce nonmethane and hydrocarbon emissions. These control technologies will control about 98 percent of the sulfur compounds and nonmethane hydrocarbons.

The emission control capital costs under existing regulations range from $13.0 to $46.8 million for a 7 million cubic meter per day (250 million standard cubic feet per day) plant. These costs range from 1 to 6 percent of the anticipated capital costs of the coal gasification plant ($870 million). The cost variations result from variations in the sulfur content of the coal and the availability of water. The associated total annualized costs range from $18.8 to $28.7 million or 8 to 12 mills per cubic meter ($0.23 to $0.35 per thousand standard cubic feet).

The proposed standards of performance would not increase the control costs over those of existing regulations for low-sulfur coal. The increase in installed capital costs to meet the proposed standards of performance for other coal would range from $1.7 to $3.3 million or 0.2 to 0.4 percent of the anticipated capital costs of a Lurgi plant. The associated total annual costs are $0.76 to $1.5 million or $0.35 to $0.70 per thousand cubic meters ($0.01 to $0.02 per thousand standard cubic ffet). These are incremental costs of emission control above these to meet existing regulations.

The emission control costs stated above exclude estimated emission control costs associated with coal handling and steam generation. These installed costs range up to $29.0 million with annualized cost up to $7.4 million or 3 mills per cubic meter ($0.09 per thousand standard cubic feet) of product.

Total costs are summarized in Table 3.6–1.

TABLE 3.6–1. COAL GASIFICATION AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	70.44	412.03
TOTAL	0.0	0.0	70.44	412.03
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	21.52	237.16
TOTAL	0.0	0.0	21.52	237.16
O&M				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	152.66	1682.32
TOTAL	0.0	0.0	152.66	1682.32
ALL ANNUAL COSTS	0.0	0.0	174.18	1919.48

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4. MOBILE SOURCE POLLUTION CONTROL

INTRODUCTION

Mobile sources are recognized as significant contributors to national air-quality problems. In areas subject to photochemical smog formation, over half the reactants can generally be attributed to motor-vehicle emissions. Similarly, motor-vehicle emissions frequently cause large concentrations of carbon monoxide in high-traffic-density urban areas during traffic peaks. In cities with large and busy commercial airports, aircraft operations are often the principal source of high levels of carbon monoxide, hydrocarbons, nitrogen oxides, and particulates in the vicinity of the runways and terminals.

Passenger cars and light-duty trucks have been highly significant and visible pollutant sources because of the large numbers in service. Consequently, they have been under Federal controls since the 1968 models. Federal controls on heavy-duty motor vehicles have been in effect since 1970, controls on aircraft emissions went into effect in 1974, and controls on motorcycles were imposed beginning with the 1978 model year.

Other mobile sources, such as railroad locomotives, marine engines, and farm, construction, and garden equipment, have been under study by EPA, but to date, no regulations for these sources have been promulgated or proposed.

RECENT FACTORS AFFECTING MOBILE SOURCES

A number of recent events will affect future mobile-source emission control costs, including the new motorcycle emission standards, the changes to the light- and heavy-duty truck regulations, the decision of the Appeals Court on the EPA's lead phase-down regulations, the 1977 amendments to the mobile-source section (Title II) of the Clean Air Act, and the new fuel economy standards.

On December 23, 1974, a three-judge panel of the U.S. Circuit Court of Appeals in Washington, D.C. set aside the EPA lead phase-down regulation which was to go into effect on January 1, 1975. The basis for the court's ruling was that there is no conclusive scientific proof that the lead emitted from gasoline-fueled vehicles is posing health hazards to a substantial portion of the general population. EPA sought a rehearing of the case (which was granted) before the entire court rather than the three-judge court which heard the case earlier, claiming that the judges misinterpreted the Clean Air Act and the evidence presented. The full court heard oral arguments from EPA and plaintiffs on May 30, 1975, and in March 1976, upheld the EPA lead phase-down regulation.

The changes in light- and heavy-duty truck regulations[1,2] call for trucks in these two classes to meet more stringent emissions standards beginning in the 1979 model year. The light-truck class was enlarged to include all trucks under 3,860 kilograms (8,500 pounds) gross vehicle weight rating. (The previous definition for light-duty trucks applied to trucks under 2,720 kilograms (6,000 pounds)). Test procedures for heavier trucks were also changed.

Emission standards for motorcycles were promulgated by EPA in 1977 to begin taking effect with the 1978 model year and to cover street-use motorcycles of 50 cc and greater displacement.

The Clean Air Act Amendments of 1977 (signed August 7, 1977) call for maintaining the 1977 standards for light-duty vehicles through the 1979 model year. In 1980 the CO standard drops to 4.3 g/km (7.0 g/mile), and in 1981 and subsequent years to 2.1 g/km (3.4 g/mile). HC is set at 0.25 g/km (0.41 g/mile) for 1980 and later model years. The NO_x standard remains at 1.24 g/km (2.0 g/m) through the 1980 model year and is set at 0.62 g/km (1.0 g/m) for 1980 and subsequent model years.

LIGHT-DUTY VEHICLE CONTROLS

Emission Standards

Since 1968, the Federal Government has regulated the output of air pollutants from the exhaust of new light-duty motor vehicles. Emission standards are expressed in terms of maximum levels of gaseous emissions per unit distance permitted from the vehicle while operating on a prescribed duty cycle. Sampling procedures and test equipment are also prescribed by the regulations. While the standards apply to new vehicles, the certification procedure requires that test cars meet emission standards after being driven over a prescribed durability schedule for 80.5 thousand kilometers (50 thousand miles).

Both emission levels and test procedures have been revised periodically in several steps of increasing stringency. Changes in the Federal Test Procedure were implemented for the 1972 and 1975 model years. Nitrogen Oxide emission levels were prescribed for 1973, and were based largely on evolving technology emission control.

The 1970 Amendments to the Clean Air Act called for the Administrator to prescribe Federal emission standards for 1975 and later model years effecting a 90 percent reduction in the hydrocarbon and carbon monoxide emissions from 1970 levels, and to prescribe the Federal standards for 1976 and later model years effecting a 90 percent reduction in nitrogen oxide emissions from 1971 levels. The 1970 Amendments further gave the Administrator the authority to grant a 1-year suspension of the 1975 and 1976 standards under specified conditions if it could be established that effective control technology was not available for compliance.

On April 11, 1973, the Administrator announced his decision[3] to suspend the 1975 statutory Federal Motor Vehicle Emissions Standards covering carbon monoxide and hydrocarbon for a period of one year. After extensive hearings in March 1973, the Administrator found that, although the necessary technology existed to meet the 1975 standards based on the use of catalytic converters, there was a high degree of uncertainty concerning the industry's ability to certify and produce catalyst-equipped cars in 1975 in large enough numbers to meet production requirements for their full model line. In addition, in-use reliability of the catalysts had not been established. Because of this, it was found that the risk associated with introducing catalysts on all vehicles in 1975 outweighed the risk to human health if the standards were delayed. The suspension was applied in two parts:

- National 1975 interim standards were established which were more strict than standards previously in force, but which were not anticipated to require catalysts on the majority of vehicles sold.
- More stringent standards were allowed for vehicles sold only in California, which would require catalysts on cars sold in that state. Under the California waiver provision in the Clean Air Act, the state was permitted to establish its own hydrocarbon and nitrogen oxide standards. A standard that is more stringent than that applicable to cars sold elsewhere was prescribed for carbon monoxide.

The 1975 statutory standards as originally established were to be applicable to all cars sold in the United States in 1976.

Similarly, the Administrator's decision[4] to suspend the statutory standards for oxides of nitrogen for 1976 and later models was announced on July 30, 1973. This decision was based on the belief that technological success in meeting the 1976 statutory standards could not be reasonably predicted. In applying this suspension, the Administrator established an interim nitrogen oxide Federal standard of 1.2 g/km (2.0 g/mile), which was attainable with existing advanced emission-control technology.

Finally, the aforementioned 1977 amendments to the Clean Air Act further delayed the light-duty passenger car requirements, as shown in Table 4.-1.

PASSENGER CARS

Control Devices, 1968–1974 Model Years

From 1968 to 1974, compliance with Federal emission standards was achieved by utilizing various combinations of the following:

- Purging crankcase fumes through the engine
- Recalibration and tighter precision in carburetor fuel metering
- Engine intake air preheat and temperature control
- Spark retard at idle and low speeds
- Reduced compression ratios and eliminating combustion chamber pockets
- Air injection into the exhaust manifold

Table 4.-1. Federal Exhaust Emission Standards and Control Levels for Light-duty Vehicles Since 1973

Year	Emission	Light-duty Gasoline Passenger car[1]	Light-duty Diesel Passenger Car[1]	Light-duty Gasoline Truck[2]	Light-duty Diesel Truck[2]
		Emission Levels in grams/kilometer (grams/mile)			
1973–1974[3]	HC	1.9 (3.0)	—	1.9 (3.0)	—
	CO	17 (28)	—	17 (28)	—
	NO_x	1.9 (3.1)	—	1.9 (3.1)	—
1975–76	HC	0.93 (1.5)	0.93 (1.5)	1.2 (2.0)	1.2 (2.0)
	CO	9.3 (15)	9.3 (15)	12 (20)	12 (20)
	NO_x	1.9 (3.1)	1.9 (3.1)	1.9 (3.1)	1.9 (3.1)
1977–1978	HC	0.93 (1.5)	0.93 (1.5)	1.2 (2.0)	1.2 (2.0)
	CO	9.3 (15)	9.3 (15)	12 (20)	12 (20)
	NO_x	1.2 (2.0)	1.2 (2.0)	1.9 (3.1)	1.9 (3.1)
1979	HC	0.93 (1.5)	0.93 (1.5)	1.1 (1.7)	1.1 (1.7)
	CO	9.3 (15)	9.3 (15)	11 (18)	11 (18)
	NO_x	1.2 (2.0)	1.2 (2.0)	1.4 (2.3)	1.4 (2.3)
1980	HC	0.25 (0.41)	0.25 (0.41)	1.1 (1.7)	1.1 (1.7)
	CO	4.3 (7.0)	11 (18)	11 (18)	11 (18)
	NO_x	1.2 (2.0)[5]	1.2 (2.0)[5]	1.4 (2.3)	1.4 (2.3)
1981–1982	HC	0.25 (0.41)	0.25 (0.41)	1.1 (1.7)	1.1 (1.7)
	CO	2.1 (3.4)[4]	2.1 (3.4)[4]	11 (18)	11 (18)
	NO_x	0.62 (1.0)[5]	0.62 (1.0)[5]	1.4 (2.3)	1.4 (2.3)
1983 and after	HC	0.25 (0.41)	0.25 (0.41)	0.45 (0.73)[7]	0.45 (0.73)[7]
	CO	2.1 (3.4)	2.1 (3.4)	5.76 (9.4)[7]	5.76 (9.4)[7]
	NO_x	0.62 (1.0)[6]	0.62 (1.0)[6]	0.74 (1.2)[7]	0.74 (1.2)[7]

[1] Under 2,720 kg (6000 lb) gross vehicle weight.
[2] Under 3,860 kg (8500 lb) gross vehicle weight.
[3] These standards have been converted to be consistent with the 1975 Federal Testing Procedures.
[4] 1981 and 1982 CO standards are waiverable to 4.3 g/km (7.0 g/mile).
[5] NO_x is waiverable to 1.5g/km (2.4 g/mile) or 2.0 g/km (3.3 g/mile).
[6] NOx is waiverable to 1.5 g/km (2.4 g/mile).
[7] Recently proposed light-duty truck standards.

Table 4.-2.
Estimated Passenger Car Emission-Control Equipment Cost, 1968–74
(current dollars)

Model Year	Item	Cost[1]
1968–69	Positive crankcase ventilation (PCV) valve	$ 0.40
	Inlet air temperature control	5.00
1970–72	Fuel evaporation control system	13.50
	Idle control solenoid	11.10
	Carburetor changes	3.00
	Hardened valves and seats (for unleaded gasoline)	2.00
	Transmission control system	—
	Ignition timing	—
	Choke heat bypass	—
	Compression ratio changes	—
1973–74	Exhaust gas recirculation (EGR) 11–14 percent	$26.00
	Speed-controlled spark timing	26.00
	Precision cams, bores, pistons	—
	Transmission changes	—

[1] List price includes both dealer and manufacturers profits.

- Changes in valve timing and recirculating exhaust gases
- Capturing fuel evaporative emissions in charcoal canisters or in the crankcase.

Table 4.-2 summarizes the EPA estimates for incremental cost increases per car due to emission control requirement for the period 1968 to 1974. These data are expressed in current dollars.

Control Devices, 1975–1976 Model Years

When the 1975 Statutory Standards were suspended for a year[5] and replaced with less stringent interim standards, it became apparent that two types of emission-control systems could be used for the 1975 model year: (1) oxidation catalyst-equipped systems, and (2) advanced engine modifications systems. The oxidation catalyst systems have been preferred by the industry, and approximately 85 percent of the 1975 model year sales included catalysts. Other changes and additions for some 1975 model-year cars included:

- Quick-heat manifold
- High-energy ignition
- Advanced carburetors
- Air injection.

Since the 1976 emission standards[7] called for the same hydrocarbon, carbon monoxide, and nitrogen oxide levels as the 1975 interim standards, only minor changes in emission control systems were made from 1975 models. Proportional exhaust gas recirculation was introduced in some models.

The EPA estimate of the initial equipment or engine modification costs per car for emission control for the 1975 and 1976 model years is $220 (updated to 1977 dollars).

Control Devices, 1977 Model Year

With the suspension of 1977 emission standards on March 5, 1975, and the carryover of standards for hydrocarbon and carbon monoxide at the 1975–76 levels, and the nitrogen oxides at a level of 1.25 g/km (2.0 g/mile) (which is 35 percent lower than the 1975–76 level), the automobile companies met the 1977 standards with only minor modifications to engines and control devices. These modifications took the form of increased use of secondary air for catalyst operation, improved exhaust gas recirculation, ignition timing modification or modified catalysts with decreased use of secondary air. EPA has estimated the incremental cost to meet 1977 emission standards at $15.

Control Devices, 1978 and 1979 Model Years

Since Congress has passed Clean Air Act Amendments (of 1977) calling for maintenance of 1977 emission levels through the 1979 model year, cumulative control costs per vehicle are maintained at the 1977 level for these cost analyses. This results in significant cost reduction from costs that would have been incurred if statutory 1978 standards had become effective in 1978. This control cost decrease is obtained, however, at the expense of increased emissions.

In addition to the modifications applied earlier, 1980 standards will require application of a three-way (HC, CO, NO_x) catalyst (in place of the single oxidation catalyst), plus electronic control modules for the following items: spark control, exhaust-gas recirculation, air-to-fuel ratio, and air injection. Costs for these modifications will vary, i.e., weight of vehicle, engine design, and engine calibration. EPA's estimate of 1980 and beyond incremental costs for an "average" vehicle is $204 if the 4.4 g/km (7.0 g/mile) CO standard is required or $260 if the 2.1 g/km (3.4 g/mile) CO standard is required.

Estimated Maintenance Costs Due to Emission Controls

The additional per-vehicle maintenance costs attributable to emission-control devices has been estimated by EPA to be $200 over the life of the car from model years 1968 through 1974 (in 1977 dollars). For the 1975, 1976, and 1977 model years, certain benefits in reduced maintenance cost are derived from the use of high-energy ignition systems, long-life exhaust systems, and unleaded fuel. For the 1975–77 model years, the maintenance cost benefits are estimated to be $90 per catalyst-equipped car over precontrolled cars. No increase or decrease in maintenance costs is expected for the 1978 and 1979 model years.

Additional maintenance costs are anticipated for the 1980 model year because of the greater complexity expected in the emission-control systems required to meet the lower hydrocarbon and carbon monoxide standards. This increase over precontrolled cars is estimated to be $17 over the lifetime of the car. For the 1981 model year and beyond, the lifetime maintenance cost increase is estimated to be $77.

Fuel-Consumption Penalties

The average fuel economy of motor vehicles decreased gradually from the 1968 through the 1974 model cars. This change can be attributed to variations in vehicle weight, engine size, optional equipment, and the effects of emission-control equipment. In particular, the specific emission-control measures that adversely affect fuel consumption are retarded ignition timing, reduced compression ratio, and exhaust-gas recirculation.

Fuel economy penalties for the 1968 to 1973 model years were obtained from an EPA study[8] of passenger car fuel economy involving tests of nearly 4,000 vehicles ranging from 1957 production models to 1975 prototypes. The fuel economy loss for 1968 and 1969 model cars decreased by about a half mile per gallon compared to the pre-1968 cars. This fuel penalty increased to about one mile per gallon in 1970 and 1971, 1.4 miles per gallon in 1972, and 1.7 miles per gallon in 1973. Only a slight change toward better fuel economy was realized in 1974.

Various industry sources as well as the EPA have indicated that catalytic systems on most 1975 and

1976 vehicles resulted in fuel economy superior to 1973 and 1974 model-year cars. By 1976, a benefit of about 0.4 miles per gallon is estimated.

No change in fuel economy is anticipated for the 1977 model year (when the NO_x standard drops from 1.9 to 1.2 g/km (3.1 to 2.0 g/mile) due to the expected extensive use of proportional exhaust gas recirculation (PEGR) and other technological improvements.

No additional fuel economy gains or penalties are estimated for model years 1978 through 1986 due to emission controls. In separate efforts to improve fuel economy, the auto companies will be reducing the size and weight of vehicles in their existing model line, improving engine efficiency, changing axle ratios, and introducing lighter, smaller models. These modifications will raise the average fuel economy of all affected models, regardless of the potential effect of pollution controls. The principal impetus for these developments is the Energy Policy and Conservation Act (P.L. 94–163) passed and signed in December 1975 that required all manufacturers to meet fuel economy standards (on the average) of 13.0, 12.3, 11.8 liters per hundred kilometers (18, 19 and 20 miles per gallon) for their 1978, 1979, and 1980 models, respectively.

A recent study by EPA has raised some question about past studies that estimate a fuel penalty due to emission controls. The pre-1968 test cars used by EPA have, in the past, been reported as getting better fuel economy than they get when compared on an age basis with the new cars being tested. When these older cars are adjusted to reflect comparable age and mileage, and all model years are adjusted for the changing weight of cars, the fuel penalty becomes zero. For this report, the traditional fuel penalty is computed and added into the total cost estimates. However, future reports may have to adjust for this recent EPA study, if it proves to be substantiated by further studies.

Fuel Cost Increases

Two EPA regulations affecting fuel costs are discussed below. One pertains to requiring gasoline marketers to make available 91 research octane number lead-free gasoline by July 1, 1974, for use in oxidation catalyst-equipped vehicles. The other EPA regulation requires that the lead content of leaded gasoline be reduced to an average of 0.13 gram per liter (0.5 gram per gallon) by October 1979. This latter regulation, aimed at reducing lead in the atmosphere for health purposes, was recently upheld by the courts as discussed earlier in this chapter. Thus, for the purposes of this report, it is assumed that lead phase-down will take place as called for by EPA. The promulgated schedule stretches the lead removal over a period of 4 years.

Lead phase-down requirements may advance the need for installation of new octane-generating capacity compared to the requirement that would naturally result from the gradual replacement of vehicles that use leaded gasolines by vehicles that use unleaded.

The lead phase-down schedule may also impose additional investment requirements that would otherwise be unnecessary in the long-term. This will happen if the specific lead phase-down schedule requires a clear pool antiknock index higher than that which would be required without the schedule. This can result if the percent of cars running on relatively high-octane leaded gasoline is large. It has been estimated that a 0.13 gram of lead per liter (0.5 gram per gallon) requirement earlier than about 1985 would require such investments in long-term excess octane generating capacity.

The costs associated with the lead phase-down requirements may logically be associated with either the petroleum-refining industry or the mobile-source category. Since the mobile-source chapter aggregates the total consumer cost of EPA regulations on automobiles, the costs for lead phase-down are included in this chapter.

Fuel cost increases due to the lead-free gasoline requirement have been estimated at 0.26 cent/liter (1.0 cent/gallon) for 1975; 0.4 cent/liter (1.5 cent/gallon) for 1976–1977; 0.45 cent/liter (1.7 cent/gallon) for 1978; 0.50 cent/liter (1.9 cent/gallon) for 1979; 0.55 cent/liter (2.1 cent/gallon) for 1980, 0.61 cent/liter (2.3 cents/gallon) for 1981; and 0.66 cents/liter (2.5 cent/gallon) for 1982–1986 (in current dollars).

The added cost of leaded fuel due to lead phase-down requirements has been estimated to be 0.5 cent per gallon from 1979–1986 (current dollars). These data are derived primarily from References [9] and [10].

It should be noted that the above cost estimate for unleaded gasoline may differ somewhat from the price differential customers pay at service stations. This is due to two factors. The demand for leaded gasoline has decreased, thus reducing its price somewhat relative to unleaded gasoline. Also, service stations tend to offer leaded gasoline at a lower mark-up in order to attract customers. The price differential used in this report is based on engineering cost estimates for the petroleum refining industry.

Light-Duty Trucks

For this report, it is assumed that emission control equipment costs for light-duty trucks are the same as for passenger cars for the 1973 and 1974 model years. Beginning with the 1975 model year, less stringent standards were set for light-duty trucks than for passenger cars. Consequently it is assumed in this report that emission control costs for model years 1975–78 will be only moderately higher than for the 1973–74 model years ($188 per vehicle in July 1977 dollars).

Annual maintenance costs for 1973 and 1974 model year light-duty trucks are estimated to be $16 per vehicle. For the 1975 to 1978 model year period, it is estimated that there will be a maintenance cost benefit of $5 per vehicle due to the use of catalysts, low-maintenance emission-control components, and unleaded fuel in a significant portion of light-duty trucks sold in that period.

The fuel economy of light-duty trucks was assumed to be the same as for light-duty passenger cars for 1973 and 1974. A fuel economy gain of 6 percent is assumed for the 1975 model year, and no change for the 1976 to 1986 period.

The revised light-duty truck regulations for 1979 and later model years[1] calls for more stringent exhaust emission standards, 1.1 g/km (1.7 g/mile) HC, 11 g/km (18 g/mile) CO, and 1.4 g/km (2.3 g/mile) NO_x, and an increase in the upper weight limit from 2,720 kg (6,000 lb) gross vehicle weight (GVW) to 3,860 kg (8,500 lb) GVW. Minor changes are also made in test procedures. The effect of these new regulations on vehicle cost is estimated to be $8 for trucks up to 2,720 kg (6,000 lb) GVW and $219 for trucks in the 2,720 kg (6,000 lb) to 3,860 kg (8,500 lb) GVW range[9]. No fuel economy or maintenance cost penalties are expected[9].

Aggregate National Costs for Light-Duty Vehicle Emission Controls

Costs to the nation for light-duty vehicle emission control will be comprised of the aggregate of equipment, maintenance, and fuel-consumption cost increments attributable to the control devices. Since the various costs attributable to emission controls are different for each model year, total costs to the nation have been estimated separately for each model year using vehicle-population data for previous years and projections for future years. Maintenance costs and total fuel cost increases are estimated using standard scrappage rates and annual-miles-driven data. Data were derived principally from References [11] and [12].

A breakdown of annual national cost estimates for passenger car emission control is presented in Table 4.-3. Equipment and maintenance costs for each calendar year are taken as the equipment cost attributable to the new model-year vehicles. Costs attributable to reduced fuel economy are based on the miles driven in a given year for a given model year car and the price of gasoline in that year. Fuel price penalties for lead-free gasoline are applied to those cars which require lead-free gasoline. Lead phase-down costs are applied to those cars using leaded gasoline. A breakdown of annual national cost estimates for light-duty truck emission control is presented in Table 4.-4.

Table 4.-3. Estimated National Emission-Control Costs for Light-Duty Passenger Cars (millions of 1977 dollars)

Year	Capital Investment	Annualized Capital Cost	Maintenance Cost	Fuel Consumption Penalty	Fuel Price Penalty: Lead-Free Cost	Fuel Price Penalty: Total Lead Phase-Down	Total O & M Cost	Annualized Cost
1968	72.36	19.09	218.44	343.64	—	—	562.08	581.17
1969	73.81	38.56	415.71	599.19	—	—	1014.90	1053.46
1970	147.50	77.47	547.28	1033.89	—	—	1581.17	1658.64
1971	474.19	202.56	714.42	1556.84	—	—	2271.26	2473.82
1972	496.76	333.61	879.69	2346.72	—	—	3226.41	3560.02
1973	1288.08	654.31	1027.65	3304.32	—	—	4331.97	4986.28
1974	1002.95	899.42	1104.54	2954.63	—	—	4059.17	4958.59
1975	1907.26	1363.65	872.54	2540.78	133.67	—	3546.99	4910.64
1976	2359.35	1860.95	653.74	2077.18	275.43	—	3006.35	4867.30
1977	2632.00	2424.23	456.22	1851.86	404.82	—	2712.90	5137.13
1978	2608.98	2772.68	387.55	1587.17	485.21	—	2459.93	5232.61
1979	2561.01	3183.70	313.26	1349.58	554.27	170.56	2387.67	5571.37
1980	3663.33	3646.95	256.41	1049.19	624.45	130.00	2060.05	5707.00
1981	5204.23	4397.42	272.20	849.61	680.33	98.64	1900.78	6298.20
1982	5073.80	5041.56	301.20	524.89	698.76	75.33	1600.18	6641.74
1983	5192.89	5723.20	300.90	366.24	718.54	53.86	1439.54	7162.74
1984	5573.75	6465.20	342.21	225.02	722.07	40.26	1329.56	7794.76
1985	5401.60	6923.75	391.53	151.95	714.31	30.29	1290.08	8213.83
1986	5446.06	6987.53	448.82	85.44	700.31	26.15	1260.72	8248.25

Table 4.-4.
Estimated National Emission-Control Costs for Light-Duty Trucks (millions of 1977 dollars)

Year	Capital Investment	Annualized Capital Cost	Maintenance Cost	Fuel Consumption Penalty	Fuel Price Penalty	Total O&M Cost	Total Annualized Cost
1973	220.00	58.04	30.00	50.00	—	80.00	138.04
1974	290.00	108.16	60.00	160.00	—	220.00	328.16
1975	250.00	174.11	50.00	210.00	10.00	270.00	444.11
1976	250.00	240.06	40.00	270.00	20.00	330.00	510.06
1977	250.00	306.01	30.00	290.00	40.00	360.00	666.01
1978	260.00	316.56	30.00	330.00	60.00	420.00	736.56
1979	720.00	456.38	30.00	440.00	100.00	560.00	1026.38
1980	750.00	588.28	30.00	580.00	160.00	770.00	1358.28
1981	790.00	730.93	30.00	740.00	230.00	990.00	1720.93
1982	820.00	881.10	20.00	890.00	290.00	1200.00	2081.10
1983	850.00	1036.74	20.00	1030.00	340.00	1390.00	2426.74
1984	880.00	1078.95	20.00	1200.00	380.00	1600.00	2678.95
1985	920.00	1123.80	20.00	1360.00	430.00	1810.00	2933.80
1986	960.00	1168.65	10.00	1530.00	480.00	2020.00	3188.65

HEAVY-DUTY VEHICLE CONTROLS

Emission Standards

Separate emission-control regulations have been in effect since 1970 for new heavy-duty gasoline and diesel truck engines manufactured for use in over-the-highway trucks and buses. These standards applied to trucks over 2,720 kilograms (6-,000 lb) gross vehicle weight through model year 1975. Starting with the 1979 model year, trucks under 3,860 kilograms (8,500 lb) gross vehicle weight will be considered light-duty vehicles (and have been dealt with in the preceding section of this Chapter.) Heavy-duty truck engine certification test procedures are performed on the engine itself and do not pertain to the vehicle, as is the case for light-duty truck and passenger car regulations.

Federal regulations for emissions from heavy-duty gasoline engines for 1970 through 1978 are shown in Table 4.-5. For 1970 through 1973, regulations covered hydrocarbon and carbon monoxide emissions measured in terms of average concentrations in the engine exhaust over a nine-mode, constant-speed, variable-load dynamometer cycle. New standards, which went into effect in 1974, are based on the same test procedure, but emissions are reported in terms of grams per unit work. The sum of hydrocarbon and nitrogen oxide emissions is limited to 6.0 microgram/joule (16 g/Bhp-hr), while the standard for carbon monoxide is 15 microgram/joule (40 g/Bhp-hr) for 1974 through 1978 model-year heavy-duty gasoline engines.

Heavy-duty diesel truck engine Federal standards for 1970–78 are also shown in Table 4.-5. Through 1970–73, standards covered smoke emissions only. In 1974, the standards were revised to include hydrocarbon, nitrogen oxide, and carbon monoxide emissions as well as more stringent smoke emissions. The permissible gaseous-emission levels are the same as for heavy-duty gasoline engines for 1974 through 1978, but the test procedure is different. For diesels, emissions

Table 4.-5.
Federal Standards for Heavy-Duty Gasoline and Diesel-Engine Emissions for Model Years 1970 Through 1978

Pollutant	Emission Standards[1] 1970–73	1974–78
	Gasoline Engines	
Hydrocarbons (HC)	275 ppm	6 microgram/joule[2] (16 g/Bhp-hr)[2]
Oxides of nitrogen (NO_x)	—	15 microgram/joule
Carbon monoxide (CO)	1.5%	(40 g/Bhp-hr)
	Diesel Engines	
Smoke:		
Opacity in accelerating mode	40%	20%
Opacity in lugging mode	20%	15%
Peak opacity in either mode	—	50%
HC + NO_x	—	6 microgram/joule (16 g/Bhp-hr)
CO	—	15 microgram/joule (40 g/Bhp-hr)

[1] For use in vehicles of more than 2,720 kilograms (6,000 lb) gross vehicle weight.
[2] HC + NO_x.

are averaged over a 13-mode, variable-speed, variable-load dynamometer cycle.

New regulations for heavy-duty gasoline and diesel engines were established in late 1977 for 1979 and later model years.[2] The new standards specify 0.56 microgram/joule (1.5 g/Bhp-hr) HC, 9.3 microgram/joule (25 g/Bhp-hr) CO, and 3.7 microgram/joule (10 g/Bhp-hr) HC + NO_x. An alternative standard calls for the same CO level, 1.9 microgram/joule (5 g/Bhp-hr) HC + NO_x, and no separate HC specification. Changes in test procedures and test instrumentation are included in the new regulations. These new standards apply to vehicles in the 3,860 kilogram-and-over (8,500 lb and-over) gross vehicle weight class because of the previously mentioned change in the light-duty truck maximum weight specification.

The Clean Air Act as amended in 1977 requires that EPA prescribe for heavy-duty engines and vehicles emission standards requiring at least a 90 percent reduction of hydrocarbons (HC) and carbon monoxide (CO) from uncontrolled levels beginning with the 1983 model year. A new test procedure is being considered which is based upon a transient driving schedule representative of on-road operation. The new test procedure, if promulgated, will require substantial new investments in capital equipment and will force the design of emission controls that function properly over representative transient operation. It is expected that oxidizing catalyst technology and unleaded fuel will be required for gasoline-fueled engines. Diesel-fueled engines will require minimal hardware additions although the new test procedure cost would be relatively high due to changes to the test facility. Using the preceding assumptions, the costs of implementing the 90 percent reduction of HC and CO along with new test procedures in 1983 could be considerably greater than the present estimates for costs to be incurred in this period. Additionally, the operating costs for gasoline engines would be increased due to the added cost of unleaded fuel. No fuel economy penalties are expected. There are no new test procedures anticipated for the 1985 NO_x standard and no cost estimated, though there is a potential hardware cost and fuel economy penalty.

Heavy-Duty Gasoline Engine Controls

The emission-control technology used for heavy-duty gasoline engines through 1973 is similar to that employed for light-duty trucks and passenger cars through the 1972 model year. In fact, many heavy-duty gasoline engines are derivatives of passenger car engines. For 1974, the nitrogen oxide control standards were generally attainable without the use of EGR, although some EGR engines were certified in the previous year to meet California standards for 1973 which were at the same level as Federal standards for 1974.

No detailed equipment cost estimates have been made by EPA for heavy-duty gasoline truck engine emission controls. In the absence of such estimates, it is assumed for purposes of this report that the per-vehicle emission-control equipment cost increment of 1970–73 engines is equivalent to that for 1970 model-year passenger car engines minus the cost of fuel evaporation controls, equalling $30 per vehicle in July 1977 dollars. It is further assumed that the 1974 to 1978 model year control equipment costs will be equivalent to those for a 1973 passenger car engine less the cost of EGR and evaporative controls, or $62 per vehicle. The 1979 heavy-duty engine standards are estimated to result in a cost increase of $120 for gasoline engines[13].

Incremental annual maintenance costs for heavy-duty gasoline truck engine controls for all years are assumed to be the same as passenger car costs for model years 1968 through 1974, or $20 per vehicle. Fuel consumption penalties are estimated to be 3 percent for the 1970–1973 period, and 5 percent for 1974 and beyond. A baseline fuel economy of 28 liters per hundred kilometers (8.5 mpg) is assumed. Estimates of total per-vehicle costs attributable to emission controls for this class of trucks are summarized in Table 4.-6.

It is estimated that the population of 1970–73 trucks of this class will peak at about 4.5 million in 1973, and that the total controlled population will have reached approximately 9.0 million in 1980. Estimated costs for heavy-duty gasoline truck Federal emission controls are presented in Table 4.-7.

Table 4.-6.
Estimated Per-Vehicle Cost Penalties for Heavy-Duty Gasoline Engine Emission Control
(costs in 1977 dollars)

Incremental Cost Item	Model Years 1970–73	1974–78	1979–86
Emission-control equipment cost	$30	$62	$120
Annual maintenance	20	22	20
Fuel consumption penalty[1]	3%	5%	5%

[1] Based on 28 liters per hundred kilometers (8.5 mpg) for pre-1970 trucks.

Table 4–7
Estimated National Costs Attributable to Gasoline-Fueled Heavy-Duty Truck Emission Controls, 1970–1986
(millions of 1977 dollars)

Year	Capital Investment	Annualized Capital Cost	Maintenance Cost	Fuel Consumption Penalty	Total O & M Cost	Total Annualized Cost
1970	30.00	7.10	20.00	20.00	40.00	47.10
1971	30.00	14.20	40.00	60.00	100.00	114.20
1972	40.00	23.67	60.00	100.00	160.00	183.67
1973	40.00	33.14	80.00	150.00	230.00	263.14
1974	80.00	52.08	110.00	300.00	410.00	462.08
1975	80.00	63.92	120.00	420.00	540.00	603.92
1976	90.00	48.13	140.00	610.00	750.00	828.13
1977	90.00	89.97	170.00	770.00	940.00	1029.97
1978	90.00	101.81	200.00	940.00	1140.00	1241.81
1979	70.00	99.45	200.00	1020.00	1220.00	1319.45
1980	60.00	99.45	210.00	1040.00	1250.00	1349.45
1981	60.00	97.08	220.00	1060.00	1280.00	1377.08
1982	80.00	94.71	220.00	1080.00	1300.00	1394.71
1983	80.00	92.34	220.00	1070.00	1290.00	1382.34
1984	80.00	84.70	230.00	1070.00	1300.00	1394.70
1985	90.00	97.07	230.00	1070.00	1300.00	1397.07
1986	90.00	99.44	220.00	1060.00	1280.00	1379.44

Heavy-Duty Diesel Engine Controls

Both smoke and gaseous emission standards, including those for 1974, have been attained largely through fuel-injection system modifications. Nitrogen oxide and smoke are the more difficult emissions to control; even uncontrolled diesels are usually well within carbon monoxide standards. Equipment cost penalties are considered nominal through the 1978 model year and are estimated to be $130 per engine for 1979 and later model years. It is estimated that no fuel consumption or maintenance cost penalties have been incurred[13].

MOTORCYCLE CONTROLS

Emission Standards

Individually motorcycles are small emitters but collectively they represent a significant source of emissions. The average uncontrolled motorcycle presently emits about twice as much CO and about six times as much HC as permitted by 1977 automobile standards.

Both interim (1978/79) and longer term (1980 and beyond) emission standards for motorcycles designed for street use were promulgated by EPA in 1977[14]. (Motorcycles with engine displacements of less than 50 cc are not covered by the regulations). The 1978/79 interim standard for HC exhaust emissions is dependent upon engine displacement, requiring control to 5.0 g/km (8.1 g/mile) for motorcycles with up to 170 cubic centimeters (10.4 cubic inches) displacement. The standard increases proportionately with displacement, from the 5.0 g/km required at 170 cc to 14.0 g/km (22.6 g/mile) required at 750 cc (45.8 cubic inches). Motorcycles with displacements above 750 cc are held to the 14.0 g/km standard regardless of size. CO emissions are limited to 17.0 gm/km (27.4 g/mile) regardless of size. No standard for oxides of nitrogen has been promulgated because a 1976 air quality analysis indicated that the motorcycle contribution to motor vehicle NO_x emissions is negligible, estimated to be less than 0.5 percent in 1990.

The promulgated long-term emission standards for the 1980 and beyond model years will be 5.0 gm/km (8.1 g/mile) HC (regardless of engine displacement) and 12.0 gm/km (19.3 g/mile) CO.

Crankcase emissions are prohibited under both the interim and long-term emission standards.

Motorcycle Control Costs

The average incremental price increases for 1978 and 1979 model year motorcycles attributable to the emission standards has been estimated to be $47 (in July 1977 dollars). Similarly, the average incremental price increase for 1980 model year motorcycles is estimated to be $18. No effect on maintenance costs is anticipated[15].

Aggregate National Costs for Motorcycle Emission Controls

Costs to the nation for motorcycle emission control will be comprised of the aggregate of equipment and fuel-consumption cost increments attributable to the control devices. Total costs have been estimated separately for each model year (after controls go into effect) using projections of vehicle population and vehicle miles travelled [15].

Motorcycle sales projections, with estimates of survival probability and mileage accumulation, were used to estimate the annual motorcycle emissions control costs given in Table 4.-8. In the costs reported here, no credit is taken for the fuel economy benefit; this is consistent with the general practice used throughout this report. The costs thus reflect only capital investment and annualized capital.

Table 4–8 Motorcycle Air Pollution Control Costs (in millions of 1977 dollars)

Year	Capital Investment	Annualized Capital
1978	46.50	12.27
1979	48.90	25.17
1980	70.90	43.87
1981	74.80	63.60
1982	78.70	84.36
1983	82.60	93.88
1984	86.50	103.80
1985	91.0	109.11
1986	95.0	114.60

AIRCRAFT EMISSION CONTROLS

Aircraft emissions have been identified as significant contributors to the regional burden of pollutants which will have to be controlled to meet National Ambient Air Quality Standards.

Airports are concentrated sources of pollutant emissions which will in many cases reduce local air quality to unsatisfactory levels even though emissions from automobiles and stationary sources are within acceptable levels within the general area.

The Clean Air Act directs the Administrator of the EPA to "establish standards applicable to emissions of any air pollutant from any class or classes of aircraft or aircraft engines which in his judgment cause or contribute to air pollution which endangers the public health or welfare". In July 1973, Federal emission standards and test procedures were established for various classes of new and in-use aircraft engines[16]. These regulations are based on the need to control emissions occurring under 900 meters (3,000 feet) to protect ambient air quality in urban areas. However, the standards are not quantitatively derived from the air-quality considerations in affected areas but, instead, reflect EPA's judgment as to the emission levels that will be practicable with present and projected technology. The requisite technology is assumed to include advanced combustion-system concepts for turbine engines and improved fuel systems for piston engines. The standards cover (a) fuel venting regulations beginning January 1, 1974, (b) smoke emission regulations taking effect in 1974, 1976, and 1978 for various engine classes, and (c) gaseous emission (carbon monoxide, hydrocarbon, and nitrogen oxide) standards for 1979 and 1981. Gaseous emissions regulations are based on a simulated landing-and-take off operating cycle which includes: (1) taxi/idle (out), (2) take off, (3) climb out, (4) approach, and (5) taxi/idle (in). Piston engines are included in the standards beginning in 1979.

EPA promulgated in August of 1976[17] regulations limiting emissions from currently certified SST aircraft manufactured after January 1, 1980, and more stringent emission standards for SST aircraft that are newly certified after January 1, 1984. By 1990, the 1980 and 1984 standards are expected to account for a 61 percent reduction in HC and a 50 percent reduction in CO emissions at an airport where SST aircraft are used.

Another aircraft emissions regulatory action promulgated late in 1976 was an extension of the compliance date for smoke emissions standards applicable to the JT3D engine (commonly used in Boeing 707s and DC-8s). The extension from January of 1978 to September of 1981 was in response to a petition by the Air Transport Association (ATA). The manufacturers claimed in the petition that durability problems had developed during tests of the low-smoke combustor which could not be overcome within the necessary time frame and, additionally, that EPA had significantly underestimated the cost of this retrofit program and its impact on the airline industry. EPA, in granting the extension, additionally required that each operator of aircraft powered by JT3D engines achieve 90 percent compliance by September of 1980. The 90 percent by 1980 requirement was added to lessen the impact of the extension and to force continued effort to develop technology required to meet the full standard. The environmental impact of the completed program is expected to be a reduction in visible smoke, and HC and CO emissions reductions of 32 percent and 13 percent, respectively, from total commercial aircraft emis-

sions in exchange for a modest 5 percent increase in NO_x.

In March, 1978, an amendment to the July, 1973, regulatory action was issued which changed the compliance date for the gaseous emission standards from January 1,1979, to January 1, 1981.[18] On this same date EPA proposed a number of changes to the gaseous emission standards originally promulgated in July, 1973; hence, the delay in compliance was granted to allow more time for analysis of comments received on the proposed changes and for a reassessment of the air quality impact of aircraft operations at large metropolitan airports.

In general, the influence of the regulations will be to contribute to the maintenance of the quality of the air in and around major air terminals throught the post-1979 era in which air traffic is undergoing expansion. The timing of these standards will not make contributions to achievement of ambient air-quality levels required by 1975 through the state implementation programs. Present aircraft emission standards[17] and their estimated cost impact[19, 20] are listed in Table 4.-9. Costs of fuel-venting and smoke emission controls through 1978, totaling $17 million, are minor in comparison to costs of controlling other sources in that time period.

Table 4–9.
Aircraft Emission Standards and Estimated Cost Impacts

Calendar Year	Standards	Implementation Technology	Estimated Cost of Implementation (July 1977 dollars)
1974	JT8D smoke standards	Combustor and fuel nozzle retrofit	None (already voluntarily completed)
1974	Fuel venting restrictions for new and in-use engines (1975 for business-aircraft engines)	Plumbing and/or operational changes	$2.5 million
1976	Smoke standards, new turbine engines except JT3D, JT8D, and supersonic.	—	None
	Gaseous emission (HC, CO, and NO_x) standards for all engines manufactured.	Modified engine hot section	$86.4 million[2]
1982	Same as 1979	Same as 1979	$6.3 million[2, 3]
1981	JT3D smoke standards[4]	Fuel nozzle retrofit	$18.8 million
1980	Gaseous emissions standards for currently certified SST aircraft mfg after January 1, 1980	—	$10.4 million
1984	Gaseous emissions standards for new SST aircraft certified after January 1, 1984	—	No estimate
1983–86	Gaseous emission standards for newly certified engines	Advanced combustor and engine concepts	$3 million

Sources: EPA, References (19) and (21).

[1] Principally development and recertification costs. Includes additional engine hardware costs which will be incurred in 1981. Maximum additional engine cost estimate to be:

$10,000 per large turbine engine
6,000 per small turbine engine over 3,600 kg (8,000 lb) thrust
2,000 per small turbine engine under 3,600 (8,000 lb) thrust, and per turboprop or APU engine
52 per piston engine.

[2] Estimated $3.6 million in piston engine fuel savings per year for 1981 and 1982 is included.

[3] Estimated $4.4 million for hardware and $1.9 million for certification.

[4] 90 percent compliance required by September, 1980.

The estimated cost of development and recertification efforts for compliance with the 1981 gaseous-emission standards is $82 million, and the additional engine-hardware costs, to be incurred in 1981, are estimated to be $4.4 million. The costs incurred in 1982 for compliance with the 1981 standards are estimated to be $4.4 million for hardware and $1.9 million for certification for a total of $6.3 million. The 1981 standards promulgated for piston-type aircraft are expected to result in significant fuel savings: $36 million over 10 years. Credit for these savings has been assumed at a uniform rate of $3.6 million per year in estimating the cost of aircraft emission controls for the 1981 to 1986 time period. Cumulative national costs through 1986 for aircraft emission control are shown in the cost summary in Table 4.-10.

UNREGULATED MOBILE SOURCE EMISSIONS.

As stated in the Introduction, a number of mobile sources are presently unregulated. These include: railroad locomotives, marine engines, and offroad farm, construction, and garden equipment.

Emission inventories have been performed on many of these unregulated mobile sources.

As a general conclusion, most small-engined mobile sources (such as garden equipment, outboard engines, and snowmobiles) each contribute less than 1 percent of the total hydrocarbon and carbon monoxide from mobile sources, and less than 0.1 percent of the total nitrogen oxide (based on 1970 data). While these percentages are increasing as passenger cars and trucks come under more stringent control, it would not appear to be cost-effective to regulate these mobile sources until some future time.

In a publication by HEW[22], it was estimated that the total carbon monoxide emissions from railroad locomotives in 1968 constituted about 1.6 percent of the emissions from all transportation sources. Percentages for hydrocarbon, total particulates, and sulfur oxides were 1.8, 16.7, and 12.5, respectively. At present, there are no proposed regulations for railroad locomotive exhaust emissions.

SUMMARY OF MOBILE SOURCE CONTROL COSTS

The preceding cost estimates for light-duty vehicles, light- and heavy-duty trucks, motorcycles and aircraft source air pollution controls are expressed in July 1977 dollars. Table 4.-10 summarizes the major cost estimates.

Table 4.-10.
Estimated Total National Costs for Mobile Source Emission Control, 1968–1986
(in millions of 1977 dollars)

	1977	1970–77	1977–81	1977–86
Investment				
Passenger Cars	2632.00	10308.09	14037.55	40525.65
Light-Duty Trucks	250.00	1260.00	2520.00	6950.00
Heavy-Duty Trucks	30.00	480.00	320.00	740.00
Motorcycles	0.00	0.00	241.10	675.50
Aircraft	0.00	2.00	115.90	160.40
Total	2912.00	12050.09	17234.55	49051.55
Annualized Capital Costs				
Passenger Cars	2424.23	7816.20	14000.75	45141.99
Light-Duty Trucks	306.01	886.38	2092.15	7381.39
Heavy-Duty Trucks	7.10	332.21	397.79	866.05
Motorcycles	0.00	0.00	144.91	650.66
Aircraft	0.50	2.00	72.71	169.40
Total	2737.84	9036.79	16708.31	54227.54
Operating and Maintenance Costs				
Passenger Cars	2712.90	23155.05	8808.43	15728.51
Light-Duty Trucks	360.00	1260.00	2740.00	10760.00
Heavy-Duty Trucks	40.00	3170.00	4890.00	11360.00
Motorcycles	0.00	0.00	0.00	0.00
Aircraft	0.00	0.00	0.00	0.00
Total	3112.90	29166.22	16438.43	37848.51
Combined Annualized Costs				
Passenger Cars	5137.13	32552.42	22809.18	60870.50
Light-Duty Trucks	666.01	2146.38	4832.15	18141.39
Heavy-Duty Trucks	47.10	3502.21	5287.79	12236.05
Motorcycles	0.00	0.00	144.91	650.66
Aircraft	0.50	2.00	72.71	169.40
Total	5850.74	38203.01	33146.74	92068.00

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22. *Nationwide Inventory of Air Pollutant Emissions— 1968*, U.S. Department of Health, Education, and Welfare, Public Health Service, Environmental Health Service, National Air Pollution Control Administration, Publication No. AP-73, August 1970.

5. CHEMICAL INDUSTRY

For the purposes of this report, the Chemicals Industries are defined as those establishments which manufacture products primarily by chemical modifications of raw materials and for which the final product is a chemical.

Those included are the:

- Petrochemicals Industry
- Vinyl Chloride Industry
- Nitric Acid Industry
- Sulfuric Acid Industry
- Phosphate Fertilizer Industry
- Nonfertilizer Phosphorus Industry
- Mercury Cell Chlor-Alkali Industry

Costs for the abatement of air pollution for these industries are summarized in Table 5.-1.1 These costs and other data are repeated below in the appropriate section together with the assumptions peculiar to the industrial sector and other details.

TABLE 5.-1. AIR POLLUTION ABATEMENT COSTS FOR THE CHEMICAL INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1970–77	1977–81	1977–86
PETROCHEMICALS	4.47	27.63	9.37	22.06
VINYL CHLORIDE	79.39	87.47	181.32	235.57
NITRIC ACID	3.98	34.34	3.26	4.80
SULFURIC ACID	72.58	499.05	144.27	325.92
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.00	7.51	1.97	4.79
MERCURY-CELL CHLOR-ALKALI	1.97	18.52	1.18	1.18
TOTAL INVESTMENT	163.38	674.51	341.08	594.32
		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
PETROCHEMICALS	29.21	94.74	142.72	376.15
VINYL CHLORIDE	27.44	29.97	296.05	765.72
NITRIC ACID	12.99	44.91	56.35	121.26
SULFURIC ACID	131.59	433.89	646.93	1586.17
PHOSPHATE FERTILIZER	0.0	0.0	0.0	0.0
NON-FERTILIZER PHOSPHATES	1.56	5.17	7.37	16.12
MERCURY-CELL CHLOR-ALKALI	8.24	28.83	35.05	71.32
TOTAL ANNUAL COSTS	211.01	637.50	1184.47	2936.75

5.1 PETROCHEMICALS INDUSTRY

Production Characteristics and Capacities

In estimating air emission control costs associated with the petrochemical industry, the production of the following major large-volume petrochemicals was considered:

- Formaldehyde
- Acrylonitrile
- Ethylene oxide
- Phthalic anhydride.

Ethylene dichloride, formerly considered in this sector, is now included in the vinyl chloride sector.

A major air-pollution problem in the petrochemical industry is the emission of hydrocarbons and carbon monoxide via off-gases produced in oxidation processes. The petrochemicals involved in this problem include not only oxygen-containing compounds, such as oxides, aldehydes, and anhydrides, but also compounds in which oxygen serves an intermediate role in the synthesis, such as acrylonitrile. In a typical process of this type, the raw material, air (sometimes oxygen), and sometimes a third reactant are fed into a vapor-phase catalytic oxidation reactor. The reactor effluent gases go to an absorber in which the desired product is scrubbed out. The off-gas from this absorber, which is vented to the atmosphere, contains mostly nitrogen and carbon dioxide, but smaller amounts of carbon monoxide and unconverted hydrocarbons are also present.

Formaldehyde

Formaldehyde is synthesized by oxidation of methanol with air and is sold as an aqueous solution (37 percent by weight). Two processes are used, one based on a metal oxide catalyst and one based on a silver catalyst; about 77 percent of the domestic formaldehyde production uses the silver process and the other 23 percent uses the metal oxide process.

Production in 1974 as reported by the Tariff Commission, was about 2.6 billion kilograms (5.8 billion pounds) of 37 percent formaldehyde. Growth is due primarily to increased demand for urea-formaldehyde and phenol-formaldehyde resins, which consume about half of all the formaldehyde produced.

Acrylonitrile

Ammoxidation of propylene, the most widely practiced method for producing acrylonitrile, consists of the catalytic reaction of propylene, ammonia, and air. Typically, the gaseous products from the oxidation chamber are passed to an absorber where the acrylonitrile is collected. The off-gas from the absorber is normally vented to the atmosphere, a process which is largely uncontrolled at present.

Production in 1974 as reported by the Tariff Commission, was about 640 million kilograms (1.4 billion pounds). Growth is due primarily to increased demand for acrylic fibers, which consume about half of all the acrylonitrile produced, and for plastics, which consume another 15 percent of total production.

Ethylene Oxide

In recent years, the dominant process for manufacturing ethylene oxide has become the direct oxidation of ethylene. There are four processes used for ethylene oxide manufacture by direct oxidation and all use a silver catalyst. Two of the processes oxidize with oxygen, the others use air. The processes which oxidize with oxygen are similar except that usually only a primary reactor and absorber are used. Compared to the processes which use air, the processes which use oxygen produce much less absorber gas but much more carbon dioxide-rich purge gas.

Phthalic Anhydride

Phthalic anhydride is produced by the oxidation of o-xyelene or naphthalene; about 55 percent of the phthalic anhydride is produced from o-xylene. This process is expected to gain an increasing share of industrial production because o-xylene is less expensive than naphthalene.

A number of processes are available for producing phthalic anhydride. Most of the naphthalene-based processes use fluidized-bed reactors, whereas all o-xylene-based processes use tubular fixed-bed reactors. Except for the reactors and the catalyst-handling facilities required for the fluidized-bed units, the processes based on the two raw materials are quite similar. In both cases, the reactor effluent gases are used to generate

Table 5.1.1
Petrochemicals Industry
Calculated Emission Factors in the Absence of Controls
(Kilograms Emitted Per 10^3 Kilograms of Product)

Petrochemical	Waste Gas Streams	CO	Hydrocarbons	SO_x (as SO_2)
Formaldehyde (37%)	Absorber vent	7.33	3.24	—
Acrylonitrile	Absorber vent	163.42	183.96	—
Ethylene oxide	Absorber vent — CO_2 purge	0.00	110.47	—
Phtalic anhydride	Absorber vent	162.46	42.96	5.05

steam in a waste heat boiler. The gases then go to a separation system in which the phthalic anhydride is condensed out as solid crystals. The condenser effluent gases are ultimately vented to the atmosphere, although in most plants they are first water-scrubbed or incinerated.

Emission Sources and Pollutants

Atmospheric emissions arising from petrochemical production result from venting off-gases from the absorber. The chief air pollutants are hydrocarbons and carbon monoxide. Corresponding emission factors for these pollutants as a function of production volume are given in Table 5.1–1.

Control Technology and Costs

The control technology judged to be most feasible for control of hydrocarbon and carbon monoxide emissions from the manufacture of petrochemicals is thermal incineration (often referred to as afterburning). Thermal incinerators were considered in place of catalytic incinerators because of the latter's higher initial investment costs and requirement for catalyst replacement costs. The investment costs for thermal incinerators was based on a compilation of costs by the Midwest Research Institute (MRI), which considered the purchase cost of a thermal incinerator plus the heat exchanger in which the effluent gases heat up the influent gases. These costs were inflated to mid-1973 using the Chemical Engineering Plant Cost Index and were found to compare closely with investment data provided in a recent report by Houdry on acrylonitrile. Annual costs were calculated from utility (fuel and power) requirements, annual maintenance, and operating labor.

Industry costs for air pollution abatement are provided in Table 5.1–2.

TABLE 5.1–2. PETROCHEMICAL INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	4.47	27.63	3.47	3.47
NEW PLANTS	0.0	0.0	5.90	18.58
TOTAL	4.47	27.63	9.37	22.06
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	3.25	10.63	14.61	32.88
NEW PLANTS	0.0	0.0	1.36	9.10
TOTAL	3.25	10.63	15.97	41.98
O&M				
EXISTING PLANTS	25.96	84.11	115.68	259.64
NEW PLANTS	0.0	0.0	11.07	74.53
TOTAL	25.96	84.11	126.75	334.17
ALL ANNUAL COSTS	29.21	94.74	142.72	376.15

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.2 VINYL CHLORIDE

Description of Sector

This sector of the chemical industry is delineated by processes from which vinyl chloride is emitted to the atmosphere. The products of such processes include:

- Ethylene dichloride (EDC) manufactured by oxychlorination
- Vinyl chloride monomer (VCM)
- Polyvinyl chloride (PVC)
- Copolymers of PVC.

Vinyl chloride is produced in the United States by two methods: the addition of hydrogen chloride to acetylene and the dehydrochlorination of ethylene dichloride. Only two plants in the United States use the first method.

Ethylene dichloride is also produced by two methods: the catalytic chlorination of ethylene with chlorine and the oxychlorination of ethylene with hydrogen chloride and oxygen.

The major use for ethylene dichloride in the United States is in the production of vinyl chloride. It is usually convenient and economical to manufacture both products in the same plant in a balanced operation in which part of the ethylene dichloride requirement for the plant is produced by the chlorination of ethylene with chlorine. After purification, the ethylene dichloride is converted to vinyl chloride and hydrogen chloride in a cracking furnace operating at about 510 C (950 F) (dehydrochlorination of ethylene dichloride). Hydrogen chloride is recovered and recycled to an oxychlorination process for the conversion of additional ethylene to additional ethylene dichloride (oxychlorination of ethylene). In this manner, essentially all of the chlorine that is used eventually winds up in vinyl chloride.

Polyvinyl chloride (and copolymers) is produced by the catalyzed polymerization of vinyl chloride (and comonomers).

Four types of processes are used in the United States to effect this polymerization. These processes and the percentage of total U.S. capacity each represented in 1973 are as follows: suspension polymerization (78 percent), dispersion or emulsion polymerization (13 percent), bulk polymerization (6 percent), and solution polymerization (3 percent).

The production of ethylene dichloride, vinyl chloride, and polyvinyl chloride was 1.15, 0.91, and 0.83 million metric tons (1.27, 1.0 and 0.91 million short tons), respectively, in 1965. By 1974 these had grown to 4.2, 2.60, and 2.15 million metric tons (4.6, 2.9, and 2.4 million short tons). Growth of the production of these chemicals is projected to continue at an average annual rate of approximately 3.5 percent. This report and its estimations of air-pollution control costs are based on the current regulations for controlling vinyl chloride emissions. It is not believed that meeting these regulations will have a particularly adverse impact on the production of polyvinyl chloride and its precursors. However, if certain contemplated control regulations are promulgated, such as zero discharge of vinyl chloride emissions from all establishments, the costs may be higher.

Description of Pollution and Controls

The primary air pollutant of concern in the manufacture of ethylene dichloride (by oxychlorination), vinyl chloride, and polyvinyl chloride is vinyl chloride monomer (VCM). When VCM is incinerated as a means of control, hydrogen chloride becomes a by-product air pollutant.

Regulations

Emissions of vinyl chloride have been recently regulated as a hazardous air pollutant under Section 112 of the Clean Air Act, as amended. The standard, as promulgated and published in the Federal Register (41FR46560–46573, October 21, 1976), is designed to minimize vinyl chloride emissions to the level attainable with best available control technology. The limitations are summarized in Table 5.2–1.

The contributions of vinyl chloride emissions from the uncontrolled sources in an EDC-VCM plant are shown in Table 5.2–2.

Table 5.2-1.
Vinyl Chloride Emission Limitations

Ethylene dichloride-vinyl chloride plants	Vinyl Chloride Emissions
EDC formation and purification	10 ppm
VCM formation and purification	0.01 g/kg (0.02 lb/ton)
Oxychlorination process	0.2 g/kg (0.4 lb/ton) EDC
Relief valve discharges	prohibited*
Manual venting of gases	prohibited*
Polyvinyl chloride plants	
Equipment through stripper	10 ppm
Equipment following stripper	2000 ppm (dispersion resins)
	400 ppm (all other resins)
Reactor openings	0.02 g/kg (0.04 lb/ton) PVC
Relief valve discharge	prohibited*
Manual venting of gases	prohibited*

* Except under emergency conditions

Table 5.2-2.
Uncontrolled Sources of Vinyl Chloride Emissions in VCM Production

Emission Source	Percent of Uncontrolled Emissions at Average Plant
Vinyl chloride formation and purification	54
Fugitive emission sources	27
Ethylene dichloride purification	11
Oxychlorination reactor	8
Total	100

The best available control technology for balanced EDC-VCM plants involves the collection and incineration of all emissions from the formation and purification of vinyl chloride and ethylene dichloride (by oxychlorination) and the control of fugitive emission sources. Fugitive emissions can be controlled by the use of:

- multipoint and portable detectors,
- control systems on sampling and transfer operations,
- collection header systems to connect equipment undergoing maintenance or inspection to either the monomer recovery system or to an add-on control device,
- rupture discs and pressure gauges prior to safety discharge valves on pressure vessels, and
- dual mechanical seals on pumps and compressors.

It is anticipated that fugitive emissions can be reduced by 90 percent by applying these above measures in the typical plant. Incineration should reduce emissions from the other sources by at least 95 percent.

Polyvinyl chloride is produced by suspension (78 percent), dispersion or emulsion (13 percent), bulk (6 percent), and solution (3 percent) polymerization processes. The percentages refer to 1973 capacity. The contributions of various emission sources to total emissions of vinyl chloride differ somewhat from process to process, but the breakdown shown in Table 5.2-3 for the dispersion process is generally typical for other processes:

Table 5.2-3.
Uncontrolled Sources of Vinyl Chloride Emissions in PVC Production (dispersion process)

Emission Source	Total Uncontrolled Emissions at Average Plant, Percent
Sources following stripper*	33
Stripper	8
Fugitive emissions sources	38
Monomer recovery system	12
Relief valve discharge	5
Reactor opening	4
Total	100

* Slurry blend tanks, concentrators, dryers, bulk storage, etc.

The best available control technology for PVC plants varies somewhat with the type of process. For all processes, fugitive emissions can generally be controlled through containment, capture, and ducting of emissions to a control system, and early leak detection and repair. Losses on opening equipment can be reduced by using water to displace VCM to a control system before opening the equipment. Reactor relief valve discharges can generally be eliminated by chemically short-stopping the polymerization reaction or manually venting gases to a recovery system. Strippers are used to remove vinyl chloride from the polymer, and carbon adsorption systems can be used to recover the monomer from the stripper.

Improved stripper effectiveness solves most of the emissions problems in operations that follow the stripper, including emissions of VCM in PVC fabrication operations, although incineration with scrubbing to remove HCl is an alternative control strategy. Emission control effected by the stripper, however, is not uniformly applicable to all processes. Current technology is available to strip the majority of resins except dispersion resins to 400 ppm or lower. Dispersion resins, however, are sensitive to the high temperatures used in stripping other resins, but they can be stripped effectively to 2,000 ppm. Most of the remaining VCM is removed from dispersion resins in the drying process.

Suspension resins and dispersion resins are polymerized in water and are ultimately blended in water slurry. This water contains some vinyl chloride, which can be removed by steam distillation. No water is involved in the bulk polymerization

process, so this emission source does not exist for the bulk process. However, this process accounts for only about 6 percent of U.S. PVC production. No consideration is given here to the solution process, which is practiced by only one company and accounts for only about 3 percent of production.

Industry costs for air-pollution abatement in the period 1970–1986 are provided in Table 5.2–4.

TABLE 5.2–4. VINYL CHLORIDE INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	71.00	71.00	144.14	144.14
NEW PLANTS	8.39	16.48	36.88	91.43
TOTAL	79.39	87.47	181.02	235.57
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	11.55	11.55	128.15	303.21
NEW PLANTS	2.68	4.00	25.45	93.53
TOTAL	14.24	15.55	153.60	396.74
O&M				
EXISTING PLANTS	10.79	10.73	118.98	281.52
NEW PLANTS	2.47	3.69	23.47	87.45
TOTAL	13.20	14.41	142.45	368.98
ALL ANNUAL COSTS	27.44	29.97	296.05	765.72

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.3 NITRIC ACID INDUSTRY

Production Characteristics and Capacities

Nitric acid is used in the manufacture of ammonium nitrate and in numerous other chemical processes. Ammonium nitrate, which is used both as a fertilizer and in explosives, accounts for about 80 percent of the nitric acid consumption. Nitric acid is produced by oxidation of ammonia, followed by absorption of the reaction products in dilute acid solution. Most nitric acid plants in the United States are designed to manufacture acid with a concentration of 55 to 65 percent, which may subsequently be dehydrated to produce 99 percent acid.

At the beginning of 1974, 46 private companies operated 76 nitric acid plants in the contiguous 48 states, in addition to seven plants operated for the U.S. Government by five companies. These government-owned plants are included in cost estimates as part of the nitric acid industry by inflating the private costs by 10 percent. Nearly all nitric acid produced in the United States is for captive consumption.

Emissions Sources and Pollutants

Nitrogen oxides, the primary pollutants of concern in the production of nitric acid, are emitted in the tail-gas from absorption towers. Numerous variations on the basic nitric acid production process affect both the emissions and the difficulty of control. Two of the more important variables are the amount of excess oxygen present in the absorption tower and the pressure under which the absorption tower operates. Many plants practice partial pollution abatement (decolorization) in accordance with local regulatory agencies. Under this practice, the highly visible reddish-brown nitrogen dioxide is converted to colorless nitric oxide. Although visible emissions are reduced, the practice does nothing to prevent emission of nitrogen oxides to the atmosphere.

Emissions from nitric acid plants consist of the oxides of nitrogen in concentrations of about 3,700 ppm nitrogen dioxide and nitric oxide, and minute amounts of nitric acid mist. Emissions from nitric acid plants are typically in the order of 25 kg nitrogen oxides per metric ton (50 pounds per short ton) of 100 percent acid produced.

Control Technology and Costs

Catalytic reduction with natural gas is a feasible and proven control technology used in nitric acid plants both here and abroad. The absorber tail-gas is mixed with 38 percent excess natural gas and passed over a platinum or palladium catalyst. Catalytic reduction with ammonia or hydrogen has the advantage of being selective in the sense that only the nitrogen oxides are reduced. However, in addition to higher costs, reduction with ammonia requires close temperature control to prevent the reformation of nitrogen oxides at higher temperatures or the formation of explosive ammonium nitrate at lower temperatures.

Table 5.3–1 shows the cost of air-pollution abatement in the period 1970–1986.

TABLE 5.3–1. NITRIC ACID INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	3.98	34.34	2.37	2.37
NEW PLANTS	0.0	0.0	0.89	2.43
TOTAL	3.98	34.34	3.26	4.80
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	5.29	18.27	22.60	42.55
NEW PLANTS	0.0	0.0	0.27	1.67
TOTAL	5.29	18.27	22.88	44.21
O&M				
EXISTING PLANTS	7.71	26.63	33.03	74.31
NEW PLANTS	0.0	0.0	0.45	2.74
TOTAL	7.71	26.63	33.48	77.05
ALL ANNUAL COSTS	12.99	44.91	56.35	121.26

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.4 SULFURIC ACID INDUSTRY

Production Characteristics and Capacities

About half of the sulfuric acid produced in the United States is used in the manufacture of phosphate fertilizers; the rest is used in myriad industrial applications ranging from steel pickling to detergent manufacturing.

Sulfuric acid is manufactured by chemical companies and by companies primarily engaged in smelting nonferrous metals; both sources compete for the same buyers. Nevertheless, the sulfuric acid manufactured by the smelter industry is primarily a byproduct resulting from the control efforts to reduce sulfur dioxide emissions to the atmosphere, and secondarily, as an attempt to generate additional revenue. For the purposes of this report, smelter produced acid is considered to be part of the smelter industry rather than the sulfuric acid industry.

The major products of the sulfuric acid industry are concentrated sulfuric acid (93 to 99 percent) and oleum. A few sulfuric acid plants associated with the fertilizer industry produce less-concentrated grades of acid. Essentially, all sulfuric acid in the United States is produced by the contact process, less than 0.4 percent being produced by the older chamber process.

In sulfur-burning plants, sulfuric acid is produced by burning elemental sulfur with dry air in a furnace to produce sulfur dioxide. The latter is catalytically converted to sulfur trioxide. The hot converter effluent is cooled and introduced to an absorption tower where the sulfur trioxide is absorbed in a sulfuric acid solution to form more sulfuric acid by its reaction with water.

Some plants (including spent-acid plants and smelter-gas plants) operate on the same principle as sulfur-burning plants, except that the sulfur dioxide is obtained from the combustion of spent acid and hydrogen sulfide or from smelter off-gas. In these plants, the sulfur-bearing gas is dried with sulfuric acid and cleaned (subjected to particulate and mist removal process) before introduction to the acid plant.

Of the known 183 sulfuric acid plants operating in 1971, 167 were contact process plants and 16 were chamber process plants. Of the 25.5 million metric tons (28.1 million short tons) of new sulfuric acid produced, 25.3 million metric tons (27.9 million short tons) were in contact process plants. This volume of production included sulfuric acid produced by the sulfuric acid industry (as defined in this report) and by the smelter industry. In 1974, 58 companies operated sulfur-burning or wet-process contact acid plants in 134 locations, and 16 companies operated smelter acid plants in 23 locations. In addition, five companies operated small chamber-acid plants in five locations. A total of 25 thousand metric tons (27,564 short tons) of new acid was produced from elemental sulfur in 1974.

Emissions Sources and Pollutants

Emissions from sulfuric acid plants consist of sulfur dioxide gases and sulfuric acid mist. These pollutants evolve from incomplete conversion of sulfur dioxide to sulfur trioxide in the converter, and from the formation of a stable mist consisting of minute particles of sulfuric acid that resist absorption in the acid absorber.

Control Technology and Costs

The controlled emission factors for existing facilities for 1976 are as specified by the SIP's; new source values were assumed to apply to both existing and new facilities in 1980.

In sulfuric acid plants using the two-stage or dual absorption control process, the gas from the first acid absorber is initially heated (sometimes removing the mist) and then sent through a single-stage converter where the sulfur dioxide is converted to sulfur trioxide. The gas from the converter is then sent to an absorber and a demister before release to the atmosphere.

Dual adsorption has reliably met EPA standards of performance for new and modified sources in applications of two types of sulfuric acid plants (sulfur-burning and wet gas) of all sizes. In addition to controlling sulfur dioxide emissions, the dual absorption method offers the added advantage of not requiring new operational skills on the part of acid plant operators. This control technology has been used in computing the sulfur dioxide control costs for all new and existing sulfuric acid plants.

Table 5.4–1 shows nonsmelter control costs for total annualized expenditures and investment requirements. The increase in sulfuric acid produced in smelters may saturate local markets, but will not affect primary sulfuric acid markets because of the cost of transportation.

TABLE 5.4–1. SULFURIC ACID INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	47.00	441.76	28.20	28.20
NEW PLANTS	25.58	57.29	116.07	297.72
TOTAL	72.58	499.05	144.27	325.92
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	68.01	237.67	289.42	542.33
NEW PLANTS	8.82	18.51	78.85	288.61
TOTAL	76.84	256.18	368.27	830.94
O&M				
EXISTING PLANTS	45.00	157.25	191.49	430.86
NEW PLANTS	9.75	20.46	87.16	324.38
TOTAL	54.75	177.71	278.66	755.24
ALL ANNUAL COSTS	131.59	433.89	646.93	1586.17

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.5 PHOSPHATE FERTILIZER INDUSTRY

Production Characteristics and Capacities

The major products of the phosphate fertilizer industry are ammonium phosphates, triple superphosphate, normal superphosphate, and granular mixed fertilizers. Phosphoric acid and superphosphoric acid are intermediate products.

All phosphate fertilizers are processed from ground phosphate rock treated with sulfuric acid to produce either normal superphosphate or wet-process phosphoric acid. A phosphoric acid intermediate may then be reacted with ammonia to produce diammononium phosphate and other ammonium phosphates, or reacted with ground phosphate rock to manufacture triple superphosphate. Superphosphoric acid, produced by dehydration of wet-process phosphoric acid, is used in preparing some mixed fertilizers. Granular mixed fertilizers are made from either normal superphosphate or triple superphosphate, with ammonia and potash. Bulk-blended mixed fertilizers and liquid mixed fertilizers are manufactured by physically mixing particles of other fertilizer components.

Bulk blending and liquid mixing processes are not major sources of air pollution and are not considered in estimating the industry abatement cost.

The phosphate fertilizer industry is characterized by a number of large, modern efficient plants located near the source of raw materials. In general, these plants manufacture the more concentrated forms of fertilizer, diammonium phosphate (DAP) and triple superphosphate (TSP). These industries are found particularly in Florida.

Smaller plants, located near the retail markets, manufacture the less concentrated forms: granulated mixed fertilizer (NPK) and normal superphosphate (NSP). The smaller NSP, NPK, and bulk-blend plants are located in the farming states. At the beginning of 1973, there were 33 DAP plants, 13 TSP plants, 45 NSP plants, and 344 ammoniation-granulation (NPK) plants. In addition, about 5,000 bulk-blending plants were operating in 1973.

Due to the seasonal demand for fertilizer, many plants manufacturing NSP and NPK operate only a portion of the year. In contrast, those plants manufacturing DAP and TSP generally operate year-round.

Emission Sources and Pollutants

Emissions from phosphate fertilizer processing plants are mainly fluorides (in the form of hydrogen fluoride and silicon tetrafluoride) and particulates. Fluorides are generated in the processes of acidulation of phosphate rock which contains calcium fluoride.

In the phosphate fertilizer industry, particulate emissions of significance originate from: phosphate rock grinding; TSP manufacture; DAP production; NSP manufacture; and NPK bulk-blending and granulation plants.

In phosphate rock processing, particulate emissions are issued from the drying, grinding, and transfer processes. The emission factors for these processes are 7.5, 10, and 1 kg per metric ton (15, 20, and 2 pounds per short ton) of rock respectively.

In granular TSP production, particulate emissions may originate from a number of points in the process. Most of the particulates are given off in the drying and product-classification processes. The off-gas from the reactor (in which phosphate rock is acidulated with phosphoric acid) and the blunger (in which the reactor effluent is mixed with recycled product fines to produce a paste) may account for a considerable percentage of the total particulates emitted.

Particulate emissions from DAP manufacture originate mainly from the granulator and the dryer. It has been estimated that the total emissions amount to approximately 20 kg per metric ton (40 pounds per short ton) of product from both sources.

Emissions from the manufacture of run-of-pile NSP originate from both the acidulation and "denning" processes. Although the emission factors for particulates are not known, they are estimated to be in the order of 5 kg per metric ton (10 pounds per short ton).

The NPK or granulation plants manufacture a variety of products. Many emission factors probably

will apply for this class of fertilizer plant. In fixing the emission factors, these plants are assumed to employ an ammoniation-granulation process similar to that used in the DAP process, or approximately 20 kg of particulates per metric ton of product (40 pounds per short ton).

The emission factors for particulates are high in the TSP, DAP, and NPK plants. The bulk of these emissions in all three processes originates from the granulation process. There is a strong economic incentive to reduce these emissions since they contain valuable products and in many cases are associated with ammonia vapors (from the ammoniation process), whose recovery is an economic necessity.

Control Technology and Costs

Most of the phosphate rock of higher available phosphorus pentoxide content is ground and beneficiated to enhance its reactivity and to eliminate some of the impurities. The particulate emissions from the grinding and screening operations may be controlled effectively by baghouses in which the dust is deposited on mechanically cleaned fabric filters. The dust-laden gas from the rock-drying (and perhaps defluorination) operations may first pass through a cyclone and then through a wet scrubber (such as a venturi). The efficiency of this combination should be better than 99 percent.

Particulate and fluoride emissions from phosphate fertilizer plants traditionally have been removed from gaseous waste streams by wet scrubbing. While efforts have been directed at removing fluorides, up to 99 percent of the particulates are simultaneously removed. Wet scrubbers of varying efficiencies have been used for this double purpose. The fluoride and particulate-laden scrubber water is usually disposed of in a gypsum pond.

For control of particulate emissions from granular TSP plants, it is assumed that various wet scrubbers will be provided for a number of gaseous waste streams. The effluent from the reactor-granulator is assumed to be scrubbed in two stages, first by a cyclone and second by a cross-flow packed scrubber. The gases from the drier and cooler are assumed to be scrubbed in venturi-type packed scrubbers. Waste gases from storage of the granular product are usually scrubbed in a cyclone scrubber, although some plants use packed scrubbers. The scrubbing liquid used in all scrubbers is assumed to be recycled pond water except for the first-stage scrubbing of gases from the reactor-granulator, where weak phosphoric acid is used and recycled to the reactor.

In DAP plants, control of particulates is assumed to be achieved for gaseous streams originating from the reactor-granulator, the drier, and the cooler, together with combined gaseous streams ventilating such solids-processing equipment as elevators, screens, and loading and unloading. Two-stage scrubbing is assumed to be employed for each of the streams listed. The first stage is assumed to consist of a cyclone scrubber; the scrubbing medium is diluted phosphoric acid (30 percent) for purposes of recovering ammonia and the product. Most of the particulate matter is assumed to be removed in the first stage, and the balance in the second stage consisting of a cross-flow packed scrubber in which recycled pond water is used as the scrubbing medium.

It is assumed that only run-of-pile normal superphosphate is produced in NSP plants. A cyclone scrubber often is employed in removing particulates in gaseous streams originating from the reactor-pugmill, den, and curing operations.

An ammoniation-granulation process is assumed for NPK plants. Cyclones are normally installed ahead of primary scrubbers. The primary scrubber (typically employing dilute phosphoric acid as a scrubbing medium) is considered an integral part of the process in which valuable reactants (ammonia) and the product are recovered.

Cross-flow scrubbers have been used in estimating costs of controlling emissions of both particulates and fluorides. Most of the control technologies described above have been applied for more than a decade. Wet scrubbers of varying efficiencies have been integral parts of many phosphate fertilizer processes. The collection of waste gaseous streams and the removal of fluorine compounds from these streams has long been practiced to protect the health and safety of process operating personnel. Collection of particulate materials from those waste gaseous streams is dictated by economic necessity because valuable products are involved.

Because of the widespread use of control devices as a part of industry processes, no costs are attributable to air pollution regulations. The USEPA has issued guidelines (Fed. Regis., March 1, 1977) by which the States are to control fluoride emissions. Depending on the States' actions, costs may accrue in the future due to this regulatory action.

5.6 NONFERTILIZER PHOSPHORUS INDUSTRY

Production Characteristics and Capacities

In 1973, 21 plants were engaged in producing elemental phosphorus, defluorinated phosphates (DFP), and calcium phosphates (Dical). The combined capacity of these plants was approximately 4,800 metric tons per day or 1.6 million metric tons per year (5,300 short tons per day or 1.8 million short tons per year) (P_2O_5 equivalent) in 1973. Ten plants producing elemental phosphorus account for over 60 percent of the total capacity involved in producing nonfertilizer phosphates. A summary of model plant size distributions and capacities for the three products is provided in Table 5.6–1.

The production of industrial phosphorus and phosphate-containing animal feeds begins with thermal and/or chemical processing of phosphate rock. Phosphates that are suitable as additives to feeds may result from the direct defluorination of phosphate rock, defluorination of phosphoric acid from wet-process acid, or by use of furnace acid (made from elemental phosphorus, which is essentially defluorinated when it is produced by thermal reduction of phosphate rock). The production of feed-grade phosphates by conversion of elemental phosphorus is expected to decline because of the energy requirements of the thermal reduction of phosphate rock. Decreased production by this process will be compensated for by increased production from wet process acids, so the overall production of feed-grade phosphates will increase at an annual rate of approximately 4 percent. Current production is estimated to be about 90 percent of capacity.

Emission Sources and Pollutants

Atmospheric emissions from the manufacture of defluorinated phosphates are primarily fluorides and particulates. Gaseous fluorides are released during the thermal and/or chemical reduction of phosphate rock with the major point of emissions in feed preparation. Emission factors may be as high as 33 kilograms of fluorine per metric ton (66 pounds per short ton) of phosphorus processed.

Table 5.6–1.
Nonfertilizer Phosphates Industry
Plant Capacity Distribution
(in metric tons/day with short tons/day in parentheses, P_2O_5 equivalent)

	Plant Capacity	No. Plants	Total Capacity	Percent Group	Percent Industry
Phosphate reduction	54 (60)	3	162 (179)	5	3
	217 (239)	4	867 (956)	29	18
	649 (715)	3	1,948 (2,147)	66	41
Subtotal		10	2,977 (3,282)	100	62
Defluorinated phosphate	31 (34)	1	31 (34)	5	nil
	93 (103)	1	93 (103)	15	2
	125 (138)	1	125 (138)	20	3
	386 (425)	1	386 (425)	60	8
Subtotal		4	635 (700)	100	14
Calcium phosphate	54 (60)	4	216 (240)	18	5
	200 (220)	2	400 (440)	33	8
	580 (639)	1	580 (639)	48	12
Subtotal		7	1,196 (1,319)	100	25
Total		21	4,808 (5,300)		100

A summary of estimated fluoride emissions from the production of defluorinated phosphates is presented below; control efficiencies of 95 percent are assumed.

	Present Controls	Further Controls
	(in metric tons/yr with short tons/yr in parentheses)	
1975		
Phosphate reduction	430 (474)	25 (28)
Defluorinated phosphate	2,560 (2,820)	158 (174)
Calcium phosphate	40 (44)	2 (2)
1985		
Phosphate reduction	260 (290)	15 (17)
Defluorinated phosphate	3,910 (4,310)	242 (267)
Calcium phosphate	50 (55)	3 (3)

Control Technology and Costs

Fluorides can be controlled by wet scrubbers. These devices, which could include liquid ejector venturi scrubbers, liquid impingement control systems, and spray towers, also serve to control particulate emissions to levels of 95 percent or more.

For DFP and Dical plants, control costs are comparable for similar sized plants but almost four times as high as for phosphate reduction plants of similar size. The lower control costs associated with animal feed production from furnace acid is due to the relatively lower percentage of fluorides contained in the phosphoric acid obtained from thermal reduction of rock. Control costs are detailed in Table 5.6–2.

TABLE 5.6–2. NONFERTILIZER PHOSPHORUS INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.68	6.35	0.41	0.41
NEW PLANTS	0.32	1.17	1.57	4.39
TOTAL	1.00	7.51	1.97	4.79
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1.03	3.61	4.40	7.31
NEW PLANTS	0.19	0.46	1.37	4.63
TOTAL	1.22	4.07	5.77	11.94
O&M				
EXISTING PLANTS	0.27	0.95	1.17	2.64
NEW PLANTS	0.06	0.15	0.43	1.54
TOTAL	0.33	1.10	1.60	4.18
ALL ANNUAL COSTS	1.56	5.17	7.37	16.12

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.7 MERCURY CELL CHLOR-ALKALI INDUSTRY

Production Characteristics and Capacities

High-purity caustic soda and chlorine are coproducts in the electrolytic process which uses flowing mercury metal as a moving cathode. The caustic soda product finds major markets in those chemical manufacturing operations requiring high purity and freedom from sodium chloride and metal impurities. Of the two basic processes, i.e., mercury cell and diaphragm cell, for producing chlorine, only the one employing the mercury cell results in mercury emissions. Chlorine is produced almost entirely by the electrolysis of fused chlorides or aqueous solutions of alkali-metal chlorides. Chlorine is produced at the anode, while hydrogen and potassium hydroxide or sodium hydroxide are produced at the cathode. Anode and cathode products must be separated, such as in a cell which employs liquid mercury metal as an intermediate cathode.

The use of the mercury cell in the United States increased from 5 percent of the total installed chlorine capacity in 1946 to a maximum of 28 percent in 1968, then declined to 21 percent in 1976. The 1976 capacity was estimated at 7,100 metric tons (7,827 short tons) of chlorine per day at 27 plants. The size distribution of these plants is given below:

Capacity Range (Chlorine Production) metric tons/day (short tons/day)	Number of Plants
< 150 (< 165)	8
150–300 (165–331)	9
301–400 (331–441)	4
> 440 (> 441)	5
Total	27

Emission Sources and Pollutants

The major sources of direct emissions of mercury to the atmosphere are the hydrogen by-product stream, end-box ventilation system, and cell-room ventilation air. The minimum known treatment of the by-product hydrogen gas that leaves the decomposer consists of cooling the stream to 43 C (110F) followed by partial removal of the resulting mercury mist. For hydrogen saturated with mercury vapor at this temperature, the daily vapor loss is estimated to be 3.4 kg of mercury vapor per hundred metric tons (6.8 pounds per hundred short tons) of chlorine produced. Condensed mercury entrained in the hydrogen stream will result in additional emissions. The uncontrolled emission of mercury vapor and mercury mist, after minimum treatment has occurred, is estimated to be up to 25 kg per hundred metric tons (50 pounds per hundred short tons) of chlorine produced.

Mercury vapor and mercury compounds are collected from the end-boxes, the mercury pumps, and the end-box ventilation system. Preliminary results of source testing by EPA indicate that the mercury emissions from an untreated or inadequately treated end-box ventilation system range from 1 to 8 kg per hundred metric tons (2 to 16 pounds per hundred short tons) of chlorine produced.

In addition to cooling the cell room, the cell-room ventilation system provides a means of reducing the cell-room mercury-vapor concentration to within the recommended Threshold Limit Value (TLV) for human exposure to mercury vapor. On the basis of data obtained from operating plants, it has been estimated that mercury emissions from the cell-room ventilation system vary from 0.2 to 2.5 kg per day per hundred metric tons (0.4 to 5 pounds per hundred short tons) of daily chlorine capacity, assuming a concentration equal to the TLV of 50 micrograms per cubic meter (22 micrograms per cubic foot) of ventilation air.

The Environmental Protection Agency has estimated that uncontrolled emissions from the production of chlorine in mercury cells averages approximately 20 kg of mercury per hundred metric tons (40 pounds per hundred short tons) of chlorine produced.

Control Technology and Costs

Control technologies and cost estimates are based on the consideration that the maximum daily mercury emission from any single site shall not exceed 2.3 kg (5.1 pounds); this assumption is in compliance with the National Emissions Standards for Hazardous Air Pollutants promulgated by EPA. Control techniques applicable to the hydrogen gas stream include: cooling, condensation, and demisting; depleted brine scrubbing; hypochlorite

scrubbing; absorption on molecular sieve; and adsorption on treated activated carbon.

With appropriate modification, the control techniques applicable to the end-box ventilation stream include cooling, condensing, and demisting; depleted brine scrubbing; and hypochlorite scrubbing. It is judged that the molecular-sieve adsorption system will become applicable in the near future to the end-box ventilation-gas stream.

This control technique will permit compliance with the hazardous emission standard.

Mercury vapor from the cell-room ventilation air can be minimized by strict adherence to recommended good housekeeping and operating procedures. No other control technique has been commercially tested at this time. All mercury emissions could be eliminated by the conversion of mercury-cell plants to the use of diaphragm cells plus a special caustic soda purification system to produce a caustic soda product of purity equal to that produced in mercury-cell plants. Such conversion is presently judged to be an unacceptable alternative due to the very high estimated cost.

Control costs were estimated on a model plant basis. These costs are based on controlling emissions from the hydrogen stream by cooling, mist elimination, and molecular sieves. No costs are included for end-box emission control. Control costs are detailed in Table 5.7–1.

TABLE 5.7–1. MERCURY-CELL CHLOR-ALKALI INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	1.97	18.52	1.18	1.18
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	1.97	18.52	1.18	1.18
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	3.01	10.55	12.82	21.32
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	3.01	10.55	12.82	21.32
O&M				
EXISTING PLANTS	5.22	18.28	22.22	50.00
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	5.22	18.28	22.22	50.00
ALL ANNUAL COSTS	8.24	28.83	35.05	71.32

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6. METALS INDUSTRIES

For the purposes of this report, the metals industries have been defined as those establishments primarily engaged in refining, extracting, processing, fabricating, or recovering ferrous or nonferrous metals and processes performed by establishments in direct support of these operations. The industries included are:

- Iron and Steel
- Iron Foundries
- Steel Foundries
- Ferroalloy
- Primary Aluminum
- Primary Copper
- Primary Lead
- Primary Zinc
- Secondary Aluminum
- Secondary Brass
- Secondary Lead
- Secondary Zinc.

Costs associated with the control of air pollution by these industries are summarized in Table 6–1. These numbers are repeated below in the appropriate section together with discussion of the assumptions peculiar to the sector and other details.

TABLE 6.-1. AIR POLLUTION ABATEMENT COSTS FOR THE METALS INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

	INVESTMENT			
INDUSTRY	1977	1970–77	1977–81	1977–86
IRON & STEEL	320.28	1258.04	1281.12	1921.68
IRON FOUNDRIES	6.03	46.67	8.04	28.02
STEEL FOUNDRIES	18.97	177.49	25.19	53.82
FERROALLOYS	24.63	328.79	0.0	0.0
PRIMARY ALUMINUM	51.84	359.91	117.86	363.17
PRIMARY COPPER	90.00	1094.00	171.70	986.00
PRIMARY LEAD	2.16	20.28	1.29	1.29
PRIMARY ZINC	6.56	42.13	13.21	30.20
SECONDARY ALUMINUM	2.44	15.64	5.28	12.41
SECONDARY BRASS	1.59	13.32	1.92	3.62
SECONDARY LEAD	1.75	12.42	2.88	6.02
SECONDARY ZINC	0.32	2.97	0.19	4.28
TOTAL INVESTMENT	526.56	3371.65	1628.67	3410.52
	ANNUAL COSTS			
	1977	1970–77	1977–81	1977–86
IRON & STEEL	519.20	1327.59	3473.60	9900.35
IRON FOUNDRIES	7.08	24.10	32.03	81.48
STEEL FOUNDRIES	47.78	170.26	208.19	494.37
FERROALLOYS	70.16	346.91	250.71	399.86
PRIMARY ALUMINUM	95.96	323.82	444.67	1007.86
PRIMARY COPPER	199.25	802.96	1011.18	2549.96
PRIMARY LEAD	4.02	14.14	17.11	30.24
PRIMARY ZINC	36.46	126.13	172.49	434.72
SECONDARY ALUMINUM	4.35	14.35	21.33	56.09
SECONDARY BRASS	2.77	9.31	12.56	30.56
SECONDARY LEAD	2.53	8.56	11.80	29.27
SECONDARY ZINC	0.86	2.65	4.51	14.66
TOTAL ANNUAL COSTS	990.42	3170.78	5660.26	15029.38

6.1 IRON AND STEEL

Production Characteristics and Capacities

The iron and steel industry production operation includes the following major sequential processes: recycling (sintering), coke production, and steelmaking. There are three types of steelmaking processes: open-hearth (OH), basic-oxygen furnace (BOF), and electric-arc furnace (EAF).

Sintering is the process by which iron-ore fines and reclaimed iron dusts, sluoges, and scale generated in various iron and steelmaking processes are agglomerated and prepared for charging in blast furnaces. Coking is the process used to convert suitable grades of coal to metallurgical coke for charging in the blast furnace. Blast-furnace operation is a smelting process by which iron ore is reduced to pig iron; open-hearth, basic oxygen, and electric-arc furnaces are used to make steel.

Sintering Plants

There are 15 companies operating 35 recycling or sintering plants ranging in size from about 180,000 metric tons (194,000 short tons) per year to 4.3 million metric tons (4.7 million short tons) per year. Sintering plants have been considered on a plant-by-plant basis and grouped by states. Sintering consists of agglomerating ore fines and reclaimed iron-containing dusts, sludge, and scale generated in various iron and steelmaking processes. Sinter is made by mixing these fines with limestone and coke (or anthracite coal), charging the mixture onto a continuous traveling grate, and igniting the mixture. Air is drawn through the mixture to support combustion. The sintering is completed by the time the end of the grate is reached. Sinter clinker is cooled, crushed, and screened to size for charging to the blast furnace.

Coke Plants

The vast bulk of the coke production is owned by iron and steel companies (or affiliates). About 10 percent of the coke is produced in merchant plants for sale in the open market to foundries, other industrial users, or for consumption for other than iron-producing purposes.

Coking coals are received at a coal preparation facility where they are finely pulverized and mixed in the required proportions to meet specifications for the blast furnace or for other end uses. The prepared coal mixture is delivered to storage bunkers above the coke oven batteries. Measured quantities of the mixture are withdrawn from the bunkers and carried to individual ovens for charging. The coal is heated in the absence of air for a period of 14 to 18 hours at temperatures of from 900° to 1100°C to convert the coal to coke having the desired properties. During the coking cycle, volatile constituents and noncondensible gases are distilled and transferred via collecting mains to the byproducts plant for the recovery of the gas and various chemicals. When the coking cycle is completed, the doors on the ends of the oven are removed and a ram pushes the incandescent coke from the oven into a quench car. The hot coke is transported to a quench tower where it is cooled under a direct water spray. The coke is then crushed and screened for use in the blast furnace or for other purposes. The fines from the crushing operation are used as a fuel in sintering operations.

Blast Furnaces

Blast furnaces are large, tall, counter-current-flow reactors used to produce molten pig iron from a charge of raw materials consisting of iron ore, iron-ore pellets, sinter, coke and limestone. The raw materials are charged into the top of the furnace and high-temperature air and sometimes hydrocarbons are blown into the bottom of the blast furnace. Reduction of the iron ore components occurs by the interaction of reducing gases rising through the raw materials as well as the interaction of the coke with molten iron oxides. Particulates are generated in the blast furnace stock house where the raw materials are recovered, weighed and transported to the charging station. These emissions are readily kept under control by the use of baghouses. A second major source of emissions are the gases and particulates generated during the time the molten pig iron is removed (tapped) from a blast furnace. These emissions consist primarily of iron oxides and flake graphite (kish). These emissions can be controlled by large enclosures in the blast-furnace cast house that direct the emissions to baghouses for collection.

Open-Hearth Steelmaking

This method is the oldest of the three steelmaking processes presently being used to produce raw

steel. Open-hearth steel production has declined from a peak of 89 million metric tons (98 million short tons) in 1964 to 21 million metric tons (23 million short tons) in 1976. In 1976, there were 19 operating open-hearth shops in the integrated iron and steel industry. It is doubtful that any new plants will be constructed. Furnace capacities range from 50 to 300 net metric tons (55 to 330 short tons) of steel.

The open-hearth furnace is a shallow-hearth furnace that can be alternately fired from either end. The process consists of charging scrap, fluxes, and molten pig iron into the furnace where the required melting and refining operations are performed to produce the desired analysis of steel. Firing of an open hearth can be done with a variety of fuels, depending on availability, cost, and sulfur content in the fuel.

Basic-Oxygen-Furnace Steelmaking

The basic oxygen furnace (BOF) was first used to produce steel in the United States in 1955. By 1965, economic replacement of the open-hearth furnace by the BOF had been well established. BOF steelmaking expanded rapidly to about 76 million metric tons (84 million short tons) in 1973. In 1973, a new process, bottom-blown oxygen converter steelmaking, was put into commercial production. This new process has been included with the BOF process for the purposes of this report. In 1973, there were 19 companies operating 38 BOF plants, ranging in size from 450,000 metric tons (496,000 short tons) to 4.3 million metric tons (4.7 million short tons) of annual capacity.

In BOF steelmaking, the pear-shaped, open-top vessel is positioned at a 45-degree angle and charged with the required amount of steel scrap, molten pig iron, and other materials. The vessel is vertically positioned and high-purity oxygen is blown into the molten bath through a water-cooled oxygen lance positioned above the bath. Products of the oxygen reaction with carbon, silicon, and manganese in the charge pass off as carbon monoxide and carbon dioxide gases, and manganese and silicon oxides in the slag. When the required content of carbon, silicon, and manganese is obtained in the melt, oxygen blowing is stopped, and ferroalloys are added as needed to attain the desired final chemical composition of the steel. The molten steel is then poured into a ladle for transfer to subsequent operations.

Electric-Arc-Furnace Steelmaking

This process has long been the established process for the production of alloy and stainless steels. More recently, it has been widely used in ministeel plants to make plain carbon steels for local markets. In 1974, electric-arc furnace production amounted to 1.9 million metric tons (2.1 million short tons) of stainless steel. In 1976 there were companies operating 130 plants having 156 electric-arc furnaces, with plant capacities ranging in size from 9 thousand metric tons (9,900 short tons) to 1.2 million metric tons (1.3 million short tons) annual capacity. The total electric-arc furnace production in 1976 was about 26 million metric tons (29 million short tons).

In 1975 electric-arc furnace steelmaking passed the open-hearth process as the second largest steelmaking process in steel production.

The electric-arc furnace is a short, cylindrical-shaped furnace having a rather shallow hearth. Three carbon electrodes project through the fixed or moveable roof into the furnace. Charge materials consist of prepared scrap, although one or two electric furnace shops make use of molten pig iron as part of the charge. After charging, the melting operation is started by turning on the electric power to the electrodes which are in contact with the scrap. Electrical resistance of the scrap produces heating and eventual melting of the scrap. Additional scrap is added, and refining is accomplished by blowing high-purity oxygen into the molten unrefined steel to remove carbon and silicon. Ferroalloys are added as needed to attain the desired final chemical composition of the steel. Power is shut off and the molten metal is tapped into a ladle.

Emission Sources and Pollutants

The processes employed in producing steel are important generators of air emissions, and therefore they must be controlled to meet State Implementation Plans and Federal New Source Performance Standards. Fugitive emissions are not considered in this study.

Sintering Plants

The emissions associated with sinter-plant operations are particulates that (1) are generated during merging of raw sinter materials, (2) become entrained in the combustion air as it is drawn through the sinter mixture into the windbox, (3) are generated during the cooling operation, and (4) are generated during the crushing and screening operations. Sulfur contained in the fuel is not considered to be a major problem, although any sulfur present in the sinter mix or in combustion fuel will be emitted as sulfur oxides.

Coke Plants

Emissions from the production of coke occur as particulates, hydrogen sulfide, sulfur oxides, car-

bon monoxide, hydrocarbons, and nitrogen oxides. Particulate emissions occur from the following sources: coal receiving and stockpiling, coal grinding and handling, charging of coke ovens, the coking operation, pushing the coke from the ovens, and coke quenching. Gaseous emissions occur during the following operations: charging the coke ovens, the coking cycle, and subsequent combustion of coke-oven gases.

Open-Hearth Steelmaking

Particulates are the primary emissions from open-hearth-furnace operations. Emissions of iron oxide occur during the time the scrap is melted and large quantities of iron, silicon, and manganese oxides are formed and carried into the exhaust system of the furnace when high-purity oxygen is blown into the steel bath to remove the carbon. Gaseous emissions are largely carbon dioxide, but sulfur oxides may result through use of sulfur-containing fuels. If the scrap used in the charge contains combustibles, greater volumes of gaseous contaminants will be produced.

Basic-Oxygen-Furnace Steelmaking

Particulates and carbon monoxide are major emissions in BOF steelmaking. Particulate emissions occur at the hot-metal transfer stations, the flux and alloy material-handling and transfer points, and the BOF vessel. Carbon monoxide and carbon dioxide are emitted at the BOF vessel.

Electric-Arc-Furnace Steelmaking

Particulates are the primary emissions released by electric-arc-furnace steelmaking. Charging, scrap melting, oxygen blowing, and tapping are major sources of particulate emissions. Blowing the molten steel with high-purity oxygen produces the highest emission rates. Emissions from the scrap charge and other operations are similar to those from other steelmaking processes and constitute the largest portion of the total emissions.

Control Technology and Costs

The following paragraphs contain a brief analysis of pollution control methods used in each process of the iron and steel industry.

Sintering Plants

Electrostatic precipitators, high-energy scrubbers, and baghouses are used to control the particulates originating from the sinter strand. Baghouses are mainly used to control particulates from other emission sources with cyclones as a secondary means of control. Developments in blast-furnace technology which require additions of limestone and dolomite to the sinter mix make the continued use of electrostatic precipitators problematical because of the difference in electrical properties between limestone dusts and iron-containing dusts. Installation of high-energy wet scrubbers may be required as replacements for some existing electrostatic precipitator installations.

Coke Plants

Although definitive control measures have not been established for coke ovens, there are several systems and operating procedures that have been developed for controlling emissions. Charging emissions are minimized by stage or sequence charging, or in some newer coke batteries by using enclosed charging systems. Emissions generated during operation are being controlled by major maintenance efforts with respect to coke-oven doors, oven standpipes, and charging hole covers. New designs are being explored for minimizing operating emissions. Several technologies have been developed and installed for the control of pushing emissions and quenching emissions.

Open-Hearth Steelmaking

Electrostatic precipitators and high-energy scrubbers are used in controlling emissions from open-hearth furnaces.

Basic-Oxygen-Furnace Steelmaking

Electrostatic precipitators and high-energy scrubbers are the principal control systems applied to the BOF. Baghouses have been suggested for use in the United States and have been tried in Europe. Baghouses are used for collecting particulates at the hot-metal stations, and the flux and ferroalloy handling locations.

The costs of air pollution control measures for all of the above operations are summarized in Table 6.1–1.

TABLE 6.1-1. IRON AND STEEL INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	320.28	1258.04	1281.12	1921.68
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	320.28	1258.04	1281.12	1921.68
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	204.69	519.85	1339.86	3872.03
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	204.69	519.85	1339.86	3872.03
O&M				
EXISTING PLANTS	314.51	807.74	2133.74	6028.32
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	314.51	807.74	2133.74	6028.32
ALL ANNUAL COSTS	519.20	1327.59	3473.60	9900.35

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.2 IRON FOUNDRIES

Production Characteristics and Capacities.

Iron foundries may be found in almost all urban areas. The economies of scale for the industry do not prohibit the continued existence of relatively small foundries. Because many of the foundries are operated in conjunction with steel-making facilities, iron foundries tend to be concentrated in the major steel-producing states: Pennsylvania, Ohio, Michigan, Illinois, and Alabama.

Iron foundries range from primitive, unmechanized hand operations to modern, highly mechanized operations. Captive plants (owned or controlled by other businesses) are more likely to be mechanized and better equipped with emission-control equipment than are noncaptive plants.

In 1973, about 6 percent of the 1,432 plants were classified as large (over 500 employees), 29 percent as medium (100 to 500 employees), and 65 percent as small (less than 100 employees).

The major markets for iron castings include motor vehicles, farm machinery, and industries that build equipment for the construction, mining, oil, metalworking, and railroad industries. Captive plants have the capability of economical production of large lots of closely related castings. Most of the largest plants are captive and do not generally produce for the highly competitive open market.

Castings for machine parts, automotive parts, and soil pipe are produced from both pig iron and scrap. Cupola, electric-arc, electric-induction, and reverberatory furnaces are used. In 1973, 79 percent of the production was by cupolas, 12 percent by electric-arc furnaces, and the remainder by induction and reverberatory furnaces. The latter two types emit relatively small quantities of pollutants and require little or no emissions-control equipment.

The cupola furnace is a vertical, cylindrical furnace in which the heat for melting the iron is provided by injecting air to burn coke which is in direct contact with the charge. An electric-arc furnace is an enclosed, cup-shaped refractory shell that contains the charge. Three graphite or carbon electrodes extend downward from the roof. An electric arc between the electrodes and the charge generates the required heat. The cupola melts the charge continuously, while the arc furnace operates in a batch mode.

Emission Sources and Pollutants

Emissions from cupolas are carbon monoxide, particulates, and oil vapors. Particulate emissions arise from dirt on the metal charge and from fines in the coke and limestone charge. Hydrocarbon emissions arise primarily from partial combustion and distillation of oil from greasy scrap charged to the furnace, but their control is not costed in this report because the emissions are small. Arc furnaces produce the same kind of emissions to a lesser degree because of the absence of coke and limestone in the charge.

The particulate emission factor for uncontrolled cupola operation is taken to be 8.5 kg per metric ton (17 lb per short ton). The best available estimate of the particulate emission factor for uncontrolled arc furnaces is taken to be 5 kg per metric ton (10 lb per short ton).

An uncontrolled cupola generates approximately 150 kg carbon monoxide per metric ton (300 lb per short ton) of charge. Half of this carbon monoxide burns in the stack. On this basis, the estimated emission factor for carbon monoxide discharged from an uncontrolled cupola is approximately 75 kg per metric ton (150 lb per short ton) of charge. Uncontrolled arc furnaces produce negligible quantities of carbon monoxide.

Control Technology and Costs

In industrial practice, large cupolas use high-energy scrubbers to control the emission of particulates to acceptable levels. Medium sized cupolas can use either a high-energy scrubber or a baghouse. For small cupolas and arc furnaces, baghouses are preferred.

High-energy scrubbers usually are operated at a particulatecollection efficiency of 95 percent. This efficiency can be increased to 99 percent by increasing the pressure drop. Fabric filters (baghouses) have an efficiency of 98 percent.

Afterburners are used to control carbon monoxide emissions from cupolas. Their efficiency is generally taken to be 94 percent.

Table 6.2-1 presents control cost data for the industry.

TABLE 6.2-1. IRON FOUNDRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	18.97	177.49	25.19	29.93
NEW PLANTS	0.0	0.0	0.0	23.88
TOTAL	18.97	177.49	25.19	53.82
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	23.33	81.84	103.10	239.45
NEW PLANTS	0.0	0.0	0.0	7.62
TOTAL	23.33	81.84	103.10	247.07
O&M				
EXISTING PLANTS	24.45	88.41	105.09	235.53
NEW PLANTS	0.0	0.0	0.0	11.77
TOTAL	24.45	88.41	105.09	247.30
ALL ANNUAL COSTS	47.78	170.26	208.19	494.37

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.3 STEEL FOUNDRIES

Production Characteristics and Capacities

Two types of steel are produced from steel foundries: carbon steel castings and alloy-stainless steel castings. Carbon steel represents 90 percent of the productive capacity. The electric-arc furnace is the established equipment for the melting of steels that are subsequently poured into molds to make castings. Castings may be in a semifinished form that requires considerable machining before use in other components, or may be high-quality products that require a minimum of additional work before subsequent use. Emissions from production of steel castings closely parallel those from production of steel.

In determining control costs, the foundries producing large castings were grouped with the foundries producing carbon-steel castings on a one-shift basis.

Emission Sources and Pollutants

Particulates comprise almost 100 percent of the emissions occurring during the production of steel for castings. Minor amounts of carbon monoxide, nitrogen oxides, and hydrocarbons may be emitted. Most of the particulate emissions, which occur during the charging operation, are carried upward by the thermal gas currents created by the hot furnace; these emissions are the most difficult to control.

Control Technology and Costs

The allowable emissions of particulates per unit of process weight per hour under State Implementation Plan (Pennsylvania standards used as typical) for electric-arc-steelmaking were used as guidelines in establishing the level of control likely to be required for electric-arc furnace steel foundries, and the subsequent costs.

Baghouses are the only reported means for controlling emissions from steel foundry electric-arc furnaces. One of the probable reasons for not using scrubbers or electrostatic precipitators is the lack of space for installing the required water-treatment facilities in the case of scrubbers, and a reluctance on the part of the smaller foundry operators to get involved with electrostatic precipitators

The inventory of electric-arc-furnace steel foundries used in the report is based on information in two foundry directories and information in the published literature. A few steel foundries still use open-hearth furnaces but these are rapidly being phased out.

Development of control costs for steel foundries is complicated by several factors: foundries do not operate the same number of hours during the year, different furnace sizes are used in a single plant, some foundries specialize in plain-carbon steel castings, and some foundries produce only those castings that can be produced in large production runs, while a small number produce large, complicated castings on a one- or two-shift basis. Table 6.3–1 shows the summary cost information for steel foundries.

TABLE 6.3-1. STEEL FOUNDRY INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	6.03	46.67	8.04	9.10
NEW PLANTS	0.0	0.0	0.0	18.92
TOTAL	6.03	46.67	8.04	28.02
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	6.14	20.75	27.76	64.42
NEW PLANTS	0.0	0.0	0.0	6.15
TOTAL	6.14	20.75	27.76	70.57
O&M				
EXISTING PLANTS	0.94	3.35	4.27	9.89
NEW PLANTS	0.0	0.0	0.0	1.01
TOTAL	0.94	3.35	4.27	10.90
ALL ANNUAL COSTS	7.08	24.10	32.03	81.48

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.4 FERROALLOY INDUSTRY

Production Characteristics and Capacities

Ferroalloys are made by three methods, with submerged-arc electric furnaces producing most of the output. Three types of furnaces are adapted to the three production methods: open furnaces, semicovered furnaces, and sealed furnaces. Metallothermic-reduction-furnace production has been included with electric furnace production in the absence of sufficient information on number, location, emissions, and air-pollution-control methods. Two domestic producers use blast furnaces for making ferromanganese and occasionally ferrosilicon.

At the end of 1972, 144 electric furnaces were in operation with a total rated capacity of 1,532 megawatts. In the spring of 1977, 113 furnaces were operating with a total rated capacity of 1,846 megawatts. Furnaces under 10 megawatts in power have decreased from 90 to 32, while furnaces of 20 or more megawatts in power have increased from 9 to 30. This illustrates the trend in the industry toward shutting down small, inefficient furnaces and replacing them with the larger, more efficient, units. The industry is composed of steel companies, chemical and mineral companies having access to particular alloying elements, and specialist producers of ferroalloys. Five companies use the metallothermic process to make specialty ferroalloys containing molybdenum, tungsten, vanadium, columbium, or titanium. Six companies produce ferrophosphorus. The remaining companies use submerged-arc electric furnaces to produce about one-half of the ferromanganese and virtually all of the silicon- and chromium-containing ferroalloys used in steelmaking.

Alloying elements required for making different steels are often added in the form of ferroalloys which contain iron and at least one other element. The ferroalloys are named according to the major alloying element: ferromanganese contains manganese as the additive; ferrochromesilicon contains both chromium and silicon. Some additives in which the iron content is very small (such as silicomanganese and silicon-chrome-manganese) are also considered as ferroalloys.

Emission Sources and Pollutants

Particulate emissions are generated during the handling of the ores, fluxes, and reductants used in producing ferroalloys. Particulate and gaseous emissions are continuously evolved during smelting operations. Fuming occurs when the ferroalloy is poured, the amount varying with the particular ferroalloy. Submerged-arc electric furnaces of the open or open-hood type are required because of the formation of crusts with certain ferroalloys; these crusts must be broken mechanically. With semicovered or low-hood type submerged-arc furnaces, the charge is fed to the furnace through openings around the electrodes. In open-hood furnaces, the collection hood is raised sufficiently to provide room for charging between the hood and the charging floor; in semicovered furnaces, the hood is lower and water-cooled. Open and semicovered furnaces produce greater emissions than sealed furnaces, which are used to prevent the escape of emissions and to minimize the influx of air.

Metallic silicon and aluminum are very strong deoxidizers which are used under high-temperature conditions to reduce the mineral oxides of molybdenum, titanium, zirconium, and similar metals in metallothermic reduction furnaces.

In blast-furnace smelting operations, particulates and gaseous emissions are carried out of the furnace in the same off-gas stream.

Control Technology and Costs

Baghouses, electrostatic precipitators (ESP), and high-energy scrubbers are all used to control emissions from submerged-arc electric furnaces. Fumes evolving from the casting of ferromanganese in blast furnace operations must also be controlled by baghouses.

In the spring of 1977, 66 baghouses, 39 scrubbers and 2 electrostatic precipitators (107 control systems) controlled the 113 furnaces in operation. Thus, some of the baghouses are large enough to control more than one furnace.

A total of 126 ferroalloy furnaces were used in developing cost estimates. Furnaces that were not identified as having specified control systems were prorated so that the totals were in the same

proportion as the 66 baghouses and 39 scrubbers (there are only two furnaces with ESP's). Costs were estimated for each furnace on the basis of control equipment air flow, or (if that information was unavailable) on the basis of furnace megawatt rating.

Control costs are summarized in Table 6.4–1.

TABLE 6.4–1 FERROALLOY INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	24.63	328.79	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	24.63	328.79	0.0	0.0
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	53.51	285.09	184.11	249.99
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	53.51	285.09	184.11	249.99
O&M				
EXISTING PLANTS	16.65	61.82	66.61	149.87
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	16.65	61.82	66.61	149.87
ALL ANNUAL COSTS	70.16	346.91	250.71	399.86

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.5 PRIMARY ALUMINUM

Production Characteristics and Capacities

The domestic primary aluminum industry includes 12 companies operating 31 reduction facilities in 16 states. Three companies, operate about two-thirds of the total capacity. Plants tend to be located in areas where low-cost electrical power is available. The plant-size distribution for the industry is as follows:

Size Range (1,000 metric tons/year, with 1,000 short tons/year in parentheses)	No. Plants	Capacity(%)
0–90 (0–99)	5	7.0
91–136 (100–150)	11	26.9
137–190 (151–209)	6	21.4
191–254 (201–280)	9	44.7
Total	31	100.0

Aluminum is one of the most abundant elements and when measured either in quantity or value, its use exceeds that of any other primary metal except steel. It is used to some extent in virtually all segments of the economy, but its principal uses have been in transportation, building construction, electrical industry, containers, packaging, consumer durables, machinery, and equipment. The annual growth rate of aluminum production in the United States has averaged 7 percent in recent years.

Bauxite ore (typically containing 50–55 percent alumina) is the principal source of aluminum. Alumina is extracted from bauxite by any one of a number of variations of the Bayer process. In turn, alumina is dissolved in molten cryolite and reduced to aluminum by electrolysis in the universally used Hall-Heroult aluminum reduction cells, which are connected in series to form a potline.

The aluminum reduction plant may be classified according to the type of anodes used in the cells. Prebaked anodes are replaced intermittently, and Soderberg anodes are replaced continuously. In the Soderberg continuous system, an anode paste is continuously supplied to a rectangular metal shell suspended above the cell. As the anode shell descends, it is baked by the heat of the cell. Two types of Soderberg anodes use different support methods: a vertical stud system supported on vertical current-carrying pins (studs), and a horizontal stud system supported by pins which are inclined slightly from the horizontal.

Emission Sources and Pollutants

All three anode systems used to produce aluminum release particulates and fluorides (in both gaseous and particulate form) which must be controlled.

Of the three anode systems in use, the vertical Soderberg system emits the lowest quantity of particulates. The prebaked and horizontal Soderberg systems are higher in pollutant emissions. On the other hand, the emissions from the prebaked system are easiest to control, those from the vertical Soderberg are somewhat more difficult, and those from the horizontal Soderberg the most difficult to control. This has led to a gradual phasing out of the latter two processes.

The principal sources of emissions at primary aluminum smelters are the electrolytic cells and, in the case of prebake-anode type plants, the anode bake furnace. The raw, uncontrolled rates of emissions from these processes have been identified as averaging 25 kg per metric ton (50 pounds per short ton) of fluorides and 56 kg per metric ton (112 pounds per short ton) of particulates per ton of aluminum produced.

Standards

The applicable standards are principally state standards and the Federal New Source Performance Standard (NSPS). The NSPS has been set at one kilogram per metric ton (two pounds per short ton) of water-soluble fluorides, which is the level to which most plants are reducing their emissions. One notable exception to this general rule is the limit of one-half kilogram of fluorides per metric ton (one pound per short ton), set by the State of Washington. The "one-half kilogram" standard results in the control of 96 percent of the fluorides and, implicity, 98 to 99 percent control of particulates.

Control Technology and Costs

In this analysis, it was assumed that all sources would be controlled to a standard allowing emis-

sions of one kilogram of fluoride per metric ton (two pounds per short ton) of aluminum produced. New sources are assumed to be of the prebaked process only. It is further assumed that the New Source Performance Standards for fluorides will be met by the same control processas applied for particulate control at no additional cost. Assumed control processes for the three production processes are shown below:

Cell Type	Primary Control	Secondary Control
Prebaked	Primary Collection (Hoods and Ducting), Plus Fluidized-Bed Dry Scrubber	None Needed
Horizontal Soderberg	Primary Collection, Wet Electrostatic Precipitator, Spray Tower, or Fluidized-Bed Dry Scrubber (experimental)	Spray Screen and Water Treatment
Vertical Soderberg	Primary Collection, Wet-Electrostatic Precipitator, or Spray Tower	Spray Screen and Water Treatment

In essence, these control measures consist of either very tight hooding of the electrolytic cell (usually possible only with prebake-anode systems) with control devices (adsorption on dry alumina followed by baghouse recovery of particulate) which control both volatile fluorides and particulate. On cells where hooding of the necessary tightness cannot be achieved, the escaping emissions are collected at the roof and controlled, usually with wet control devices capable of dealing with the more dilute concentrations of fluoride and particulate. In the case of prebake-anode type plants, separate control devices are applied to the anode-bake furnace (usually a wet scrubber to collect fluorides and hydrocarbons from the hot furnace gases). Carbon grinding and milling (in the paste plant) are usually controlled with baghouses or wet scrubbers.

Table 6.5–1 shows the estimated costs for air-pollution abatement. Note that the prebaked anode process is the dominant one now, and that all new plants are assumed to employ this process. Two new production processes, the Alcoa and the Toth, which are claimed to be essentially nonpolluting, are now being investigated. If successful, costs for new sources beyond 1980 might be substantially lower than indicated.

TABLE 6.5–1 PRIMARY ALUMINUM INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	51.84	359.91	41.62	41.62
NEW PLANTS	0.0	0.0	76.24	321.55
TOTAL	51.84	359.91	117.86	363.17
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	58.57	192.88	261.39	453.81
NEW PLANTS	0.0	0.0	23.55	192.35
TOTAL	58.57	192.88	284.94	646.16
O&M				
EXISTING PLANTS	37.39	130.94	159.37	358.57
NEW PLANTS	0.0	0.0	0.36	3.12
TOTAL	37.39	130.94	159.73	361.70
ALL ANNUAL COSTS	95.96	323.82	444.67	1007.86

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.6 PRIMARY COPPER

Production Characteristics and Capacities

Copper is one of the most important of the nonferrous metals, its usage is surpassed only by iron in ore tonnage produced in the Uhited States. Its extensive use depends chiefly upon its electrical and heat conductivity, corrosion resistance, ductility, and the toughness of its alloys. Mechanical properties (and sometimes special properties) are enhanced by alloying with zinc to form brass, with tin to form bronze, with aluminum or silicon to form the higher strength bronzes, with beryllium to form highstrength-high conductivity bronzes, with nickel to form corrosion-resistant alloys, and with lead to form bearing metals.

Principal users of copper include the electrical, electronic, and allied industries for manufacturing power transmission lines, other electrical conductors, and machinery. The automobile industry (radiators, wiring, and bearings) and building-construction industry (tubing, plumbing) are the second- and third-largest consumers of copper in the United States.

Copper ore is either surface- or underground-mined, concentrated by ore-beneficiation techniques, then sent to the smelter. Processing of copper concentrates at a smelter involves the following operations.

- Roasting
- Converting to matte
- Converting to blister copper
- Fire refining
- Electrolytic refining.

Roasting is normally used to dry the finely ground concentrates and to remove some sulfur, arsenic, antimony, and selenium impurities. Roasting is frequently bypassed in modern smelters because better concentration methods remove free pyrite and permit the substitution of simple dryers for roasters at some smelters. The roasted concentrate is treated in a reverberatory furnace to produce an intermediate material called matte, which nominally contains copper, iron, and sulfur. The matte is converted to impure blister copper by blowing with air or an air-oxygen mixture in a vessel called a converter to remove the sulfur and the iron. Removal of the impurities from blister copper is sometimes limited to fire-refining, in which the impurities are removed in a furnace by volatilization and oxidation. More often, it entails a two-step procedure: fire-refining to produce electrodes for further refining by electrolytic methods.

The principal sectors of the primary copper industry (mining, smelting, refining, fabricating, and marketing) are dominated in varying degrees by three large, vertically integrated companies. The plant size distribution for 15 active smelter operations, based on equivalent roaster charge, is shown in the tabulation below:

Capacity Range 1,000 metric tons/yr, (short tons/year in parentheses)	No. Plants
0–181 (0–200)	1
182–363 (201–400)	4
364–544 (401–600)	4
545–816 (601–900)	3
817–907 (901–1,000)	3

Emission Sources and Pollutants

Emissions from coppper smelters are primarily particulates and sulfur oxides from the roaster, reverberatory, and converter furnaces. The density and continuity of emissions vary with the furnace type. Particulates can contain considerable byproduct credits, particularly noble metals and selenium. Accordingly, part of the traditional production process is to recycle particulates up to the limit of economic viability, between 90 and 99.5 percent control, leaving the rest to be discharged as uncontrolled emission.

The roasting process may be bypassed by modern smelters that have better concentration methods to remove free pyrite. Half of the plants operating in 1971 were able to bypass the roaster process.

Sulfur dioxide is emitted from all three smelter operations; however, the concentration of sulfur dioxide in the gases varies considerably among the three. Sulfur dioxide concentrations for fluid-solid roasters, reverberatory, and converter furnaces are 6–10 percent, 0.50–2 percent, and 2–5 percent by volume, respectively.

Control Technology and Costs

In 1971, approximately 95 percent of the particulate emissions from copper smelters were being controlled because of the economic advantage of recovering precious metals. Further removal of particulates is required to allow the sulfur dioxide control devices to operate effectively.

It is assumed that most smelters will manufacture sulfuric acid by the contact process from the sulfur dioxide in the roaster and the converter gases. Two major conditions must be met: (1) the concentration of sulfur dioxide in the gas stream should be at least 4 percent by volume, and (2) the gas must be practically free of particulate matter to avoid poisoning the catalyst in the acid plant. Eleven smelters already have acid plants. One plant in Michigan does not require an acid plant because of the low sulfur content of the ore, and therefore no costs are assigned to it in this report.

Several methods have been proposed and have been considered here for the purpose of removing the sulfur dioxide from the reverberatory gas stream. These include:

- Absorption of sulfur dioxide in dimethylaniline, followed by desorption and recovery.
- The Cominco absorption process in which sulfur dioxide is absorbed into an ammonium sulfite solution, which yields concentrated sulfur dioxide and an ammonium sulfate by-product.
- Wet lime scrubbing, whereby the reverberatory furnace gases are scrubbed in a slurry of lime and water.
- Wet limestone scrubbing, essentially similar to wet lime scrubbing except that a slurry of limestone is used as the scrubbing medium.

Control costs are detailed in Table 6.6–1.

TABLE 6.6–1. PRIMARY COPPER INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	90.00	1094.00	171.70	986.00
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	90.00	1094.00	171.70	986.00
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	156.95	603.56	693.28	1803.11
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	156.95	603.56	693.28	1803.11
O&M				
EXISTING PLANTS	42.30	199.40	317.90	746.85
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	42.30	199.40	317.90	746.85
ALL ANNUAL COSTS	199.25	802.96	1011.18	2549.96

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.7 PRIMARY LEAD

Production Characteristics and Capacities

Lead production in the United States involves three major steps: mining, crushing, and grinding of sulfide ores, and beneficiation to produce lead concentrates; smelting of the concentrates by pyrometallurgical methods to produce impure lead bullion; and refining the bullion to separate other metal values and impurities.

The U.S. primary lead industry has some 80 small mining companies in 14 states that mine and mill their own concentrates; some of the smaller mines utilize custom mills. Smelting and refining of lead in the United States is done by four companies that operate six smelters and five refineries. Only one company is not involved in custom smelting (outright purchase of concentrates) or toll smelting (smelting of concentrates for a fee).

Battery components accounted for 56 percent of the 1.40 million metric tons (1.54 million short tons) of lead consumed in 1976. Gasoline antiknock additives accounted for 16 percent, pigments 6 percent, ammunition 5 percent, solder 4 percent, cable covering 3 percent, and miscellaneous metal products, such as castings, weights, and ballast, the remainder.

Emission Sources and Pollutants

Emissions from lead smelters are primarily particulates and sulfur dioxide from two sources: sintering machines and blast furnaces. Most of the sulfur dioxide is generated in the sintering machine. The density of emissions varies with the source.

Flue-gas particulates include the following metals: lead (as high as 30 percent), and traces of zinc, antimony, cadmium, and copper. In western smelters, often significant quantities of noble metals are also emitted; at one smelter over 1 kg per metric ton (30 ounces per short ton) of silver and 4.8 g per metric ton (0.14 ounces per short ton) of gold was recovered from flue-gas particulates. Thus, there is an economic reason to recover particulates in addition to fume control. The emissions from the slag furnaces (used in the western smelters to recover zinc) also include particulates containing zinc oxide and zinc dust.

Stack emission factors are presently under review. The outcome of this review will be published in a lead control technique document. The ambient air quality standard of 1.5 milligrams per cubic meter (6.6×10^4 grains per cubic foot) will require stringent control. The earliest attainment date for this standard is anticipated to be mid-1982.

Control Technology and Costs

Sulfur oxides and particulates in sintering machine off-gases are being controlled by the use of sulfuric acid plants in three of the six U.S. smelters. In these smelters, particulate control is required for effective operation of the acid-plant system. In the three U.S. smelters without acid plants, most of the particulates in the processing off-gases are removed from the cooled off-gases in a baghouse before the stack. Sulfur oxide in the off-gases is not controlled. One of these smelters has an acid plant which is used only on the off-gases from a copper converter in an adjoining plant.

Each of the six U.S. plants was examined in terms of equipment required to bring the area surrounding the plant within Federal ambient standards. Acid plants were assumed for those plants which do not now control sulfur oxide emissions. Methods of metallurgical operation at all six plants are similar, the differences stem from the type of ore handled by the three Missouri smelters and by the three western smelters. In the West, lead ore concentrates are leaner and have much higher amounts of gold, silver, zinc, cadmium, copper, antimony, and arsenic present. Except for a slag-fuming furnace operation in the western smelters to remove the higher amounts of zinc in the concentrates, there are no major differences in the basic smelter operations. There is a difference in degree in the refining operations, but off-gases are not a problem in the refineries. Refining involves kettle operations at low temperatures just above the melting point of lead; no fumes are produced.

To determine control costs, the following conditions were assumed: the feed has a sulfur content of 15 percent, of which 85 percent is removed as sulfur dioxide in the sinter step. Particulate emissions are 60 kg per metric ton (120 pounds per short ton) of feed in the sinterer, and 15 kg per metric ton (30 pounds per short ton) of feed in the blast furnace.

Sulfur dioxide from the sinter step is available for conversion into acid. The acid plant is assumed to convert 90 percent of the sulfur dioxide it receives, emitting the rest. With an acid plant on the sinter, the additional gas-cleaning scrubber is assumed to remove 90 percent of particulates.

Control costs are summarized in Table 6.7-1.

TABLE 6.7-1. PRIMARY LEAD INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	2.16	20.28	1.29	1.29
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	2.16	20.28	1.29	1.29
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	3.30	11.55	14.05	23.35
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	3.30	11.55	14.05	23.35
O&M				
EXISTING PLANTS	0.72	2.59	3.06	6.89
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.72	2.59	3.06	6.89
ALL ANNUAL COSTS	4.02	14.14	17.11	30.24

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.8 PRIMARY ZINC

Production Characteristics and Capacities

Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1973 were zinc-base alloys, particulary die-cast alloys used in automotive and electrical equipment (41 percent); galvanized steel used in construction and electrical transmission equipment (36 percent); brass and bronze used for plumbing, heating, and industrial equipment (14 percent); zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent); and rolled zinc used in dry cells and lithographic plates (2 percent).

The principal ore minerals are sulfides, which may be predominantly zinc ores or lead-zinc ores. Also, some zinc is obtained from lead-base and copper-base ores. Zinc sulfide concentrates produced from these ores are converted to the oxide state (calcine) by roasting, and then reduced to metallic zinc either by electrolytic deposition or by distillation in retorts or furnaces. In plants using distillation methods, the calcine is given an additional sintering step to provide a more compact feed as well as to remove impurities. Some zinc-producing companies also produce zinc oxide. In pyrolytic plants, both zinc metal and zinc oxide are produced from zinc vapor, either condensed to zinc metal, or oxidized in a chamber.

Over three-quarters of the domestic mine production comes from six states: Tennessee, Colorado, Missouri, New York, Idaho, and New Jersey. Numerous small companies participate in only the mining and beneficiation sector of the zinc industry; these companies sell their concentrates to custom smelters.

In 1973, six companies operated eight primary zinc plants, all of which operate as custom smelters to some extent. The main product of zinc reduction plants is slab zinc. Ore concentrate capacity in 1973 was 1,337 thousand metric tons (1,474 thousand short tons) per year, equivalent to 763 thousand metric tons (841 thousand short tons) of slab zinc. Approximately 24 percent of this capacity utilizes horizontal retort plants, all of which are scheduled for phasing out.

In 1973, the three types of pyrothermic plants (electrothermic, vertical retort, and horizontal retort) accounted for almost two-thirds of the primary zinc capacity. This will change because three new electrolytic plants are in the early stages of construction. Plant size distribution of the three new U.S. electrolytic plants is tabulated below.

Capacity Feed (1,000 metric tons/yr, 1,000 short tons/yr in parentheses)	Capacity, Slab Zinc (1,000 metric tons/yr, 1,000 short tons/yr in parentheses)	% of U.S. Capacity After Closing Horizontal Retort Plants
296 (326)	163 (180)	29
264 (291)	145 (160)	26
82 (90)	45 (50)	8

Emission Sources and Pollutants

Emissions from zinc reduction plants are primarily particulates and sulfur dioxide from the roasters in the electrolytic plants, and from the roasters and traveling-grate sintering machines in the pyrothermic plants. In the electrolytic plants, the calcine from the roaster is substantially sulfur free so that there is a heavy concentration of sulfur dioxide in the off-gases. For the pyrothermic plants, roaster off-gases are also heavy in sulfur dioxide, but there are only light concentrations of sulfur dioxide in the sintering machine off-gases. Particulates are relatively heavy in both streams.

Control Technology and Costs

Sulfur oxide and particulates in roaster off-gases are now being controlled by the use of sulfuric acid plants in six of the present eight plants. In these six, particulate control necessary for the effective operation of the acid plant system is achieved with associated gas-cleaning equipment. With the closing of the three horizontal retort plants, all the roasters in the primary zinc plants are controlled with acid plants. In the two remaining pyrothermic plants, the sintering machine particulates are controlled in one plant by settling flues, electrostatic precipitators, and a baghouse, in the other, by a venturi scrubber.

In general, the control scheme for the primary zinc industry is to use acid plants on the roaster off-

gases where most of the sulfur dioxide is given off. All other operations, with the exception of three plants using a horizontal retort, have particulate control devices. For those plants with horizontal retorts, conversion to vertical retort equipment is the practical control scheme; however, costs for this conversion were not obtained, as this involves a major plant renovation.

With the closing of the three horizontal retort plants, the only new control equipment required for the industry is the acid plants and associated gas cleaning equipment necessary to control sulfur dioxide and particulates in the three new electrolytic plants under construction; these controls come under New Source Performance Standards.

Control costs are detailed in Table 6.8–1.

TABLE 6.8–1. PRIMARY ZINC INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	4.23	39.80	2.54	2.54
NEW PLANTS	2.33	2.33	10.67	27.66
TOTAL	6.56	42.13	13.21	30.20
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	6.48	23.36	27.57	45.14
NEW PLANTS	0.38	0.38	5.74	24.32
TOTAL	6.86	23.74	33.31	69.46
O&M				
EXISTING PLANTS	29.60	102.40	125.97	283.44
NEW PLANTS	0.0	0.0	13.21	81.32
TOTAL	29.60	102.40	139.18	365.26
ALL ANNUAL COSTS	36.46	126.13	172.49	434.72

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.9 SECONDARY ALUMINUM

Production Characteristics and Capacities

For the purpose of this report, the secondary aluminum industry is defined as that industry which produces secondary aluminum ingot to chemical specifications from aluminum scrap and sweated pig. The industry is viewed as consisting of secondary aluminum smelters excluding primary aluminum companies, nonintegrated fabricators, and scrap dealers.

Aluminum has become one of the most important metals in industry; only iron surpasses it in tonnages used. Major uses of the metal are in the construction industry, aircraft, motor vehicles, electrical equipment and supplies, beverage cans, and fabricated metal products which include a wide variety of home consumer products. The automotive industry is a large user of secondary aluminum ingot.

Secondary aluminum ingot is produced to specification; melting to specification is achieved mainly by segrating the incoming scrap into alloy types. The magnesium content can be removed with a chlorine gas treatment in a reverberatory furnace.

As a result of improved recycling, increased municipal mixed-solid waste processing and the increased number of recycling facilities that have been constructed, the secondary aluminum industry will continue to increase over what has been its historical share of about 20 percent of the total aluminum supply. In addition, aluminum has penetrated further into market areas such as transportation, construction, packaging, and distribution. Based on these trends, it is estimated that the demand for aluminum may increase 6 percent per year for the period 1976–1985.

Emission Sources and Pollutants

The most serious emission sources during secondary aluminum smelting are: the drying of oil from borings and turnings, the sweating furnace, and the reverberatory furnace. Emissions from the drying process are vaporized oils, paints, vinyls, etc; the sweating furnace produces vaporized fluxes, fluorides, etc; and the reverberatory furnace emissions are similar to the other two plus hydrogen chloride, aluminum chloride, and magnesium chloride from the chlorine gas treatment used to remove magnesium. As of 1970, an estimated 25 percent of chlorination station emissions were controlled, and it is estimated that by 1980, 80 percent will be controlled.

The several processes that cause emissions during the operation of a reverberatory furnace must be understood to calculate control costs properly; these are:

- Emissions at the forewell,
- Emissions from the bath, and
- Emissions caused by chlorination.

Emissions at the Forewell

Secondary smelters charge scrap directly into the forewell of the reverberatory furnace, and any oil, paint, vinyl, grease, etc., on the scrap vaporizes. The emissions from the charging process vary greatly with the material charged. Quantitative data on forewell emissions or the need for control are not available and costs or possible costs cannot be estimated.

Emissions From the Bath

During the time the aluminum bath is molten, it is covered with a flux to protect it from oxidation.

Emissions Caused by Chlorination

The magnesium content of aluminum can be reduced by chlorination, but chlorination produces chloride emissions. Maximum magnesium removal requires about 18 kilograms of chlorine per metric ton (36 pounds per short ton) of aluminum which has an emission rate of 9 kilograms of particulates per metric ton (18 pounds per short ton) of aluminum. Magnesium removal is practiced by plants representing 92 percent of the estimated industry capacity. A small portion of these plants use aluminum fluoride fluxing for magnesium removal rather than chlorine. This report assumes that control costs for these few plants are similar to those that use chlorination. Wet scrubbing is the usual means of controlling chlorination station emissions; recent innovations on a dry control process are being tested.

Control Technology and Costs

Dryer emissions are often treated with afterburners; however, there are insufficient data relating to

the drying operations to permit evaluations of possible costs that might be expended to meet air-quality specifications.

Sweating furnace emissions, fluoride emissions from fluxes, organic materials, oils, etc., can be controlled by using afterburners, followed by a wet scrubber or baghouse, for which control costs have been reported. However, no data are available on the number, capacity, or location of sweating furnaces. Thus, realistic estimate of control costs cannot be made. Industry costs are included in Table 6.9–1.

TABLE 6.9–1. SECONDARY ALUMINUM INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	1.50	14.05	0.90	0.90
NEW PLANTS	0.95	1.59	4.38	11.51
TOTAL	2.44	15.64	5.28	12.41
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1.85	6.46	7.86	17.69
NEW PLANTS	0.21	0.33	2.23	8.86
TOTAL	2.06	6.79	10.09	26.55
O&M				
EXISTING PLANTS	2.06	7.19	8.75	19.70
NEW PLANTS	0.23	0.37	2.48	9.84
TOTAL	2.29	7.56	11.23	29.54
ALL ANNUAL COSTS	4.35	14.35	21.33	56.09

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.10 SECONDARY BRASS AND BRONZE

Production Characteristics and Capacities

The secondary brass and bronze industry may be divided into two segments: ingot manufacturers and brass mills. Both segments of the industry charge scrap into a furnace where it is melted and alloyed to meet design specifications for chemical composition. Ingot manufacturers use either a stationary reverberatory furnace or a rotary furnace for most of their production. The daily capacity range is from 4.5 to 90 metric tons (5 to 100 short tons) for reverberatory furnaces, and from 2 to 27 metric tons (2 to 30 short tons) for rotary furnaces. Small quantities of special alloys are processed in crucible or electric-induction furnaces. A few cupolas exist in which highly oxidized metal, such as skimmings and slag, is reduced by heating the charge in contact with coke. Ingot manufacturing invariably requires injection of air to refine the scrap. Brass mills use scrap that does not require such extensive refining; the channel induction furnace is the most common type used in these mills.

The number of ingot manufacturing furnaces in 1972 was calculated to be 122. Of these furnaces, 13 were large, 29 were medium, and 80 were small. The large furnaces produced 50 percent of the total annual ingots, while the medium furnaces produced 30 percent, and the small furnaces produced 20 percent.

No substantial growth is expected in the ingot manufacture; in 1980, ingot production is expected to be at the level of 272 thousand metric tons (300 thousand short tons). Adequate capacity currently exists in terms of additional available operating hours to be able to meet the slight production increase from 1973.

The capacity of channel induction furnaces for brass mills ranges from 0.5 to 5 metric tons (0.6 to 6 short tons), with smaller furnaces being the most common. It was estimated that there were 35 plants in 1973 with an average of 3.7 furnaces per plant, or a total of 130 furnaces.

Emission Sources and Pollutants

Metallurgical fumes containing chiefly zinc oxide and lead oxide are the major emissions from the reverberatory and rotary furnaces used by ingot manufacturers and from the induction furnaces used by the brass mills. Fly ash, carbon, and mechanically produced dust are often present in the exhaust gases, particularly from the furnaces used by the ingot manufacturers. Zinc oxide and lead oxide condense to form a very fine fume which is difficult to collect. The emission factors for particulates are 35 kg per metric ton (70 pounds per short ton) of metal charged for a reverberatory furnace, 30 kg per metric ton (60 pounds per short ton) for a rotary furnace, 3.2 kg per metric ton (6.4 pounds per short ton) for an electric induction furnace, 6 kg per metric ton (12 pounds per short ton) for a crucible furnace, and 36.75 kg per metric ton (73.5 pounds per short ton) for a cupola furnace.

Control Technology and Costs

Ingot manufacturers use fabric-filter baghouses, high-energy wet scrubbers, and electrostatic precipitators because of their high efficiency in collecting the fine zinc oxide fumes; 67 percent use a baghouse, 28 percent use a scrubber, and 5 percent use an electrostatic precipitator.

Assumptions were that the collected dust has a value of 10 cents per kilogram (4.5 cents per pound), and an average collector 97.5 percent efficiency. This value of collected dusts was applied as a credit to control costs.

Fabric filter baghouses are used on the brass induction furnaces to collect the particulates. Investment and annual costs were obtained from three plants that use furnaces with capacities ranging from 22 to 32 metric tons (24 to 35 short tons) per day. The average value for the three plants was used for the model furnace of 25 metric tons (27.6 short tons) per day. No credit for collected dust is assumed for brass mills.

Control costs are detailed in Table 6.10–1.

TABLE 6.10–1. SECONDARY COPPER INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	1.34	12.61	0.80	0.80
NEW PLANTS	0.25	0.72	1.12	2.82
TOTAL	1.59	13.32	1.92	3.62
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1.66	5.79	7.05	15.87
NEW PLANTS	0.09	0.19	0.74	2.59
TOTAL	1.75	5.97	7.79	18.46
O&M				
EXISTING PLANTS	1.00	3.30	4.72	11.58
NEW PLANTS	0.02	0.04	0.15	0.52
TOTAL	1.02	3.34	4.87	12.10
ALL ANNUAL COSTS	2.77	9.31	12.66	30.56

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.11 SECONDARY LEAD

Production Characteristics and Capacities

The secondary lead industry is defined as the industry that recovers lead or lead alloys by smelting and/or refining lead scrap; this does not include the activities of scrap dealers who may sweat lead. A total of 22 companies in the secondary lead industry operate 45 plants. The two leading producers are estimated to account for about 64 percent of secondary lead production.

Approximately 526 thousand metric tons (580 thousand short tons) of secondary lead were recovered from scrap in 1975. In 1971, production rose to 528 thousand metric tons (582 thousand short tons) and, by 1973 the production of secondary lead had risen to approximately 593 thousand metric tons (653 thousand short tons).

The assumption of an average emission factor for cupolas and reverberatory furnaces allows the breakdown of the secondary lead industry on the basis of capacity alone. Available capacity data indicate three model plant sizes. The estimated industry capacity and model plant data are given in Table 6.11-1.

Emission Sources and Pollutants

Emission of particulates occurs from lead-processing furnaces. Generally, about 67 percent or more of the output of the secondary lead industry is processed in blast furnaces or cupolas that are used to reduce lead oxide in the form of battery plates or dross, to lead. If oxide reduction is not needed, then lead scrap can be processed in reverberatory furnaces. Kettle or pot furnaces may be used to produce small batches of alloys for molding or refining lead. These lead processing furnaces represent obvious particulate emission sources, the primary emissions being lead oxide fumes. Other particulate emission sources are the slag tap and feeding ports on the cupolas and reverberatory furnaces. Although lead is occasionally sweated in a reverberatory furnace, reclamation of secondary lead by this means represents a very small portion of the total lead production. Emissions factors from slag operations are not known.

The industry estimate of 90 percent net control in 1970 indicates that nearly all plants had emission controls of some sort. A control increase to 98 percent estimated by 1980 is based on implementation of the proposed New Source Performance Standards.

The emission factors for stack emissions are presently under review and the outcome of this review will be published in a lead control techniques document. For fugitive emissions, the ambient air quality standard of 1.5 micrograms per cubic meter (6.6×10^{-7} grains per cubic foot) will require

Table 6.11-1.
Model Plant Descriptions for Secondary Lead Industry
(capacities in metric tons per day with short tons per day in parentheses)

	Capacity Range	No. Plants	Total Capacity	Model Plant Capacity
Plant Model I	83–181 to (92–200)	23	2,482 (2,736)	109 (120)
Plant Model II	27–82 (31–91)	6	327 (360)	54 (60)
Plant Model III	12–26 (13–30)	16	253 (279)	15.8 (17.4)
Totals		45	3,062 (3,375)	

stringent costs. The earliest attainment date is anticipated to be mid-1982.

Control Technology and Costs

Either a baghouse or a wet scrubber can be utilized to achieve emission control. The baghouse is chosen for this cost analysis because it is generally less expensive; it is assumed baghouse life averages 15 years.

Annual costs include capital charges, operating and maintenance, and credits for byproduct recovery value. Since the lead oxide collected in the control equipment is recycled into the smelting furnace, it has value as a byproduct; therefore, the recovery of this lead oxide lowers estimated operating and maintenance costs.

The calculated air pollution abatement costs for the secondary lead industries presented in Table 6.11–2 were based on the following key assumptions:

- Model I plants are assumed to require two separate baghouse installations; Model II and Model III were assumed to need only one baghouse for control.
- Baghouse airflow needs were estimated at 11.2 cubic meters per metric ton (360 cubic feet per short ton) of daily capacity.
- The value of lead oxide recovered from baghouse operations was estimated to be 5 cents per kilogram (2.3 cents per pound), plus 50 percent. It was further assumed that only the lead oxide recovered by going from 90 percent net control in 1970 to an estimated 98 percent net control in 1980 should be credited against control costs. This amounts to 5.6 kilograms per metric ton (11.2 pounds per ton) of lead processed. In addition, production at full capacity was assumed.

Estimated control costs are summarized in Table 6.11–2.

TABLE 6.11–2. SECONDARY LEAD INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	1.27	11.94	0.76	0.76
NEW PLANTS	0.48	0.48	2.12	5.26
TOTAL	1.75	12.42	2.88	6.02
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	1.57	5.49	6.68	15.03
NEW PLANTS	0.06	0.06	0.94	3.86
TOTAL	1.63	5.56	7.62	18.89
O&M				
EXISTING PLANTS	0.86	2.96	3.67	8.26
NEW PLANTS	0.03	0.03	0.52	2.12
TOTAL	0.90	3.00	4.19	10.38
ALL ANNUAL COSTS	2.53	8.56	11.80	29.27

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.12 SECONDARY ZINC

Production Characteristics and Capacities

Zinc ranks after aluminum, copper, and lead in tonnage of nonferrous metals produced in the United States. Major uses in 1976 were zinc-base alloys, particularly die-cast alloys used in automotive and electrical equipment (38 percent), galvanized steel used in construction and electrical transmission equipment (38 percent), brass and bronze used for plumbing, heating, and industrial equipment (15 percent), zinc chemicals, particularly zinc oxide, used in the rubber, paint, and ceramic industries (4 percent), and rolled zinc used in dry cells and lithographic plates (3 percent).

Secondary zinc comes from two major sources: the zinc-base alloys and the copper-base alloys. Most of the secondary zinc that is recovered comes from reconstituted copper-base alloys; slab zinc is next, in importance, followed by chemical products, and zinc dust. For purposes of this report, the 14 operating plants that comprise the secondary zinc industry use sweating and/or distilling operations to produce zinc slab, dust, and oxide solely from scrap. The secondary zinc industry is not considered to include the activities of:

- Primary zinc producers that may manufacture zinc from scrap and ore
- Secondary brass and bronze plants that recover zinc in copper alloys
- Chemical manufacturers that produce zinc compounds by chemical treatment of zinc scrap
- Scrap dealers that may sweat zinc.

Assuming that the total secondary zinc industry operated at an average of 84 percent capacity, the total secondary industry zinc slab capacity stood at 26,430 metric tons (29,134 short tons) at the end of 1974. Total redistilled secondary zinc slab production in 1974 was 86,400 metric tons (95-,240 short tons), of that total 22,200 metric tons (24,470 short tons) were produced by the secondary zinc industry and the remainder was produced by the primary zinc industry. Other zinc materials produced by the secondary zinc companies included zinc dust and zinc oxide. In 1974, slightly over 29,300 metric tons (32,300 short tons) of zinc in the form of zinc oxide was produced from zinc scrap. It is assumed that nearly all of this oxide is produced by the secondary zinc companies.

The production of zinc dust from zinc-base scrap in 1974 totaled 29,350 metric tons (32,350 tons). It is assumed that much of this production came from the secondary industry. From these production figures, the capacity of the secondary zinc industry is estimated to be approximately 96 thousand metric tons (106 thousand short tons) of contained zinc per year.

No data are available for sweating capacity which can be performed in various types of furnaces. It is assumed that much of the feed material for production of refined secondary zinc is sweated; sweating capacity is therefore placed at 63.5 thousand metric tons (70 thousand short tons) per year.

Emission Sources and Pollutants

At least four operations generate emissions in the secondary zinc industry: materials handling, mechanical pretreatment, sweating, and distilling. This analysis considers only control costs for emissions from the sweating and distilling operations, as insufficient data are available for calculating the possible costs of controlling emissions from the other sources.

In the sweating operation, various types of zinc-containing scrap are treated in either kettle or reverberatory furnaces. The emissions vary with the feed material used and the feed material varies from time-to-time and from plant-to-plant. Emissions may vary from nearly 0 to 15 kg of particulates per metric ton (0 to 30 pounds per short ton) of zinc reclaimed. For purposes of this report, it is assumed that the maximum emission rate applies.

In the case of the various types of zinc distilling furnaces, the accepted emission rate is 23 kilograms per metric ton (46 pounds per short ton) of zinc processed. Some distillation units produce zinc oxide, and normally utilize a baghouse for collection of the product. This report assumes that these baghouses are sufficient to meet national ambient standards. However, for the purpose of calculating control costs, it was assumed that essentially all of the estimated zinc oxide capacity

could be switched to slab zinc or dust production, and emission controls would be required.

Controlled and uncontrolled emissions from secondary zinc sweating operations cannot be estimated with an acceptable degree of probable accuracy because reliable data are not available.

Control Technology and Costs

The major emission of concern is particulates, consisting mainly of zinc oxide. Baghouses have been shown to be effective in controlling both distillation and sweating-furnace emissions except when the charge contains organic materials such as oils.

A complete accounting of secondary zinc plants by type of furnaces used and the product or products produced is not available. Based on the limited information, it is assumed that the industry's 14 plants can be represented by two models: two Model I plants, each consisting of 7,260 metric tons per year (8,000 short tons per year) sweating capacity and 10,900 metric tons per year (12,000 short tons per year) distilling capacity; and twelve Model II plants, each consisting of 4,080 metric tons per year (4,500 short tons per year) of sweating capacity and 4,990 metric tons per year (5,500 short tons per year) of distilling capacity.

Estimated control costs for the secondary zinc industry are detailed in Table 6.12-1.

TABLE 6.12-1. SECONDARY ZINC INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.32	2.97	0.19	0.19
NEW PLANTS	0.0	0.0	0.0	4.09
TOTAL	0.32	2.97	0.19	4.28
ANNUAUZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	0.39	1.36	1.66	3.73
NEW PLANTS	0.0	0.0	0.0	1.44
TOTAL	0.39	1.36	1.66	5.17
O&M				
EXISTING PLANTS	0.47	1.28	2.85	6.77
NEW PLANTS	0.0	0.0	0.0	2.72
TOTAL	0.47	1.28	2.85	9.49
ALL ANNUAL COSTS	0.86	2.65	4.51	14.66

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7. QUARRYING AND CONSTRUCTION INDUSTRIES

For the purposes of this report, the Quarrying and Construction Industries are defined as those establishments which gather, process, and prepare materials to be used in the construction industry. Wood products are specifically excluded; these are covered in Chapter 9. The industrial sectors covered in this chapter are the:

- Cement Industry
- Clay Construction Industry
- Lime Industry
- Asphalt Concrete Industry.

Costs for the abatement of air pollution for these industries are summarized in Table 7–1. These costs and other data are repeated below in the appropriate section together with the assumptions and other details specific to each industrial sector.

TABLE 7.-1. AIR POLLUTION ABATEMENT COSTS FOR THE QUARRYING & CONSTRUCTION INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1970–77	1977–81	1977–86
CEMENT	4.44	14.58	18.04	41.24
CLAY CONSTRUCTION	11.04	96.06	10.24	15.66
LIME	14.67	137.94	8.80	8.80
ASPHALT	25.63	252.80	59.23	94.76
TOTAL INVESTMENT	55.78	501.37	96.31	160.46
		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
CEMENT	3.29	7.48	24.22	79.18
CLAY CONSTRUCTION	37.32	128.59	162.81	337.42
LIME	25.05	87.68	106.61	220.90
ASPHALT	93.72	352.33	426.51	915.16
TOTAL ANNUAL COSTS	159.39	576.10	720.14	1562.65

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7.1 CEMENT INDUSTRY

Production Characteristics and Capacities

Portland cement, which accounts for approximately 96 percent of cement production in the United States, is processed from a blend of various calcareous, argillaceous, and siliceous materials including limestone, shell, chalk, clay, and shale. As the binder in concrete, portland cement is the most widely used construction material in the United States. The four major steps in producing portland cement are: quarrying and crushing; blending, grinding, and drying; heating the materials in a rotary kiln to liberate carbon dioxide and cause incipient fusion; and fine-grinding the resultant clinker, with the addition of 4 to 6 percent gypsum. Finished cement is shipped either in bulk or in bags. All portland cement is produced by either wet or dry grinding processes, the distinguishing characteristic being whether the raw materials are introduced into the kiln as a wet slurry or as a dry mixture.

In 1971, 170 plants producing portland cement clinker plus five plants operating grinding mills to produce finished cement were controlled by 51 companies and were located in 41 states and Puerto Rico. By 1974 (year end), some 168 plants were in operation with an annual capacity of 82 million metric tons (91 million short tons). Fifty percent of this cement industry capacity is owned by multiplant companies, and the eight leading companies account for about 47 percent of the total. Overcapacity has resulted in low profit margins and has inhibited modernization and construction of new plants. More stringent air-pollution regulations have increased both capital and operating costs. Recent trends are toward an increase in utilization, as evidenced by a current ratio of 87 percent. Recent trends are toward increased operations through installation of larger kilns to replace older marginal kilns, permitting more economic and efficient pollution control. The cement manufacturing plant capacity and size distribution are in Table 7.1–1.

Size distribution is expected to shift upwards as new plants are constructed and existing plants modified or closed, so the total number of plants is expected to remain about the same. It is also assumed that there will be no major shift in production capacity percentages between dry and wet grinding processes, with the latter presently estimated at 59 percent.

Emission Sources and Pollutants

Primary emission sources are the dry-process blending and grinding, kiln operation, clinker cool-

Table 7.1–1.
Cement Manufacturing Plant Size Distribution
(capacities in metric tons with short tons in parentheses)

Daily Capacity Range	No. Plants	No. Kilns	Total Annual[1] Capacity (1,000,000)	Total Capacity (%)
Less than 544 (less than 600)	4	7	1.13 (1.25)	0.8
544–1042 (600–1149)	45	87	11.1 (12.2)	13.6
1043–1541 (1150–1699)	51	130	21.2 (23.4)	24.2
1542–2086 (1700–2299)	35	103	20.0 (22.1)	23.3
2087–2539 (2300–2799)	12	38	7.1 (7.8)	10.4
2540 and up (2800 and up)	21	101	21.9 (24.1)	27.7
Totals	168	466	82.4 (90.8)	100.0

[1] Based on 334-day operation.

er, and finish grinding. Other sources include the feed and materials-handling systems. The primary air pollutant is dust particulates. The estimated dust-emission factor for an uncontrolled dry-process kiln is 122 kg per metric ton (244 pounds per short ton) of cement, compared with 114 kg per metric ton (228 pounds per short ton) for the wet-process plant, giving a weighted average emission factor of 117 kg per metric ton (234 pounds per short ton) of product. The corresponding emission factors for the blending, grinding, and drying processes are 48 kg (dry) and 16 kg (wet) per metric ton (96 and 32 pounds per short ton), respectively, for a weighted average of 29 metric ton per kg (58 pounds per short ton).

Control Technology and Costs

Emissions from the blending, grinding, and drying processes are generally controlled with fabric filters. Where ambient gas temperatures are encountered during grinding, conveying, and packaging processes, fabric filters are used almost exclusively. The greatest problems are encountered with high-temperature gas streams which contain appreciable moisture.

Both fabric filters and electrostatic precipitators are used in controlling dust emissions from the kilns. Condensation problems from the high-moisture content in the wet-process plant may be overcome by insulating the ductwork and preheating the systems on start-up. Current state regulations may be met either with fabric filters or with electrostatic precipitators; however, New Source Performance Standards may require the filters. At least one plant has a wet scrubber, but costs for the plant were estimated on the basis of an electrostatic precipitator.

The total cost of control for portland cement plants was found by estimating the costs for control devices for grinding, mixing, and drying (drying not included in the wet processes) and/or kilns, which are the major sources of pollutant. Baghouses are used for dry-process kilns and electrostatic precipitators for wet-process kilns. Baghouses were assumed to have been used for the combined grinding, mixing, and drying processes. Other sources, including clinker coolers, packaging, and crushing, are not costed due to prevailing industry control prior to the 1970 Clean Air Act and/or minimal costs.

The capital cost of baghouses is assumed to be proportional to the 0.91 power of capacity, while the capital cost of electrostatic precipitators is proportional to the 0.67 power of capacity; in each case, the operating cost is linearly proportional to the capacity. The cost of baghouses for the grinding, mixing, and drying operations was scaled in the same manner. However, the required size was scaled by 0.78 (dry) and 0.26 (wet) to account for the smaller airflow rates of these processes, and the absence of control required for the wet-process raw material grinding mills.

Control costs for the cement industry are detailed in Table 7.1–2. It should be noted that only costs for new sources are indicated; reportedly all existing plants are in compliance with State Implementation Plans. (EPA report FR-41U-649, August, 1972).

TABLE 7.1–2. CEMENT INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	4.44	14.58	18.04	41.24
TOTAL	4.44	14.58	18.04	41.24
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	1.92	4.36	13.57	44.13
TOTAL	1.92	4.36	13.57	44.13
O&M				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	1.37	3.13	10.64	35.06
TOTAL	1.37	3.13	10.64	35.06
ALL ANNUAL COSTS	3.29	7.48	24.22	79.18

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.2 STRUCTURAL CLAY PRODUCTS INDUSTRY

Production Characteristics and Capacities

Currently 466 plants in the United States manufacture structural clay products, including common brick, fireclay or refractory brick, and sewer pipe. The brick category represents approximately 90 percent of the total production of structural clay materials, with common brick being by far the largest category, representing approximately 75 percent of total production. Values of shipments in 1972 were $404 million, $143 million, and $13 million for common brick, clay sewer pipe, and fireclay brick, respectively. Plants are located in 45 states with North Carolina, South Carolina, Ohio, Pennsylvania, and Texas accounting for about 45 percent of production capacity.

For purposes of estimating air abatement costs, the industry was divided into those plants using either continuous tunnel kilns or periodic kilns; an average plant capacity was selected for each process, as shown in Table 7.2–1.

Miscellaneous clays and shales are used to manufacture common brick, sewer pipe, and refractory brick. Typically, the plants are located in the proximity of the clay mines. The clays are crushed and ground at the plant, after which they are screened and mixed with water for the forming operation. Common brick, sewer pipe, and some refractory brick are formed by extrusion; most refractory brick is formed by die pressing.

The formed materials are fire-treated by either continuous tunnel or intermittent periodic kiln processes. In the continuous tunnel kiln, the charge is preheated by airflow escaping from the bake oven, passed through the oven at temperatures of approximately 1,050 C (1,900 F), then passed through a cooling stage. In contrast, the periodic kiln heats the charge from ambient temperature to a peak temperature, after which the fuel is shut off, allowing the charge to cool to ambient temperature again; this cycle requires about 2 weeks, during which fuel is burned about 50 percent of the time. The remainder of the period is used for cooling and physical discharging of the product, steps which emit few, if any, air pollutants.

A process frequently practiced by manufacturers of common brick is flashing. This process involves firing the brick in a reducing atmosphere to achieve architecturally desirable surface colorations. The process is noted because when it is used in conjunction with periodic kilns, carbon monoxide and/or hydrocarbon emissions usually result.

Emission Sources and Pollutants

Atmospheric emissions from the manufacture of clay construction products are primarily sulfur dioxides released during the firing process. These originate from the sulfur contained in the clay and in the fossil fuels consumed in the firing operation. Uncontrolled sulfur dioxide emissions are estimated to be about 3.7 kg per metric ton (7.4 pounds per short ton) of clay processed. The flashing process associated with the manufacture of certain types of brick can also result in hydrocarbon and carbon monoxide emissions. Approxi-

Table 7.2–1.
Plant Distribution Assumed for Structural Clay Industry
(capacity in thousands of metric tons per year with thousands of short tons per year in parentheses)

	Average Capacity	No. Plants	Estimated 1974 Capacity (thousands)	Total Capacity(%)
Periodic kilns	21 (23)	336	6.9 (7.6)	35
Continuous Tunnel kilns	100 (110)	130	12.9 (14.2)	65
Totals		466	19.8 (21.8)	100

mately 4.2 kg of hydrocarbons and/or carbon monoxide are estimated to be released per metric ton (8.4 pounds per short ton) of brick flashed.

Control Technology and Costs

It is anticipated that wet scrubbers will be used to control sulfur dioxide emissions from the production of clay construction materials. Only a few plants were found to be exercising this or any other control option. Hydrocarbon and carbon monoxide emissions can be controlled by using afterburners. The requirement for afterburners will depend on the duration of the flashing treatment at different plants. Likewise, it is probable that certain plants will have minimal requirement for scrubbers because of the negligible sulfur content of some clays. About 10 percent of existing plants producing common brick, sewer pipe, and refractory brick were assumed to be either equipped with adequate controls or using new clay materials sufficiently low in sulfur content to avoid the need for wet scrubbers.

Costs and industry operating statistics are detailed in Table 7.2–2.

TABLE 7.2–2. STRUCTURAL CLAY PRODUCTS INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	11.04	96.06	7.12	7.12
NEW PLANTS	0.0	0.0	3.13	8.55
TOTAL	11.04	96.06	10.24	15.66
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	15.63	53.86	67.16	112.90
NEW PLANTS	0.0	0.0	1.01	6.19
TOTAL	15.63	53.86	68.18	119.08
O&M				
EXISTING PLANTS	21.69	74.74	93.22	209.75
NEW PLANTS	0.0	0.0	1.41	8.59
TOTAL	21.69	74.74	94.63	218.33
ALL ANNUAL COSTS	37.32	128.59	162.81	337.42

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.3 LIME INDUSTRY

Production Characteristics and Capacities

As of 1976, there were 167 lime-producing plants in the United States. These plants can be divided into seven size ranges, based upon output capacity; the number of plants in each size range and their estimated capacities are shown in Table 7.3–1.

The U.S. lime industry can be conventionally divided into two product sectors. Approximately 35 percent of the output is consumed by the producers, while the remaining 65 percent is sold in the open market. Plants are located in 41 states and Puerto Rico. Over 22 percent of U.S. capacity is in Ohio, and other major capacities are located in Pennsylvania, Texas, and Michigan. Recent trends are toward the closing of small, old plants and replacing old kilns with larger units.

Table 7.3–1.
Lime Industry Production Distribution in 1974
in thousands of metric tons per year (with thousands of short tons per year in parentheses)

Size Range	No. Plants	Estimated 1974 Production (1,000)	Percent of Total
0–9 (0–10)	28	157 (173)	1
9–23 (10–25)	35	576 (635)	3
23–45 (25–50)	18	568 (626)	3
45–91 (50–100)	28	1830 (2017)	9
91–181 (100–200)	28	2867 (3160)	15
181–363 (200–400)	33	8338 (9191)	42
More than 363 (More than 400)	9	5296 (5838)	27
Total	173	19,632 (21,641)	100

Source: Mineral Yearbook, Bureau of Mines, 1974.

As shown in the table above, there were 173 plants in the Lime Industry in 1974. In the two-year period between 1974 and 1976, 6 plants were closed down. In 1976, producers at 167 plants sold or used 20.1 million metric tons (22.2 million short tons). Should the use of lime in processes for the removal of sulfur oxides from combustion gases become standard practice, the demand for lime will be increased substantially. The number of plants, meanwhile, has declined from 195 in 1970 to 167 in 1976. Further consolidation may be expected to economically justify the increased cost of emissions controls.

Lime is formed by expelling carbon dioxide from limestone or dolomitic limestone by high tempertures. This calcination process forms quicklime. Hydrated lime is made by the addition of water to the quicklime. The calcination of dolomite results in dead-burned (refractory) dolomite. Major uses of lime are for basic oxygen steel furnaces, alkalies, water purification, other chemical processes, and refractory dolomite.

About 70 percent of lime is produced in two basic types of rotary kilns: the long rotary kiln, and the short rotary kiln with external preheater. Vertical kilns are used to supply 28 percent of lime. Almost all new lime production is done using the rotary process.

Emission Sources and Pollutants

Atmospheric emissions from lime manufacture are primarily particulates released when crushing the limestone to kiln size, calcining the limestone in a rotary or vertical kiln, and crushing the lime to size; also, fly ash is released if coal is used in calcination. Other emissions, such as sulfur oxides, may be generated by fuel combustion.

Uncontrolled emissions from rotary kilns are about 100 kg per metric ton (200 pounds per short ton) of lime processed, compared with 10 kg per metric ton (20 pounds per short ton) from vertical kilns. However, economics favor use of the rotary kiln, and virtually all new and expanded production is expected to use this method.

Control Technology and Costs

Gases leaving a rotary kiln are usually passed through a dust-settling chamber where the coarser material settles out. In many installations, a first-stage, primary dry cyclone collector is used. The removal efficiency at this stage can vary from 25 to 85 percent by weight of the dust being discharged from the kiln.

The selection of a second stage to meet the high efficiency level of 23 mg per actual cubic meter (0.01 grain per actual cubic foot) may be either a high-energy wet scrubber, fabric filter, or electrostatic precipitator. The higher capital cost of the electrostatic precipitator may be more than offset for specific installations by lower operating and maintenance costs.

It is believed that vertical kilns can be effectively controlled to allowable emission limits with baghouses, scrubbers, or cyclone/scrubber combinations. In the latter cases, efficiencies of 99 percent have been reported.

Capital costs for fabric filters for existing plants were assumed to be twice the cost for new plants. Capital costs for wet scrubbers and electrostatic precipitators in existing plants were assumed to be 50 percent greater than in new plants.

A new source performance standard of 0.15 kg/metric ton (0.3 lb/short ton) is expected to be promulgated in early 1978. The costs in this report do not reflect this expected change in regulations. Baghouses, scrubbers, and electrostatic precipitators can be used to meet these standards. Control cost data are presented in Table 7.3–2.

TABLE 7.3–2. LIME INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	14.67	137.94	8.80	8.80
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	14.67	137.94	8.80	8.80
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	18.83	65.89	80.11	171.27
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	18.83	65.89	80.11	171.27
O&M				
EXISTING PLANTS	6.23	21.80	26.50	59.62
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	6.23	21.80	26.50	59.62
ALL ANNUAL COSTS	25.05	87.68	106.61	230.90

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.4 ASPHALT CONCRETE PROCESSING INDUSTRY

Production Characteristics and Capacities

Asphalt concrete comprises a mixture of aggregates and an asphalt cement binder. Aggregates usually consist of different combinations of crushed stone, crushed slag, sand, and gravel. Asphalt concrete plant processing equipment includes raw-material apportioning equipment, raw-material conveyors, a rotary dryer, hot-aggregate elevators, mixing equipment, asphalt-binder storage, heating and transfer equipment, and mineral-filler storage and transfer equipment.

About 4,400 asphalt concrete plants in the United States directly employ about 15,400 people. In 1975, production was estimated to be 265 million metric tons (292 million short tons). Based on a 1974 survey conducted by the National Asphalt Pavement Association (NAPA) covering 960 plants, 78 percent were stationary plants and 22 percent were portable. Continuous mixers comprised 27 percent of the portable plants, compared with only 4 percent for stationary plants.

Estimation of the size distribution of plants is difficult because of a lack of data. Of the plants surveyed by NAPA, 12 percent were less than 98 metric tons per hour (108 short tons per hour) capacity at average moisture condition. About 60 percent were between 99 and 198 metric tons per hour (109 and 218 short tons per hour) and 28 percent were larger than 198 metric tons per hour (218 short tons per hour). The average size was 160 metric tons per hour (176 short tons per hour). The balance of the industry, 80 percent of the plants, has only 75 percent of the capacity. By difference, the average for these plants is 94 metric tons per hour (104 short tons per hour). The overall industry average is 110 metric tons per hour (121 short tons per hour).

Plants operate an average of only 666 hours per year because of the seasonal and intermittent nature of the work.

Asphalt concrete production is essentially a batch-type operation; continuous-mix represents, at most, 10 percent of the industry.

Emission Sources and Pollutants

The predominant emissions are dust particulates from the aggregates used in making asphalt concrete. The largest sources of particulate emissions are the rotary dryer and screening, weighing, and mixing equipment. Additional sources that may be significant particulate emitters, if they are not properly controlled, are: the mineral-filler loading, transfer, and storage equipment; and the loading, transfer, and storage equipment that handles the dust collected by the emission-control system. Generally, the uncontrolled emissions from asphalt batching plants amount to 22.5 kg of dust per metric ton (45 pounds per short ton) of product.

Control Technology and Costs

Practically all plants use primary dust collection equipment, such as cyclones or settling chambers. These chambers are often used as classifiers with the collected aggregate being returned to the hot-aggregate elevator to combine with the dryer aggregate load.

The gases from the primary collector must be further cleaned before venting to the atmosphere. To meet SIP requirements, 98.3 percent abatement is sufficient. This can be achieved by the use of multiple centrifugal scrubbers. NSPS issued in 1975 allows no more than 90 mg/dscm (0.04 grain per cubic foot) of particulates or an opacity greater than 20 percent. In effect this requires the use of a high energy scrubber or a fabric filter (baghouse). The most common secondary collector used to meet NSPS is expected to be the baghouse, although venturi scrubbers are used in some plants. The baghouse allows dry collection of dust which can be returned to the process or disposed of in a landfill. The venturi scrubber makes dust hauling expensive due to the wetting of the dust. Also, the use of large settling ponds and the possible need for water treatment discourage the use of venturi scrubbers.

Control costs are detailed in Table 7.4–1.

TABLE 7.4–1. ASPHALT CONCRETE INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	11.61	225.31	6.97	6.97
NEW PLANTS	14.01	27.49	52.26	87.79
TOTAL	25.63	252.80	59.23	94.76
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	36.67	142.02	151.21	234.87
NEW PLANTS	4.47	6.67	41.02	120.88
TOTAL	41.14	148.68	192.23	355.74
O&M				
EXISTING PLANTS	52.58	203.65	216.82	487.85
NEW PLANTS	0.0	0.0	17.46	71.57
TOTAL	52.58	203.65	234.28	559.41
ALL ANNUAL COSTS	93.72	352.33	426.51	915.16

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8. OTHER MANUFACTURING AND SERVICES

The subject group of industries include the following categories:

- Paint Manufacturing
- Surface Coatings
- Dry Cleaning.

These types of activities have in common the characteristics of (1) not being based on primary raw materials, their starting materials being manufactured items and (2) generating similiar types of emissions, i.e., solvents and other hydrocarbons.

Costs for the control of air pollution in these industries are given in summary form in Table 8–1. The specific aspects and costs of air pollution control for the individual industry segments are given in more detail in the following sections.

TABLE 8.-1. AIR POLLUTION ABATEMENT COSTS FOR OTHER MANUFACTURING AND SERVICE INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

	INVESTMENT			
INDUSTRY	1977	1970–77	1977–81	1977–86
PAINT MANUFACTURING	4.85	34.33	8.59	18.14
SURFACE COATING	0.0	0.0	658.82	1707.64
DRY CLEANING	10.04	141.75	6.75	13.27
TOTAL INVESTMENT	14.89	176.08	674.16	1739.06
	ANNUAL COSTS			
	1977	1970–77	1977–81	1977–86
PAINT MANUFACTURING	11.11	36.55	52.33	117.96
SURFACE COATING	0.0	0.0	374.38	1858.20
DRY CLEANING	23.07	86.06	95.58	156.53
TOTAL ANNUAL COSTS	34.18	122.61	522.30	2132.70

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8.1 PAINT MANUFACTURING INDUSTRY

Production Characteristics and Capacities

Paint manufacturing involves mixing or dispersing pigments in oil, resin, resin solution, or latex at room temperature. Mixing is then followed by the addition of specified proportions of organic solvents or water to obtain the desired viscosity.

In 1972, 1,599 plants manufactured paint products in the United States. Plant size varied, with approximately 32 percent of the plants accounting for nearly 90 percent of production.

Production of paint by 1976 is estimated to be about 4,645 million liters (1,227 million gallons). Since about 520 plants will produce about 4,134 million liters (1,092 million gallons) of paint per year, the average production from these larger plants will be 7.95 million liters (2.1 million gallons) per year or roughly 31,800 liters (8,400 gallons) per day. The balance of the plants were omitted from control cost considerations because they collectively account for only about 511 million liters (135 million gallons) per year, so their average annual production is only about 6 percent of that of the average plant in the larger category.

Current trends in the industry should decrease the future hydrocarbon emission levels associated with paint manufacturing. These include the use of water-based paints and new application techniques such as powder coating. These developments will continue to have a negative impact on the demand for organic solvent-based paints; it is estimated that water-based paints currently represent about 22 percent of total production volume.

Emission Sources and Pollutants

Air pollutants from paint manufacturing are hydrocarbons originating from organic solvents, and particulates from paint pigments. About 909 grams of particulates are emitted per metric ton (1.8 pounds per short ton) of pigment dispersed. Assuming that 78 percent of the projected 1976 volume of paint produced was solvent-based, estimated uncontrolled hydrocarbon emissions were about 24,310 metric tons (26,750 short tons).

Control Technology and Costs

Reduction of hydrocarbon emissions from paint production by 85 percent, which will meet all SIPs, may be accomplished by flame combustion, thermal combustion, catalytic combustion, or adsorption. Thermal combustion (with heat exchange) is considered the most feasible method of control; equipment incorporating heat-exchange devices was chosen because of currently anticipated future fuel shortages and assumed removal efficiences of 95 percent. Catalytic combustion units, while highly promising from the standpoint of lower fuel requirements (but higher initial investment costs), still present technical operating problems. Baghouses (fabric filters) are suitable for control of particulate emissions from pigments; particulate removal efficiences of more than 95 percent are readily achieved.

Estimates for air-pollution control for the total industry were based on assumed compliance by plants averaging about 7.95 million liters (2.1 million gallons) of paint production per year; about 520 plants of this capacity were assumed to be in operation. Future cost predictions are complicated by the emergence of technological trends away from the use of solvent-based paints. Control costs are detailed in Table 8.1-1.

TABLE 8.1–1. PAINT MANUFACTURING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	4.85	34.33	3.72	3.72
NEW PLANTS	0.0	0.0	4.87	14.42
TOTAL	4.85	34.33	8.59	18.14
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	5.59	18.39	24.77	42.93
NEW PLANTS	0.0	0.0	1.56	10.06
TOTAL	5.59	18.39	26.33	52.99
O&M				
EXISTING PLANTS	5.52	18.16	24.46	55.03
NEW PLANTS	0.0	0.0	1.55	9.94
TOTAL	5.52	18.16	26.00	64.97
ALL ANNUAL COSTS	11.11	36.55	52.33	117.96

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.2 SURFACE COATINGS INDUSTRY

Production Characteristics and Capacities

Emission-abatement costs associated with the use of organic-based surface coatings in four industries were considered: automobiles and light-duty trucks, wood furniture, major appliances, and metal or coil coatings. These industries are considered together because of the general similarities between the coating processes employed, the nature of the resulting emissions, and the abatement technologies deemed applicable.

In 1971, approximately 560 million liters (148 million gallons) of coatings, i.e., paint, shellac, lacquer, and primers, were consumed by these industries. Most of the coatings materials used were solvent-based and significant emissions of volatile organic chemicals (VOC) resulted during the application and curing stages of the process. Future estimates of the volume of hydrocarbon emissions attributable to surface coating processes must be considered in light of the following factors:

- Increased use of low-hydrocarbon solvent materials, such as water-based solutions.
- Application techniques involving solvent-free systems, i.e., powder coatings applied by electrostatic spraying or fluidized-bed coating.

Where applicable, these process alternatives would provide up to 90 percent reduction in VOC emissions, depending on the type of coating previously used. Faced with the alternative of conventional emission-control techniques (i.e., incineration or activated carbon adsorption) industries are expected to adopt the newer coating formulations and application techniques at an accelerated pace. By 1986, as much as 50 percent of the coating processes may employ low-hydrocarbon based materials.

The coating process consists basically of two steps: application (followed by flash-off) and curing. Both stages produce hydrocarbon emissions through evaporation. The coating is generally applied by a spray gun in a paint spray booth, and the surface is then cured or dried in a drying oven where the remaining solvent is evaporated. A summary of industry production is presented in Table 8.2-1.

Table 8.2-1.
Surface Coatings Industry
Distribution (1971)

	No. of Plants	Coating Consumption (with millions of gallons in parentheses)
Automobiles and light-duty trucks	47	193 (65)
Wood Furniture	300	208 (50)
Furniture Metal/ Coil Coating	56	87 (25)
Major Appliances	147	72 (20)
Total		560 (160)

Automotive Finishing. In 1971, 100 motor vehicle (auto, truck, and bus) assembly plants were located in 28 states. Included in this product group are: motor vehicles and car bodies, truck and bus bodies, motor vehicle parts and accessories, truck trailers, and travel trailers and campers. This study is limited to the 47 plants that assemble automobiles and light-duty trucks. They are classified in SIC 3711 and 3733. These plants consumed about 193 million liters (51 million gallons) of surface coatings in 1976. The average increase in consumption is estimated at 1 percent per year through 1986.

Furniture Finishing. About 7,000 establishments are engaged in manufacturing the following types of furniture in the United States:

SIC No.

- 2511 • Wood Household Furniture
- 2512 • Wood Furniture – Upholstered
- 2514 • Metal Household Furniture
- 2517 • Wood Cabinetry
- 2519 • Household Furniture, Not Elsewhere Classified
- 2521 • Wood Office Furniture
- 2522 • Metal Office Furniture
- 2531 • Public Building Furniture
- 2541 • Wood Partitions and Fixtures
- 2599 • Furniture and Fixtures, Not Elsewhere Classified.

This study is limited to the 6,300 establishments engaged in the manufacture of wood furniture,

including SIC categories 2511, 2512, 2517, 2521, and 2541, and parts of 2531 and 2599.

Manufacturers of wood furniture used about 208 million liters (55 million gallons) of surface coatings in 1976. Unlike the metal surfaces coatings, the use of water-based paints and finishes for wood furniture is limited in practice because of the tendency for the occurrence of surface distortions in the wood. Virtually all wood furniture coatings used, therefore, are hydrocarbon-based and range from 30 to 70 percent by weight in volatile organic content. The average increase in consumption is estimated at 3 percent per year through 1986.

Coil Coating. The coil-coating process consists primarily of the pretreatment of sheet metal in the strip or coil form, followed by the application of an organic coating and subsequent curing (or baking) to obtain the desired surface characteristics. It is estimated that 56 plants in the United States are engaged in this coating process. Almost 60 percent of the plants are located in Pennsylvania, Ohio, Illinois, and California. Coil-coated metal is a small part of SIC 3479.

Consumption of coatings by the coil-coating industry increased by nearly 10 percent per year between 1968 and 1974. Projecting this growth rate through 1986 gives consumption of 87 million liters (23 million gallons in 1976 and 220 million liters (58 million gallons) in 1986.

Major Appliances. In 1976, 147 U.S. plants were engaged in producing major household appliances including: cooking equipment, refrigerators and freezers, and laundry equipment. These plants produce products classified in SIC 3631, 3632, and 3633. Coatings use was about 72 million liters (19 million gallons) in 1976, having increased by slightly more than 2.9 percent per year since 1964. Projecting this same growth rate, consumption should be about 98 million liters (26 million gallons) in 1986.

Emissions and Sources of Pollutants

While paint spray booths are a source of hydrocarbon emission, the volume of solvent released to the air through evaporation is dependent on the degree of overspray, which can vary anywhere from 10 to 90 percent. Aerosols resulting from overspray are usually removed by filters or water scrubbers, but these devices have little impact on removal of emissions due to solvent evaporation. The major source of emissions attributable to coating processes is usually the spray booth and its associated flash-off area.

Control Technology and Costs

EPA's recommended emission limitations are based on different control technologies for the different industries. For coil-coating, where the entire coating and curing operation can be isolated from personnel, concentrations of VOC emissions can be high (25 percent of the lower explosive limit), and thermal incineration with primary heat recovery is recommended. "Primary heat recovery" means using a heat exchanger to heat gases coming into the incinerator with the heat of gases exiting the incinerator.

For the manufacture of automobiles and light-duty trucks, major household appliances, and wood furniture, the presence of personnel in spray booths means that large quantities of air must be injected into the spray booths to dilute the concentration of VOC's to limits tolerable to humans. Consequently, incineration of emissions from spray booths and their associated flash-off areas is not economically practical because of the large fuel consumption required. Incineration from ovens may be technically feasible, but ovens discharge only about 15 percent of the VOC emissions from a coating line. For the automotive industry, electrodeposition is recommended for prime coats and the use of high-solids enamels instead of low-solids lacquers for topcoats. Two automobile plants in California use water-borne topcoats, but this option is not generally feasible. For manufacturers of major household appliances, either electrodeposition or water-borne coatings are recommended for the prime coat and high-solids, solvent-borne coatings for the topcoat.

None of these options is technically and economically practical for the manufacturers of wood furniture. If emissions from the manned coating-application and associated flash-off area can be drawn through the low-temperature curing oven, adsorption of VOC's with an activated carbon system appears to be the most practical means of emission control.

A summary of estimated investment and annual operating costs is provided in Table 8.2–2.

TABLE 8.2-2. SURFACE COATING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.0	0.0	658.82	1662.66
NEW PLANTS	0.0	0.0	0.0	44.99
TOTAL	0.0	0.0	658.82	1707.64
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	0.0	0.0	211.11	1033.94
NEW PLANTS	0.0	0.0	0.0	5.91
TOTAL	0.0	0.0	211.11	1039.85
O&M				
EXISTING PLANTS	0.0	0.0	163.27	812.79
NEW PLANTS	0.0	0.0	0.0	5.56
TOTAL	0.0	0.0	163.27	818.35
ALL ANNUAL COSTS	0.0	0.0	374.38	1858.20

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.3 DRY CLEANING INDUSTRY

Production Characteristics and Capacities

There are primarily two types of dry cleaning installations that release organic-solvent vapors resulting in the formation of photochemical oxidants in the atmosphere. They are those using synthetic solvent such as perchloroethylene and those using petroleum solvent such as Stoddard. The trend in dry cleaning operations is towards the "laundromat" facility and the industrial establishments. Business in the commercial sector (small neighborhood dry cleaning shops) continues to decline. It has been estimated that approximately 70 percent of dry cleaning is done using synthetic solvents with the remaining 30 percent using petroleum solvents.

Emission Sources and Pollutants

In perchloroethylene plants, average solvent losses have been estimated to be about 10–12 kg of solvent per 100 kg of clothing. Unlike petroleum plants, where no emission controls are used, many dry cleaner operations using perchloroethylene solvents have vapor adsorbers to reduce solvent usage. Others are equipped with regenerative filter and a muck cooker. For these facilities, the total consumption rates averages about 8.1 kg of solvent per 100 kg of clothing. For adsorber-equipped plants, the solvent usage is approximately 4.9 kg per 100 kg of clothing, equivalent to a 40 percent reduction in solvent loss.

Because there is no solvent recovery during the drying cycle nor from the filter muck, petroleum plants have much higher solvent losses than synthetic plants. Emissions for petroleum dry cleaners are estimated to average 23–29 kilograms of solvent per 100 kilograms of materials cleaned. At the present time, no control systems are known to be operating in petroleum plants in the U.S. One plant, however, is currently installing a carbon adsorber.

Control Technology and Costs

Fire-hazards, economics, and the law-based capacity are the primary reason why carbon adsorbers are not widely used in the petroleum dry cleaning industry. The low cost of petroleum solvent provides little incentive to reduce losses.

However, rising cost of perchloroethylene solvent has made carbon adsorption attractive. Presently 39 to 50 percent of synthetic solvent plants are equipped with adsorption units. Maintenance, however, is generally very poor.

Carbon adsorption can be used in perchloroethylene and petroleum plants to reduce vented emissions from the washer, dryer, storage tanks, distillation systems, and chemical separators to a concentration less than 200 ppm in petroleum plants and 100 ppm in perchloroethylene plants.

The application of add-on controls and better house-keeping practices can reduce annual dry cleaning solvent consumption by an average of 60–70 percent.

Because of the higher capital investment and operating costs required for emissions controls on petroleum-solvent plants, it is believed that most new plants will use synthetic solvent and that many of the petroleum-naphtha solvent plants will shut down or convert to synthetic solvent operations by the early 1980s. Increasing solvent costs will provide an incentive for more effective evaporative emission control.

Control costs and industry operating statistics are detailed in Table 8.3–1. Cost calculations indicate that the installation of controls will result in a net credit in operating "costs" because of the value of reclaimed solvent. A zero cost is shown for operating and maintenance costs.

TABLE 8.3–1. DRY CLEANING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	9.07	138.96	2.44	2.44
NEW PLANTS	0.97	2.79	4.31	10.84
TOTAL	10.04	141.75	6.75	13.27
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	22.62	85.16	92.05	144.56
NEW PLANTS	0.45	0.90	3.54	11.97
TOTAL	23.07	86.06	95.58	156.53
O&M				
EXISTING PLANTS	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	0.0
ALL ANNUAL COSTS	23.07	86.06	95.58	156.53

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9. FOREST AND AGRICULTURAL PRODUCTS INDUSTRIES

For the purpose of this report, the Forest and Agricultural Products Industries are defined as those establishments which process products grown on the land. Those covered here are:

- The Kraft Pulp Industry
- The NSSC Paper Industry
- The Feed Mills Industry
- The Grain Mills Industry

The costs of air pollution control for these categories of industry are listed in summary form in Table 9–1. The industries and more specific details of controls and costs are discussed in the following sections.

TABLE 9.-1. AIR POLLUTION ABATEMENT COSTS FOR THE FOREST & AGRICULTURAL PRODUCTS INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1970–77	1977–81	1977–86
KRAFT PAPER	250.00	862.50	412.50	425.00
NSSC PAPER	14.00	58.50	17.00	17.00
FEED MILLS	212.66	1700.61	323.81	812.97
GRAIN HANDLING	229.38	1623.20	446.14	968.38
TOTAL INVESTMENT	706.04	4244.80	1199.45	2223.34

		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
KRAFT PAPER	120.80	247.75	678.20	1606.81
NSSC PAPER	9.68	22.87	54.94	129.72
FEED MILLS	301.52	1023.07	1370.31	3409.44
GRAIN HANDLING	272.03	880.71	1309.69	3359.65
TOTAL ANNUAL COSTS	696.55	2154.83	3375.84	8420.05

9.1 KRAFT PULP INDUSTRY

Production Characteristics and Capacities

The kraft pulp industry currently has a capacity of about 35.3 million metric tons (38.9 million short tons) of paper per year, with little scheduled capacity growth. While supplies may be restricted in several years, current operation is at about 85 percent of capacity, so some increase in production can be expected from current capacity.

Conventional kraft pulping processes are highly alkaline in nature and utilize sodium hydroxide and sodium sulfide as cooking chemicals. One modification used for the preparation of highly purified, or high-alpha cellulose pulp utilizes an acid hydrolysis of the wood chips prior to the alkaline cook; this is the prehydrolysis kraft process. Kraft processes enjoy the advantages of being applicable for nearly all species of wood and of having an effective means of recovery of spent cooking chemicals for reuse in the process.

Kraft pulping, in simplified terms, consists of seven separate processes. The digesting liquor in this process flow is a solution of sodium hydroxide and sodium sulfide. The spent liquor (black liquor) is concentrated, then sodium sulfate is added to make up for chemical losses, and the liquor is burned in a recovery furnace, producing a smelt of sodium carbonate and sodium sulfide. The smelt is dissolved in water to form green liquor, to which is added quicklime to convert the sodium carbonate back to sodium hydroxide, thus reconstituting the cooking liquor. The spent lime cake (calcium carbonate) is recalcined in a rotary lime kiln to produce quicklime (calcium oxide) for recausticizing the green liquor.

Included in the uses of kraft pulp are the production of linerboard, solid-fiber board, high-strength bags, wrapping paper, high-grade white paper, and food-packaging materials.

Emission Sources and Pollutants

Main emission sources in the kraft process are the recovery furnace, lime kiln, smelt dissolving tank, and the power boilers. The kraft pulping economics depend upon reclamation of chemicals from the recovery furnace and lime kiln. Hence, emissions from these processes are controlled to minimize losses of chemicals.

Particulates and gases are emitted from the various sources of the kraft process. Numerous variables affect the quality and quantity of emission from each source of the kraft pulping process. There are several sources of emissions in the process and the applicable control technology and attainable efficiencies of the control methods depend on the quantity and quality of emissions. The gaseous emissions occur in varying mixtures, and are mainly hydrogen sulfide, methyl mercaptan,

Table 9.1–1.
Rates of Emissions from Kraft Process
(in kg/ADMT with lb/ADT in parentheses)[1]

Process	Particulates	TRS	Sulfur Dioxide
		Uncontrolled	
Digester	0.0 (0.0)	0.72 (1.44)	Trace
Washer	0.0 (0.0)	0.05 (0.10)	Trace
Multiple Effect Evaporator	0.0 (0.0)	0.18 (0.36)	Trace
Recovery Furnace	60.0 (120)	2.95 (5.90)	1.2 (2.4)
Smelt Tank	7.8 (15.6)	0.05 (0.10)	Trace
Lime Kiln	34.0 (68.0)	0.22 (0.44)	Trace
Power Boiler[2]	35.3 (70.6)	0.0 (0.0)	19.7 (39.4)
Totals	137.1 (274.2)	4.17 (8.34)	20.9 (41.8)
		Controlled	
Digester	0.0 (0.0)	Trace	Trace
Washer	0.0 (0.0)	Trace	Trace
Multiple Effect Evaporator	0.0 (0.0)	Trace	Trace
Recovery Furnace	2.00 (4.00)	0.25 (0.50)	1.2 (2.4)
Smelt Tank	0.25 (0.50)	Trace	Trace
Lime Kiln	0.50 (1.0)	Trace	Trace
Power Boiler	2.47 (4.94)	0.0 (0.0)	10.5 (21.0)
Totals	5.22 (10.44)	0.25 (0.50)	11.7 (23.4)

[1] ADMT = Air-dried metric ton (ADT = Air-dried short ton).
[2] Fuel requirement = 3.26 x 10^{10} joules/ADMT (3.09 x 10 Btu/ADT). Coal provides 35%, oil 27%, gas 26%, and bark/wood 12% of the energy. Sulfur content = coal 1.9% and oil 1.8%. Ash content = coal 8.1% and bark/wood 2.9%.

dimethyl sulfide, dimethyl disulfide, and some sulfur dioxide. The sulfur compounds are generally referred to as reduced sulfur compounds. These very odorous compounds are detectable at a concentration of a few parts per billion. The particulate emissions are largely sodium sulfate, calcium compounds, and fly ash.

The rates of uncontrolled and controlled emissions of particulate, total reduced sulfur (TRS), and sulfur dioxide from various sources of kraft pulping processing in 1974 were as shown in Table 9.1-1.

Most states do not have emission regulations for pulp and paper making. For this study it has been assumed that all the states would adopt the most stringent current state regulations—those of Oregon and Washington. Costs for compliance are based on all mills meeting these regulations. The regulations include the following control provisions:

1. Total reduced sulfur (TRS) compounds from the recovery furnace: No more than 1 kg/ADMT (2 lb/ADT) (1972) to be reduced to no more than 0.25 kg/ADMT (0.5 lb/ADT) by 1975.
2. Noncondensible gases from the digesters and multiple-effect evaporators: Collected and burned in the lime kiln or proven equivalent.
3. Particulates from the recovery furnace: No more than 2 kg/ADMT (4 lb/ADT).
4. Particulates from the lime kiln: No more than 0.5 kg/ADMT (1 lb/ADT).
5. Particulates from smelt tank: No more than 0.25 kg/ADMT (0.5 lb/ADT).
6. Emissions from power boiler will meet the Federal emission standard.

Control Technology and Costs

The cost estimates for kraft pulping take into account the costs associated with each constituent process. Costs are summarized in Table 9.1-2.

TABLE 9.1-2. KRAFT PULP INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	250.00	862.50	412.50	425.00
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	250.00	862.50	412.50	425.00
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	113.40	236.65	624.50	1470.86
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	113.40	236.65	624.50	1470.86
O&M				
EXISTING PLANTS	7.40	11.10	53.70	135.95
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	7.40	11.10	53.70	135.95
ALL ANNUAL COSTS	120.80	247.75	678.20	1606.81

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9.2 NEUTRAL SULFITE SEMICHEMICAL PAPER INDUSTRY

Production Characteristics and Capacities

Current industry capacity is about 3.92 million dry metric tons (4.32 million short tons) per year. Most of new capacity is replacement or expansion capacity due to the high cost of completely new mills. Mills are currently operating at between 85 and 90 percent of capacity, so the industry has some marginal capacity to fill limited increases in demand.

Semichemical pulps are produced by digesting pulp wood with reduced amounts of chemicals, followed by mechanical treatment to complete the fiber separation. The most prevalent semichemical pulping process is the neutral sulfite semichemical process. In this process, sodium sulfite in combination with sodium bicarbonate, or ammonium sulfite buffered with ammonium hydroxide, are used as cooking chemicals. These cooks are slightly alkaline in contrast to the highly alkaline kraft, and highly or moderately acidic sulfite cooks. The semichemical pulping processes are used for production of high-yield pulps ranging from 60 to 85 percent of dry wood weight charged to the digestion vessel, and can include kraft and sulfite processes suitably modified to reduce pulping action in order to produce higher-than-normal yield pulps.

Semichemical pulps are used in preparing corrugating medium, coarse wrapping paper, linerboard, hardboard, and roofing felt, as well as fine grades of paper and other products.

Emission Sources and Pollutants

Discussions and calculations of air emissions from the Neutral Sulfite Semichemical (NSSC) process are limited to particulate and sulfur dioxide. The used cooking liquors are discharged to sewers or in some cases they are evaporated and cross-recovered with an adjacent kraft mill or treated in a fluidized-bed system. In this study, fluidized-bed combustion was assumed for the liquor treatment. Emissions are summarized in Table 9.2–1.

Control Technology and Costs

For the purposes of this report it was assumed that particulate emissions from the recovery furnace and power boilers burning coal and bark/wood, and sulfur dioxide emission from power boilers burning high-sulfur coal and oil were subject to control. To meet the particulate emissions standard from recovery furnaces, a control efficiency of at least 90 percent is required for the control system. A sodium-based, double alkali system was assumed for the control of sulfur dioxide from coal- and oil-burning power boilers.

Table 9.2–1.
Controlled and Uncontrolled Emissions From Various Processes in the NSSC Paper Industry (in kg per ADMT with lb per ADT in parentheses)[1]

Process	Particulate		Sulfur Dioxide	
	1971 Controls	Legislated Controls	1971 Controls	Legislated Controls
Recovery Furnace	20.0 (40.0)	2.0 (4.0)	0.01 (.02)	0.01 (.02)
Power Boiler	35.3 (70.0)	2.47 (4.94)	19.7 (39.4)	10.5 (21.0)
Totals	55.3 (110.6)	4.47 (8.94)	20.71 (41.42)	10.5 (21.0)

[1] ADMT = Air-dried metric ton (ADT = air-dried short ton).

Source: Atmospheric Emissions from the Pulp and Paper Manufacturing Industry – Report of NCASI – EPA Cooperative Study Project, Technical Bulletin No. 69, February 1974.

Control methods for new plants were selected as follows:

Process	Pollutant	Control Methods
Recovery Furnace	Particulate	Electrostatic Precipitator
Power Boiler	Particulate	Electrostatic Precipitator
	Sulfur Dioxide	Double alkali

Costs are summarized in Table 9.2-2. Since cost data were taken from a specific source, rather than developed within the computer model, new plant costs are included with existing plants.

TABLE 9.2-2. NSCC PAPER INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	14.00	58.50	17.00	17.00
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	14.00	58.50	17.00	17.00
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	7.48	19.57	37.32	85.87
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	7.48	19.57	37.32	85.87
O&M				
EXISTING PLANTS	2.20	3.30	17.65	44.15
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	2.20	3.30	17.65	44.15
ALL ANNUAL COSTS	9.68	22.87	54.97	129.72

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9.3 GRAIN HANDLING INDUSTRY

Production Characteristics and Capacities

Traditionally, grain handling is considered in terms of series of grain storage facilities starting from the delivery by the farmer and ending with the ultimate user. These grain storage facilities or grain elevators, provide storage space and serve as collection, transfer, drying, and cleaning points. There are two main classifications of grain elevators—country and terminal elevators. Country elevators receive grains from nearby farms by truck for storage or shipment to terminal elevators or processors. Terminal elevators (this category is subdivided into inland and port terminals), are generally larger than country elevators and are located at significant transportation or trade centers. Inland terminals receive, store, handle, and load these grains in rail cars or barges for shipment to processors or port locations. Port terminals receive grain and load ships for export to foreign countries. Particulate emission is a function both of the amount of grain handled and of the operations involved in handling. The cost of equipment for emission control is a function of the size of the facility and operations involved. Consequently, model sizes for the types of operations and size of country elevators, inland terminals and port terminals have been selected, ranging from 0 to 70 thousand cubic meters (0 to 2 million bushels, dry measure), 70 to 700 thousand cubic meters (2 to 20 million bushels), and 0.7 to 7 million cubic meters (20 to 200 million bushels). It should be noted that very few country elevators fall within the second range, while some inland terminal elevators may fall within the first capacity range.

Using data for the number and storage capacities of the country and terminal elevators by states as of September 30, 1972, size ranges and number of facilities per size range are listed in Table 9.3–1.

Emission Sources and Pollutants

Grain handling includes a variety of operations which emit differing amounts of air pollutants, primarily particulates. The particulates consist of attrition of the grain kernels and dirt. Hence, the amount of the dust (particulates) emitted during the various grain-handling operations depends on the type of grain being handled, the quality or grade of the grain, the moisture content of the grain, the speed of the belt conveyors used to transport the grain, and the extent and efficiency of the dust-collecting system being used, such as hoods and sheds.

Control Technology and Costs

Systems used to control particulate emissions from grain handling operations consist either of extensive hooding and aspiration systems leading to a dust collector or of methods for eliminating emissions at the source. Techniques which eliminate the sources of dust emissions or which retain dust within the process are: enclosed conveyors, covers on bins, tanks and hoppers, and mainte-

Table 9.3–1.
Grain Handling Industry
Facilities Production Capacities
(in thousands of cubic meters, millions of bushels in parentheses)

Ranges	Total Annual Volume Handled (1,000)	Average Total Volume(%)	No. of Facilities	Annual Volume
0–70 (0–2)	217 (6.16)	55.5	7,147	30.4 (0.863)
70–700 (2–20)	70.9 (2.01)	18.1	413	171.6 (4.787)
700–7,000 (20–200)	103 (2.92)	26.4	64	1,615 (45.83)
Totals	390.9 (11.09)	100.0	7,624	

nance of the system's internal pressure below the external pressure so that airflow is inward rather than outward from the openings.

Control methods are also available to capture and collect the dust entrained or suspended in the air. The dust- collection systems generally used are cyclones and fabric filters.

In order to meet the emission standards, it was assumed that (except for grain drying) fabric filters will be installed in all existing plants that do not have them or as replacements for cyclones and other control devices. After costs were developed for this industry, a New Source Performance Standard was developed (promulgated 8/3/78) which contained a size cut-off 88 thousand cubic meters (2 1/2 million bushel) storage. To approximate this development, no NSPS control costs were assigned to the expansion of the small model plant category described above. Further, the above assumption of the use of fabric filters may result in an overstatement of costs, since the standard may be attainable by the use of high-performance cyclones. The cost data for this industry are given in Table 9.3.-2.

TABLE 9.3–2. GRAIN HANDLING INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	147.39	1385.43	88.43	88.43
NEW PLANTS	82.00	237.77	357.71	879.95
TOTAL	229.38	1623.20	446.14	968.38
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	182.15	634.25	775.10	1743.97
NEW PLANTS	31.26	61.80	240.59	833.30
TOTAL	213.41	696.06	1015.69	2577.27
O&M				
EXISTING PLANTS	45.68	159.06	194.39	437.36
NEW PLANTS	12.94	25.59	99.61	345.02
TOTAL	58.62	184.65	294.00	782.38
ALL ANNUAL COSTS	272.03	880.71	1309.69	3359.65

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9.4 FEED MILLS INDUSTRY

Production Characteristics and Capacities

Feed manufacture is the process of converting grain and other constituents into the form, size, and consistency desired in the finished feed. Feed milling involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading.

As of July 1, 1974, the number of existing feed mills was estimated at 7,866 plants, with a total capacity of 134 million metric tons (148 million short tons) per year. For this report, these have been grouped into the size categories as shown in Table 9.4–1.

Table 9.4–1.
Feed Mills Industry Production Capacities, 1974
(in metric tons with short tons in parentheses)

Daily Size Range	No. Mills	Annual Capacity (1,000)	Total Capacity (%)	Model Mill Size
0–44 (0–49)	4,170	47 (52)	31.8	40 (44)
45–90 (50–99)	2,790	70 (77)	47.3	90 (99)
91–136 (100–150)	906	31 (34)	20.9	128 (141)

Emission Sources and Pollutants

The primary emissions from feed manufacture are particulates, especially dust. The factors affecting emissions include the type and amount of grain handled, the degree of drying, the amount of liquid blended into the feed, the type of handling (conveyor or pneumatic), the configuration of the receiving pits, and the degree of control. An indication of the relative ranking of emission sources in a typical feed mill is given below:

Mill Operations	Particulates Generated (%)
Rail unloading	25
Collectors for product recovery and dust control	21
Truck unloading	15
Truck loading (bulk loadout)	11
Bucket elevator leg vents	5
Bin vents	5
Scale vents	3
Grinding system (feeder, spills)	4
Incinerator (waste paper)	2
Small boiler (oil)	1
Rail car loading (bulk loadout)	1
Miscellaneous (conveying spouts, pellet mills, feeder lines)	7

Unloading of bulk incredients is generally acknowledged to be one of the most troublesome dust sources in feed mills. Centrifugal collectors used for product recovery and dust control represent the second largest emission source.

Control Technology and Costs

It is estimated that 88.1 percent of the volume handled in pellet-cooler operations and 56 percent of the volume handled in grinding operations have some type of emission control, largely cyclones. In receiving, transfer, and storage operations, roughly one-third of the total volume is controlled by either cyclones or fabric filters, while only a few installations have installed controls in shipping operations.

Table 9.4–2 shows the costs of air pollution controls on an annualized and investment basis.

TABLE 9.4–2. FEED MILLS INDUSTRY AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	172.98	1625.97	103.78	103.78
NEW PLANTS	39.68	74.64	220.02	709.18
TOTAL	212.66	1700.61	323.81	812.97
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	213.77	748.20	909.67	2046.76
NEW PLANTS	9.81	14.41	107.01	477.47
TOTAL	223.59	762.61	1016.68	2524.23
O&M				
EXISTING PLANTS	74.71	255.72	318.39	725.15
NEW PLANTS	3.22	4.73	35.23	160.06
TOTAL	77.94	260.45	353.62	885.21
ALL ANNUAL COSTS	301.52	1023.07	1370.31	3409.44

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

10. SOLID WASTE DISPOSAL OR REDUCTION

Except for ocean dumping (which is no longer widely practiced), the only ultimate disposal for solid wastes is on the land, either in sanitary landfills or in open dumps. Frequently, however, the volume of solid waste is reduced by burning, shredding, or composting prior to final disposal in order to conserve available land disposal areas.

Solid waste reduction contributes to air pollution through incineration, with or without heat recovery, and by open burning. Air pollutants emitted to the atmosphere from these practices include particulates, carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, fluorocarbons, hydrochloric acid, and odors. The levels of pollutants emitted are primarily dependent upon the particular waste being burned. Incinerator emission levels are also dependent upon the incinerator design and upon the method of operation.

Particulate emissions are the greatest, making them the specific pollutant subject to controls. There are no current Federal regulations for odors, hydrochloric acid, or fluorocarbons. Besides air-pollution laws, federal and state solid waste management regulations have had an effect on air pollution by reducing open dumps, and thereby reducing open burning. The relative effect of air-pollution laws versus solid waste regulatory laws has not been determined.

The solid waste reduction methods that are discussed in the following paragraphs were in use in 1976 in the amounts shown in Table 10–1:

Table 10–1.
Methods of Reduction of Solid Waste and Amounts in 1976
(in millions of metric tons
with millions of short tons in parentheses)

Reduction Method	Raw Solid/Waste Amount
Municipal Incinerators	16 (18)
Industrial Commercial Incinerators	7.6 (8.4)
Open Burning Dumps	3.4 (4)
Refuse-fired Steam Generators	0.5 (0.5)
Sewage Sludge Incinerators	3.6 (4)

The costs for control of air pollution from these categories of operations are shown in summary form in Table 10–2. The cost of sewage sludge incineration is not included in this report. These costs appear in the Cost of Clean Water Report in Chapter 2.

These costs represent the application of various control devices to the different types of incinerators except for the case of open burning dumps, where the costs represent the conversion to sanitary landfills. Details of each category and the associated costs are given in the following sections.

TABLE 10.-2. AIR POLLUTION ABATEMENT COSTS
(IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1970–77	1977–81	1977–86
SOLID WASTE DISPOSAL & REDUCTION				
OPEN BURNING	145.33	1744.12	718.62	2023.34
MUNICIPAL WASTE REDUCTION	0.29	3.11	0.91	1.32
COAL-FIRED STEAM GENERATION	4.00	24.00	10.40	23.40
INDUSTRIAL & BUILDINGS INCINERATORS	57.02	256.61	275.62	693.80
TOTAL INVESTMENT	206.65	2027.84	1005.56	2741.87
		ANNUAL COSTS		
	1977	1970–77	1977–81	1977–86
OPEN BURNING	1112.22	4762.36	5419.23	15076.59
MUNICIPAL WASTE REDUCTION	1.64	7.56	6.76	15.35
COAL-FIRED STEAM GENERATION	4.41	16.63	23.81	59.80
INDUSTRIAL & BUILDINGS INCINERATORS	93.09	270.33	596.43	2013.17
TOTAL ANNUAL COSTS	1211.37	5056.87	6046.23	17164.90

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10.1 OPEN BURNING AND OPEN BURNING DUMPS

Emission Sources and Pollutants

Open burning refers to the unconfined burning of any kind of waste, such as leaves, agricultural waste, residential waste, etc. An open burning dump may be either a municipal or an industrial dump, at which open burning occurs. Emissions from open burning reflect the composition of the waste (volume of paper, plastic, wood, rubber, etc.), and its physical state (degree of compaction, moisture content, etc). The primary emissions from open burning are particulates, carbon monoxide, and hydrocarbons.

Control Technology and Costs

There is no control technology that can be applied to open burning in general. Many common uses of open burning, such as burning for silvicultural, agricultural, range, and wildlife management; training fires for firefighters; and heating for outdoor workers, are allowed only under limited conditions of weather, time, and location. Other frequent sources of open burning, such as forest fires and coal-refuse pile fires, are accidental, and are extinguished as soon as possible. The only suitable emission control for open dumps is to substitute the use of sanitary landfills. For the purposes of this report, it was assumed that the waste currently going to open dumps would be diverted to sanitary landfills.

Costs for converting open burning dumps to sanitary landfills are detailed in Table 10.1–1.

TABLE 10.1–1. OPEN BURNING AND OPEN DUMP AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	145.33	1744.12	158.43	158.43
NEW PLANTS	0.0	0.0	560.19	1864.92
TOTAL	145.33	1744.12	718.62	2023.34
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	225.77	962.82	977.52	2199.41
NEW PLANTS	0.0	0.0	128.00	891.45
TOTAL	225.77	962.82	1105.52	3090.86
O&M				
EXISTING PLANTS	886.45	3799.54	3828.20	8613.43
NEW PLANTS	0.0	0.0	485.52	3372.30
TOTAL	886.45	3799.54	4313.71	11985.73
ALL ANNUAL COSTS	1112.22	4762.36	5419.23	15076.59

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

10.2 MUNICIPAL INCINERATORS

Operating Characteristics and Capacities

There are two basic types of municipal incinerators. The refractory-lined furnace is the most common type in this country and is the type discussed in this chapter. The other type is the water-wall, or waste-heat recovery type, more common in Europe. That type is discussed in the section on refuse-fired steam generators.

Conventional refractory-lined incinerators are usually continuously fed, large rectangular chambers.

The amount of air supplied to the combustion chamber is greatly in excess of the amount theoretically needed for combustion. The excess air serves as a cooling medium, but it also causes turbulence and entrains large amounts of particulate matter. The air-pollution-control equipment must be large enough to handle the great volumes of air and particulates. With strict air-pollution-control requirements, it has become very costly to build adequate air-pollution-control systems for these incinerators. The result has been the substantial decrease in the popularity of the refractory-lined incinerator noted above.

Since 1920, 322 municipal-scale incinerators have been built, and 42 modifications have been made to increase the capacity of these facilities. As of December, 1974, only 145 of these plants were still operating. The number of units in operation has continued to fall to a current (1977) level of about 50. Estimated current capacity of these incinerators is 52.6 thousand metric tons (58 thousand short tons) per day.

Emission Sources and Pollutants

Municipal incinerators contribute to air pollution by releasing a variety of pollutants to the atmosphere, but primarily particulates. The levels of these pollutant emissions are directly related to the design and operation of the incinerator, as well as to the composition of the refuse burned. Particulate limitations generally range from 80 to 200 grams of particulate per 100 kg (0.08 to 0.2 pound per 100 pounds) of refuse charged.

Control Technology and Costs

Electrostatic precipitators and wet scrubbers are used to control particulates. Most commonly, however, incinerators are closing, rather than upgrading facilities to meet air regulations. Thirty-nine percent (39%) of the operating incinerators closed from 1969 to 1974.

Costs are summarized in Table 10.2-1.

TABLE 10.2-1. MUNICIPAL WASTE INCINERATOR AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	0.29	3.11	0.91	1.32
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.29	3.11	0.91	1.32
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	0.75	3.81	2.12	3.60
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.75	3.81	2.12	3.60
O&M				
EXISTING PLANTS	0.89	3.75	4.64	11.75
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.89	3.75	4.64	11.75
ALL ANNUAL COSTS	1.64	7.56	6.76	15.35

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

10.3 REFUSE-FIRED STEAM GENERATORS

Operating Characteristics and Capacities

Domestic, commercial, and industrial solid wastes contain large quantities of combustible material which can be used as fuel in a steam generater. In some cases, refuse may be the only fuel or refuse may be supplemental to fossil fuels. Both cases are covered in this section. Other waste-to-energy techniques, such as pyrolysis and small modular incinerators which recover energy in the form of hot water, are not covered.

The amount of recoverable, dry, combustible material in various wastes is shown in Table 10.3–1.

It is estimated that solid wastes from the largest metropolitan areas in the U.S. could be converted to supply a small but significant percentage of the nation's energy needs.

Two principal technologies are used for refuse-fired steam generators. One is production of steam in a waterwall incinerator, burning refuse (with or without prior shredding and classifiction) on moving grates. The other technology is the preparation of refuse-derived fuel (RDF), which involves shredding, followed by separation of the wastes into the light organic (fuel) fraction, and the heavy, principally inorganic, fraction which may undergo additional processing for recovery of metals and glass. The RDF is generally suspension-fired in a utility-type boiler, often as a supplement to fossil fuel.

Of the 14 existing refuse-fired steam generators in the U.S., four are RDF-fired utility boilers, and 10 are waterwall incinerators. Five RDF facilities are under construction, or expected to be under construction by the end of 1977. Two waterwall incinerators are under construction. It has been estimated that 30–40 such facilities will be committed by 1982. Therefore an average growth rate of 4 facilities per year was assumed.

Emission Sources and Pollutants

Refuse-fired steam generators emit principally particulates, sulfur oxides, and nitrogen oxides. Uncontrolled emissions from coal-fired utility boilers and for municipal incinerators are shown in Table 10.3–2. Proposed regulations will limit particulates to 13 g per 10^9 joules (0.03 pound per 10^6 Btu) input at new sources. Existing sources are limited to 34 g per 10^9 joules (0.08 pound per 10^6 Btu).

Control Technology and Costs

Electrostatic precipitators are capable of meeting the particulate standards for existing sources. Most utility boilers burning supplemental RDF will be equipped with ESP's. The proposed regulations for new sources will necessitate the installation of fabric filters. Sulfur oxides are not expected to occur in excess of standards due to the low sulfur content of solid waste. Nitrogen oxides emissions are controlled by maintaining the furnace temperature within a range in which nitrogen oxides do not form in significant amounts.

Costs for pollution control for a typical waterwall incinerator and for a typical utility boiler burning supplemental RDF are as shown in Table 10.3–3.

Table 10.3–1.
Recoverable, Dry, Combustible Material in Various Wastes

	Early 70's		1980		1990	
Waste Stream	Million Metric Tons	Million Short Tons	Million Metric Tons	Million Short Tons	Million Metric Tons	Million Short Tons
Municipal Solid Waste	61.1	67.4	78.0	86.0	98.0	108.0
Sewage Sludge	11.5	12.7	14.0	15.4	16.5	18.2
Industrial Waste	42.3	46.6	48.2	53.1	49.9	55.0
Agricultural Waste	210.2	231.7	316.2	348.5	384.6	424.0
Total	325.1	358.4	456.4	503.0	549.0	605.2

Table 10.3–2.
Uncontrolled Emissions Factors From Coal-Fired Utility Boilers, and From Incinerators
(in kg per metric ton feed with lb per short ton feed in parentheses)

	Particulates[2]	Sulfur Oxides[3]	Nitrogen Oxides
Pulverized bituminous coal-fired boilers[1]	[8(16)] [A][2]	[19 (38)] [S][3]	9 (18)
Municipal incinerators[4]	15 (30)	1.25 (2.5)	1.5 (3)

(1) For utility boilers with greater than 100x10⁶ Btu/hour heat input.
(2) The constant A stands for the percent ash in the coal.
(3) The constant S stands for the percent sulfur in the coal.
(4) For municipal incinerators burning more than 50 tons/day of refuse.

Table 10.3–3.
Pollution Control Costs For a Typical Utility Boiler Burning Refuse-Derived Fuel
(in 1977 dollars)

		Existing Source	New Source
Waterwall incinerator:	Investment	2,000,000	860,000
	O&M	14,000	98,000
RDF/Utility	Investment	2,000,000	950,000
	O&M	14,000	100,000

Total costs for the control of emission from refuse-fired steam generators are summarized in Table 10.3–4. In this particular case, costs associated with new plants are included in the same category as existing plants, due to the nature of the cost data available.

TABLE 10.3–4. REFUSE FIRED STEAM GENERATION AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	4.00	24.00	10.40	23.40
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	4.00	24.00	10.40	23.40
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	4.23	15.95	20.18	45.08
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	4.23	15.95	20.18	45.08
O&M				
EXISTING PLANTS	0.18	0.68	3.63	14.71
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	0.18	0.68	3.63	14.71
ALL ANNUAL COSTS	4.41	16.63	23.81	59.80

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

10.4 SEWAGE SLUDGE INCINERATION

Operating Characteristics and Capacities

Incineration is one of several methods currently practiced for disposing of sludges accumulated by municipal sewage treatment plants.

The majority of existing installations are the multiple-hearth type. The estimated capacity distribution of sewage sludge incinerators in 1976 is shown in Table 10.4–1.

Based upon projected municipal sewage treatment plant construction, it is estimated that 80 new sludge incinerators will be constructed annually in the United States during the next few years. The growth reflects more widespread use of incineration as an alternative to other disposal methods such as landfills, barging to sea, and fertilizer application.

Emission Sources and Pollutants

Particulate emissions from uncontrolled sewage-sludge incinerators are estimated to be 50 kg per metric ton (100 pounds per short ton) dry solids incinerated. Particulate emissions from existing facilities controlled by wet scrubbers are estimated to be 1.5 kg per metric ton (3 pounds per short ton) dry solids. New Source Performance Standards proposed by EPA limit the particulate emissions to no more than 650 grams per metric ton (1.30 pounds per short ton) dry solids, and an opacity of 20 percent.

Control Technology

All sewage sludge incinerators in the United States are equipped with wet scrubbers that have varying collection efficiency. The scrubbers range from low-energy types, with pressure drops in the 60 to 150 kg per square meter (2.5 to 6 inches of water), to high-energy scrubbers with a pressure drop of 460 kg per square meter (18 inches of water).

The costs associated with the control of sewage sludge incineration are included in the Cost of Clean Water Report in Chapter 2. The 1978 Needs Survey takes into account the cost of sewage sludge disposal, including air pollution control. Since the air pollution control problem would not exist without the imposition of effluent limitations, these costs are being attributed to the Federal Water Pollution Control Act.

Table 10.4–1.
Size Distribution of Sewage Sludge Incinerators Operating in 1976
(in metric tons per day dry solids with short tons per day in parentheses)

Percent of Installations (by number)	Capacity Range	Average Capacity	Total Capacity	Capacity (%)
27.1	0.24–8.2 (0.27–9.1)	4.8 (5.3)	794 (875)	5.1
54.8	8.3–41.1 (9.2–45.3)	18.8 (20.7)	6,253 (6,893)	39.9
14.3	41.2–82.3 (45.4–90.7)	57.5 (63.4)	5,004 (5,516)	31.9
3.8	82.4–247 (90.8–272)	157.3 (173.4)	3,618 (3,988)	23.1
100.0			15,689 (17,272)	100.0

10.5 INDUSTRIAL, COMMERCIAL, AND BUILDING INCINERATORS

Operating Characteristics and Capabilities

In 1972, approximately 100,000 on-site incinerators were in use in this country. These intermediate-sized units are usually associated with office buildings, large retail stores, and apartment buildings. Of the over 24 million metric ton (26 million short tons) of solid waste incinerated annually in the United States, more than one-third is processed by on-site units that typically process about 82 metric ton (90 short tons) annually, or approximately 103 kg (228 pounds) per hour. States bordering the Great Lakes (Minnesota, Ohio, Illinois, Wisconsin, Michigan, Indiana, New York, and Pennsylvania) account for about 60 percent of the total number of on-site units in the United States.

There are two types of commercial building and industrial incinerators: single-chamber and multiple-chamber. Single-chamber incinerators are similar to residential or domestic units and consist of a refractory-lined chamber with a grate on which the refuse is burned. Combustion products are formed by contact between underfire air and waste on the grate. Additional air (overfire air) is admitted above the burning waste to promote complete combustion. Multiple-chamber incinerators employ a second chamber to which combustion gases from the primary chamber are directed for further oxidation of combustible gases. Auxiliary burners are sometimes employed in the second chamber to increase the combustion temperature.

It is estimated that the use of apartment incinerators, which account for about 6 percent of installations for refuse disposal, will virtually disappear during the 1976–85 period. The number of industrial and commercial units should remain stable during that decade because new installations will primarily be replacements of older units.

Approximately 88 percent of all on-site incinerators are the multiple-chamber type; emissions from multiple-chamber incinerators are generally lower than from the single-chamber incinerators. The design capacity of the incinerator considered in this report is from 23 kg (50 pounds) per hour to 1,800 kg (4,000 pounds) per hour, and the average incinerator operates between 3–5 hours a day.

Emission Sources and Pollutants

While on-site units emit various products of combustion, only particulates are released in sufficient quantities to warrant installation of controls. Approximate emission factors for single-chamber and multiple-chamber incinerators of intermediate size are respectively 7.5 and 3.5 kg per metric ton (15 and 7 pounds per short ton) of refuse charged. Estimated uncontrolled particulate emissions in 1978 are projected to be approximately 23 thousand metric tons (25 thousand short tons).

Control Technology and Costs

Operating conditions (e.g., air supply to the combustion chamber), refuse composition, and basic incinerator design have a pronounced effect on the volume and composition of air emissions. Afterburners and wet scrubbers can be installed to control particulate emissions and some other combustion products. However, with the shortage of natural gas and the expense of fuel oil, the use of afterburners as retrofit controls on building incinerators will probably be curtailed. Furthermore, the newer multiple-chamber units already employ auxiliary firing techniques which, in effect, fulfill the function of an afterburner.

Wet scrubbers will achieve an approximately 80 percent reduction in particulates emissions. This level of control is sufficient to meet Federal particulate emission standards of 2 kg per metric ton (4 pounds per short ton) of refuse charged.

Unit investment cost for a wet scrubber required to control an intermediate size incinerator (approximately 82 metric tons or 90 short tons per year) is estimated to be $7,500. Annual operating and maintenance costs will be about $1,500 per installation.

Control costs are detailed in Table 10.5–1. No costs are shown in the "new plant" category due to the above-mentioned conditions of net decreasing use of such incinerators.

TABLE 10.5–1 INDUSTRIAL AND COMMERCIAL INCINERATOR AIR POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS		
	1977	1970–77	1977–81	1977–86
INVESTMENT				
EXISTING PLANTS	57.02	256.61	275.62	693.80
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	57.02	256.61	275.62	693.80
ANNUALIZED COSTS				
ANNUAL CAPITAL				
EXISTING PLANTS	41.76	121.28	267.59	859.36
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	41.76	121.28	267.59	859.36
O&M				
EXISTING PLANTS	51.32	149.05	328.84	1153.81
NEW PLANTS	0.0	0.0	0.0	0.0
TOTAL	51.32	149.05	328.84	1153.81
ALL ANNUAL COSTS	93.09	270.33	596.43	2013.17

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

THE COST OF CLEAN WATER

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1. INTRODUCTION AND SUMMARY

PURPOSE AND SCOPE

Section 516(b) of the Federal Water Pollution Control Act amendments (PL92-500, hereafter FWPCA) of 1972 requires an annual report on the costs of meeting the provisions of that act; this report is submitted in response to these requirements.

Costs reported include those attributable directly to control measures (devices, process changes, etc.) and program costs for research, administration, enforcement at the Federal, state, and local levels. Sources of water pollution are broken down into industrial, municipal, and nonpoint categories, and direct control costs are estimated for these categories.

Industrial costs at the plant level are taken for the most part from the Effluent Guidelines Development Documents, which were prepared under Sections 304, 306, and 307 of PL92-500. These documents define the levels of pollutant removal that must be achieved by each industry category at the interim level, best practicable technology (BPT) to be achieved by July 1, 1977, and the final level, best available technology (BAT) to be achieved by July 1, 1983.

This report was prepared in 1978, and reflects the regulatory framework in existence early in 1978. Projections beyond past expenditures are subject to change. Significant changes in regulations will shortly affect the control technologies and associated costs.

The Clean Water Act of 1977 allows for less stringent controls for conventional pollutants. However, more stringent guidelines may result for the 21 industries covered by the 1976 Consent Agreement.

The magnitude of these changes will vary considerably on an industry-by-industry basis. An extreme example is the Explosives industry. The Cost of Clean Water estimates show slightly over $2 billion of investment from 1977-1986. Preliminary estimates emanating from the current BAT-review process indicate that new investment will be only about $3-4 million for this industry. While this is not representative of the magnitude of the changes to be expected, it does indicate the degree of uncertainty in the present estimates. *Therefore, the reader should keep in mind that the costs presented here represent what industries would have had to pay if the regulations in effect in early 1978 remained unchanged.*

Municipal costs are presented as total capital investment achievable under the existing and projected Federal contract authority (i.e., what will be spent rather than what is needed), as distinguished from the industrial costs, which are estimates of what will be required to achieve given control levels. This assumption is a recognition of the fact that the municipal needs are substantially in excess of available resources.

All abatement costs in this report are stated in July 1, 1977 dollars. Where costs were derived relative to another time period, these costs were updated using the implicit price deflater of the gross national product (Fixed non-residential investment part).

No measures have been promulgated by the agency that apply to the control of pollutants for non-point sources. A section of this report does discuss the problem of control of water pollution from non-point sources. Estimates of the costs for these controls assuming that the coals of PL 92-500 are applied to this category appear in Chapter 10.1. However, these estimates are not presented in the National totals.

This report does not attempt to include all costs associated with the reduction of the pollution of the Nation's waterways. Various state and local regulations, with associated costs, antedated Federal water pollution control regulations. Thus the costs described in this document are restricted to incremental costs, over and above any costs of control incurred on the level of control practiced prior to the FWPCA. Fiscal year 1972 is taken to be the baseline from which incremental costs were calculated.

Within this framework, the estimated direct costs and benefits of measures to control water pollution from industrial and other sources are calcu-

lated. Investment costs are projected through 1986.

Note that this report specifically does not dictate EPA policy with respect to the application of presently available or projected technology for the control of effluent quality to any industry or activity. Simplifying assumptions were required in order to estimate the effect of EPA Regulations on the industries included. The control technologies, or mix thereof, which were assumed in order to provide these estimates are neither specifically required by law nor by EPA; no contrary interpretation of the contents of this document should be made.

A uniform costing methodology has been applied to the industrial sectors incurring water pollution abatement costs. Being free of the requirements of macroscopic input-output models, this methodology permits examining each industrial sector at the most appropriate level of disaggregation and allows independent determination of industry growth. In addition, municipal charges have been included in a uniform manner which is consistent with Federal policy.

As a result of court action or industry objection some of the regulations proposed or promulgated under PL 92-500 have been withdrawn, suspended, or revoked. For the purposes of this report, with one exception, the assumption has been that the regulations were defective only in a technical sense and that similar regulations, incurring similar costs but possibly with differing standards for effluent quality, will be promulgated.

COSTS OF IMPLEMENTING THE ACT

Estimates of the capital investment and annualized costs required for implementing the FWPCA over the periods 1972-77, 1977-81 and 1977-86 and the year 1977 are summarized in Table 1-1. Each number in Table 1-1 is repeated within the appropriate chapter of this report where specific assumptions and background data are presented and discussed.

Table 1-1 does *not* include an estimate for the control of nonpoint sources. EPA has not yet issued regulations controlling nonpoint sources; and the control technology and degree of control is still uncertain. This report does contain a discussion of nonpoint sources (agriculture, silviculture, urban runoff and new construction runoff control) in Chapter 10.1. Preliminary estimates indicate that future investment needs will be about $58 billion in the next five years. No estimate is available on what portion of this investment need will actually be spent.

TABLE 1.-1. WATER POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

	1977	1972–77	1977–81	1977–86
TOTAL INVESTMENT	10926.43	35930.34	28244.47	61609.75
TOTAL ANNUAL COSTS	8891.23	22459.90	46339.13	130714.96
			INVESTMENT	
COST TO GOVERNMENT	5065.00	21593.00	19677.00	45882.00
			ANNUAL COSTS	
COST TO GOVERNMENT	4049.00	11761.90	22343.00	66123.00

			INVESTMENT	
INDUSTRY	1977	1972–77	1977–81	1977–86
METALS INDUSTRIES				
ORE MINING AND DRESSING INDUSTRY	152.50	389.59	251.00	251.00
IRON & STEEL	660.94	1410.22	1056.48	1692.30
FERROALLOYS	1.33	11.06	1.57	3.26
BAUXITE REFINING	0.0	52.81	0.0	0.0
PRIMARY ALUMINUM	19.51	40.45	29.21	46.95
SECONDARY ALUMINUM	2.23	5.20	3.49	7.82
NON-FERROUS METALS	1.43	3.11	0.0	0.16
ELECTROPLATING	49.79	264.74	81.55	81.55
TOTAL INVESTMENT	887.73	2177.18	1423.30	2083.04

			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
ORE MINING AND DRESSING INDUSTRY	84.58	145.97	603.18	1340.06
IRON & STEEL	556.66	1984.58	321.63	8805.44
FERROALLOYS	5.56	16.52	29.49	75.54
BAUXITE REFINING	12.58	38.40	50.34	113.26
PRIMARY ALUMINUM	15.31	28.31	82.26	228.45
SECONDARY ALUMINUM	2.49	5.05	14.73	44.52
NON-FERROUS METALS	1.77	3.32	7.29	15.47
ELECTROPLATING	141.74	316.31	751.27	1771.01
TOTAL ANNUAL COSTS	820.69	2538.46	4660.19	12393.93

			INVESTMENT	
INDUSTRY	1977	1972–77	1977–81	1977–86
MINERAL-BASED MANUFACTURING				
MINERAL MINING	28.53	87.96	0.0	0.0
GLASS MANUFACTURING	0.87	2.64	11.97	18.83
INSULATION FIBERGLASS	2.60	6.97	2.72	7.57
ASBESTOS	0.33	1.90	3.13	6.31
CEMENT MANUFACTURING	3.30	20.59	6.93	15.04
PAVING & ROOFING	0.24	1.41	3.37	4.90
TOTAL INVESTMENT	35.87	121.47	28.11	52.64

			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
MINERAL MINING	23.02	42.33	110.14	234.60
GLASS MANUFACTURING	0.80	1.75	9.99	37.88
INSULATION FIBERGLASS	2.11	4.41	10.43	29.40
ASBESTOS	0.88	2.03	6.49	22.92
CEMENT MANUFACTURING	5.20	12.58	24.66	62.38
PAVING & ROOFING	1.48	5.62	9.17	26.14
TOTAL ANNUAL COSTS	33.48	68.72	170.87	413.32

TABLE 1.-1. WATER POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

INDUSTRY	1977	1972–77	INVESTMENT 1977–81	1977–86
FOREST PRODUCTS INDUSTRIES				
TIMBER PRODUCTS	10.04	55.05	74.04	99.15
GUM & WOOD CHEMICALS	0.02	3.58	0.20	0.22
PULP PAPER & PAPERBOARD MANUFACTURING	700.00	2178.75	441.25	1511.05
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
TOTAL INVESTMENT	710.07	2237.38	518.29	1615.22

	1977	1972–77	ANNUAL COSTS 1977–81	1977–86
TIMBER PRODUCTS	42.34	73.92	203.41	548.85
GUM & WOOD CHEMICALS	1.13	4.60	4.74	10.31
PULP PAPER & PAPERBOARD MANUFACTURING	528.53	1146.20	2281.20	6478.66
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
TOTAL ANNUAL COSTS	572.01	1224.71	2490.72	7050.41

INDUSTRY	1977	1972–77	INVESTMENT 1977–81	1977–86
FOODS AND AGRICULTURAL INDUSTRIES				
GRAIN MILLS	1.56	3.83	4.41	7.58
SUGAR PROCESSING				
RAW CANE SUGAR PROCESSING	1.18	3.54	2.91	6.03
CANE REFINING SEGMENT	2.84	8.21	14.87	23.86
BEET SUGAR PROCESSING	3.73	9.91	5.13	9.01
CANNED AND PRESERVED FRUITS & VEGETABLES	193.99	636.69	93.94	134.06
CANNED AND PRESERVED SEAFOOD	22.98	43.59	79.44	114.78
DAIRY PRODUCTS PROCESSING	21.27	136.96	20.41	39.52
FEEDLOTS	26.66	97.92	12.06	29.34
MEAT PRODUCTS	9.86	24.82	147.76	211.78
LEATHER TANNING & FINISHING	10.67	29.36	101.44	135.25
TOTAL INVESTMENT	294.74	994.83	482.39	711.21

	1977	1972–77	ANNUAL COSTS 1977–81	1977–86
GRAIN MILLS	0.89	1.73	5.92	19.08
SUGAR PROCESSING				
RAW CANE SUGAR PROCESSING	1.34	3.08	7.72	21.72
CANE REFINING SEGMENT	1.75	3.68	13.07	43.40
BEET SUGAR PROCESSING	1.55	3.05	7.97	21.91
CANNED & PRESERVED FRUITS & VEGETABLES	843.07	1844.29	3412.54	7760.00
CANNED AND PRESERVED SEAFOOD	9.77	17.62	67.93	211.91
DAIRY PROD PROCESSING	21.23	57.95	93.98	232.80
FEEDLOTS	27.86	69.65	119.69	290.26
MEAT PRODUCTS	11.22	29.25	173.49	657.09
LEATHER TANNING & FINISHING	8.01	16.27	83.42	294.73
TOTAL ANNUAL COSTS	926.69	2046.58	3985.74	9552.89

TABLE 1.-1. WATER POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

INDUSTRY	1977	1972–77	1977–81	1977–86
			INVESTMENT	
MISCELLANEOUS				
TOXIC SUBSTANCES	1.09	1.09	1.09	1.09
PHARMACEUTICAL MANUFACTURING	15.52	46.23	15.03	40.55
HOSPITALS INDUSTRY	24.50	69.77	25.65	69.56
TOTAL INVESTMENT	41.11	117.08	41.77	111.20
			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
TOXIC SUBSTANCES	0.55	0.55	4.43	9.97
PHARMACEUTICAL MANUFACTURING	10.79	23.09	51.47	139.39
HOSPITALS INDUSTRY	16.37	34.69	79.65	219.62
TOTAL ANNUAL COSTS	27.71	58.34	135.55	368.98

2. GOVERNMENT EXPENDITURES FOR WATER POLLUTION CONTROL

INTRODUCTION

Government funds for water pollution control are spent for three major purposes:

- To conduct programs of monitoring, enforcement, technical assistance, grant assistance, and research,
- To abate pollution created at government-owned facilities, and
- To treat wastewater at municipal treatment facilities.

Generally, states have primary responsibility for monitoring and enforcement, with financial and other assistance provided by the Federal government; research is conducted primarily by the Federal government, and treatment of municipal wastewater is the responsibility of local and state governments, with major financial assistance from the Federal and state governments.

Federal and State Program Costs

This discussion centers on the general program of Federal and state governments, and it projects their respective program costs over a 10-year period; it also includes estimates of the cost of abating pollution at Federal facilities. Details of the analysis are not presented here since the main purpose of this effort is to determine the magnitude of this category of expenditure in relation to other expenditures in the report.

Federal and state program costs are summarized in Table 2.-1. Federal expenditures (exclusive of construction grants and grants to states) are projected to decrease from the 1975 level of 326 million dollars to 187 million dollars in 1978. The Federal share of program expenditures is also projected to decline over the forecast period as the states gradually assume greater responsibility in implementing the programs and regulations. Total decade expenditures for this category are projected at 3,171 million dollars.

Federal Program Costs

Federal responsibilities that are exercised primarily through the U.S. Environmental Protection Agency (EPA), encompass a broad range of authorities, particularly since enactment of the Federal Water Pollution Control Act Amendments of 1972 and 1977. On the one hand, they encourage compliance through grants and other types of assistance; on the other hand, they require compliance through regulatory programs.

Assistance Programs

The EPA conducts several assistance programs, including grants for wastewater treatment works, grants for regional water quality planning program development, technical assistance, and manpower development.

The construction grants program is by far the largest, involving authorization of as much as $5

Table 2.-1.
Projected State and Federal Program Costs

Costs per Fiscal Year
(In Millions of 1977 Dollars)

	1976	Transition[3]	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Federal[1,2]	211	41	215	187	187	187	162	162	162	162	162	1,838
State	130	33	130	130	130	130	130	130	130	130	130	1,333
Totals	341	74	345	317	317	317	292	292	292	292	292	3,171

1 Excludes Construction Grant costs which are included in the Municipal Cost section.
2 Excludes State Program Grant costs which are included in the state totals.
3 Three-month period July 1 through October 31, 1976, caused by change of Fiscal Year from July 1-June 30, to October 1-September 30.

billion in Federal funds per year for fiscal years 1979–1982. The level of assistance has gradually increased since the first permanent Federal pollution control legislation was enacted in 1956; today, the Federal share is 75 percent of most project capital costs. A variety of projects are eligible for funding, including treatment plants and interceptor sewers.

The EPA also provides program grants to assist the states, interstate, and regional agencies to expand and improve a variety of activities essential to the control of water pollution. The activities include water quality planning and standards setting, surveillance, enforcement, issuance of permits, executive management, and administration of the construction grants program. The level of assistance varies from one activity to another, as well as from year to year. In 1975 and 1976 over $200 million was granted to regional agencies for areawide waste treatment management plans. However, in the future, funding for this program will drop to a low maintenance level.

The feasibility of a new consolidated grants program is currently under study by the Agency. The new program would combine the state assistance programs for water quality, air quality, water supply, and solid waste. If such a program were initiated, the cost of abatement and control would drop by an amount roughly equal to the water quality state assistance program. Since allocation of these consolidated funds among four categories might become a state option, forecasting future water quality expenditures would require additional analysis.

Technical assistance is another program receiving major EPA attention. Many pollution problems are too complex for states, communities, and industries to handle alone. The EPA assists in such cases by providing services ranging from technical advice and consultation to extensive, long-term field and laboratory studies. Within the limits of available resources, this assistance is provided on request, primarily to the states and municipalities.

As might be expected, the rapid expansion of pollution control activities has placed a strain upon the supply of trained manpower. In providing assistance, the EPA pursues a number of approaches; these include providing short-term training by EPA staff to upgrade the skills of those already in the field, and employing a variety of ways to train sewage treatment plant operators.

Regulatory Programs

To facilitate enforcement of the many new pollution control requirements, the 1972 Act and 1977 Amendments replaced former enforcement authorities with new authorities and provided a new regulatory scheme based largely on the imposition of specific requirements through a system of permits termed the National Pollutant Discharge Elimination System (NPDES). Permit conditions and other requirements of the Act are enforceable through EPA compliance orders and civil suits; violators are subject to penalties. A state may assume the responsibility if it meets certain requirements, including the capability and authority to modify, suspend, or revoke a permit, and it has the powers and procedures necessary for criminal penalties, injunctive relief, and other enforcement mechanisms.

The Act also required Federal agencies to comply with Federal, state, interstate, and local pollution control and abatement requirements to the same extent as any person must comply. The EPA's role stems from the Act and is amplified in Executive Order 11752. The role includes review of Federal facilities compliance with applicable standards, providing guidance to the Federal agencies for implementing provisions of the Order, providing coordination of Federal agencies' compliance actions with state and local agencies, and providing technical advice on waste treatment technology.

Table 2.-2 projects a stabilized Federal water quality program beyond FY78, reflecting the need for Federal fiscal restraints and the gradual acceptance of greater environmental responsibilities by the states. Water quality program expenditures are usually divided into three categories: (1) **abatement and control** covers the numerous management and assistance activities of the water quality program, (2) **research and development** provides the scientific and technical support for the program, and (3) **enforcement** covers actions seeking compliance with the law. Table 2.-2 shows projected Federal program expenditures according to the three categories listed.

Expenditures by Other Federal Agencies

Although covering a wide range of activities, Federal environmental programs are classified in three broad categories: pollution control and abatement; understanding, describing, and predicting the environment, and environmental protection and enhancement activities. It is difficult to attribute non-EPA Federal expenditures to specific pollution control legislation in many cases, but an approximation of P.L. 92–500 related expenditures is given by the water quality expenditures in the Pollution Control and Abatement category. Principal activities in this category include actions necessary to reduce pollution from Federal facili-

Table 2.-2.
Projected Federal Water Quality Program Expenditures

Fiscal Year Expenditures
(In Millions of 1977 Dollars)

	1976	Transition	1977	1978	1979	1980	1981	1982	1983	1984	1985
Abatement and Control	145.2	24.6	148.8	120.8	120.8	120.8	95.8	95.8	95.8	95.8	95.8
Research and Development	44.6	11.2	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6
Enforcement	21.1	5.3	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
Totals	210.9	41.1	214.5	186.5	186.5	186.5	161.5	161.5	161.5	161.5	161.5

ties; the establishment and enforcement of standards; research and development; and the identification of pollutants, their sources, and their impact on health. Non-EPA water quality expenditures by the Federal government in FY1976, the transition quarter, and FY1977 are 527, 83, and 467 million dollars, respectively.

Since Federal spending is strongly influenced by policy and competing social needs, forecasting is always problematical. The best estimate is that such expenditures will remain stable over the next several years, with only minor growth or decline. If non-EPA Federal outlays in this category were to be held constant at the FY1977 level, total decade expenditures would be about 4.8 billion dollars. While this is a large amount on an absolute basis, it is relatively small compared to total expenses in the nation for P.L. 92-500.

State Program Costs

State Role

Although the Federal government has taken an increasingly greater hand in dealing with water pollution, the states continue to bear the major share of the responsibility. States inherently have broad powers to deal with water pollution, and these powers, together with delegated Federal authorities, place the states in a strong position to regulate all sources of pollution. State powers and responsibilities under the Act are exercised through a broad range of activities, including:

- States prepare an annual strategy and program report that describes the interim goals to be achieved during the year, the state resources to be assigned in meeting the goals, and the method of assigning resources.
- States prepare basin water quality mangagement plans, as required by Section 303(e) of the 1972 Act. These plans are designed to be the central management tools of the states in administering their water quality programs.
- States are responsible for reviewing areawide waste treatment management plans called for by Section 208 and prepared by local agencies.
- States have major responsibilities in the administration of the construction grants program, including the responsibility for assigning priorities to projects eligible for Federal financial assistance. It is intended that certain Federal responsibilities, such as review of plans and specifications, be transferred to the states as they are able to assume them. Some states provide funds to assist communities in constructing waste treatment works. Primary responsibility for monitoring municipal treatment plants to see that they operate correctly also rests with the states.
- States have the basic responsibility for planning and implementing programs for control of nonpoint sources of pollution.
- Some states have assumed, and others are in the process of assuming, responsibility for the NPDES permit program. States that have received the responsibility have concurrently assumed extensive enforcement responsibilities associated with permit compliance.
- States and the Federal government share responsibility for enforcement.
- States establish and implement water quality standards. Under the 1972 Act, such standards are extended to intrastate, as well as interstate, waters.
- States perform monitoring and surveillance functions to identify and assess existing and potential water pollution problems, and also to measure the effectiveness of the permit and construction grants programs.

Aggregate State Program Expenditures

As shown in Table 2-1, state program expenditures are expected to remain level at about $130 million per year. Within this stable budget, expenditures will gradually shift from planning to enforcement. The assumptions behind the analysis suggest a continuation of activity in almost every area. Revisions of water quality standards, issuance of a new round of permits, compliance, monitoring, and construction grant review, in fact, may require the maintenance of state programs at a higher expenditure level than projected. However, anticipated revenue constraints at the State and Federal level, combined with competing social needs, lend credence to a level projection.

Municipal Control Costs

Introduction

The 1972 amendments to the Clean Water Act established technology objectives and water quality objectives for controlling pollution from municipal sources. The objectives were restated and clarified by the 1977 amendments to the Act. The technology objectives require that all publicly owned treatment works be upgraded to secondary treatment levels by 1977 and best practicable wastewater treatment levels by 1983. Currently, secondary treatment (85 percent removal of organic and suspended solids waste loads, with the plant effluent quality not to exceed 30 mg/1 for both BOD_5 and suspended solids, and PH between 6.0 and 9.0) is considered equivalent to best practicable treatment. In addition, publicly owned treatment works must control their waste discharge as necessary to meet water quality standards by 1983. These standards are based on achieving a level of water quality that will provide for the protection and propagation of fish, shellfish, and wildlife, and will provide for recreation in and on the water. This section reports the costs associated with meeting these dual objectives.

Defining And Measuring Need

The 1978 Survey conducted in compliance with Sections 205(a) and 516(b)(2) of the Act (known as the 1978 Needs Survey), requested that municipal treatment authorities estimate the expenditures required to meet existing technology and water quality standards and to provide for replacement or expansion of facilities as necessary to serve the population projected to 2000. Thus, a "need" consists of the resources associated with the upgrading, replacement, expansion, or construction of treatment facilities which State or local governments consider to be necessary, based upon the Federal standards, or more stringent state standards.

Details of the Needs Survey may be found in a separate report, "Cost Estimates for Construction of Publicly Owned Wastewater Treatment Facilities – 1978 Needs Survey," EPA-430/9-79-001.

Defining Cost

While all other sections of the report estimate costs for compliance with effluent or emission standards, several complications preclude presenting that type of analysis in this case. Compliance with the Federal Water Pollution Control Act by all publicly owned sewage treatment plants in existence on July 1, 1977 would require them to achieve a secondary treatment level for all effluents. Because of the difficulty facing municipalities in raising capital, and limitations in Federal construction grants, treatment plants cannot be built fast enough to assure compliance with the Act. Instead, it is assumed in this report that new plants will only be built as rapidly as permitted by Federal appropriations and state and local matching funds. The total investments shown in Table 2.-3 are composed of Federal outlay estimates for the given year, plus required state and local matching funds.

Table 2.-3
Projected Federal, State and Local Investment for Sewage Treatment Systems Assuming Increased Funding of $4.5 Billion per Year for Period FY78-FY87

(Millions of Current Dollars)

Fiscal Year		Calendar Year	
1976	3,628	1976	4,465
TQ	1,304	—	—
1977	5,282	1977	5,065
1978	4,414	1978	4,538
1979	4,913	1979	5,034
1980	5,413	1980	5,276
1981	4,866	1981	4,829
1982	4,720	1982	4,873
1983	5,333	1983	5,333
1984	5,333	1984	5,333
1985	5,333	1985	5,333
1986	5,333	1986	5,333
TOTALS	55,925		55,416

Not all costs reported herein are properly attributable to the standards created under the authority of P.L. 92-500. The costs attributable to those standards are incremental; only those costs associated with upgrading from an existing level of treatment to a higher level of treatment necessary to meet technology and water quality objectives are properly attributable to the standards. Thus, costs for replacement of facilities built prior to 1972 which do not require a different level of treatment, the cost associated with the lower level of treatment that would otherwise have been achieved in facilities built after 1972, and the cost associated with a higher level of treatment than is necessary to meet the standards should be ex-

cluded from the costs attributed to meeting standards. However, since Section 516(b) directs assessment of the costs of "carrying out the provisions of the Act," and the construction grant program is an integral part of the Act, the entire range of costs attributed to that program are reported herein.

Status of Public Sewerage

Since 1940, the nation's public sewage treatment systems have improved dramatically through expansions in the scope of their coverage and in their capabilities for treatment, but the systems have not kept pace with the amount of residuals to be processed. The coverage of the systems has kept pace with population growth and expanded to encompass parts of the population previously not served. According to a survey done by Engineering News Record, between 1940 and 1974, U.S. population served by sewers increased by 146 percent, and the population served by treatment facilities increased by 337 percent. The 1978 Needs Survey showed that 70.0 percent of the population in 1977 was served by collection systems, and that 69.1 percent was served by treatment systems.

The capability of the systems to treat waste has improved as well. In the period 1940 to 1976, the number of persons whose wastes receive at least primary treatment (physical processes that remove roughly 40–50 percent of solids and about 35 percent of BOD_5) had almost quadrupled. The population employing secondary treatment more than doubled, and now includes about 60 percent of the population employing sewers. Not only have more persons been connected to more advanced types of sewerage treatment facilities, but technological modifications have improved the removal efficiencies of each type.

Although the coverage and treatment capability of the systems have increased, the systems have not kept pace with the increasing volume of residuals to be removed. While one portion of the system, the treatment facilities, increased by over 400 percent the amount of BOD_5 diverted from our waterways another portion, sanitary sewers, more than offset that improvement by delivering more BOD_5 for treatment. These figures may be overly pessimistic as they pertain to sanitary sewerage only; they do not reflect the net result of initiating public treatment for a large (but unknown) number of industrial facilities that previously discharged directly into our waterways. On the other hand, they do not take into account the increased concentration of wastes in sanitary sewage resulting from such innovations as kitchen garbage disposals.

Although expenditures in the past two decades have significantly expanded the capital stock of public sewerage facilities, the prospect for future decades is that replacement expenditures may consume larger proportions of the annual investment in sewerage facilities. Between 1855 and 1973, the nation invested an estimated $61.8 billion (1977 dollars) in its public sewerage facilities (see Table 2.-4). This investment represents about 5 percent of the total state and local government capital expenditures for all purposes since 1915 and resulted in approximately $34 billion worth of facilities in place by 1971. The replacement costs shown here represent an upper bound since they are based on conservative lifetimes of 50 and 25 years for sewers and treatment plants, respectively.

Table 2.-4.
Investment in Public Sewerage Facilities

(Billions of 1977 Dollars)

Period	Gross Investment[1]	Replacement[2]	Net Investment	End of Period Capitalization
1856–69	$ 0.5	$ 0.1	$ 0.4	$ 0.4
1870–79	0.6	0.1	0.5	0.9
1880–89	0.8	0.2	0.6	1.5
1890–99	1.2	0.4	0.8	2.3
1900–09	1.5	0.6	0.9	3.2
1910–19	2.7	0.9	1.8	5.0
1920–29	5.7	1.6	4.1	9.1
1930–34	2.5	1.3	1.2	10.3
1935–39	4.8	1.6	3.2	13.5
1940–45	2.1	2.3	(0.2)	13.3
1946–56	10.8	5.1	5.7	19.0
1957–61	7.5	3.2	4.3	23.3
1962–67	9.1	4.8	4.3	27.6
1968–73	12.0	5.4	6.6	34.2
Totals	$61.8	$27.6	$34.2	

[1] Based on data published by the Department of Commerce and by the EPA; all values converted to 1977 dollars through use of the EPA's sewerage construction cost indices and the discontinued Associated General Contractor's Index of Construction Costs.

[2] Estimated funds required to "replace" existing facilities, rather than add new capacity. Computed at a rate of 2 percent for sewers and 4 percent for plants, based on estimates of the relative weight of each in each period.

Two aspects of this series of investments stand out. First, the bulk of sewerage capital has been installed very recently; almost 80 percent since 1929, 60 percent since World War II, and more than 30 percent since 1961. Second, the stock of capital-in-place is so large compared to annual investments that replacement of existing facilities has absorbed approximately 50 percent of all capital expenditures since 1961. The current level of replacement costs is close to $1 billion a year and rising in proportion to the growth of the capital stock.

Needs Survey Summary

Although the Needs Survey data are not used

directly in preparation of the comprehensive national cost estimates, they do provide essential background for comparison with actual estimated expenditures that are strongly influenced by Federal subsidies. In this interest, the 1978 Needs Survey is summarized below.

Categories of Need

The states' estimates of the cost of constructing publicly owned treatment works needed to meet the 1983 goals of the Act are divided into the five major categories used in the 1973 Survey, plus one new category for treatment and/or control of stormwaters; two of these categories were divided for the 1974 Survey and retained for the 1976 and 1978 Surveys. All six categories are briefly described below.

Category I. This includes the costs of facilities which would provide a legally required level of secondary treatment, or best practicable wastewater treatment technology (BPWTT). For the purpose of the Surveys, BPWTT and secondary treatment were to be considered synonymous. Included in Category II are the costs necessary to raise the treatment level of Category II facilities to secondary levels, e.g., if the existing treatment level of a facility is primary then costs necessary to raise the treatment level to secondary are reported in Category II together with the costs for treatment levels greater than secondary.

Category II. Costs reported in this category are for treatment facilities that must achieve more stringent levels of treatment. This requirement exists where water quality standards require removal of such pollutants as phosphorous, ammonia, nitrates, or organic substances.

Category IIIA. These costs are for correction of sewer system infiltration/inflow problems. Costs could also be reported for a preliminary sewer system analysis and for the more detailed Sewer System Evaluation Survey.

Category IIIB. Requirements for replacement and/or major rehabilitation of existing sewage collection systems are reported in this category. Costs were to be reported if the corrective actions were necessary to the total integrity of the system. Major rehabilitation is considered extensive repair of existing sewers beyond the scope of normal maintenance programs.

Category IVA. This category includes costs for replacement or major rehabilitation of existing collection systems necessary to the total integrity and performance of waste treatment works.

Category IVB. This category consists of costs of new collection systems in existing communities with sufficient existing or planned capacity to adequately treat collected sewage.

Category V. Costs reported for this category are to prevent periodic bypassing of untreated wastes from combined sewers to an extent violating water quality standards or effluent limitations. It does not include treatment and/or control of stormwaters.

Category VI. States were also asked to make a rough cost estimate in a sixth category, "Treatment and/or Control of Stormwaters". This includes the costs of abating pollution from stormwater run-off channelled through sewers and other conveyances used only for such run-off. The costs of abating pollution from stormwaters channelled through combined sewers that also carry sewage are included in Category V. Category VI was added so the survey would provide an estimate of all eligible facility costs, as explicitly required by P.L. 93–243.

The estimates were to be reported in January 1978 dollars. Estimates were to be based on the projected 2000 population.

Results of the Survey

The results of the 1978 Survey are presented in Table 2.-5 in aggregate national totals, by category. Various subtotals are presented to give an indication of needs versus priorities. For example, 36 percent of the $167.8 billion total is required for stormwater control. State-by-state data for the same categories may be found in the aforementioned separate report.

Table 2.-5.
Summary Table of National Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities
(Billions of 1978 Dollars)

Needs Category	2000 EPA Assessment	Backlog Estimate
I (Secondary Treatment)	15.09	9.66
II (More Stringent Treatment)	20.51	10.63
A. To achieve Secondary Levels	(10.2)	
B. Advanced Secondary Levels	(6.8)	
C. Advanced Treatment Levels	(3.5)	
IIIA (Infiltration/Inflow)	2.44	2.44
IIIB (Replacement/Rehabilitation)	4.88	4.87
IVA (New Collector Sewers)	19.02	19.02
IVB (New Interceptor Sewers)	18.47	6.69
V (Combined Sewer Overflows)	25.74	25.74
Total I, II, and IVB	54.07	26.98
Total I-V	106.15	79.05
VI (Control of Storm Water)	61.67	45.70
Total I-VI	167.82	124.75

Assessment of Backlog

A new addition to the Survey in 1976 and retained in 1978 was the assessment of need for present populations (the backlog of need). Needs for Categories I-V present populations are estimated to be $79.1 billion, or 74 percent of the 2000 needs. Note that because of their nature, 2000 Needs for Categories IIIA and IIIB are almost exclusively all backlog needs as well. In addition, because of the limitations of eligibility for Category IVA as detailed in Section 211 of P.L. 92-500 and the Construction Grant Regulations (40 CFR 35.925-13), all of the Category IVA needs for 2000 are theoretically backlog needs. The differences, therefore, are most graphically illustrated in Categories I, II, and IVB, where backlog needs represent 50 percent of the 2000 needs.

The costs reported for the backlog are sufficient only for the facilities necessary to serve the June 1977 populations. They do not include any costs for the reserve capacity which would be required by the Act to be included in these facilities for population growth beyond 1977. They also exclude estimates for treatment and sewers that were not necessary at all in 1977, but are projected to be necessary for the 2000 populations.

Table 2.-3 shows the anticipated year-by-year capital investment for municipal treatment facilities as controlled by Federal grant awards. Some of the funds expended during the period are from grants awarded prior to P.L. 92-500, which were matched by state and local funds averaging about 60 percent of total project costs. The $18 billion from P.L. 92-500, the $480 million from P.L. 94-447, and the $1 billion from P.L. 95-26 require only 25 percent state and local matching funds. The matching funds are included in the totals. 1986 values are projected to be the same as 1985 values.

The total investment over the decade of $26.4 billion is seen to be 83 percent of the category I, II, and IVB backlog total needs, but only 35 percent of the category I-V backlog total and 24 percent of the category I-VI backlog total. Therefore, the EPA recommended in 1977 that the construction grant program be augmented by $4.5 billion per year for the period 1978-1987. If Congress were to appropriate these funds, the expenditure schedule shown in Table 2.-3 would result, with the 1976-85 decade total being $55.9 billion, which exceeds the Category I, II, and IVB (highest priority) requirements for 2000 population. The amounts actually authorized by Congress in the 1977 Amendments were $4.5 billion for fiscal year 1978, and $5 billion for fiscal years 1979-82.

Time Phasing and Annualization of Costs

Annual costs are the sum of the annualized capital costs and O&M costs. These annualized capital costs are calculated by amortizing the investment over its economic life at a discount rate of 10 percent.

Capital investment is assumed to be equal to the schedule presented in Table 2-3. This assumes funding past 1983 is equal to 1983 funding.

As in the industrial sectors, the total capital-in-place used to calculate annualized capital costs is the cumulative investment beginning with year 1972. The standard capital recovery formula was used to calculate increased annualized costs as a function of new investments.

Results of these analyses are in Table 2.-6.

Table 2.-6.
Total Municipal Cost of Water Pollution Control, 1977-1986

(Billions of 1977 Dollars)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1977-1986 Total
Annualized Capital	2.54	3.07	3.66	4.28	4.85	5.42	6.05	6.67	7.30	7.93	51.77
O&M	1.09	1.19	1.27	1.34	1.44	1.58	1.67	1.78	1.90	2.02	15.28
Total	3.63	4.26	4.93	5.62	6.29	7.00	7.72	8.45	9.20	9.95	67.05

3. ENERGY INDUSTRIES

For the purpose of this report, the broad category "Energy Industries" was defined to include those industries that gather, transfer, process, and deliver energy to the ultimate user. These include:

- Coal Mining
- Petroleum & Natural Gas Extraction
- Petroleum Refining
- Steam-Electric Power Generation

Costs for the reduction of water pollution for these industries are summarized in Table 3.-1.

These costs and other data are repeated below in the appropriate sections together with the assumptions peculiar to the industry and other details.

TABLE 3.-1. WATER POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

INDUSTRY	1977	1972–77	1977–81	1977–86
			INVESTMENT	
ENERGY INDUSTRIES				
COAL MINING	9.24	53.50	16.25	30.34
OIL & GAS EXTRACTION	554.61	892.33	337.42	651.78
PETROLEUM REFINING	735.68	2575.30	668.80	789.59
STEAM-ELECTRIC POWER GENERATION	1026.78	1638.67	877.15	2637.12
TOTAL INVESTMENT	2326.30	5159.80	1899.62	4108.83
			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
COAL MINING	56.31	147.75	227.56	567.89
OIL & GAS EXTRACTION	381.24	547.74	1699.04	4272.51
PETROLEUM REFINING	502.57	1242.84	2505.84	6287.09
STEAM-ELECTRIC POWER GENERATION	722.76	1295.68	2404.96	5923.74
TOTAL ANNUAL COSTS	1662.88	3234.02	6837.40	17051.24

3.1 COAL MINING

Introduction

The disruption of the earth's surface by mining operations causes chemical and physical modifications that often adversely affect both surface- and ground-water resources. The major causes of concern are sedimentation from disturbed areas and acid mine drainage discharges.

Although coal mining activities exist in numerous states acid mine drainage is a more critical problem in the eastern coal fields. Because of limited coal production, variations in mining practices, lack of precipitation, abundance of limestone, high natural alkalinity of surface water, and scarcity of acid-forming materials in some coal producing areas, the distribution of acid mine drainage varies markedly from state to state and within the states. While significant areas of disturbed land may be identified in most states, the estimated costs of abating acid mine water pollution developed for this report are based on the treatment of water from active operations, assuming compliance with all promulgated (BPT) and proposed (BAT, NSPS) regulation.

Current Production

The preliminary 1976 *Mineral Industries Surveys* indicates a production of 603 million metric tons (665 million short tons) of bituminous and lignite coal, and anthracite coal production for 1976 is reported to be 5.8 million metric tons (6.4 million short tons). It is estimated that 40.5 percent of bituminous and lignite, and 99.2 percent of anthracite coals were cleaned by some physical method in 1976. Industry sources estimate that the industry had a 1976 capacity of about 735 million metric tons (810 million short tons) of coal. The industry indicates plans for expansion to a 1985 capacity of 1.1 billion metric tons (1.2 billion short tons), with conservative estimates of demand at about 910 million metric tons (1.0 billion short tons) of coal in 1985.

Current Bituminous and Lignite Coal Production.

Mine water must be pumped out to allow mining to continue. This technique is also used to prevent aquifers from being polluted by metals in solution, COD, and acid formation, although flooding the mine may also prevent acid formation. To develop costs for BPT, BAT, and NSPS compliance, "Economic Document" model plants and costs were used for BPT and NSPS compliance levels. For BAT compliance costs, neutralization equipment, chemicals, and distribution piping and pumps remained the same but the settling pond was doubled in size and cost, and a limited amount of flocculation agents were added. To determine costs for BPT and BAT level compliance, production for 1976, 1983, and 1986 was split into large, medium, and small model mines. It was assumed that all mines will require treatment at least for suspended solids and pH.

Anthracite Coal

Anthracite coal is showing a long term decreasing production trend. Costs were estimated using model facility costs as in the previous section. In estimating mine pumpout treatment costs it was assumed that 42 percent of yearly production is surface mined and 10 percent is deep-mined (the remainder is assumed to be comb-bank and auger-mined). Because the production rate of anthracite is decreasing, it was assumed that treatment facilities equivalent to 6.4 million metric tons (7 million short tons) per year capacity would be required to install water treatment facilities.

This methodology has overstated costs in that many cleaning plants are at the "mine mouth", and mine pumpout is often used as process water in the cleaning plant (the effluent then needs treatment only once).

The resulting estimated costs of compliance are listed in Table 3.1–1.

TABLE 3.1-1. COAL MINING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	6.78	44.29	0.90	0.90	0.90
BAT	0.0	0.0	4.27	5.69	5.69
NEW PLANTS	2.46	9.20	11.07	17.43	23.75
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	9.24	53.50	16.25	24.03	30.34
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	9.24	53.50	16.25	24.03	30.34
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	14.23	38.99	17.36	17.49	17.49
BAT	0.0	0.0	3.08	5.98	7.06
NEW PLANTS	2.68	7.32	12.99	20.44	29.91
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	16.91	46.31	33.42	43.92	54.46
O&M					
EXISTING PLANTS					
BPT	32.65	84.95	132.92	199.55	299.49
BAT	0.0	0.0	14.35	33.49	62.19
NEW PLANTS	6.76	16.50	46.87	83.57	151.75
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	39.40	101.45	194.14	316.60	513.43
INDUSTRY TOTAL	56.31	147.75	227.56	360.52	567.89
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	56.31	147.75	227.56	360.52	567.89
ALL ANNUAL COSTS	56.31	147.75	227.56	360.52	567.89

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.2 OIL AND GAS EXTRACTION

(Some or all of the regulations governing this industry were revoked on May 12, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Industry Structure

The extraction of gas and oil through the use of conventional wells, the subject of this chapter, constitutes all of the commercial activity in SIC category 1311 since the other activities (producing oil from oil sands and oil shale) are at the present time only in the research and development stage in the United States. The extraction of oil and gas consists of the production from wells onshore and offshore. The number of onshore and coastal wells in the United States in 1975 was 497,000. Of these 368,000 or about three-fourths of the total were stripper wells. In addition, there were about 900 far-and near-offshore platforms, primarily in the Gulf of Mexico off the coast of Louisiana. The offshore wells beyond the historic state limit, in what is known as the Outer Continental Shelf (or Far Offshore) Waters are under Federal jurisdiction. Wells in offshore waters inside the State limit are classified as being in Near Offshore Waters. The bayous and estuaries of Louisiana and Texas are known as Coastal Waters. In the Coastal Waters, things are complicated because water from a well onshore may discharge its formation water to a bayou nearby or a platform built out in the water may pipe its formation water onshore for treatment followed by dumping or injection. The onshore wells can be subdivided into stripper wells, wells with beneficial use of formation water, and other nonstripper wells. Stripper wells are those that produce 10 barrels of oil per day or less. Wells that produce water that is sufficiently low in salinity that it can be used for agricultural or livestock watering purposes constitute the beneficial use category. The balance of the onshore wells in the United States can be categorized as other nonstripper onshore wells. The pollution regulations discussed below are grouped by these categories.

The interrelation of gas and oil production is complex. When oil and gas are found together, the usual case, the gas is spoken of as being associated gas. Gas from wells having no oil production is called nonassociated gas. However, the nonassociated gas has a high content of vapors of petroleum liquids; before the natural gas is put into the pipeline, these vapors are condensed and sold as natural gas liquids. (This activity is discussed in the section of the Clean Air Report on Natural Gas Processing). Some oil wells have so little associated gas that it is not economical to bring this gas to a pipeline.

Gas wells have been included for the offshore region since these data were readily available and the costs of the proposed regulations are so high. Nonassociated gas wells onshore have been ignored in this study as well as in the EPA studies done previously since the pollution problems involved are small.

Nature of Pollutants and Control Technologies

The chief pollutant from the operation of oil and gas wells onshore is the brine that is produced with the oil and gas. (In certain areas of the West, the water is low in salts and is acceptable for watering stock). There are a number of ways to handle brine produced onshore. It can be stored in a pit and allowed to evaporate or it can be reinjected into the producing formation or into some other formation beneath the surface. The last is by far the most common disposal technique.

Although the salts in the brine are nonpolluting when added to ocean water, the oil dispensed in the brine is a potential pollutant. The oil-laden water can be treated with coalescers and dissolved air flotation equipment to lower the oil content to an acceptable level before discharge to the ocean. If complete elimination of oil discharge is derived, injections into underground strata can be used, although this is expensive, especially if the well is in deep water. In the regions close to shore, it is also possible to send the water ashore by pipeline for treatment followed by dumping, reinjection, or by evaporation from a pit area.

One way to increase the total amount of oil that is recovered is to inject water into the formation, a

process known as water flooding. Very frequently, the production water is reinjected. Since this is an economic use of the water and is not related to the pollution abatement that is obtained as an incidental by-product, the cost of reinjection for purposes of secondary recovery is not included in this report.

Another source of pollution is oil from drill cuttings and from spent muds that are discharged. Water-based muds and drill cuttings can be washed before dumping offshore. Onshore, they can be landfilled. Oil-based muds used offshore can be collected and hauled ashore and then disposed of in a landfill. Hauling to shore is also used to dispose of refuse and toxic chemicals from platforms. Water running off the deck of a platform is another possible source of pollution since the deck is frequently spotted with oil. Deck washings and rain water can be collected and treated in the same manner as the produced water. Another potential source of water pollution is the sanitary sewage water. This can be treated and then chlorinated and discharged. All of the above potential sources of pollution are from activities that are more or less expected in every-day operations. The prevention of blowouts and catastrophic spills is not treated here.

Regulations

Each of the states where oil and gas is produced has its own set of regulations governing the discharge of water, casing depth, reinjection of water, as well as the disposal of solid waste from drilling and operation of the well. Since the coastal states have jurisdiction out to their historic boundary (usually 3 miles, but in the case of Texas, 9 miles offshore), they also promulgate regulations concerning possible pollutants from offshore oil and gas rigs and platforms in the coastal and near offshore waters. The State of California has a limit of 20 parts per million for the long-term average of oil and grease. Louisana's limit is 30 ppm. In Texas, a permit is issued for each platform based on the potential impact on the local water quality. Some of the permits in sensitive areas have a limit of oil and grease as low as 25 ppm. In the area of Federal control, the outer continential shelf, the U.S. Geological Survey (USGS) has the authority to issue regulations designed to protect the environment and to make navigation safe. For example, the USGS's regulations limit the average oil and grease discharge to no more than 50 ppm.

The EPA has issued effluent guidelines that cover Best Practicable Control Technology Currently Available (40FR42543, 41FR44942). Proposed guidelines for New Source Performance Standards, Best Available Technology Economically Achievable and pretreatment standards have been published (40FR42573, 41FR44949). Although no EPA regulations are in effect at this time, in the analysis for this report it was assumed that the proposed regulations would go into effect in 1978 or 1983, as is appropriate.

Cost of Abatement Equipment and Operation for the Disposal of Formation Water

The costs given in the Development Document were used for the contiguous 48 states. The Alaskan offshore platforms pipe their produced formation water to shore where it is treated and dumped. The costs for Alaska are assumed to be about three times as high as they would be for the contiguous 48 states. (The water is treated and dumped even though the fields use water for secondary recovery. This is because the produced formation water is incompatible with the sea water that is used for the repressurization of the reservoir).

Cost of Meeting Other Pollution Regulations

EPA requirements concerning the disposal of trash, drill cuttings, spent mud, and sanitary wastes from offshore platforms duplicate requirements that were in the various state or U.S. Geological Survey Regulations. Hence, no incremental costs are occasioned by the Water Pollution Control Act. The cost of extra casing to meet the Clean Drinking Water Act's provisions have not been included in this analysis.

Number of Wells or Platforms Impacted

The costs for disposal of oil from onshore wells in Alaska has been omitted from this study because there is a lack of data. The number of wells, the amount of water produced, and the cost of abatement under the rigorous Arctic conditions have not been reported.

California Offshore The cost impacts have been estimated using the number of discharge points as detailed in the study for the National Commission on Water Quality, which were then disaggregated by flow per day. There are an estimated 566 discharge points in the Far Offshore Region, 66 in the Near Offshore Region and 805 in Coastal Waters.

Alaska Offshore The data from the Offshore Economic Analysis showed that 14 platforms exist in Alaska. One discharge per platform was assumed (currently produced water is piped to shore, treated and discharged).

Onshore The number of onshore wells not injecting produced water, the average well size, and average water production were calculated from data in the Economic Analysis. The formation water from an estimated 12,967 wells is not reinjected. Of these 3,209 wells produce water that is used beneficially.

Growth of Unit Numbers

The growth of the number of discharge points in the offshore region was estimated as follows. For the coastal and near offshore regions, it was assumed that the number of abandonments would equal the number of new wells so that there would be no net growth. For the far offshore, the historic rate of growth of platforms was used as an approximation of the growth with the number of discharge points, using data from *Offshore* (June 20, 1977). For 1977–1978, a 10 percent increase was assumed; for 1979–1985, 15 percent per year. This is consistent with the rate of growth for offshore oil projected by President Carter in his National Energy Plan.

These percentages include expected growth in the Gulf of Alaska and offshore Atlantic.

The growth rate for onshore well numbers is based on the Project Independence Report using the Business-as-usual, $11 per barrell scenario.

The cost for the abatement of pollution problems in oil and gas extraction has been calculated to be as shown in Table 3.2–1.

TABLE 3.2–1. OIL & GAS EXTRACTION INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	554.61	892.33	25.43	25.43	25.43
BAT	0.0	0.0	224.71	299.62	299.62
NEW PLANTS	0.0	0.0	87.28	168.86	326.73
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	554.61	892.33	337.42	493.91	651.78
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	554.61	892.33	337.42	493.91	651.78
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	117.32	167.97	482.65	723.97	1085.95
BAT	0.0	0.0	59.09	137.87	256.05
NEW PLANTS	0.0	0.0	24.09	62.87	169.55
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	117.32	167.97	565.83	924.71	1511.55
O&M					
EXISTING PLANTS					
BPT	263.92	379.77	1076.88	1613.42	2418.24
BAT	0.0	0.0	39.45	92.05	170.95
NEW PLANTS	0.0	0.0	16.89	54.13	171.78
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	263.92	379.77	1133.21	1759.60	2760.97
INDUSTRY TOTAL	381.24	547.74	1699.04	2684.32	4272.52
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	381.24	547.74	1699.04	2684.32	4272.52
ALL ANNUAL COSTS	381.24	547.74	1699.04	2684.32	4272.52

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.3 PETROLEUM REFINING INDUSTRY

(Some or all of the regulations governing this industry were remanded on August 11, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capacities

As of early 1977, the petroleum refining industry comprises about 139 firms operating about 266 refineries in 39 states, plus 3 in Puerto Rico, one in the Virgin Islands, and one in Guam. All refineries are necessarily multi-product. As of 1974, the 17 largest firms accounted for about 80 percent of the industry's capacity.

The petroleum refining industry produces hundreds of distinguishably different products, which can be grouped into four broad product classes: gasoline, middle distillate, residual oil, and all others. Gasoline accounts for about 45 percent of industry output. Middle distillates, comprise about 33 percent (this description includes military and commercial jet fuel, kerosene, space heating oil, and diesel fuel). Residual fuel amounts to about 8 percent of domestic petroleum production. Other products include asphalt, lubricants, liquefied petroleum gas (mostly propane), naphthas and solvents, coke, petrochemicals, and petrochemical feedstocks. Crude oil is the most important raw material used by the industry. Natural gasoline and gas liquids which are products of the natural gas industry furnish about 5 percent of refinery intakes. There are no other significant raw materials.

Although a typical oil refinery is technically complex, the process is conceptually simple. Crude oils, which are liquid mixtures of many carbon-containing compounds, are first separated into several fractions of varying molecular size. The chemical composition of some of these fractions is then altered by changing the average molecular size and/or the shape or structure of the molecules. Many of the intermediate fractions are "treated" to make the impurities innocuous or to remove them completely. These are then blended to produce finished products, to which various substances, known as additives, may be added to impart certain desirable properties.

Based upon an analysis fo refinery raw waste loads, EPA has divided the industry into five subcategories for the purpose of regulating effluents:

Topping

Topping plants are refineries whose processing is largely confined to converting oil into raw products by simple atmospheric distillation. The topping subcategory excludes all refineries with cracking processes.

Cracking

Refineries in this subcategory are those that have topping and cracking operations but make neither petrochemicals nor lubricants. The term cracking applies to a group of processes in which high molecular weight fractions are broken down into lower molecular weight fractions. Catalytic cracking, hydro cracking, and thermal cracking processes like coking and visbreaking are included in this definition.

Petrochemical

Plants in this subcategory have topping, cracking, and petrochemical operations.

Lube

This subcategory includes refineries with topping, cracking, and lube oil manufacturing processes.

Integrated

Integrated refineries are those with topping, cracking, lube oil manufacturing processes, and petrochemical operations.

In general, the number and complexity of refining operations increases with increasing refinery size. Most of the simple topping refineries are small while the petrochemical and integrated refineries are generally large. There are some fairly small lube oil refineries.

Waste Sources and Pollutants

Wastewater pollutants generated in the various refining processes, such as BOD, COD, total organic carbon, total suspended solids, oil and

grease, phenols, ammonia, sulfides, chromium, and pH, are present in untreated refinery effluent. Some pollutants enter the wastewater directly from processing, while others enter the waste stream from washing tanks, equipment, catalysts, etc.; from cooling water blowdown; and from leaks and spillage. Additional flows and waste loads are created by storm water runoff from the refinery grounds and from the disposal of tanker ballast water.

The following parameters are covered under the effluent limitations guidelines: BOD_5, total suspended solids, COD, oil and grease, phenolic compounds, ammonia (as N), sulfide, total chromium, hexavalent chromium, and pH. The effluent limitations for each pollutant varies with the type, size, and complexity of the refinery.

Control Technology and Costs

Wastewater treatment processes currently used in the petroleum refining industry include equalization and storm water diversion; initial oil and solids removal (API separators or baffle plate separators); further oil and solids removal (clarifiers, dissolved air flotation, or filters); carbonaceous waste removal (activated sludge, aerated lagoons, oxidation ponds, trickling filter, activated carbon, or combinations of these); and filters (sand or multimedia) following biological treatment methods.

BPT guidelines are based upon both in-plant and end-of-pipe control practices widely used within the industry. These include the above listed end-of-pipe technologies plus:

- Installation of sour water strippers to reduce the sulfide and ammonia concentrations entering the treatment plant.
- Elimination of once-through barometric condenser water by using surface condensers or recycle systems with oily water cooling towers.
- Segregation of sewers, so that unpolluted storm runoff and once-through cooling waters are not treated with the process and other polluted waters.
- Elimination of polluted once-through cooling water by monitoring and repair of surface condensers or by use of wet and dry recycle systems.

BAT guidelines call for further reductions of water flow in-plant, and the addition of a physical-chemical treatment step (activated carbon) in the end-of-pipe treatment system. BAT in-plant technology is based on control practices now in use by some plants in the industry and include:

- Use of air cooling equipment.
- Reusing: sour water stripper bottoms in crude desalter; once-through cooling water as make-up to the water treatment plant; boiler condensate as boiler feedwater; overhead accumulator water in desalters; and heated water from the vacuum overhead condensers to heat the crude.
- Recycling: water from coking opertions, waste acids from alkylation units, and overhead water in water washes.
- Use of wastewater treatment plant effluent as: cooling water, scrubbing water, and influent to the water treatment plant.
- Use of closed compressor and pump cooling water system.
- Use of rain water runoff as cooling tower make-up or water treatment plant feed.

Control costs are detailed in Table 3.3–1.

TABLE 3.3–1. PETROLEUM REFINING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	670.58	2123.40	85.00	57.83	-186.71
BAT	0.0	0.0	440.00	662.00	662.00
NEW PLANTS	65.10	451.90	143.80	212.00	314.30
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	735.68	2575.30	668.80	931.83	789.59
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	735.68	2575.30	668.80	931.83	789.59
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	271.41	605.17	1115.19	1676.26	2457.08
BAT	0.0	0.0	140.60	295.64	549.48
NEW PLANTS	57.76	146.03	290.60	455.96	736.68
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	329.17	751.20	1546.39	2427.86	3743.25
O&M					
EXISTING PLANTS					
BPT	106.71	323.04	461.06	699.63	1057.49
BAT	0.0	0.0	162.79	342.32	636.26
NEW PLANTS	66.70	168.60	335.60	526.40	850.10
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	173.41	491.64	959.45	1568.35	2543.85
INDUSTRY TOTAL	502.57	1242.84	2505.84	3996.21	6287.10
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	502.57	1242.84	2505.84	3996.21	6287.10
ALL ANNUAL COSTS	502.57	1242.84	2505.84	3996.21	6287.10

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

3.4 STEAM ELECTRIC POWER GENERATING INDUSTRY

(Some or all of the regulations governing this industry were remanded on May 16, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Industry Categories and Production Capacities

The steam electric power industry has been divided into three subcategories according to size and age of generating plants, and a fourth based on area runoff. A summary of the subcategories follows:

Subcategory	Generating Capacity, MW	Date of Initial Operation
Generating Unit	≥ 25	After 1-1-1974
	≥ 500	After 1-1-1970
Small Unit	< 25	
Old Unit	≥ 500	On or before 1-1-1970
	< 500	On or before 1-1-1970
Area Runoff	all sizes	

The steam electric power industry can also be subdivided according to the type of fuel consumed in the production of electricity, i.e., fossil fuels (coal, gas, and oil) and nuclear fuels. Capacity, by fuel type, in 1974 and as projected for 1983 and 1985 is shown in Table 3.4.-1:

Table 3.4.-1.
Recent and Projected National Steam-Electric Power Generating Capacity by Fuel Type (in millions of KW)

Fuel	1974	1983	1985	% Change 1974–1985
Coal	185.8	310.1	332.9	+ 72.9
Oil	66.3	93.2	91.2	+ 37.6
Gas	87.4	44.	41.	- 53.1
Nuclear	31.6	110.7	132	+317.7

Pollutants, Pollutant Sources and Entrainments

Effluent guidelines promulgated October 8, 1974 (39 FR 36186–36207) control the following pollutants:

- pH
- PCB
- TSS
- Oil and grease
- Total copper
- Total iron
- Free available chlorine
- Total residual chlorine
- Corrosion inhibitors
- Zinc
- Chromium03;
- Phosphate
- Heat

Main sources contributing to the total waste load are:

- Low volume wastes which include scrubber waters, discharge from ion exchange treatment systems, water treatment, evaporator blowdown, laboratory and sampling streams, floor drainage, cooling tower basin cleaning wastes, and blowdown from recirculating house service water systems
- Metal cleaning wastes
- Ash transport water
- Boiler and cooling tower blowdown
- Area runoff from material storage and construction areas.

Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

Projected 1985 capacity affected by chemical, thermal, and entrainment regulations are shown in Table 3.4–2:

Table 3.4–2.
Projected 1985 Steam-Electric Power Generating Capacity Affected by FWPCA Regulation by Fuel Type (in millions of KW)

Fuel	Chemical	Thermal	Entrainment
Coal	195	69.7	3.4
Oil	91.2	7.3	1.8
Gas	41	0.8	0.8
Nuclear	52.5	32.3	4.5

Pretreatment standards for steam electric power generating facilities discharging to publicly-owned treatment works are in the process of being developed. The capacity of plants discharging to municipal sewers is approximately 14,500 megawatts. Pollutants that would be controlled by Level

C pretreatment as described in the Development Document[1,2] are:

- TSS
- Iron
- Copper
- pH
- Oil and grease
- Free chlorine

Pollution Control Technology

A variety of control and treatment technologies are in use by or available to the steam electric power generating industry. Water management programs thus vary among plants.

The amount of heat rejected to available waters is reduced by in-process means, use of cooling towers, and by dissipating the heat in on-property cooling ponds or lakes.

Clarification, flotation, and filtration are common methods of removing suspended solids. Chemical reduction, ion exchange, and chemically-induced precipitation are among the methods used to control metals in wastewater. Oil and grease is removed by skimming flotation, demulsification and coagulation.

Approaches to controlling chlorine in effluents involve reducing dosage frequency, amount, and/or duration, splitting the effluent into two streams and chlorinating one stream at a time, use of feedback control systems, dissipation, and aeration.

Costs

A summary of the costs to the steam-electric generating industry associated with the implementation of the FWPCA provision is given in Table 3.4–3.

TABLE 3.4–3. STEAM ELECTRIC POWER INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	852.71	1110.16	38.42	38.42	38.42
BAT	0.0	0.0	0.44	0.59	0.59
NEW PLANTS	174.07	528.52	838.29	1409.55	2598.11
PRETREATMENT	0.0	0.0	0.00	0.00	0.00
SUBTOTAL	1026.78	1638.67	877.15	1448.56	2637.12
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1026.78	1638.67	877.15	1448.56	2637.12
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	145.96	218.95	596.46	898.47	1351.49
BAT	0.0	0.0	0.12	0.27	0.50
NEW PLANTS	69.49	155.53	547.20	1016.86	2080.24
PRETREATMENT	0.0	0.0	0.00	0.00	0.00
TOTAL	215.44	374.48	1143.78	1915.60	3432.24
O&M					
EXISTING PLANTS					
BPT	145.15	216.69	599.86	901.09	1315.41
BAT	0.0	0.0	0.01	0.02	0.03
NEW PLANTS	362.17	704.51	661.32	817.92	1176.07
PRETREATMENT	0.0	0.0	0.00	0.00	0.00
TOTAL	507.32	921.20	1261.18	1719.02	2491.51
INDUSTRY TOTAL	722.76	1295.68	2404.96	3634.62	5923.75
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	722.76	1295.68	2404.96	3634.62	5923.75
ALL ANNUAL COSTS	722.76	1295.68	2404.96	3634.62	5923.75

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

REFERENCES

1. Supplement for Pretreatment to the Development Document for the Steam-Electric Power Generating Point Source Category, Draft EPA, 440/1-76/084, November 1976.

2. "Draft Development Document for Pretreatment Standards — the Steam-Electric Power Generating Industry" Prepared for EPA HIT-667, September, 1976.

4. CHEMICALS INDUSTRIES

For the purpose of this report, the Chemicals Industries are defined as those establishments which manufacture products primarily by chemical modification of raw materials and for which the final product is a chemical. These include:

- Organic Chemicals
- Inorganic Chemicals
- Plastics & Synthetics
- Rubber Manufacturing
- Soaps & Detergents
- Carbon Black Industry
- Explosives Industry
- Pesticides & Agricultural Chemicals
- Fertilizer Manufacturing
- Phosphate Manufacturing
- Paint Formulating
- Printing Ink Formulating
- Photographic Processing
- Textiles Industry

The textiles industry has been included in this grouping primarily because it is largely the chemical operations within that industry which are responsible for water pollution. Costs associated with the implementation of the FWPCA for the Chemicals Industries are summarized in Table 4–1.

TABLE 4.-1. WATER POLLUTION ABATEMENT COSTS (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1972–77	1977–81	1977–86
CHEMICAL INDUSTRIES				
ORGANIC CHEMICALS	835.88	1704.54	1140.52	2322.07
INORGANIC CHEMICALS	179.78	471.65	379.38	547.91
PLASTICS & SYNTHETICS	89.92	241.25	118.73	367.47
RUBBER MANUFACTURING	72.25	169.04	19.76	46.47
SOAPS & DETERGENTS	2.33	4.24	2.74	4.68
CARBON BLACK INDUSTRY	0.90	2.38	0.0	0.0
EXPLOSIVES INDUSTRY	232.56	612.00	1327.56	2057.56
PESTICIDES & AGRICULTURAL CHEMICALS	9.63	25.50	0.0	0.0
FERTILIZER MANUFACTURING	70.46	145.67	113.25	200.66
PHOSPHATE MANUFACTURING	39.09	56.00	33.29	64.71
PAINT FORMULATING	2.20	8.46	3.03	8.36
PRINTING INK FORMULATING	0.20	1.96	0.58	0.80
PHOTOGRAPHIC PROCESSING	6.21	14.47	5.59	15.69
TEXTILES INDUSTRY	24.21	87.84	1030.21	1410.16
TOTAL INVESTMENT	1565.61	3544.99	4174.64	7046.53
		ANNUAL COSTS		
	1977	1972–77	1977–81	1977–86
ORGANIC CHEMICALS	322.34	575.73	1929.38	5211.75
INORGANIC CHEMICALS	136.53	285.22	787.06	2277.54
PLASTICS & SYNTHETICS	42.26	91.46	221.11	665.48
RUBBER MANUFACTURING	39.67	79.67	171.12	412.96
SOAPS & DETERGENTS	0.82	1.51	4.80	12.73
CARBON BLACK INDUSTRY	0.36	0.71	1.57	3.53
EXPLOSIVES INDUSTRY	120.46	242.13	943.98	3069.88
PESTICIDES & AGRICULTURAL CHEMICALS	6.48	13.04	13.41	30.17
FERTILIZER MANUFACTURING	81.53	135.43	441.49	1260.92
PHOSPHATE MANUFACTURING	14.38	24.76	78.32	229.54
PAINT FORMULATING	2.05	5.06	9.98	27.62
PRINTING INK FORMULATING	0.34	1.16	1.58	3.80
PHOTOGRAPHIC PROCESSING	4.46	8.45	21.99	59.67
TEXTILES INDUSTRY	27.42	64.01	1089.87	4499.59
TOTAL ANNUAL COSTS	799.12	1528.35	5715.66	17765.15

4.1 ORGANIC CHEMICALS INDUSTRY

(Some or all of the regulations governing this industry were revoked on February 10, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capacities

Approximately 470 companies operating over 680 establishments are engaged in producing organic chemicals; however, the four largest producers account for a minimum of 36 percent, and the hundred largest for more than 92 percent of the total shipments. Much of the industry's production is accounted for not only by the large chemical companies, but also by the major petroleum refineries. At the other end of the spectrum are many small companies operating small plants. There are about 27 plants employing more than 1,000, and about 220 plants with less than 10 employees.

The organic chemicals industry includes a vast number of products and processes. The Phase I effluent limitations guidelines cover only part of the organic chemicals industry. At the time of this report, no Phase II regulations had been proposed for other parts of the organic chemicals industry. Primary petrochemical processing, (i.e., chemicals produced at petroleum refineries), plastics, fibers, agricultural chemicals, pesticides, detergents, paints, and pharmaceuticals are not included. These are discussed elsewhere in this report.

Synthetic organic chemicals are derivative products of naturally occurring raw materials (petroleum, natural gas, and coal) which have undergone at least one chemical conversion. The organic chemicals industry was initially dependent upon coal as its sole source of raw materials. However, during the last two decades it has moved so rapidly from coal to petroleum-based feedstocks that the term "petrochemicals" has come into common use.

The basic raw materials are usually obtained by physical separation processes in petroleum refineries. The raw materials are then chemically converted to a primary group of reactive precursors; these precursors are then used in a multitude of specific chemical conversions to produce both intermediate and final products.

Processing of organic chemicals usually involves four stages:

- Feed preparation — vaporization, heating, compressing, and chemical or physical purification of raw materials
- Reaction — the reaction of the raw materials, frequently in the presence of a catalyst
- Product separation — condensation, distillation, absorption, etc., to obtain the desired product
- Product purification — distillation, extraction, crystallization, etc., to remove impurities.

Processing methods may be carried out either in continuous operations or in individual batches. Facilities using the continuous processing method manufacture products at much greater volumes and at lower unit costs than those using batch methods.

The effluent limitations guidelines promulgated to date by EPA (for Phase I) apply only to those products of the organics chemicals industry produced in continuous processing operations. These operations have been divided into seven subcategories, based first upon the degree of process water used, and second upon the raw waste loads generated; Table 4.1-1 lists the seven subcategories and the products and processes included.

Waste Sources and Pollutants

Water is used in many production processes as a reaction vehicle, and also as a vehicle to separate or to purify the final products by scrubbing, steam stripping, or absorption. In addition, a considerable amount of water is used for heating (steam) and cooling, and for washing reaction and storage vessels, etc.

The effluent limitations guidelines for the organic chemicals industry cover the following pollutants:

BOD_5, COD, total suspended solids, phenols, and pH. The limitation placed upon pH in all cases is between 6.0 and 9.0. It should be noted that process wastewaters subject to limitations include all process waters exclusive of auxiliary sources, such as boiler and cooling water blowdown, water treatment backwash, laboratories, and other similar sources.

Control Technology and Costs

Technologies employed in the organic chemicals industry for the control of wastewater pollutants include in-process modifications, pollution control equipment, and end-of-pipe wastewater treatment. From a pollution-control standpoint, the most significant change that can be made in process chemistry is from a "wet" process to a "dry" process; that is, the substitution of some other solvent for water in which to carry out the reaction or to purify the product. Other in-process technologies observed or recommended for the organic chemicals industry include the substitution of surface heat exchangers for contact cooling water, the substitution of mechanical pumps for vacuum pump steam jet ejectors, the recycle of scrubber water, and the regeneration of contact process steam from contaminated condensate.

Biological treatment systems are the most common end-of-pipe technologies used in the organic chemicals industry today. These systems include activated sludge, trickling filters, aerated lagoons, and anaerobic lagoons. Other systems used include stripping towers, deep-well disposal, physical treatment, activated carbon, and incineration. Where phenols are present in wastewaters, they may be removed by solvent extraction, carbon absorption, caustic precipitation, or steam stripping. Cyanide may be removed by oxidation. Five of 34 plants surveyed discharged their effluent to a municipal treatment system; three had no current treatment systems.

In-process controls commensurate with BPT include segregation of waste streams, the substitution of nonaqueous media in which to carry out the reactions or to purify the products, recycling or reuse of process water, and the recovery of products and byproducts from the wastewaters by solvent extraction, absorption, or distillation. End-of-pipe treatment commensurate with BPT is based on the use of biological systems as mentioned above. These systems include additional treatment operations such as equalization, neutralization, primary clarification with oil removal, nutrient addition, and effluent polishing steps, such as coagulation, sedimentation, and filtration. Phenol removal is also required in some cases.

Table 4.1-1.
Organic Chemicals Manufacturing Industry Products and Related Processes

Subcategory A	Non Aqueous Processes
Products	Process Descriptions
BTX Aromatics	Hydrotreatment of pyrolysis gasoline
BTX Aromatics	Solvent extraction from reformate
Cyclohexane	Hydrogenation of benzene
Vinyl Chloride	Addition of hydrochloric acid to acetylene
Subcategory B	**Process with Process Water Contact as Steam Diluent or Absorbent**
B1 Products	B1 Process Descriptions
Acetone	Dehydrogenation of isopropanol
Butadiene	Co-product of ethylene
Ethyl benzene	Alkylation of benzene with ethylene
Ethylene and Propylene	Pyrolysis of naphtha or liquid petroleum gas
Ethylene dichloride	Direct chlorination of ethylene
Ethylene oxide	Catalytic oxidation of ethylene
Formaldehyde	Oxidation of methanol
Methanol	Steam reforming of natural gas
Methyl amines	Addition of ammonia to methane
Vinyl acetate	Synthesis of ethylene and acetic acid
Vinyl chloride	Cracking of ethylene dichloride
B2 Products	B2 Process Descriptions
Acetaldehyde	Dehydrogenation of ethanol
Acetylene	Partial oxidation of methane
Butadiene	Dehydrogenation of n-butane
Butadiene	Oxidative-dehydrogenation of n-butane
Styrene	Dehydrogenation of ethylbenzene
Subcategory C	**Aqueous Liquid Phase Reaction Systems**
C1 Products	C1 Process Descriptions
Acetic acid	Oxidation of acetaldehyde
Acrylic acid	Synthesis with carbon monoxide and acetylene
Coal tar	Distillation of coal tar
Ethylene glycol	Hydrogenation of ethylene oxide
Terephthalic acid	Catalytic oxidation of p-xylene
Terephthalic acid	Purification of crude terephthalic acid
C2 Products	C2 Process Descriptions
Acetaldehyde	Oxidation of ethylene with oxygen
Caprolactam	Oxidation of cyclohexane
Coal Tar	Pitch forming
Oxo Chemicals	Carbonylation and condensation
Phenol and Acetone	Cumene oxidation and cleavage
C3 Products	C3 Process Descriptions
Acetaldehyde	Oxidation of ethylene with air
Aniline	Nitration and hydrogenation of benzene
Bisphenol A	Condensation of phenol and acetone
Dimethyl terephthalate	Esterification of terephthalic acid
C4 Products	C4 Process Descriptions
Acrylates	Esterification of acrylic acid
p-cresol	Sulfonation of toluene
Methyl methacrylate	Acetone cyanohydrin process
Terephthalic acid	Nitric acid process
Tetraethyl lead	Addition of ethyl chloride to lead amalgam

Source: EPA Development Document, April 1973, pp. 28–29.

Technology commensurate with BAT includes the addition of activated carbon to the BPT biological systems to achieve substantial reductions of dissolved organic compounds. In-process controls applicable to BAT include:

- Substitution of non-contact heat exchangers for direct contact water cooling
- Use of nonaqueous quench media
- Recycle of process water
- Reuse of process water as a make-up to evaporative cooling towers
- Use of process water to produce low pressure steam by non-contact heat exchange
- Recovery of spent acids or caustic solution for reuse
- Recovery and reuse of spent catalysts
- Use of nonaqueous solvents for extraction products.

End-of-pipe technology for NSPS is defined as biological treatment with suspended solids removal via clarification, sedimentation, and sand or dual-media filtration. In addition, exemplary in-process controls, as previously enumerated, are also assumed to be applicable, particularly where biotoxic pollutants must be controlled.

Costs

A summary of the costs to the organic chemicals industry associated with the implementation of FWPCA provisions is given in Table 4.1–2.

TABLE 4.1–2 ORGANIC CHEMICALS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	693.92	1189.57	462.61	462.61	462.61
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	141.96	514.97	677.91	1097.72	1859.46
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	835.88	1704.54	1140.52	1560.33	2322.07
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	835.88	1704.54	1140.52	1560.33	2322.07
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	156.40	238.94	860.19	1294.62	1946.28
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	67.71	163.62	485.78	881.21	1712.45
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	224.10	402.57	1345.96	2175.83	3658.73
O&M					
EXISTING PLANTS					
BPT	72.31	110.47	397.71	598.57	899.86
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	25.93	62.69	185.71	336.60	653.17
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	98.24	173.17	583.42	935.16	1553.03
INDUSTRY TOTAL	322.34	575.73	1929.38	3111.00	5211.75
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	322.34	575.73	1929.38	3111.00	5211.75
ALL ANNUAL COSTS	322.34	575.73	1929.38	3111.00	5211.75

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.2.1 INORGANIC CHEMICALS INDUSTRY (PHASE I)

(Some or all of the regulations governing this industry were remanded on March 10, 1976 and/or revoked on November 11, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capacities

The complex and heterogeneous inorganic chemicals industry produces thousands of chemicals. Each of the chemicals covered by the effluent guidelines is manufactured by one or more processes, most of which are covered by the current guidelines. Because the various products and processes differ considerably from one another, it is not possible to describe them in detail. Generally, they can be said to involve the chemical reaction of raw materials, followed by the separation, collection, and purification of the product. Table 4.2.1–1 identifies each of the processes covered and summarizes briefly the raw materials used and the nature of each process.

Table 4.2.1–1
Inorganic Chemicals (Phase I)
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Aluminum chloride (catalyst in petrochemical and plastics industry)	All	Gaseous chlorine, molten aluminum Bauxite, coke, chlorine Hydrated alumina or bauxite ore; hydrochloric acid	Chlorine introduced below surface of aluminum, product sublimes and is collected by condensation. Produces anhydrous aluminum chloride.
Aluminum sulfate (water purification)	All	Bauxite ore or other aluminum compound, concentrated sulfuric acid	Ground ore and acid reacted in a digester. Muds and insolubles settled and filtered out.
Calcium carbide (manufacture of acetylene)	Uncovered furnaces only	Limestone; coke, petroleum coke or anthracite	Limestone and carbon reacted in a furnace.
Calcium chloride (deicing and dust control on roads, stabilizer in pavement and cement)	Brine extraction	Salt brines or Solvay process waste liquor	Brines concentrated and purified then evaporated to yield product which is flaked and calcined to yield a dry product.
Calcium oxide and calcium hydroxide (lime) (many chemical and industrial uses)	All	Limestone	Limestone calcined in a kiln.
Chlorine and sodium or potassium hydroxide (chlor-alkali) (many industrial uses)	Mercury cell Diaphragm cell	Sodium chloride or potassium chloride brines	Brines purified, then electrolyzed. Products collected at electrodes and purified.
Hydrochloric acid (many industrial and chemical uses, particularly pickling of steel)	Direct chlorine-hydrogen reaction	Chlorine, hydrogen	Hydrogen and chlorine gases reacted in a vertical burner. Acid is cooled and absorbed in water.
Hydrofluoric acid (production of fluorinated organics and plastics, etc.)	All	Sulfuric acid, fluorspar	Materials reacted in a furnace, acid cooled and absorbed in water, then redistilled.

Table 4.2.1–1 (Continued)
Inorganic Chemicals (Phase I)
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Hydrogen peroxide (bleaching agent)	Electrolytic process	Ammonium (or other) bisulfate; water	Bisulfate electrolyzed to persulfate, which is then reacted with water.
	Organic process	Alkyl anthraquinone; hydrogen; oxygen	Alkylanthraquinone reduced by hydrogen over a catalyst, then oxidized in a forced gas stream to produce the original alkylanthraquinone and hydrogen peroxide.
Nitric acid (fertilizers, explosives)	Only concentrations up to 66% by weight. Reaction of sodium nitrate and sulfuric acid not included.	Ammonia; air; water	Ammonia oxidized over a catalyst to form nitrogen dioxide which is reacted with water under pressure to form the product.
Potassium metal (used in organo-potassium compounds and in sodium-potassium manufacture)	All	Potassium chloride; sodium vapor	Potassium chloride melted, then exposed to sodium vapors in an exchange column.
Potassium dichromate (glass pigment and photographic development)	All	Sodium dichromate; potassium chloride	Potassium chloride added to a dichromate solution. Product crystallized out.
Potassium sulfate (agriculture)	All	Langbeinite; potassium chloride	Potassium chloride added to a solution of crushed langbeinite. Product precipitated out.
Sodium bicarbonate (baking soda) (wide variety of uses including food processing and manufacturing)	All	Sodium carbonate; water; carbon dioxide	Materials reacted under pressure. Product precipitated.
Sodium carbonate (soda ash) (glass and non-ferrous metals, other products)	Solvay process	Ammonia; salt brine; carbon dioxide	Sodium bicarbonate produced from reacting the raw material in an aqueous solution. This is then converted to soda ash by heating.
Sodium chloride (table salt)	Solar evaporation	Salt water	Salt water concentrated by evaporation in open ponds. Sodium chloride is then crystallized from the brine.
	Solution brine mining	Water; salt deposits	Water pumped into an underground salt deposit. Brine pumped out and purified. Product crystallized out.
Sodium dichromate (manufacturing of pigments, other industrial uses, corrosion inhibition)	All	Chrome ore; sodium carbonate; lime; sulfuric acid	Raw materials calcined, then leached. Soluble chromates converted to dichromates with sulfuric acid. Dichromates crystallized out.
Sodium metal (manufacture of tetraethyl lead and other products; nuclear coolant)	Downs cell process	Sodium chloride; alkali flourides;calcium chloride	Mixture melted and electrolyzed. Sodium collected at cathode.
Sodium silicate (manufacture of silica gel) then charged into a	All	Caustic soda; silica	Caustic soda and silica sand mixed, furnace. Water and steam added to dissolve the silicate. Silicate evaporated.
Sodium Sulfite (bleaching; food preservative; boiler feed water additive)	Reaction of sulfur dioxide and soda ash	Sulfur dioxide gas; sodium carbonate (soda ash)	Gas passed into a soda ash solution. Solution heated. Sulfate is purified, filtered, crystallized.

Table 4.2.1–1 (Continued)
Inorganic Chemicals (Phase I)
Industry Products and Processes

Product (Use)	Processes Covered by Phase I Effluent Limitations Guidelines	Raw Materials	Description
Sulfuric acid (fertilizer, petroleum refining, explosives, others)	Contact process (single and double absorption)	Sulfur	Sulfur burned to yield sulfur dioxide, mixed with air, heated, and then introduced into a catalytic converter to produce sulfur trioxide. This gas is then cooled and absorbed in a sulfuric acid solution.
Titanium dioxide (white pigment in paint, ink, and other products)	Chloride process	Titanium dioxide ores; chlorine; coke	Chlorination of ores produces titanium tetrachloride, which is then oxidized to form the product.
	Sulfate process	Titanium dioxide ores; sulfuric acid	Ores dissolved in sulfuric acid at high temperatures to produce titanium sulfate which is hydrolyzed to form a hydrate. This is then calcined to form the product.

Production capacity of some of the chemicals is concentrated in the hands of a few producers; in the case of potassium dichromate, there is only one. The market for other products is much more competitive; for example, there are over 100 producers of lime. The total production of the inorganic chemicals covered by the Phase I effluent limitations guidelines was about 126 million metric tons (139 million short tons) in 1971. Of this total production, about 44 million metric tons (48 million short tons) or 34 percent actually comes within the control of the guidelines. The remaining 66 percent is comprised of chemicals which are either produced by processes not covered by the guidelines or are produced in plants that are classified as other industries, such as pulp mills and steel mills.

Waste Sources and Pollutants

Water is used in inorganic chemical manufacturing plants for three principal purposes:

- Cooling. Non-contact cooling water.
- Process. Contact cooling or heating water, contact wash water, transport water, product and dilution water.
- Auxiliary water.

The effluent limitations guidelines apply to process wastewater pollutants only. This includes those wastewater constituents in water which directly contacts the product, byproduct, intermediate, raw material, or waste product. Examples are waters used for barometric condensers; contact steam drying; steam distillation; washing of products, intermediates, or raw materials; transporting reactants or products in solution, suspension, or slurry form; and water which becomes an integral part of the product or is used to form a more dilute product.

The following basic pollutant parameters are covered in the effluent limitations guidelines for the inorganic chemicals industry: total suspended solids (TSS), cyanide, chromium, chemical oxygen demand (COD), iron, lead, mercury, total organic carbon (TOC), and pH.

Control Technology and Costs

The manufacture of some of the inorganic chemicals covered by the effluent limitations guidelines produces no waterborne wastes. In these cases, the only control technology required is the isolation, handling, and often reuse of water from leaks, spills, and washdowns. The most common wastewater treatment practices in the remainder of the industry are neutralization, the settling of suspended solids in ponds, storage, and discharge of the neutralized and clarified effluent to surface waters. Deep-well disposal is also used, particularly for sodium chloride brine-mining waters. When more control is necessary because of the presence of harmful wastes, more advanced technology, such as ion exchange and chemical reduction and precipitation, is employed. In-process control measures commonly employed include monitoring techniques, safety practices, good housekeeping, containment provisions, and segregation practices.

Table 4.2.1.-2. summarizes the control techniques associated with BAT and BPT guidelines. BPT as-

sumes the normal use of practical in-process controls, such as recycling and alternative use of water, and recovery and/or reuse of wastewater constituents. BAT assumes the highest degree of in-process controls that are available and are economically achieveable.

New source performance standards (NSPS) are the same as BPT for all chemicals except calcium chloride, chlorine (chlor-alkali), hydrogen peroxide, sodium chloride, sodium dichromate, sodium metal, sodium sulfite, and titanium dioxide. Metal anodes may be used in chlorine production to eliminate lead discharges. For both chlorine and sodium dichromate, NSPS guidelines assume decreased water discharges based on improved water-processing designs in new plants. NSPS for the other exceptions are the same as BAT.

Table 4.2.1–2.
Inorganic Chemicals (Phase I)
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Aluminum chloride (anhydrous)	No water scrubbers for white or grey aluminum chloride production, For yellow aluminum chloride production, gas scrubbing and sale of scrubber wastes as aluminum chloride solution, or Gas scrubbing followed by chemical treatment to precipitate aluminum hydroxide and recycle	Same as BPT
Aluminum sulfate	Settling pond and reuse	Same as BPT
Calcium carbide	Dry dust collection system	Same as BPT
Hydrochloric acid chlorine burning	Acid containment and isolation with centralized collection of acid wastes and reuse	Same as BPT
Hydrofluoric acid	Acid containment and isolation, and reuse	Same as BPT
Sodium bicarbonate	Evaporation and product recovery, or Recycle to process	Same as BPT
Sodium chloride (solar process)	Good housekeeping to prevent contamination of waste salts	Same as BPT
Sodium silicate	Storage of wastes in an evaporation pond, or Ponding and clarification	Ponding or clarification and recycle of treated wastewater
Sulfuric acid (sulfur burning contact process)	Acid containment and isolation with recycle to process or sell as weak acid	Same as BPT
Lime	Dry bag collection systems, or Treatment of scrubber water by ponding and clarification and recycle	Same as BPT
Hydrogen peroxide (electrolytic)	Ion exchange to convert sodium ferrocyanide to ammonium ferrocyanide which is then reacted with hypochlorite solution to oxidize it to cyanate solutions, and Settling pond or filtration to remove catalyst and suspended solids	Same as BPT plus segregation of wastewater from cooling water and evaporation of the waste stream and recycle of the distillate
Sodium dichromate and sodium sulfate	Isolation and containment of spills, leaks, and runoff, and Batchwise treatment to reduce hexavalent chromium to trivalent chromium with NaHS, plus precipitation with lime or caustic; and Settling pond with controlled discharge	Same as BPT plus evaporation of the settling pond effluent with recycling of water and land disposal or recovery of solid waste

Table 4.2.1-2. (Continued)
Inorganic Chemicals (Phase I)
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Chlor-alkali (diaphragm cell)	Asbestos and cell rebuild wastes are filtered or settled in ponds then land dumped, and Chlorinated organic wastes are are incinerated or land dumped, and Purification muds from brine purification are returned to salt cavity or sent to evaporation pond/settling ponds, and Weak caustic-brine solution from the caustic filters is partially recycled	Same as BPT plus: Reuse or sell waste sulfuric acid Catalytic treatment of the hypochlorite waste and reuse or recovery Recycle of all weak brine solutions Conversion to stable anodes
Chlor-alkali (mercury cell)	Cell rebuilding wastes are filtered or placed in settling pond, then used for landfill, and Chlorinated organic wastes are incinerated or placed in containers and land dumped, and Purification muds from brine purification are returned to brine cavity or sent to evaporation/settling ponds, and Partial recycle of brine waste streams, and	Same as BPT plus: Reuse or recovery of waste sulfuric acid Catalytic treatment of the hypochlorite waste and reuse or recovery Recycle of all weak brine solutions
Nitric acid	Acid containment and isolation and reuse	Same as BPT
Potassium (metal)	No process water used in manufacture	Same as BPT
Potassium dichromate	Replacement of barometric condensers with non-contact heat exchangers; recycle of process liquor	Same as BPT
Potassium sulfate	Evaporation of brine waters with recovery of magnesium chloride, or Reuse of brine solution in process in place of process water	Same as BPT
Calcium chloride (brine extraction)	Settling pond or clarification	Same as BPT plus replacement of barometric condensers with non-contact heat exchangers and additional recycle
Hydrogen peroxide (organic)	Isolation and containment of process wastes; oil separation and clarification	Chemical decomposition for peroxide removal and carbon adsorption for organic removal
Sodium (metal)	Salting pond, and Partial recycle of brine waste solution after treatment	100% brine recycle and reuse or sale of spent sulfuric acid
Sodium chloride (solution mining)	Containment and isolation of spills, packaging wastes, scrubbers, etc; partial recycle to brine cavity	Same as BPT plus replacement of barometric condensers with non-contact heat exchangers
Sodium sulfite	Air oxidation of sodium sulfite wastes to sodium sulfate—94% effective, and final filtration to remove suspended solids	Same as BPT plus recovery of waste sodium sulfate
Soda ash (sodium carbonate) Solvay Process	Settling ponds	Settling ponds and clarification
Chlor-alkali (mercury cell) (continued)	Recovery and reuse of mercury effluent by curbing, isolation and collection of mercury-containing streams, then treatment with sodium sulfide	

Table 4.2.1–2. (Continued)
Inorganic Chemicals (Phase I)
Industry Summary of Control Technologies

Chemical	Best Practicable Technology (BPT)	Best Available Technology (BAT)
Titanium dioxide (chloride process)	Neutralization with lime or caustic, and Removal of suspended solids with settling ponds or clarifier-thickener, and Recovery of byproducts	Same as BPT plus additional clarification and polishing
Titanium dioxide (sulfate process)	Neutralization with lime or caustic, and Removal of suspended solids with settling ponds or clarifier-thickener, and Recovery of byproducts	Same as BPT plus additional clarification and polishing

Six chemicals in Phase I of the Inorganic Chemicals Industry were found for which the manufacturers do or may discharge process wastewaters to publicly owned treatment works (POTWs) and for which pretreatment guidelines and standards were recommended. These products are:

- aluminum chloride,
- aluminum sulfate,
- calcium carbide,
- calcium chloride,
- potassium dichromate, and
- sodium bicarbonate.

No pretreatment of process wastewater was found to be needed for facilities that manufacture calcium carbide, calcium chloride or sodium bicarbonate. Recommended pretreatment technologies are shown in Table 4.2.1–3.

Table 4.2.1–3.
Recommended Pretreatment Technologies for Phase I of the Inorganic Chemicals Industries

	Aluminum Chloride	Aluminum Sulfate	Potassium Dichromate
Metal Precipitation	X	X	(a)
Neutralization	X	X	X
Settling	X	—	—
Thickening	—	—	X
Filtration	X	X	X
Discharging to POTW	X	X	X
Sanitary Landfilling	X	X	—
Chemical Landfilling	—	—	X

(a) Chemical chromate removal

Control costs and other industry data are summarized inn Table 4.2.1–4.

TABLE 4.2.1–4. INORGANIC CHEMICAL INDUSTRY (PHASE I) WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	162.58	416.85	7.59	7.59	7.59
BAT	0.0	0.0	327.39	436.52	436.52
NEW PLANTS	7.71	29.63	33.17	51.32	80.83
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	170.29	446.48	368.15	495.43	525.94
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	170.29	446.48	368.15	495.43	524.94
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	54.81	112.70	223.21	334.82	502.22
BAT	0.0	0.0	86.09	200.87	373.04
NEW PLANTS	3.89	9.60	26.32	46.40	86.00
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	58.70	122.30	335.62	582.08	961.26
O&M					
EXISTING PLANTS					
BPT	63.18	129.95	255.90	382.69	570.65
BAT	0.0	0.0	112.87	263.37	487.96
NEW PLANTS	5.86	14.41	40.05	70.97	132.74
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	69.04	144.36	408.82	717.03	1191.34
INDUSTRY TOTAL	127.74	266.66	744.45	1299.11	2152.60
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	127.74	266.66	744.45	1299.11	2152.60
ALL ANNUAL COSTS	127.74	266.66	744.45	1299.11	2152.60

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.2.2. INORGANIC CHEMICALS—(PHASE II)

(Some or all of the regulations governing this industry were revoked on November 23, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capabilities

Of the 41 inorganic chemicals included in this category, effluent limitations guidelines and new source performance standards have been proposed for 27. No standards have been proposed for the following 14 products, which will not be considered further in this report:

Ammonium hydroxide	Potassium permanganate
Barium carbonate	Sodium bisulfite
Carbon dioxide	Sodium hydrosulfide
Cuprous oxide	Sodium hydrosulfite
Ferrous sulfate	Sodium thiosulfate
Manganese Sulfate	Sulfur dioxide
	Nitric acid (strong)

Five other compounds in this category are also excluded from this study, for the following reasons. Treatment costs for chromic acid are included in Phase I under sodium dichromate. There are no water effluents, hence no treatment costs, for stannic oxide or refinery by-product hydrogen. Only one facility not associated with the DOE produces fluorine, and that uses a process from which there is no waterborne discharge. Finally, there are no water-treatment costs cited in the Development Document for facilities that produce chrome pigments and iron blue.

The Phase II inorganic chemicals included in this study may be divided into four categories based on the character of pollutants in the treated effluents. The basis for the categorization is as follows:

Category A chemicals have processes that yield no discharge of suspended solids or harmful materials in their treated effluent waters.

Category B chemicals have processes which yield suspended solids in the treated effluent, but there are no harmful materials present.

Category C chemical processes have treated effluents containing no suspended solids, but harmful materials are present.

Category D chemical processes have treated effluents containing both suspended solids and harmful materials.

Some of these inorganic chemicals are produced by more than one process and occupy more than one category. A summary of the categorization is shown in Table 4.2.2–1.

Table 4.2.2–1.
Categorization of Phase II Inorganic Chemical Processes

Category	Product	Process
A	Ammonium Chloride	anhydrous neutralization
	Borax	mining and Trona
	Boric Acid	Trona
	Bromine	
	Calcium Hydroxide	
	Copper Sulfate	
	Ferric Chloride	
	Hydrogen Cyanide	acrylonitrile by-product
	Iodine	
	Lithium Carbonate	Trona
	Potassium Chloride	mining and Trona
	Sodium Fluoride	anhydrous neutralization
	Zinc Sulfate	
	Zinc Oxide	dry
B	Calcium Carbonate	
	Lithium Carbonate	Spodumene ore
C	Ammonium Chloride	
	Carbon Monoxide and Hydrogen	reforming
	Nitrogen and Oxygen	air distillation
D	Aluminum Fluoride	
	Boric Acid	
	Copper Sulfate	recovery
	Hydrogen Cyanide	Andrussow
	Lead Oxide	
	Nickel Sulfate	impure raw materials
	Potassium Iodide	
	Silver Nitrate	
	Sodium Fluoride	from Sodium Silicofluoride
	Sodium Silicofluoride	

Table 4.2.2–2 shows the latest production and capacity data for the 22 products included in this category. No production data are available after 1975, and for many of the products the data are even older. Capacity data are given in terms of numbers and average sizes of model plants. When actual plant sizes were not known, estimates were based on production and the number of plants.

Table 4.2.2–2.
Production and Model Plants for
Phase II Inorganic Chemicals
(Production and Capacity in thousands of metric tons/yr with thousands of short tons/yr in parentheses)

Product	Production[1]	Model Plants: Average	Range	Plants	Capacity
Aluminum fluoride	127 (140)[2]	24 (26)[3]	?	6	100.00
Ammonium chloride	16.5 (18.2)[4]	3 (3.3)[3]	?	6	100.00
Borax (from ore)	456 (503)[5]	346 (381)	50–650	2	100.00
Boric acid	68 (75)	25 (28)[3]	?	3	100.00
Bromine	189 (208)	13.6 (15)	< 40 (< 44)	5	23.80
		54.4 (60)	40+ (44+)	4	76.20
Calcium carbonate	182 (200[6]	10.6 (11.7)	?	19	100.00
Carbon monoxide and by-product hydrogen	148 (163)[6,7]	9 (9.9)[3]	?	18	100.00
Copper sulfate, from copper		2 (2.2)[3]	?	9	40.91
Copper sulfate, recovered	38 (42)[8]	2 (2.2)	?	13	59.09
Ferric chloride	75 (83)	9.7 (10.8)	< 25 (< 27.5)	10	25.55
	56.6 (62.4)	25+	(27.5+)	5	74.45
Hydrogen cyanide	79 (87)[8,9]	56 (61.7)	36–91 (37–100)	3	100.00
Iodine	1 (1.1)[4]	0.3 (.33)	?	4	100.00
Lead monoxide	127 (140[9]	9.4 (10.4[3]	?	15	100.00
Lithium carbonate	12 (13[4]	2.7 (3.0)[3]	?	5	100.00
Nickel sulfate	9 (10)[4]	0.8 (.9)[3]	?	12	100.00
Oxygen and nitrogen	42,320 (46,650)[10]	22 (35)	< 75 (< 82)	40	4.48
		98 (108)	75–149 (83–164)	43	14.72
		251 (277)	150–500 (165–550)	40	34.86
		661 (729)	> 500 (> 500)	20	45.94
Potassium chloride	2,006 (2,211)	178 (196)	< 300 (< 300)	6	37.95
		438 (493)	300+ (330)+	4	62.05
Potassium iodide	1 (1.1)[4]	9.12 (10.1)[3]	?	9	100.00
Silver nitrate	4 (4.4)[3]	0.6 (.66)[3]	?	7	100.00
Sodium silicofluoride	55 (61)[4]	10.2 (11.2)[3]	?	6	100.00
Zinc Sulfate	19 (21)[6]	9.2 (10.0)	4–20	6	100.00

Sources: Development Document
Chemical Economics Handbook
1977 Directory of Chemical Producers

[1]Unless otherwise indicated by footnote, production is for 1975.
[2]Production for 1973.
[3]Average model plant size estimated by assuming production was at 90 percent of capacity, then dividing estimated capacity by number of plants.
[4]Figure cited in Development Document as 1971 production.
[5]Total production was 531 thousand kkg (531 thousand tons), of which 456 thousand kkg (503 thousand tons) was estimated to have been produced from ore (rather than brine).
[6]Production for 1974.
[7]Production based on carbon monoxide.
[8]Total production was 122 thousand kkg (134 thousand tons), of which 79 thousand kkg (87 thousand tons) was estimated to be primary (versus recovered).
[9]Production for 1972.
[10]Number represents quantity of air separated, and was derived from oxygen produced and ratio of oxygen to oxygen plus nitrogen.

Waste Sources and Pollutants

The major wastewater pollutants generated in the production of inorganic chemicals are suspended solids and dissolved or suspended materials that may be harmful to one or more forms of life. These harmful materials may be unrecovered products or may be by-products of the main process.

Category A — Many chemicals in this category are produced in nonaqueous processes. In other cases, the process waters are continuously recycled and evaporated for recovery of products. A relatively small amount of wastewater is produced in housekeeping operations. Because proposed BPT and BAT guidelines specify no discharge of process water pollutants, wastewater quality parameters are not defined for this category.

Category B — Wastewaters generated in the production of Category B chemicals carry a substantial burden of suspended solids from process streams, including wet air scrubbers. In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: (1) total suspended solids (TSS) and (2) pH.

Category C — Production of chemicals in this category involves generation of process wastewaters which contain relatively little suspended solids but which are potentially harmful because of the presence of toxic materials, oils, or oxygen-depleting pollutants. Commonly, these wastewaters are wet scrubber effluents. In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT: (1) total suspended solids (TSS), (2) five-day biochemical oxygen demand (BOD_5), (3) chemical oxygen demand (COD), (4) oil and grease (O & G), (5) ammonia (NH3), (6) fluoride (F), (7) manganese ion (Mn), and (8) pH.

Category D — Most of the chemicals in this category are toxic to many life forms, and in all cases toxic pollutants are generated in their production. Wastewaters usually carry a substantial burden of suspended solids as well as heavy metal or other toxic ions. In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: (1) total suspended solids (TSS), (2) chemical oxygen demand (COD), (3) biochemical oxygen demand (BOD_5), (4) oil and grease (O & G), (5) ammonia (NH3), (6) cyanide (CN), (7) fluoride (F), (8) sulfide (S), (9) sulfite (SO_3), (10) silver ion (Ag), (11) arsenic ion (As), (12) barium ion (Ba), (13) copper ion (Cu), (14) hexavalent chromium ion (Cr^{6+}), (15) manganese ion (Mn), (16) nickel ion (Ni), (17) lead (Pb), (18) selenium ion (Se), (19) zinc (Zn), (20) iron (Fe), and (21) pH.

Control Technology and Costs

Wastewater control technologies differ among the various categories of inorganic chemical production.

Category A — The only wastewaters generated in production of most Category A chemicals result from housekeeping operations. Where significant process wastewaters are produced, current practice provides disposal without discharge. Some of the chemicals, such as borax, are produced in arid regions, and wastewaters may be contained in evaporation ponds. Others, such as copper sulfate, are produced from pure chemicals, so that all process waters may be recycled for product recovery. Bromine and iodine are manufactured by brine extraction, and the spent brine is returned to the well. Proposed BPT and BAT guidelines and New Source Performance Standards for plants in this category specify no discharge of process water pollutants to be achieved by improved containment and reuse of wastewaters.

Category B — Only calcium carbonate and lithium carbonate from spodumene ore are classified in this category. BPT guidelines can be achieved by neutralization and settling, but evaporation to remove dissolved solids is required to meet BAT guidelines.

Category C — This category includes ammonium chloride as a by-product of the Solvay soda ash process, carbon monoxide and hydrogen from reforming, and oxygen and nitrogen from air distillation. For ammonium chloride, BPT guidelines can be met by neutralization, returning filter muds and sludges to the Solvay process, and replacing one barometric condenser to reduce ammonia emissions. All barometric condensers must be replaced to meet BAT guidelines. For carbon monoxide/hydrogen production, oil separation, neutralization, and sludge disposal are sufficient to meet BPT guidelines. Additional segregation of wastes is required to meet BAT guidelines. Both BPT and BAT guidelines can be met for air distillation by oil separation, ponding, isolation of oil-contaning water, separation, and disposal.

Category D — Wastewaters generated in production of chemicals in this category are treated chemically for removal of toxic materials and retained in settling ponds for removal of suspended solids. Specific treatment processes may be required, e.g. wastewaters from barium carbon-

ate production contain barium sulfide, which can be precipitated as barium sulfate by vigorous aeration. Other materials, such as heavy metals, are precipitated by lime. Proposed BPT guidelines for plants discharging to waterways call for removal of toxic ions by appropriate chemical treatment and removal of suspended solids by settling and filtration. Proposed BAT guidelines and New Source Performance Standards specify no discharge of process water pollutants for most subcategories, to be achieved by evaporation.

Nine chemicals in Phase II of the Inorganic Chemicals Industry were found for which the manufacturers do or may discharge process wastewaters to publicly-owned treatment works (POTWs) and for which pretreatment guidelines and standards were recommended.

These products are:

- copper sulfate,
- ferric chloride,
- lead monoxide,
- nickel sulfate,
- nitrogen and oxygen
- potassium iodide
- silver nitrate
- sodium fluoride.

No pretreatment of process wastewaters was found to be necessary for facilities that manufacture potassium iodide. Recommended pretreatment technologies for the others are shown in Table 4.2.2-3.

Costs

Control costs for the various Phase II inorganic products are shown in Table 4.2.2–4.

Table 4.4.2–3
Recommended Pretreatment Technologies for Phase II Of The Inorganic Chemicals Industries

	Copper Sulfate	Ferric Chloride	Lead Monoxide	Nickel Sulfate	Nitrogen and Oxygen	Silver Nitrate
Metal Precipitation	X	X	X	X	—	X
Neutralizating	X	X	X	X	—	X
Flocculating	—	—	—	—	—	X
Coalescing	—	—	—	—	X	—
Settling	X	X	X	X	—	—
Filtering	—	—	—	—	—	X
Centrifuging	—	X	—	—	—	—
Discharging to POTW	X	X	X	X	X	X
Chemical Landfilling	—	—	—	X	X	—
Recycling	—	X	X	—	—	X

TABLE 4.2.2–4. INORGANIC CHEMICALS INDUSTRY (PHASE II) WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	8.76	22.65	0.46	0.47	0.47
BAT	0.0	0.0	8.55	17.11	17.11
NEW PLANTS	0.51	1.95	2.20	3.41	5.38
PRETREATMENT	0.22	0.58	0.01	0.01	0.01
SUBTOTAL	9.49	25.17	11.23	21.00	22.97
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	9.49	25.17	11.23	21.00	22.97
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	2.98	6.19	12.15	18.23	27.35
BAT	0.0	0.0	1.69	5.62	12.37
NEW PLANTS	0.26	0.63	1.74	3.07	5.69
PRETREATMENT	0.08	0.16	0.31	0.46	0.70
TOTAL	3.31	6.98	15.88	27.38	46.11
O&M					
EXISTING PLANTS					
BPT	4.79	9.95	19.52	29.26	43.86
BAT	0.0	0.0	2.72	9.08	19.96
NEW PLANTS	0.55	1.34	3.95	7.14	13.83
PRETREATMENT	0.14	0.29	0.54	0.80	1.18
TOTAL	5.48	11.58	26.73	46.28	78.84
INDUSTRY TOTAL	8.79	18.56	42.61	73.66	124.94
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	8.79	18.56	42.61	73.66	124.94
ALL ANNUAL COSTS	8.79	18.56	42.61	73.66	124.94

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.3 PLASTICS AND SYNTHETICS INDUSTRY

(Some or all of the regulations governing this industry were remanded on March 10, 1976 and revoked on August 4, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capacities

The plastics and synthetics industry comprises 13 product subcategories in Phase I (for which the promulgated effluent guidelines and standards were revoked on August 4, 1976) and eight product subcategories in Phase II. The subcategories in Phase I include polyvinyl chloride, polyvinyl acetate, polystyrene, polypropylene, polyethylene (high-density and low-density), cellophane, rayon, acrylonitrile-butadiene-styrene (ABS) and styrene-acrylonitrile (SAN), polyester fiber, nylon 66, nylon 6, cellulose acetate, and acrylics. Those in Phase II include ethylene-vinyl acetate copolymers (EVA), polytetrafluoroethylene, polypropylene fibers, alkyds and unsaturated polyester resins, cellulose nitrate, polyamide (nylon 6/12), polyester resins (thermoplastic), and silicones. Other products covered in the Development Documents but for which there are no effluent limitations guidelines include epoxy, phenolic, melamine, and urea resins, cellulose derivations (ethyl cellulose, hydroxyethyl cellulose, methyl cellulose, and carboxymethylcellulose), polyvinylidene chloride, polyvinyl butyral, polyvinyl ethers, nitrile barrier resins, and Spandex fibers.

Production of the various resins and plastics materials involves a variety of chemical polymerization processes in which large synthetic polymers are formed from small monomers. Organic fibers, such as polyester, polypropylene, the nylons, rayon, and cellulose acetate, are produced by adding a spinning process after the polymer has been produced.

Waste Sources and Pollutants

In order to set effluent limitations guidelines, the dimension of wastewater characteristics was chosen as a basis for subcategorization. The four major subcategories are defined as:

- Major Subcategory I: Low waste load (< 10 kg/metric ton), low attainable BOD_5 concentration (< 20 mg/1). Products affected: polyvinyl chloride, polyvinyl acetate, polystyrene, polyethylene, polypropylene, ethylenevinyl acetate, fluorocarbons, and polypropylene fiber.
- Major Subcategory II: High waste load (> 10 kg/metric ton), low attainable BOD_5 concentration (< 20 mg/1). Products affected: ABS/SAN, cellophane, and rayon.
- Major Subcategory III: High waste load (> 10 kg/metric ton), medium attainable BOD_5 concentration (30–75 mg/1). Products affected: polyesters, nylon 66, nylon 6, cellulose acetates, alkyd and unsaturated polyester resins, cellulose nitrate, polyamides, saturated thermoplastic polyesters, and silicones.
- Major Subcategory IV: High waste load (> 10 kg/metric ton), low treatability. Product affected: acrylics.

The main sources contributing to the total waste load come from spills, leaks, and accidents. Other sources include: washdown of process vessels, area housekeeping, utility blowdown, and laboratory wastes. Waste streams from cooling towers, steam-generating facilities, and water treatment facilities are generally combined with process wastewater and then are sent to the treatment plant.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT, BAT, and NSPS: BOD_5, COD, TSS, zinc, pH, phenolic compounds, and total chromium.

Control Technology and Costs

Waste treatment methods in the plastics and synthetics industry include the following: biological treatment, single- or double-stage aeration, adsorption, granular activated carbon systems, chemical precipitation, anaerobic processing, air stripping, chemical oxidation, foam separation, algal systems, incineration, liquid extraction, ion ex-

change, reverse osmosis, freeze-thaw, evaporation, electrodialysis, and in-plant controls.

BPT guidelines for existing point sources are based on the application of end-of-pipe technology, such as biological treatment for BOD reduction by activated sludge, aerated lagoons, trickling filters, aerobic-anaerobic lagoons, etc., with preliminary treatment typified by equalization, dampening of shock loadings, settling, and clarification. BPT also calls for chemical treatment for the removal of suspended solids, oils, and other elements, as well as pH control and subsequent treatment typified by clarification and polishing processes for additional BOD and suspended solids removal, and dephenolizing units for phenolic compound removal when needed. In-plant technology and other changes that may be helpful in meeting BPT include segregation of contact process wastewater from non-contact wastewaters, elimination of once-through barometric condensers, control of leaks, and good housekeeping practices.

BAT standards call for the segregation of contact process waters from non-contact wastewater, maximum wastewater recycle and reuse, elimination of once-through barometric condensers, control of leaks, good housekeeping practices and end-of-pipe technology, further removal of suspended solids and other elements typified by multi-media filtration, chemical treatment, etc. Also included are further COD removal as typified by the application of adsorptive flocs, and incineration for the treatment of highly-concentrated, small-volume wastes, as well as additional biological treatment for further BOD_5 removal when needed.

New Source Performance Standards are based on BPT and call for the maximum possible reduction of process wastewater generation and the application of multi-media filtration and chemical treatment for additional suspended solids, other element removal, and additional biological treatment for further BOD removal as needed.

Control costs are detailed in Table 4.3–1.

TABLE 4.3–1. PLASTICS AND SYNTHETICS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	68.37	168.04	4.25	4.25	4.25
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	21.24	72.47	114.46	195.86	363.20
PRETREATMENT	0.31	0.74	0.02	0.02	0.02
SUBTOTAL	89.92	241.25	118.73	200.13	367.47
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	89.92	241.25	118.73	200.13	367.47
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	22.09	45.83	90.61	135.91	203.86
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	9.53	22.51	73.53	138.41	286.39
PRETREATMENT	0.10	0.20	0.40	0.61	0.91
TOTAL	31.72	68.54	164.54	274.92	491.16
O&M					
EXISTING PLANTS					
BPT	6.65	13.77	26.92	40.01	59.19
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	3.75	8.85	29.08	54.85	113.85
PRETREATMENT	0.14	0.29	0.57	0.86	1.28
TOTAL	10.54	22.91	56.57	95.72	174.32
INDUSTRY TOTAL	42.26	91.46	221.11	370.64	665.48
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	42.26	91.46	221.11	370.64	665.48
ALL ANNUAL COSTS	42.26	91.46	221.11	370.64	665.48

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.4. RUBBER MANUFACTURING

Production Characteristics and Capacities

This industry includes the manufacture of tires and inner tubes; synthetic rubber; general molded, extruded, and fabricated rubber products; reclaimed rubber; latex-dipped products; and latex foam.

Tires and inner tubes are classified in SIC 3011. The typical tire manufacturing process includes the following:

- Preparation or compounding of the raw materials
- Transformation of these compounded materials into five tire components—tire bead coating, tire treads, tire sidewall, inner liner stock, and coated cord fabric
- Building, molding, and curing the final product.

The raw materials used include a variety of synthetic and natural rubbers; three categories of compounding materials: filler, extenders, and reinforcers (carbon black and oil are two common examples); and other chemicals that are used as antioxidants, pigments, or curing and accelerating agents. Compounding is usually carried out in a batch-type, internal mixing device called a Banbury mixer. After mixing, the compound is sheeted out in a roller mill, extruded into sheets, or pelletized. The sheeted material is tacky and must be coated with a soapstone solution to prevent the materials from sticking together during storage. The compounded rubber stock is transformed into one of the tire components by molding, extruding, calendering, and a variety of other operations. The tire is built up as a cylinder on a collapsible, round rotating drum by applying the inner layer, then by adding layers of cord, beads, belt, and tread. Finally the "green" tire is molded and cured in an automatic press, and the excess rubber is ground off. Inner tubes are produced using the same basic processing steps.

Tire and tube products are produced in 56 plants in the United States; about 70 percent of these plants are operated by Firestone, General Tire, Goodrich, Goodyear, and Uniroyal. The remaining plants are operated by 11 other companies. Tire plants vary widely in capacity; the largest produce approximately 30,000 tires per day, and the smallest produces less than 5,000 per day.

The production of synthetic rubber is classified in SIC 2822. For the purpose of establishing effluent limitations guidelines, the synthetic rubber industry has been divided into three subcategories: emulsion crumb, solution crumb, and latex. Crumb rubbers, generally for tires, are sold in a solid form, and are produced through two different processes: emulsion polymerization and solution polymerization. Latex rubbers, generally for specialty products, are sold in latex form, and are produced through emulsion polymerization.

Emulsion polymerization is the traditional and dominant process for producing synthetic rubber. The raw materials (monomers) are usually styrene and butadiene, to which a catalyst, activator, and modifier are added in a soap solution to produce an emulsion in an aqueous medium; polymerization proceeds step-wise through a train of reactors. The product rubber is formed in the emulsion phase of the reaction mixture, which is a milky white emulsion called latex. Unreacted monomers are then recovered from the latex by vacuum stripping; the production process ends at this point for latex rubbers. If crumb rubber is desired, sulfuric acid and sodium chloride are added to the latex to coagulate out the crumb rubber, which is then dewatered, rinsed, filtered, and finally dried with hot air to produce the final product.

The production of synthetic rubbers by solution polymerization is a step-wise processing operation very similar to emulsion polymerization. For solution polymerization, the monomers must be extremely pure, and the solvent (hexane, for example) must be completely anhydrous. The polymerization reaction is more rapid (1 to 2 hours) and is taken to over 90 percent conversion as compared to 60 percent conversion for emulsion polymerization. Both monomers and solvents are generally passed through drying columns to remove all water. After reaction, the mixture leaves the reactor as a rubber cement; i.e. polymeric rubber solids dissolved in solvent. As with emulsion polymerization, coagulation, washing, dewatering, and drying processes produce the final product.

Fourteen companies operating 28 plants produce the major synthetic rubbers in the United States. Most of these plants are part of diversified complexes that produce other products, such as rub-

ber processing chemicals, plastics, and basic intermediate organic chemicals. Latex is produced by 21 plants owned by 13 companies, nine of which are not included in the preceding listing. The U.S. production of major elastomers in 1976 was as follows:

	Production thousands of metric tons (thousands of short tons)
Styrene-butadiene (SBR)[1]	1,346 (1,484)
Butyl	126 (139)
Nitrile[1]	77 (85)
Polybutadiene	354 (390)
Polyisoprene	74 (82)
Ethylene-propylene	134 (148)
Other[2]	256 (282)
Total	2,368 (2,610)

[1] Includes latex.
[2] Includes neoprene.

General molded, extruded, and fabricated rubber products include such disparate items as rubber footwear (SIC 3021), rubber hose and belting (SIC 3041), fabricated rubber products not elsewhere classified (SIC 3069), rubber gaskets, packings, and sealing devices (SIC 3293), and tire retreading (SIC 7534). SIC 7534 was not included in this analysis. There are about 1,450 plants in the other four 4-digit SIC codes. The value of shipments by all establishments in these four categories is estimated to have been $6 billion in 1976 and should reach about $10.5 billion in 1986.

The manufacturing processes for these rubber products include compounding of the rubber stocks, then forming of the compounded stock by a variety of means, such as molding, extrusion, lay-up, or other fabrication means.

Reclaimed rubber is classified in SIC 3031. The reported consumption of reclaimed rubber declined from 268,000 metric tons (295,000 short tons) in 1966 to 172,000 metric tons (190,000 short tons) in 1973. Because of higher costs of petrochemical feedstocks for synthetic rubber, consumption of reclaimed rubber may have reached 204,000 metric tons (225,000 short tons) in 1976 and could reach 272,000 metric tons (300,000 short tons) in 1986.

Scrap separation and size reduction steps are common to all reclaim rubber processes. In wet digestion processes, the ground rubber is partially depolymerized by heating with reclaiming agents and water in an autoclave, followed by digestion with defibering agents to remove fibers. In the pan process, the ground rubber scrap is further reduced in size and defibered by additional grinding. It is blended with reclaiming oils and heated in open pans in a pressure vessel. In the continuous mechanical process, the finely ground, fiber-free scrap is fed continuously into a heated, high-shear screw machine in the presence of reclaiming agents and depolymerization agents. The reclaimed products are shipped in slabs or bales.

Latex-based products are included in SIC 3069, Fabricated Rubber Products not Elsewhere Classified. Information is Not available relative to the number and sizes of plants producing latex-dipped products and latex foam products. Plants producing such products are not considered separately in this report from the category of general molded, extruded, and fabricated rubber products.

Waste Sources and Pollutants

The primary water usage in the tire and inner tube industry is for non-contact cooling and heating. Discharges from service utilities supplying cooling water and steam are the major source of contaminants in the final effluent. However, these non-process related discharges are not covered by effluent limitations guidelines for this industry. The process wastewaters consist of mill area oily waters, soapstone slurry and latex dip wastes, area washdown waters, emission scrubber waters, and contaminated storm waters from raw material storage areas, etc. For the purposes of establishing effluent limitations guidelines for manufacturers of tires and inner tubes, the following pollutant parameters have been designated as significant: suspended solids, oil and grease, and pH. Pollutant parameters considered to be of less significance are biochemical oxygen demand, chemical oxygen demand, dissolved solids, temperature (heat), and chromium.

The principal waste streams from synthetic rubber manufacture are steam and condensate from the monomer recovery stripping operation, overflow of coagulation liquors, and overflow of the crumb rubber rinse waters. Area washdown and equipment clean-out wastewaters are also major sources of pollutants, particularly in latex rubber plants where clean-up is more frequent because of smaller production runs. For manufacturers of synthetic rubbers, the following pollutant parameters have been designated as significant: chemical oxygen demand, biochemical oxygen demand, suspended solids, oil and grease, and pH. Pollutants also present in measurable quantities in the waste streams, but not designated as significant, include: total dissolved solids, surfactants, color, and temperature (heat).

The major wastewater streams from the production of general molded, extruded, and fabricated rubber products are spills, leakage, washdown, and runoff from processing and storage areas; vulcanizer condensate from the curing of lead-sheathed and cloth-wrapped hoses; and vulcanizer condensate from the cure of cement-dipped items. Process wastewaters are of a low flow rate and have little impact on the total effluent flow rate. The most significant process wastewater streams occur by spillage, leakage, washdowns, and runoff. They contribute the majority of the suspended solids and oil in the final effluent. The flow rate of this type of process wastewater is dependent on plant size, and increases relative to production level as plant size decreases.

The primary source of process wastewater loadings for wet-digestion reclaimed rubber is dewatering liquor. High COD and oil loadings are characteristic of this discharge. When mechanically defibered scrap is fed to the wet digester process, suspended solids are contained in the dewatering liquor owing to the carrying over of depolymerized rubber fines. If defibering is carried out chemically in the digestion step, additional suspended solids due to the fiber will be present.

A second major source of contaminant loadings for both wet and dry processes is spills, leaks, and washdown from processing areas. The discharge is qualitatively similar to the corresponding discharge from general fabricating processes; however, flow rates and loading on a per-day basis are substantially higher. Another major source of contaminant loadings is air-pollution control equipment used to collect light organics which are vaporized or entrained in the vapors leaving the pan devulcanizers or the wet digester system. Flows and loadings from the wet digester process are substantially higher than those of the pan process. In the wet digestion process, the oil contained in these condensates can be recycled.

Product wash waters are the principal source of wastewaters from the manufacture of latex-based products. These waters are characterized by loadings of BOD, COD, dissolved solids, and suspended solids. In addition, wash waters from latex foam facilities can contain high concentrations of zinc. Spills, leaks, washdown, and runoff from latex storage, compounding, and transfer areas will contain latex and are characterized by COD, BOD, suspended solids, dissolved solids, oil, and surfactants. Form cleaning wastewaters in latex-dipping operations may contain COD, BOD, suspended solids, and possibly chromium (from chromic acid cleaning solutions).

Control Technology and Costs

In the tire and inner tube industry, the emphasis for present environmental control and treatment technologies is placed on the control of air quality and the reduction of pollutants in non-process wastewaters. As a result, no adequate overall control and treatment technology is employed by plants within the industry. Primary emphasis is on removal of separable solids from the non-process boiler blowdowns and water treatment wastes, and from process washdown waters from the soapstone area. Because of substantial dilution of process wastewater by non-process waters, treatment is much less effective than could be expected, especially for oil and grease.

The technologies recommended to meet the effluent limitations guidelines for the manufacture of tires and inner tubes are:

1. Elimination of any discharge of soapstone solution by:
   - Recycling
   - Installation of curbing and the sealing of drains in the soapstone dipping area
   - Reuse of the recirculating system washwater as make-up for fresh soapstone solution.
2. Elimination of any discharge of latex solution by:
   - Installation of curbing and the sealing of drains in the latex dipping area
   - Containment of all wastewaters in the area and disposal by landfill.
3. Segregation, control, and treatment of all oily waste streams.
4. Isolation of process waters from non-process wastewaters.
5. Treatment of process wastewaters with API-type gravity separators to remove separable oil and solids.
6. Additional treatment through an absorbent filter for further oil removal.

The control and treatment technology recommended to meet BPT and NSPS guidelines for emulsion crumb and latex plants is chemical coagulation and biological treatment, improved housekeeping and maintenance practices, as well as in-plant modifications, particularly the use of crumb pits to remove crumb rubber fines from coagulation liquor and crumb rinse overflows. BAT

has been defined as BPT plus the equivalent of dual-media filtration followed by activated carbon treatment of the effluent from the biological treatment systems. Because solution crumb wastewaters do not contain uncoagulated latex solids, the chemical coagulation step is not necessary. BPT and NSPS technology for solution crumb plants have been defined as comparable to primary clarification and biological treatment, with the use of crumb pits to catch crumb rubber fines before treatment. BAT for solution crumb plants is the same as that for emulsion crumb plants.

The control and treatment technology recommended for general molded, extruded, and fabricated products plants to meet BPT and NSPS guidelines consists of eliminating anti-tack or latex solution discharge and isolation, control, and treatment of all oily waste streams. The discharge of anti-tack and latex solutions can be eliminated by recycling of soapstone solution, installation of curbing around the soapstone dipping area and latex storage and transfer areas, sealing of drains in the dipping area and latex use areas, reuse of the recirculating system wash water as make-up for fresh soapstone solution, and the containment of all latex-contaminated waste streams.

Control and treatment of oily waste streams involves segregation, collection, and treatment of runoff from oil storage and unloading areas and leakage and spills in the process areas. Press and mill basins, when present, are included in the process area. BAT guidelines are the same as BPT guidelines except for limitations on lead effluents for plants that use a lead-sheathed cure in hose production. Flow rates of these emissions are small, and they can sometimes be controlled by containerization. In other cases, precipitation or ion exchange will be required.

Only one wet-digestion reclaim rubber plant discharges directly, and it is meeting BAT guidelines through use of a waste stream recycle and reclaim system. No new plants will use the wet-digestion process.

Wastes from the pan, mechanical, and dry digestion reclaim processes are comparable to those from the general molded rubber plants. The technology recommended for meeting BPT, BAT, and NSPS guidelines includes eliminating anti-tack solution discharge and segregation, control, and treatment of all oily waste.

The control and treatment technology recommended for latex-dipped products to meet BPT, BAT, and NSPS guidelines includes chemical coagulation, separation, and disposal of waste latex followed by treatment of the clarified waste stream in an aerated lagoon and subsequent settling and removal of the settled solids. Careful housekeeping and good latex handling practices can reduce or potentially eliminate the latex-laden wastes.

For latex foam, the technologies recommended to meet BPT and NSPS guidelines include chemical coagulation and clarification of latex-bearing wastewaters and chemical precipitation of zinc from the rinse waters. The clarified wastewaters from these two streams are combined in a neutralization tank and the pH is adjusted to a level suitable for biological treatment. For BAT guidelines, an activated sludge biological treatment is recommended.

A minimum level of pretreatment must be given to wastewaters that will be discharged from new production facilities to publicly owned treatment works, and pollutants which would inhibit or upset the performance of such treatment works must be eliminated. Pretreatment recommendations for process wastewaters from the tire and inner tube industry include the separation of oils and solids in an API gravity separator and the use of an equalization basin to prevent shock loads of oil, suspended solids, or batch dumps of dipping solutions. For non-process wastewaters, such problems as acidity, alkalinity, solids, oils, and heavy metals may require control at the plant to conform to local ordinances for discharge to publicly owned treatment works.

The following pretreatment requirements apply to wastewater discharges to publicly owned water works from synthetic rubber plants:

Emulsion Crumb Subcategory — Gravity separation of crumb fines in crumb pits, chemical coagulation and clarification of latex-laden wastewaters, and neutralization or equalization of utility wastes.

Solution Crumb Subcategory — Gravity separation of crumb fines in crumb pits, and neutralization or equalization of utility wastes.

Latex Subcategory — Chemical coagulation of latex-laden wastewaters, and neutralization or equalization of utility wastes.

Pretreatment recommendations for process wastewaters from facilities producing molded, extruded, and fabricated rubber products; wet-digestion reclaimed rubber; and pan, mechanical, and dry digestion reclaimed rubber include the separation of oils and solids and the use of an

equalization basin to prevent shock loads of oil, suspended solids, or batch dumps of dipping solution from upsetting the performance of treatment works. In addition, lead-laden wastewaters from general rubber products, chromium from latex-dipped products, and zinc from latex foam products must be treated. If fibers are digested with rubber scrap, a large sedimentation lagoon may be required.

Control costs are detailed in Table 4.4.-1.

TABLE 4.4–1 RUBBER INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	68.08	153.18	1.55	1.55	1.55
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	4.17	15.86	18.22	28.33	44.92
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	72.25	169.04	19.76	29.88	46.47
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	72.25	169.04	19.76	29.88	46.47
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	20.14	39.47	81.37	122.06	183.09
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	2.09	5.12	14.22	25.17	46.91
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	22.22	44.59	95.59	147.22	229.99
O&M					
EXISTING PLANTS					
BPT	15.63	30.63	63.16	94.74	142.12
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	1.81	4.44	12.36	21.89	40.85
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	17.44	35.08	75.53	116.64	182.97
INDUSTRY TOTAL	39.67	79.67	171.12	263.86	412.96
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	39.67	79.67	171.12	263.86	412.96
ALL ANNUAL COSTS	39.67	79.67	171.12	263.86	412.96

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.5 SOAP AND DETERGENT INDUSTRY

Production Characteristics and Capacities

Soap and detergent industry establishments are engaged in the manufacture of soap, synthetic organic detergents, inorganic alkaline detergents, or any combination of these processes. The term "soap" refers to those cleaning agents which are derivatives of natural fat. The term "detergent" is generally restricted to cleaning compounds derived largely from petrochemicals.

Soaps and detergents are produced by a variety of manufacturing processes. For the purpose of establishing effluent limitation guidelines and standards of performance the industry has been divided into 19 subcategories based on processes and products:

Soap Manufacture

- Soap Manufacture — Batch Kettle and Continuous
- Fatty Acid Manufacture by Fat Splitting
- Soap From Fatty Acid Neutralization
- Glycerine Recovery
- Glycerine Concentration
- Glycerine Distillation
- Soap Flakes & Powders
- Bar Soaps
- Liquid Soap

Detergent Manufacture

- Oleum Sulfonation & Sulfation (Batch & Continuous)
- Air-SO_3 Sulfation and Sulfonation (Batch & Continuous)
- SO_3 Solvent and Vacuum Sulfonation
- Sulfamic Acid Sulfation
- Chlorosulfonic Acid Sulfation
- Neutralization of Sulfuric Acid Esters & Sulfonic Acids
- Spray Dried Detergents
- Liquid Detergent Manufacture
- Detergent Manufacturing By Dry Blending
- Drum Dried Detergents
- Detergent Bars & Cakes

The leading products for each class are toilet bars in the soap segment and laundry detergents in the detergent segment. In 1976 household laundry detergents accounted for 59 percent of the total value of shipments of soaps and detergents made by all industries.

Data from the *U.S. Industrial Outlook, 1977*, identify 642 establishments in the industry. The largest fraction of these establishments, 32 percent, is located in the North Central region of the United States. Although there are a large number of producers, the soap and detergent industry is an oligopolistic industry. Fifteen of the establishments, 2 percent, account for 47 percent of the industry's value of shipments, and 33 establishments, 5 percent, account for 69 percent of the industry's value of shipments. The "big three" companies in the soap and detergent industry are Proctor & Gamble, Lever Brothers, and Colgate-Palmolive.

According to the *U.S. Industrial Outlook, 1977*, the value of shipments for the soap and detergent industry in 1976 was $5.7 billion, a 14 percent increase over 1975. Estimates for 1977 are $6.5 billion, a 14 percent increase over 1976. Continued growth is expected.

Production is expected to increase at an annual growth rate of 6.5 percent until 1980, and 4.6 percent during the period 1980 to 1985.

Waste Sources and Pollutants

The manufacturing of soaps and detergents represents a minor source of water pollution. Approximately 98 percent of the plant effluents go to municipal treatment plants with the remaining 2 percent of the industry discharging as point sources. Raw waste loads from the soap and detergent manufacturing processes vary considerably.

The processes that are heavy effluent generators are: (1) batch kettle, (2) fatty acid manufacturing by fat splitting and distillation, (3) glycerine recovery, (4) bar soap manufacture, (5) spray drying of detergents, and (6) manufacture of liquid detergents. The major pollution sources for these processes are: washout of equipment, leaks and spills, discharge of barometric condenser water, cooling tower blowdown, and discharge of scrubber waters from air pollution control equipment. Constituents of these wastewater streams are fats, fatty acids, glycerine, oil and grease, salts, lye, and the soap or detergent produced in the plant.

The other processes are able to recycle their wastewater or use a dry cleanup process. Therefore, they are virtually non-polluting.

The pollutants covered by the effluent limitations guidelines for the soap and detergent industry are BOD_5, COD, suspended solids, surfactants, oil and grease, and pH.

Control Technology and Costs

The largest reductions in the pollution load from this industry can be made through lower process water usage. One of the biggest improvements would be either changing the operating techniques associated with the barometric condensers or replacing them entirely with surface condensers. Large reductions in water usage in the manufacture of liquid detergents could be achieved through the installation of additional water recycling, and by the use of air rather than water to blow out filling lines.

BPT guidelines call for plants to adopt good housekeeping procedures, adopt recycling where appropriate, and install biological secondary treatment (bioconversion). BAT guidelines assume improvement in manufacturing processes such as the replacement of barometric condensers by surface condensers, the installation of tandem-chilled water scrubbers (for spray-dried detergents), and the use of a batch counter-current process in air-SO_3 sulfation and sulfonation. In addition, improvements in end-of-pipe treatment are expected including the addition of sand or mixed-media filtration or the installation of a two-stage, activated sludge process. New source performance standards are the same as BAT for most product subcategories. Improvements over BAT are expected where the installation of new, lower-polluting processes, such as continuous processes instead of batch processes, is possible.

Since approximately 98 percent of the soap and detergent manufacturers discharge into municipal sewers, the total cost to the industry of meeting these guidelines is low. For the purpose of estimating annualized control costs, three model plants were created. These models contain principally those processes to be heavily impacted by the effluent guidelines recommendations. The models are:

(1) a small soap company
(2) a small liquid detergent company
(3) a very large integrated soap and detergent company

The control costs for the industry are shown in Table 4.5.-1.

TABLE 4.5–1. SOAP AND DETERGENT INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.99	3.00	0.75	0.75	0.75
BAT	0.0	0.0	0.53	0.70	0.70
NEW PLANTS	0.34	1.23	1.46	2.12	3.22
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	2.33	4.24	2.74	3.57	4.68
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	2.33	4.24	2.74	3.57	4.68
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.39	0.63	1.97	2.96	4.44
BAT	0.0	0.0	0.14	0.32	0.60
NEW PLANTS	0.16	0.39	1.14	1.97	3.58
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.56	1.02	3.25	5.26	8.62
O&M					
EXISTING PLANTS					
BPT	0.19	0.30	0.95	1.42	2.14
BAT	0.0	0.0	0.06	0.15	0.27
NEW PLANTS	0.08	0.19	0.54	0.94	1.71
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.27	0.49	1.55	2.51	4.11
INDUSTRY TOTAL	0.82	1.51	4.80	7.77	12.73
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.82	1.51	4.80	7.77	12.73
ALL ANNUAL COSTS	0.82	1.51	4.80	7.77	12.73

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.6. CARBON BLACK INDUSTRIES

The Product and Its Manufacturing Processes

Carbon black is a black, fluffy, finely divided powder consisting of 90 to 99 percent elemental carbon. Carbon black is uniquely different from other bulk carbons, such as charcoals and cokes, both in terms of properties and applications. Although there are many different grades of carbon black, it is generally treated as a single product.

In essence, carbon black is manufactured by producing carbon from either liquid or gaseous hydrocarbon materials. Depending upon the process, the production is achieved either by thermal degradation or incomplete combustion. In the United States, there are currently four different manufacturing processes employed. Each process is briefly described below.

The Furnace Black Process

In the furnace black process, carbon black is produced by the partial combustion of natural gas or petroleum distillates. In the gas furnace process, natural gas is partially combusted in refractory-lined furnaces. The carbon particles are removed from the gas stream by means of bag filters. Yields (in terms of the percent of carbon in the feedstock actually converted to carbon black) for plants employing the gas furnace range from 10 to 30 percent.

In the oil furnace variation, low-sulfur oil, similar to residual oil, is generally atomized into a natural gas-fired combustion zone. The carbon black particles are collected by bag filters in the same manner as the in gas furnace variation. Yields for the oil furnaces range from 35 to 65 percent. Higher yields, coupled with an increasing shortage of natural gas, have been responsible for a trend toward oil furnace installations.

In terms of total installed capacity the furnace black process is the predominant one.

The Thermal Black Process

The thermal black process is based on the cracking of hydrocarbons rather than on partial combustion, as in the case of furnace black. Thermal black furnaces are operated in alternating heating and production cycles. During the heating cycle, the furnace is heated by burning hydrogen gas previously liberated from a production or cracking cycle. When heated to the proper temperature, the feedstock (generally natural gas) is introduced into the furnace, and the production cycle begins. Carbon is collected from quenched effluent gases also by means of bag filters. Yields generally range from 40 to 50 percent. Although the thermal process is the second most predominant production process, the increasing price of natural gas does not favor its growth.

The Channel Black Process

The channel black process is an almost obsolete process in which carbon black is made by partially burning natural gas in special chambers where the flames are made to impinge upon cooled surfaces. Carbon black deposited on the surfaces is continuously removed by mechanical scrapers. The yields are very low, varying from 1 to 5 percent. Low yields, coupled with the rising price of natural gas, have virtually eliminated this process. In fact, there is only one channel black plant currently in operation.

The Lampblack Process

The lampblack process is the oldest method of manufacturing carbon black (its origin dates back to ancient times). Lampblack, as carbon black manufactured by this process is called, is manufactured by burning selected oils in a restricted supply of air. In terms of its contribution to total industry-wide production, lampblack manufacture is relatively insignificant. Since there are certain special applications for lampblack, it is still manufactured in the United States at two different plants.

Manufacture, Production, and Markets

Carbon black is currently manufactured by eight U.S. firms in a reported total of 36 active manufacturing facilities. As of 1974, the carbon black industry had a production capacity of approximately 1.89 million metric tons (2.09 million short tons) per year.

Over three fourths of the carbon black production capacity is located in Louisiana and Texas. The concentration of carbon black plants in the Gulf

Coast area was originally the result of a need to be near natural gas feedstock suppliers.

More than 91 percent of all carbon black currently produced is manufactured by the furnace process. Most of the remainder is manufactured by the thermal process. The amount of carbon black manufactured by the channel and lampblack processes is essentially insignificant (less than 0.1 percent of total production). The carbon black industry typically operates reasonably close to its production capacity. During 1973, the total production was 1.59 million metric tons (1.75 million short tons) or 83 percent of estimated total capacity.

In terms of markets, the carbon black industry has a very clearly defined group of major end users. The major end users of carbon black are found in the manufacture of rubber, printing ink, paint, paper and plastics. Typically, more than 93 percent of total carbon black consumption is in rubber applications, and the rubber tire industry is by far the principal consumer. (Upwards of 90 percent of all carbon black produced is destined for tire manufacturing.) Printing ink represents the second largest use of carbon black. The United States is a net exporter of carbon black (typically 5 percent of total production). Recently installed overseas production capacity has resulted in a trend toward shrinking U.S. exports, however.

Water Pollution Control Problems, Technology, and Costs

Neither the channel black process nor the lampblack process produces a contaminated process wastewater stream.

The thermal black process produces an inherent process wastewater stream. It consists of a recirculating cooling water purge contaminated with carbon black. In the thermal black process, furnace gas is quenched with water to reduce its temperature before it is passed through bag filters where the product carbon is removed. The hydrogen-containing exit gas thus contains an appreciable humidity, which must be removed before recycling the hydrogen back into the process as a fuel. The humidity in the gas stream is removed by cooling the gas stream with water sprays, thus lowering the gas temperature below the boiling point of water and thereby condensing out most of the moisture. The spent spray water undergoes a temperature rise caused by the liberated heat of condensation and must, therefore, be cooled prior to reuse. Typically, the spray water is part of a cooling water circuit in which fresh makeup water is added to replenish inevitable losses within the system. As with most cooling circuits, it is necessary to purge or "blow down" a certain fraction of the total circulation to prevent the buildup of undesirable contaminants. In the thermal black process, this blowdown stream is contaminated with small amounts of carbon black lost from the process. Certain thermal black plants eliminate this blowdown stream by using it to quench the hot gases leaving the furnaces. Otherwise, the purge stream forms a point-source discharge.

Carbon black manufacturing plants employing the furnace black process do not produce an inherent process wastewater stream. Certain furnace black plants, however, do have small plant washdown streams and stormwater runoff streams. The local rainfall/evaporation relationship plays a large role in determining whether there is, or is not, a point-source discharge from the plant. Of a total of 29 furnace black plants, 19 do not have point-source discharges. Some plants have no discharge primarily because of favorable climate conditions, while others are able to use excess water as quench water.

At least two (possibly three) out of a total of four thermal black plants presently do not discharge.

The cost model used here is based on two wastewater treatment steps: Step 1 consists of sedimentation and Step 2 consists of filtration. It is anticipated that certain plants will require only Step 1, while other plants will require both Step 1 and Step 2. In any case, the cost model provides for the treated effluent to be totally recycled back to the process.

Furnace Black

Of the 29 plants in this subcategory, only 10 plants (representing approximately 35 percent of the total furnace black production) discharge wastewater; therefore, it is unlikely that the other 19 will incur wastewater treatment costs.

Thermal Black

Of the four plants in this subcategory, only two plants appear to have point-source wastewater discharge.

Costs and other data for the Carbon Black Industry are summarized in Table 4.6.-1.

TABLE 4.6–1. CARBON BLACK INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.90	2.38	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.90	2.38	0.0	0.0	0.0
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.90	2.38	0.0	0.0	0.0
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.31	0.63	1.25	1.88	2.82
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.31	0.63	1.25	1.88	2.82
O&M					
EXISTING PLANTS					
BPT	0.05	0.08	0.32	0.48	0.72
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.05	0.08	0.32	0.48	0.72
INDUSTRY TOTAL	0.36	0.71	1.57	2.35	3.53
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.36	0.71	1.57	2.35	3.53
ALL ANNUAL COSTS	0.36	0.71	1.57	2.35	3.53

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.7. EXPLOSIVES INDUSTRIES

Production Characteristics and Capacities

The U.S. explosives industry includes over 600 plants. Explosives plants generally are evenly distributed in the eastern portion of the United States, away from large population centers. Plant sites range from a few hundred to several thousand acres. The general production process for the manufacture of explosives involves the nitration of an organic molecule. Raw materials used in this process are nitric acid, acting as a nitrate source, and sulfuric or acetic acid, acting as a dehydrating agent. After nitration, these organic molecules produce the following products: nitroglycerin and dinitroglycerin; trinitrotoluene and dinitrotoluene, trinitroresorcinol; nitromonnite; and nitrocellulose, respectively.

For the purpose of establishing effluent limitations guidelines, the explosives industry has been divided into the following 4 subcategories based upon the raw material used and the process employed:

- Explosives — Category A
- Propellants — Category B
- Load, Assemble, and Pack plants (LAP) — Category C
- Initiating-Compound Plants — Category D.

Explosives are compounds or mixtures of compounds which, when ignited, decompose rapidly, releasing a large volume of gases and heat. Propellants differ in their mode of decomposition in that they are designed to burn rather than detonate. Manufacturing plants in these two categories are generally large and complex. Load, Assemble, and Pack Plants are those that may buy all the necessary ingredients from an outside supplier and then mix and pack them as a final product. Initiating-Compound Plants are those manufacturing "sensitive" explosives.

Waste Sources and Pollutants

The wastewater sources associated with each subcategory are presented in the following:

Manufacture of Explosives

The wastes from this category are characteristically high in BOD_5, COD, nitrates, sulfates, and TOC. Highly variable pH is also characteristic of the wastewater from the explosive industry. The major waste loads generally come from the finishing area where the crude explosive becomes the finished product.

Manufacture of Propellants

The waste loads associated with the manufacture of propellants are usually higher than those associated with the manufacture of explosives. Suspended solids are a troublesome problem, specially in the manufacture of nitrocellulose. Wide variation in pH is also a problem. High BOD_5, COD, and TOC levels can be attributed to the organic compounds and solvents involved in the processes, while high nitrate and sulfates can be attributed to the use of nitric acids and sulfuric acids respectively.

Load, Assemble, and Pack Plants

Waste loads from this category are the mildest in the explosive industry but the most variable. BOD_5, COD, nitrates, sulfates, TOC, TSS, are in the effluent waste loads.

Initiating-Compound Plants

The waste loads associated with the manufacture of initiating compounds are the highest of any category in the explosive industry, due to the highly concentrated waste streams and small volumes of production. Because of the small quantities, batch processes are used in this category and recovery of spent materials is not attempted. Waste loads are high in the following parameters: BOD_5, COD, nitrates, sulfates, TOC, TSS, and TKN (Total Kehldahl Nitrogen).

For the purpose of establishing effluent guidelines for the explosive industry the following parameters have been defined to be of major polluting significance: BOD_5, COD, TSS, pH, and oil and grease.

Control Technology and Costs

The technology for the control and treatment of waterborne pollutants in the explosive industry can be divided into two broad categories: in-process and end-of-pipe. In-process depends on two major conditions.

- Altering the processes that generate water pollutants
- Controlling water use in non-process as well as process areas.

Specific in-process control practices applicable to the explosive industry include good water management, which, with recycling of process cooling water, can have a significant effect on hydraulic loading and would reduce treatment costs. Separation of process and non-contact waters is a first step in economical pollution abatement. Prior to end-of-pipe treatment, the following plant control measures will be mandatory: neutralization facilities, catch tanks on finishing explosive lines, and other pretreatment facilities.

The recommended technology for achieving BPT guidelines relies upon the use of an activated sludge treatment plant for Categories A, B, and D. For Category C an extended aeration package system was recommended. Also, since many of the waste streams have extreme pH values, neutralization is necessary.

The recommended technology for achieving BAT guidelines relies upon the use of dual-media filtration and activated carbon adsorption for Categories A, B, and D. For Category C treatment consists of chemical coagulation and filtration added to the BPT extended aeration package treatment system.

Costs for this industry are summarized in Table 4.7-1.

TABLE 4.7-1. EXPLOSIVE INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	232.56	612.00	232.56	232.56	232.56
BAT	0.0	0.0	1095.00	1825.00	1825.00
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	232.56	612.00	1327.56	2057.56	2057.56
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	232.56	612.00	1327.56	2057.56	2057.56
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	80.46	161.73	433.96	656.03	989.15
BAT	0.0	0.0	303.92	735.82	1455.64
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	80.46	161.73	737.88	1391.85	2444.78
O&M					
EXISTING PLANTS					
BPT	40.00	80.40	160.00	240.00	360.00
BAT	0.0	0.0	46.10	126.80	265.10
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	40.00	80.40	206.10	366.80	625.10
INDUSTRY TOTAL	120.46	242.13	943.98	1758.65	3069.88
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	120.46	242.13	943.98	1758.65	3669.88
ALL ANNUAL COSTS	120.46	242.13	943.98	1758.65	3669.88

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.8. PESTICIDES AND AGRICULTURAL CHEMICALS

The pesticide chemicals manufacturing industry is classified under SIC 2879, and has been subdivided for pollution control purposes into six subcategories. Five of these relate to the type of product, and the sixth to a specialty operation concerned with formulating and packaging. The subcategories are as follows:

- Subcategory A — Halogenated Organics production
- Subcategory B — Organo-phosphorus production
- Subcategory C — Organo-nitrogen production
- Subcategory D — Metallo-organic production
- Subcategory E — Formulation and packaging
- Subcategory F — Miscellaneous pesticides not otherwise classified.

In 1974, the United States International Trade Commission reported that 82 companies in the U.S. manufactured pesticides.

Products

The products of the pesticide industry have generally been divided into three basic classes — herbicides, fungicides, and insecticides. The largest group in terms of value is the herbicides. In 1975, this group accounted for 60 percent of the total value, while providing less than 45 percent of the total poundage.

The products of this industry are highly varied and over 400 have been identified according to the various subcategories. Note that separate, more strict standards have been enacted for several pesticides as toxic pollutants. These are discussed in Chapter IX under the heading of Toxic Substances.

Halogenated Organic Compounds

Ninety eight products were identified in this subcategory. These have been further broken down into 5 groups, and are related to their major use as shown in Table 4.8.-1.

Organo-Phosphorus Compounds

This category contains 93 compounds used primarily as insecticides. Some widely used materials in this group are listed below:

Methyl parathion
Fenthion
Ronnel
Diazinon
Guthion
Malathion
Disulfoton

Table 4.8.-1.
Halogenated Organic Pesticide Groupings and Use

Group	Compound	Use
A1	DDT*	Insecticide
	Dithiocarbamates	Fungicide
	Methoxychlor	Insecticide
A2	2,4-D	Herbicide
	2,4,5-T*	Herbicide
	MCPA	Herbicide
A3	Toxaphene	Insecticide
	Chlordane/heptachlor	Insecticide
	Endrosulfan	Insecticide
	Endrin	Insecticide
A4	Methyl bromide	Fumigant (insects, weeds, rodents, etc.)
	Lindane	Insecticide
A5	Dicamba*	Herbicide

*Representative of the subcategory and used in the economic impact analysis of the prepared standards on this subcategory.

Organo-Nitrogen Compounds

Two-hundred-nine (209) compounds were identified as belonging to this group which contains some of the largest selling pesticides produced. These have been further classified into seven groups, as shown in Table 4.8.-2. Most of the large selling items are herbicides, with minor production of insecticides and fungicides.

Table 4.8–2.
Nitrogen Containing Pesticide Groupings and Use

	Grouping	Primary Use
C1)	Aryl and alkyicarbonates	Insecticides, herbicides
C2)	Thiocarbamates	Herbicides
C3)	Amides and amines	Herbicides
C4)	Ureas and Uracils	Herbicides
C5)	s-Triazines	Herbicides
C6)	Nitro compounds	Herbicides
C7)	Other	Fungicides, herbicides

Metallo-organic Compounds

This is the smallest category of pesticides in both volume and value. Products are primarily fungicides and herbicides.

Formulations

In addition to the many pesticides directly manufactured, there are also many products on the market produced by formulation of combinations of pesticides or other chemicals. Good statistics are not readily available on the distribution of establishments belonging to this classification.

The chemistry involved in the production of pesticides is highly varied and complex, so that many different chemical operations are used. In addition, the plants which formulate rather than produce the pesticides usually employ a number of operations.

Trends

Annual growth trends show that from 1960–1968 there was strong overall growth in the pesticide industry. This growth slowed during the 1968–1974 period to about one-third that of the earlier rate. However, the three basic segments of the industry did not have a uniform growth pattern. The most rapid early growth, and subsequent slowdown, was in the herbicide sector. The pattern for insecticides came closest to matching the pesticide industry. By contrast, the fungicide sector was nearly static during the 1960–1968 period. In the 1968–1974 period there has been very little change in the volume of the fungicide market, but a very sharp increase in the value of the products produced.

Pollutant Characteristics

The pesticide chemical manufacturing industry is involved in the production of many complex organic materials utilizing sophisticated processes. Wastewater pollution is therefore, highly variable from plant to plant.

Halogenated Organic Pesticides

The manufacture of this type of pesticide, usually results in wastewaters that contain high loadings of organic materials from operations such as decanting, distillation, and stripping. Spillage, washdowns, and runoff can also be significant if suitable operational control is not maintained. The most significant pollutants are BOD, COD, suspended solids, phenol, and the pesticide product.

Organo-Phosphorus Pesticides

There are many sources of wastewater from the manufacture of organophosphorus pesticides. These include decanter units, distillation towers, overhead collectors, solvent strippers, caustic scrubbers, contact cooling, hydrolysis units, and equipment washing.

The most significant pollutants are considered to be BOD, COD, suspended solids, ammonia, nitrogen, phosphorus, and the pesticide product.

Organo-Nitrogen Pesticides

In the manufacture of this type pesticide, the principal sources of wastewater are decanting, extractor/precipitator units operations, scrubbing, solvent stripping, product purification, rinsing, and runoff of spillage. The significant pollutants are the same as those identified for organophosphorus pesticides.

Metallo-Organic Pesticides

The primary wastewater sources from the production of organo-metallic pesticides are product stripping, washing, caustic scrubbing, and cleaning operations. The significant pollutants are dissolved solids, suspended solids, BOD, COD, and the pesticide product.

Formulation and Packaging

Washing and cleaning operations are the principal sources of wastewater in the establishments.

Multicategory Producers

Previous discussions were related to plants for which the production was restricted to one category of pesticide, or to plants for which the waste from one category was identifiable. However, there are plants which produce more than one category of pesticide and, for these, the individual wastes are not readily separated.

Control and Treatment Technology

The plants producing pesticides are highly variable in nature; therefore, the control technology in plants producing essentially the same product can also be highly variable. Factors such as economics, pollutant concentration, and wastewater flow have to be considered when choosing the control and treatment technology to be used.

As in the case of other industries, treatment technologies can conveniently be divided into (1) in-plant control and treatment and (2) end-of-pipe control and treatment.

In-Plant Control and Treatment

In-plant control and treatment includes steps to reduce wastewater strength and/or volume. Important in-plant techniques include proper waste-

water segregation in the plant, use of dry housekeeping equipment, replacement of steam jet ejectors and barometric condensers by vacuum pumps and surface condensers, and replacement of process water by an appropriate organic solvent.

End-of-Pipe Control and Treatment

The recommended methods for end-of-pipe treatment basically involve various clean-up steps such as settling, skimming, equalization, or other treatment, followed by detoxification, usually with carbon absorption, followed by biological treatment. However, because of the highly variable nature of this industry, it is difficult to generalize about the advantages and disadvantages of the various treatments. Rather, the approach used has been to handle each on an individual basis, and to provide case histories from background information which has been obtained.

Control Costs

For the purpose of this report the approach used to estimate control costs was to develop model systems which would meet the wastewater guidelines and then make cost estimates for implementing those model systems in actual plants.

Model systems were planned (1) for end-of-pipe treatment to a BPT level of Subcategories A, B, and C only. Plants in Subcategories D and E should not have a wastewater discharge if properly operated. All three model plants are similar in that each waste stream contains separable organics which must be removed by an oil separator of the API type. Wastewater streams for Subcategory C also contain considerable quantities of suspended solids which can be removed in combination with the organic material. Some wastestreams contain materials from distillation tower bottoms which need to be removed and incinerated. Wastewater from Subcategory A can be detoxified by carbon absorption, while hydrolysis is the most satisfactory method for detoxification of wastes from Subcategories B and C.

The basic biological treatment consists of an activated sludge system. This should include aeration basins, flocculator-clarifiers, and sludge handling facilities.

Cost data are summarized in Table 4.8–3.

TABLE 4.8–3. PESTICIDE AND AGRICULTURAL CHEMICALS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	9.63	25.50	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	9.63	25.50	0.0	0.0	0.0
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	9.63	25.50	0.0	0.0	0.0
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	3.35	6.75	13.41	20.11	30.17
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	3.35	6.75	13.41	20.11	30.17
O&M					
EXISTING PLANTS					
BPT	3.13	6.28	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	3.13	6.28	0.0	0.0	0.0
INDUSTRY TOTAL	6.48	13.04	13.41	20.11	30.17
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	6.48	13.04	13.41	20.11	30.17
ALL ANNUAL COSTS	6.48	13.04	13.41	20.11	30.17

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

REFERENCE

Development Document for Interim Final Effluent Limitations Guidleines for the Pesticide Chemicals Manufacturing Point Source Category, EPA 440/1-75/060d, United States Environmental Protection Agency, November, 1976.

4.9 FERTILIZER MANUFACTURING INDUSTRY

Production Characteristics and Capacities

The fertilizer industry can be divided into phosphate and nitrogen fertilizer production areas, containing a total of 11 subcategories:

Phosphate Fertilizers

- Phosphate rock grinding
- Wet process phosphoric acid
- Phosphoric acid concentration
- Normal superphosphate (NSP)
- Triple superphosphate (TSP)
- Ammonium phosphates
- Sulfuric acid

Nitrogen Fertilizers

- Ammonia
- Urea
- Ammonium nitrate
- Nitric acid

These subcategories include both mixed and nonmixed fertilizers.

The manufacture of these fertilizers involves a variety of chemical processes. Three of the processes — phosphate rock grinding, phosphoric acid concentration, and phosphoric acid clarification — do not require process waters. The remaining processes are summarized in Table 4.9–1.

Sulfuric acid and nitric acid are intermediate products in the basic fertilizer chemicals industry. Approximately 25 percent of the plants produce these chemicals as part of the production of the final products listed above; they are not considered as separate plants for the purposes of this report. Plants which produce sulfuric acid or nitric acid as end products are covered under the inorganic chemicals industry.

Because fertilizers are traded in a world-wide market, and the raw materials used are also used in a wide variety of markets, the fertilizer market is subject to many outside influences. These influences include world-wide agricultural demand, the use of nitrates in explosives, and hence pressures from the international military situation, and the world market for synthetic fibers.

In 1972, the fertilizer industry was suffering from overcapacity with no new plants being built. However, in 1973, world demand increased so dramatically that substantial shortages were created in the industry. Several new plants have become operational since 1974.

Projections published by the National Fertilizer Development Center of the Tennessee Valley Authority indicate that the shortages in supply of phosphate materials will be alleviated as significant surpluses develop by 1977. The nitrogen

Table 4.9–1.
Basic Fertilizer Chemicals Manufacturing Process

Product	Raw Material	Process
Wet process Phosphoric acid	Phosphate rock, sulfuric acid, water.	Mixing.
Normal superphosphate	Sulfuric acid, ground phosphate rock, water.	Mixing, curing for 3–8 weeks.
Triple superphosphate	Ground phosphate rock, phosphoric acid, water.	Run of pile process mixing, curing. or Granular triple superphosphate process (GTSP) = mixing into a slurry, drying.
Ammonium phosphates	Ammonia, wet process phosphoric acid.	Similar to GTSP above.
Sulfuric acid	SO_2, O_2, pelletized vanadium oxide catalyst, water. added to form final product.	Sulfur-burning process SOg2 catalyzed to form SO_3, water
Ammonia	Natural gas or other hydrogen source, nitrogen from air, catalysts.	Hydrogen production followed by catalysis with nitrogen to form ammonia.
Urea	Ammonia, carbon dioxide.	Ammonium carbamate formed then dehydrated by prilling or crystallization to form urea.
Ammonium nitrate	Ammonia, nitric acid.	Combined to neutralize acid, then prilled or evaporated to concentrate the product.
Nitric acid	Ammonia, air, water, platinum-rhodium gauze catalyst.	Ammonia oxidized catalytically by air, nitrogen pentoxide absorbed in water.

shortage is expected to continue longer, with a balanced market developing in the late 1970's. The shortage of natural gas in the winter of 1976–1977 further compounded the nitrogen shortage.

Waste Sources and Pollutants

The major fertilizer waste components include the following: pH, phosphorus, fluorides, total suspended solids (TSS), total dissolved solids (TDS), high temperature, cadmium, total chromium, zinc, vanadium, arsenic, uranium, radium 226, COD, oil and grease, ammonia, ammonia nitrogen, organic nitrogen, nitrate nitrogen, iron, and nickel.

The main waste sources contributing to the total waste load can be identified as coming from the following processes in each production area:

Phosphate Fertilizers

- Water treatment plant effluent including raw water filtration and clarification, water softening, and water deionization.
- Closed-loop cooling tower blowdown.
- Boiler blowdown.
- Contaminated water (gypsum pond water).
- Spills and leaks.
- Area-source discharges including surface runoff from rain or snow that become contaminated.

Nitrogen Fertilizers

- Water treatment plant effluent including raw water filtration and clarification, water softening, and water deionization.
- Closed-loop cooling tower blowdown.
- Boiler blowdown.
- Process condensate.
- Spills and leaks that are collected in pits or trenches.
- Area sources collected from rain or snow.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT:

- Phosphate Fertilizers: phosphorus, fluorides, total suspended solids and pH
- Nitrogen Fertilizers: ammonia, organic nitrogen, nitrate, and pH.

Control Technology and Costs

Waste treatment practices in the fertilizer industry include: monitoring units, retaining areas, cutoff impoundments, reuse, recycling, atmospheric evaporative cooling, double-liming (two-stage lime neutralization) surrounding dikes with seepage collection ditches, sulfuric acid dilution with pond water, evaporation, ammonia stripping (steam and air), high pressure air/steam stripping, urea hydrolysis, nitrification and denitrification, ion exchange, cation/anion separation units, selective ion exchange for ammonia removal, oil separation, and ammonium nitrate condensate reuse.

BPT guidelines for the phosphate segment call for limitations on pH, TSS, phosphates, and fluorides by installing the following: double-lime treatment of gypsum pond water, pond design to contain a 10-year storm, monitoring system for sulfuric acid plant control, and facilities for contaminated water isolation. BPT guidelines for the nitrogen segment can be met by installing the following: ammonia steam stripping, urea hydrolysis, leak and spill control, containment and reuse, plus oil separation.

BAT guidelines call for increased limitations of the above parameters by installation of pond water dilution of sulfuric acid for the phosphate segment, and by installation of one of the following for the nitrogen segment: ammonia steam stripping followed by either high-flow ammonia air stripping or biological nitrification-denitrification, continuous ion exchange followed by denitrification, or advanced urea hydrolysis followed by high-flow ammonia air stripping.

NSPS standards call for the following process improvements for the nitrogen segment (the phosphate segment NSPS is the same as BAT):

- Integrate ammonia process condensate steam stripping column into condensate boiler feed water systems of ammonia plant.
- Use centrifugal rather than reciprocating compressors.
- Segregate contaminated water collection systems so that common waste streams can be treated more efficiently and cheaply.
- Locate cooling towers upwind to minimize chance of absorbing ammonia in tower water.
- Design low velocity airflow prill tower for urea and ammonium nitrate to minimize dust loss.
- Design lower pressure steam levels in order to make process condensate and recovery easier and cheaper.
- Install air-cooled condensers and exchangers to minimize cooling water circulation and blowdown.

Control costs are summarized in Table 4.9–2.

TABLE 4.9-2. FERTILIZER MANUFACTURING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	61.32	111.49	0.0	0.0	0.0
BAT	0.0	0.0	72.16	96.21	96.21
NEW PLANTS	9.14	34.18	41.10	64.68	104.45
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	70.46	145.67	113.25	160.89	200.66
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	70.46	145.67	113.25	160.89	200.66
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	14.66	21.25	58.63	87.94	131.92
BAT	0.0	0.0	18.97	44.27	82.22
NEW PLANTS	4.49	10.98	31.17	55.58	104.87
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	19.15	32.23	108.77	187.80	319.00
O&M					
EXISTING PLANTS					
BPT	49.56	71.86	198.23	297.34	446.00
BAT	0.0	0.0	45.76	106.78	198.30
NEW PLANTS	12.82	31.34	88.72	158.02	297.61
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	62.38	103.20	332.72	562.14	941.91
INDUSTRY TOTAL	81.53	135.43	441.49	749.94	1260.92
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	81.53	135.43	441.49	749.94	1260.92
ALL ANNUAL COSTS	81.53	135.43	441.49	749.94	1260.92

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.10 PHOSPHORUS CHEMICALS INDUSTRY

PHOSPHORUS CHEMICALS (PHASE I)

Production Characteristics and Capacities

Establishments included in the phosphorus chemicals manufacturing industry as defined by the Phase I effluent limitations guidelines are manufacturers of the following chemicals:

- Phosphorus
- Ferrophosphorus
- Phosphoric acid (dry process)
- Phosphorus pentoxide
- Phosphorus pentasulfide
- Phosphorus trichloride
- Phosphorus oxychloride
- Sodium tripolyphosphate
- Calcium phosphates (food grade)
- Calcium phosphates (animal feed grade).

This industry is almost entirely based on the production of elemental phosphorus from mined phosphate rock. Elemental phosphorus and ferrophosphorus (a byproduct) are manufactured by the reduction of phosphate rock by coke in very large electric furnaces, using silica as a flux. Because elemental phosphorus is relatively low in weight compared to phosphate rock and to phosphoric acid, the elemental phosphorus is produced near the mining site and shipped to locations near the final markets for further processing.

Over 87 percent of the elemental phosphorus is used to manufacture high-grade phosphoric acid by the burning of liquid phosphorus in air, the subsequent quenching and hydrolysis of the phosphorus pentoxide vapor, and the collection of the phosphoric acid mists.

The manufacture of the anhydrous phosphorus chemicals-phosphorus pentoxide (P_2O_5), phosphorus pentasulfide (P_2S_5), and phosphorus trichloride (PCl_3) — is essentially the direct union of phosphorus with the corresponding element. Phosphorus oxychloride ($POCl_3$) is manufactured from PCl_3 and air or from PCl_3, P_2O_5, and chlorine.

Sodium tripolyphosphate is manufactured by the neutralization of phosphoric acid with caustic soda and soda ash in mix tanks. The resulting mixture of mono-and di-sodium phosphates is dried and the crystals calcined to produce the tripolyphosphate.

The calcium phosphates are similarily made by the neutralization of phosphoric acid with lime. The amount and type of lime used and the amount of water needed in the process determine whether anhydrous monocalcium phosphate monohydrate, dicalcium phosphate dihydrate, or tricalcium phosphate is the final product. Animal feed grade dicalcium phosphate is produced by almost the same process as the other calcium phosphates. Because of the lower purity needed in the final product, defluorinated, wet process phosphoric acid is normally used and the reaction may be conducted without excess water.

For the most part, the products included in the phosphorus chemical industry are produced by divisions of large chemical or petroleum companies. The derivatives of phosphorus are generally manufactured by the same companies that produce elemental phosphorus, but in different locations. Furthermore, a large proportion of the products are used internally by the producing company for the production of other products and, hence, are not sold on the open market.

The biggest factors determining the future of the industry are government regulations and technological innovations. The declining production of phosphorus, for example, is the result of government bans on phosphate detergents. In addition, the TVA plant was shut down in 1976, as a shift to production of wet phosphoric acid was accomplished.

Waste Sources and Pollutants

Water is primarily used in the phosphorus chemical industry for eight principal purposes: non-contact cooling water, process and product water, transport water, contact cooling or heating water, atmospheric seal water, scrubber water, auxiliary process water, and water used for miscellaneous purposes. Very large quantities of non-contact cooling water are used for cooling the electric

furnaces used in phosphorus production. Contact cooling water is used to quench the slag from the phosphorus furnaces. Process or product water contacts and generally becomes part of the product, such as the hydrolysis and dilution water used in phosphoric acid manufacture and the water used as a reaction medium in food-grade dicalcium phosphate manufacture. Because yellow phosphorus spontaneously ignites on contact with air, air is kept out of reaction vessels with a water seal. Liquid phosphorus is protected by storage under a water blanket; these seal waters are considered process waters. Auxiliary process waters include those used in such auxiliary operations as ion exchange regeneration, equipment washing, and spill and leak washdown.

The following pollutant parameters have been designated for the industry's process wastewaters: total suspended solids, phosphate and elemental phosphorus, sulfates and sulfites, fluoride, chloride, dissolved solids, arsenic, cadmium, vanadium, radioactivity, temperature (heat), and pH. The primary parameters, i.e., those which need to be used to set effluent standards, are total suspended nonfilterable solids, total phosphorus, fluoride, arsenic, and pH. The remaining pollutants are either adequately treated when the primary parameters are treated, or are present only in waste streams for which a no discharge standard has been set.

The effluent limitations guideline for most of the phosphorus chemical industry is no discharge of process wastewater pollutants to navigable waters. Process water is defined as any water that comes into direct contact with any raw material, intermediate product, byproduct, or gas or liquid that has accumulated such constituents.

The only exceptions to these standards are the BPT guidelines for phosphorus and ferrophosphorus, phosphorus trichloride, phosphorus oxychloride, and food-grade calcium phosphates.

Control Technology and Costs

Traditional sanitary engineering practices that treat effluents containing organic material in order to reduce biological oxygen demand are inapplicable to the phosphorus chemical industry where such pollutant constituents are not significant. Hence, control and treatment of wastes are of the chemical and chemical engineering variety. These include neutralization, precipitation, ionic reactions, filtration, centrifugation, ion exchange, demineralization, evaporation and drying. In-process abatement measures include segregation of waste streams, recycling of scrubber water, dry dust collection, containment of leaks and spills, and minimization of the quantity of wash water. Many of the manufacturing establishments currently have no treatment installed, while others have already achieved a no discharge status.

The technology recommended to achieve zero discharge of wastewaters in the phosphorus chemical industry consists of:

- Recycling atmospheric seal ("phossy") waters, scrubber liquors, and other process waters following lime treatment and sedimentation (or alternative methods of reducing water flow, such as the use of dilute caustic or lime slurry instead or pure water in the process)
- Use of dry dust collectors
- The return of process waste streams and blowdown streams to the process.

Zero discharge of arsenic-rich still residues from the manufacture of phosphorus trichloride can be achieved through treatment with trichloroethylene.

For those industry subcategories where some discharge is allowed, the recommended treatment consists of waste-reducing steps such as those above, but with some discharge following lime treatment and sedimentation, sometimes with flocculation. Additional treatment to achieve no discharge for these subcategories consists of:

- Total recycling of all process waters by the phosphorus producer
- Control of PCl_3 vapors by installation of refrigerated condensers, minimization of wastewaters with treatment by lime neutralization followed by evaporation to dryness (for manufacturers of phosphorus trichloride and phosphorus oxychloride)
- The addition of vacuum filtration of treated wastewaters followed by total recycling (for producers of food-grade calcium phosphates).

PHOSPHORUS CHEMICALS (PHASE II)

Production Characteristics and Capacities

Establishments included in this industry sector manufacture phosphate products by processes that include a defluorination step. The specific products included are defluorinated phosphate rock, defluorinated phosphoric acid (both in SIC 2874, Phosphate Fertilizers), and sodium tripolyphosphate (STPP, in SIC 2819, Industrial Inorganic Chemicals, N.E.C.) produced from wet-process phosphoric acid. The one plant that prod-

uces STPP by this process was included in the Phase I report with the 17 plants that use furnace process phosphoric acid, so STPP will not be considered further.

The defluorination of phosphate rock is accomplished in a rotary kiln or fluid-bed reactor. The rock is blended with sodium-containing chemicals, wet-process phosphoric acid, and silica then defluorinated in the reactor at 1200–1400C (2200–2600F).

Wet-process phosphoric acid is defluorinated by either of three processes. In two of the processes, wet-process phosphoric acid is dehydrated by evaporation to produce superphosphoric acid, and defluorination is accomplished adventitiously. The evaporation may be accomplished by either vacuum or submerged combustion processes. Defluorinated phosphoric acid can be produced by an aeration process in which fine silica is added to wet-process phosphoric acid and is removed ultimately, along with fluoride, as volatile silicon tetrafluoride under conditions that do not remove water.

The 1976 capacity for producing defluorinated phosphate rock is 462 thousand metric tons (510 thousand short tons) per year in four plants. Ten plants produce superphosphoric acid, with an aggregate capacity of 894 thousand metric tons (985 thousand short tons) per year. The two plants that produce defluorinated phosphoric acid have a combined annual capacity of 118 thousand metric tons (130 thousand short tons).

The major use for defluorinated phosphate rock is as an ingredient of animal feeds. Production of this product has been increasing at a rate of nearly 4.5 percent per year since 1968, and is expected to show a similar growth rate through 1986. A large fraction of defluorinated phosphoric acid is used to produce dicalcium phosphate for animal feeds. Increasingly large quantities are being used in liquid fertilizers and as an intermediate in the production of dry mixed fertilizers. The production of superphosphoric acid from wet-process phosphoric acid is expected to increase at about 9.5 percent per year. Defluorinated phosphoric acid other than the super acid is expected to increase at about 4 percent per year.

Waste Sources and Pollutants

The major source of water pollution in these processes is the water used to scrub contaminants from gaseous effluent streams. Process conditions are such that recirculated contaminated water can be used for this purpose. Spills and leaks are collected and added to the contaminated water pond.

The proposed effluent limitations guidelines specify no discharge of process wastewaters except under certain chronic or catastrophic precipitation events. If wastewaters must be discharged under such events, they must be treated so they do not exceed the following limitations:

	Daily Maximum, mg/l	30-Day average, mg/l
Suspended solids	150	50
Phosphorus	105	35
Fluoride	75	25

pH Within the range 6.0 to 9.0

Control Technology and Costs

The major control technology is the use of ponds of adequate size. To accommodate rainfall incidents for BPT, at least 60 cm (24 inches) freeboard is required (150 cm or 60 inches in Florida). For BAT, additional dike height is required (assumed for cost purposes to be 15 cm or 6 inches).

To achieve the necessary reduction of contaminants for discharge of waters, pond water can be treated with lime to neutralize phosphorus and fluorides. Solids are then settled prior to discharge. Two separate settling ponds are needed for contaminated water treatment — one each for calcium fluorides and calcium phosphates. Most of the existing plants already meet BAT guidelines.

Estimated costs for controlling water pollution in this industry are included in Table 4.10–1.

TABLE 4.10–1. PHOSPHORUS CHEMICALS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	36.74	47.10	0.00	0.00	0.00
BAT	0.0	0.0	21.24	28.31	28.31
NEW PLANTS	2.36	8.90	12.06	20.21	36.39
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	39.09	56.00	33.29	48.53	64.71
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	39.09	56.00	33.29	48.53	64.71
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	6.19	9.60	24.77	37.15	55.73
BAT	0.0	0.0	5.58	13.03	24.20
NEW PLANTS	1.17	2.93	8.45	15.54	31.11
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	7.36	12.53	38.80	65.72	111.04
O&M					
EXISTING PLANTS					
BPT	5.53	8.49	22.53	33.87	50.88
BAT	0.0	0.0	6.10	14.24	26.45
NEW PLANTS	1.50	3.75	10.88	20.19	41.17
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	7.02	12.24	39.52	68.30	118.50
INDUSTRY TOTAL	14.38	24.76	78.32	134.02	229.54
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	14.38	24.76	78.32	134.02	229.54
ALL ANNUAL COSTS	14.38	24.76	78.32	134.02	229.54

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.11 PAINT FORMULATING INDUSTRY

(Some or all of the regulations governing this industry were revoked on May 12,1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

Production Characteristics and Capacities

The manufacturing of paint involves the mixing or dispersion of pigments in oil, resin, resin solution, or latex. Mixing is then followed by the addition of specified portions of organic solvents or water to obtain the desired viscosity.

In 1972 there were 1,599 plants manufacturing paint and allied products in the United States. Production is not divided evenly among these plants. The 629 plants each employing fewer than 10 persons shipped only 3.3 percent of the total value of shipments for the industry, whereas the 53 plants each employing 250 or more shipped 32.9 percent of the total.

The trend since 1963 has been to fewer and larger plants. In 1963 there were 1,788 plants, 34 percent of which employed 20 or more persons. In 1967 there were 1,701 plants, 40 percent of which employed 20 or more. In 1972, 43 percent of the 1,599 plants employed 20 or more. This trend toward fewer and larger plants is expected to continue.

Production of paint in 1972 was about 3,848 million liters (1,017 million gallons), of which nearly 20 percent was water-based. In 1976, total production is estimated at 4,644 million liters (1,227 million gallons), with about 22 percent water-based. It is estimated that total production will be about 7,525 million liters (1,988 million gallons) in 1986, 29 percent of which is expected to be water-based. Production of water-based paints was 754.4 million liters (199.3 million gallons) in 1972, about 1,022 million liters (270 million gallons) in 1976, and should be about 2,184 million liters (577 million gallons) in 1986.

Effluent Sources and Pollutants

The products of the paint industry are either solvent-based or water-based. The production of solvent-based paints produces little wastewater effluent. The bulk of the wastewater from the industry is the result of clean-up operations in the manufacture of water-based paints. Most paint plants are located in highly industrialized urban areas near the markets, and most of the wastewater is discharged to municipally operated sewer systems, with or without pretreatment.

The major wastewater contaminants in paint plants are pigments and latex. Other significant water pollutants are driers and wetting agents, oils, resins, and caustics (used in cleaning). There may also be some contamination by fungicides (including mercurials), heavy metals, and solvents. Recent State and Federal regulations are forcing the paint industry to find substitutes for mercurial biocides. Cadmium, lead, and other heavy metals should appear mainly as insoluble pigments and should be readily controllable as suspended solids. Furthermore, the Lead-Based Paint Poisoning Prevention Act of 1973 has forced the search for suitable replacements for lead pigments and drying agents. The quantities of organic solvents that reach wastewater streams are very small.

Control Regulations

The published regulations cover only solvent-based production operations. The technical and economic background documents are based on the premise that water-based production operations would also be required to achieve no discharge of process wastewater pollutants. The following discussion is based on the same premise as the background documents. In cases where the discharge of water-based paint wastes could cause sewer maintenance problems because of solids settling in low spots or adhering to sewer walls, pretreatment is required.

Control Technology and Costs

For solvent-based paint production, good housekeeping, with control of spills and leaks, will allow all wastewater pollutants to be collected in sumps, placed in drums, and periodically disposed of in a landfill. The base level of practice is already no discharge of process waste liquids, so BPT, BAT, and NSPS can be achieved at no cost. Negligible cost would be required to insure good housekeep-

ing and prevent leaks and spills from being discharged to surface waters.

For water-based paints, the control technology selected to minimize costs is greatly affected by plant size. Small plants, averaging about 7,600 liters per day (2,000 gallons per day) of paint production, can best achieve zero discharge by minimizing water use and recycling wash waters through a packaged system for settling and sludge collection. Larger plants, averaging about 19,000 liters per day (5,000 gallons per day) production, would be better off installing a mechanical automatic high-pressure spray-cleaning system with recycle.

The added cost of achieving no discharge of water pollutants in manufacturing oil-based paints is zero. Most water-based paints are produced for trade sales, not industrial finishes. Data extrapolated from a survey conducted by the National Paint and Coatings Association (NPCA) shows that only 44 plants producing trade sales paints were discharging water pollutants to surface water. All other plants producing trade sales paints were discharging wastewaters in some apparently approved manner, and should have no compliance costs for meeting EPA standards. Of these 44 nonconforming plants, 22 were large, 10 medium, 6 small, and 6 very small.

Based on the anticipated production of approximately 2,200 million liters (575 million gallons) of water-based paints in 1986, new capacity above the 1972 level will be required to produce about 1,400 million liters (370 million gallons) per year, or about 5.5 million liters (1.44 million gallons) per day. This new production can be achieved with 240 new large plants, producing an average of 23,000 liters (6,000 gallons) of paint per day. These new plants will be required to meet New Source Performance Standards. Control costs based on the above condition are summarized in Table 4.11-1.

TABLE 4.11-1 PAINT FORMULATION INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	1.57	6.23	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.62	2.23	3.03	4.92	8.36
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	2.20	8.46	3.03	4.92	8.36
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	2.20	8.46	3.03	4.92	8.36
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.82	2.04	3.28	4.91	7.37
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.29	0.71	2.13	3.88	7.59
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.11	2.74	5.41	8.80	14.96
O&M					
EXISTING PLANTS					
BPT	0.69	1.72	2.77	4.16	6.24
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.25	0.60	1.80	3.29	6.42
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.94	2.32	4.57	7.44	12.65
INDUSTRY TOTAL	2.05	5.06	9.98	16.24	27.62
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	2.05	5.06	9.98	16.24	27.62
ALL ANNUAL COSTS	2.05	5.06	9.98	16.24	27.62

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.12. PRINTING INK FORMULATING

Production Characteristics and Size

The ink manufacturing industry bears many resemblances to the paint manufacturing industry, although it is considerably smaller in size. The industrial sector described here is contained in SIC 2893 with captive shops appearing in SIC 27.

Printing ink production in the United States now exceeds 450 thousand metric tons (one billion pounds) per year. The major components include drying oils, resins, varnish, shellac, pigments and many specialty additives. In 1974 the industry was comprised of 670 printing ink producers, but seven companies share over 50 percent of the market.

The profile of the paint industry is applicable to inks also. Many of the raw materials are the same and the methods of producing ink and the equipment used are nearly identical to those for producing paint. Milling is used more extensively in the ink industry as a method of dispersing pigments.

Printing inks can be either water- or oil-base. Many of the raw materials are the same regardless of the vehicle. The waste characteristics are similar to the paint counterpart.

A check of the Refuse Act Permit Program applications and consultation with industrial representatives led to the conclusion that there are no ink manufacturing plants in the country discharging process wastes to surface streams.

Many of the plants that are on municipal systems practice no discharge of wastewater pollutants. Ink process wastewaters are either sent to sanitary landfills for disposal or the wastewaters are recycled and reused within the plant. A limitation of "no discharge of wastewater pollutants" would have little, if any, effect on the industry.

Waste Sources and Pollutants

Oil-base ink discharges contain substances whose entry into most municipal sewer systems or surface waters is prohibited. Most cities have waste ordinances which have attempted to deal with the release of these obviously deleterious substances. Due to the highly volatile nature and the odor of these materials, the source of any substances that do find their way into the sewer system through accidental spills could quickly be located.

Water-base ink discharges would generally be classified as acceptable to municipal treatment systems. The possibility of solids causing sewer maintenance problems depends on the pipe size and hydraulic load in the sewer. Some of the organic pigments have colors that are highly persistent and therefore they are not removed by existing treatment methods.

The general practice of the ink formulating industry is to discharge only to municipal sewers. There are no known discharges of process wastes directly to waterways.

Control Technology and Costs

As ink formulators do not discharge wastes to water courses and their wastes are generally considered to be compatible with municipal treatment except for problems of brilliant colors and solids, there are few data available on the waste characteristics. The practices of recycling wastewater and water conservation can reduce the quantity of ink waste discharged to the sewers.

The significant parameters for measuring the pollution potential of ink wastes are BOD_5, COD, pH, total suspended solids (TSS), heavy metals, and brilliant color.

As the ink manufacturing plants discharge only to municipal systems, there is little sophistication in the treatment methods. The complexity of the treatment process is a function of the restrictions applied by the municipality. In areas where high surcharges are placed on BOD and TSS, there is a trend toward strict water conservation, reuse, and disposal of ink solids to landfills.

Sedimentation is the most common treatment method employed due to the high level of suspended solids in the wastewater. Flocculation is also used to increase the effectiveness of removing suspended solids. Neutralization, principally of caustic cleaning solutions, is employed to some degree.

The only wastewaters requiring control in the ink industry are the wash and rinse solutions resulting from cleanup. A summary of the costs for the printing ink industry is shown in Table 4.12–1.

TABLE 4.12–1. PRINTING INK FORMULATING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.20	1.96	0.58	0.74	0.80
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.20	1.96	0.58	0.74	0.80
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.20	1.96	0.58	0.74	0.80
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.26	0.94	1.23	1.93	3.02
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.26	0.94	1.23	1.93	3.02
O&M					
EXISTING PLANTS					
BPT	0.09	0.22	0.35	0.52	0.78
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.09	0.22	0.35	0.52	0.78
INDUSTRY TOTAL	0.34	1.16	1.58	2.45	3.80
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.34	1.16	1.58	2.45	3.80
ALL ANNUAL COSTS	0.34	1.16	1.58	2.45	3.80

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.13 PHOTOGRAPHIC PROCESSING

The photographic processing subcategory of the photographic point source category is defined to include all film processing activities listed under SIC 7221 (Photographic Studios, Portrait), SIC 7333 (Commercial Photography, Art, and Graphics), SIC 7395 (Photofinishing Laboratories), and SIC 7819 (Developing and Printing of Commercial Motion Picture Film).

Nature of the Industry

Of the estimated 12,500 processing plants in the United States, approximately 3,000 are amateur operations, 3,000 are "captive" laboratories in business and industrial firms, 650 are major labs specializing in work for professional and industrial photographers, and the remaining plants are portrait and commercial studios.

The photographic processing subcategory serves the photographic trade, the military establishment, the scientific community, the medical profession, the dental profession, and the general public in the developing of films and in photoprinting and enlarging. Of the estimated 12,500 photographic processing plants in the United States, only 650 of these facilities are considered major laboratories with significant wastewater discharges. Approximately 5 percent of all major photoprocessing plants are classified as existing point sources and, therefore, are subject to the effluent limitations discussed here. The remaining 95 percent of the plants discharge their wastewater to municipal treatment systems and are regulated by the pretreatment guidelines for those systems.

Plant sizes range from small amateur operations to the major laboratories which may process as much as 9,000 square meters (100,000 square feet) of film and paper daily. Many plants process between 2,000 and 5,000 square meters (between 25,000 and 50,000 square feet) per day. These plants are located in urban areas throughout the country.

The products produced by the industry are primarily finished color and black and white films and prints of both, produced in a wide variety of photoprocessing machines used to finish a specific film or paper. The nature, basic principles and waste characteristics of the photographic processing are the same in all facilities regardless of size and age. Only the quantity of waste per unit of production shows a consistent relationship.

Waste Characterization

The raw waste loadings (RWL) for the photoprocessing industry were determined from analyses of samples collected during plant visits. The overall industry RWL flow is 163 liters per square meter (4 gallons per square feet); the overall industry RWL, BOD_5 is 36.7 grams per square meter (7.50 lbs per 1,000 square feet) and the overall industry RWL, COD is 123.0 grams per square meter (25.1 lbs per 1,000 square feet). The field survey revealed no full scale secondary treatment plant installations for stand-alone photographic processing plants.

Concentrations of the various parameters were determined from grab samples collected from the combined wastewater overflows and wash waters from each process.

The constituents of the wastewater for which RWL were determined were those parameters which are frequently present in the wastewater and which may have significant ecological consequences once discharged. Other parameters which may be potentially toxic to municipal treatment plants, such as cadmium and chromium were generally found in trace quantities.

Parameters of major concern are BOD_5, COD, silver and cyanides in various forms including complexes (ferrocyanide and ferricyanide).

BOD_5 and COD have been selected as pollutants of significance because they are the primary measurements of organic pollution. In the survey of the industrial categories, most of the effluent data collected from wastewater treatment facilities were based upon BOD_5, because most of the end-of-pipe treatment facilities and municipal treatment systems were biological processes. Where other processes (such as evaporation, incineration, activated carbon or physical/chemical) are utilized, either COD or TOC may be a more appropriate measure of pollution.

After varying degrees of in-plant pollution abatement measures which serve as a pretreatment step most photographic processing plants dis-

charge their effluents to municipal sewer systems. Certain constituents (i.e., silver and cyanide) which could exert toxic effects on a biological system and various non-biodegradable material may also be present. Therefore, in-plant measures or pretreatment to reduce the concentrations of such contaminants to levels acceptable to local authorities must be utilized.

Control Technology and Cost

To avoid substantial economic injury to small business concerns, a size exemption for photographic processing plants handling less than 150 square meters (1,600 square feet) per day of film was established. Implicit in the recommended guidelines for the photographic processing subcategory of the photographic point source category is the use of in-plant control measures to reduce silver and cyanide. In-plant modifications will lead to reductions in wastewater flow, increasing the quantity of water used for recycle, and improving the raw wastewater quality. In-plant treatment technologies should be utilized by the photographic processing subcategory to achieve BPT effluent limitations and guidelines.

To meet BAT effluent limitations and new source performance standards, treatment technologies equivalent to in-plant treatment followed by cyanide destruction, dual-media filtration, and ion exchange for silver removal are recommended.

The selection of technology options depends on the economics of that technology and the magnitude of the final effluent concentration. Control and treatment technology may be divided into two major groupings: in-plant pollution abatement and end-of-pipe treatment. Applicable technologies are outlined as follows:

In-plant Pollution Abatement—Regeneration and Reuse:

A. Silver Recovery
   Metallic Replacement
   Electrolytic Recovery
   Ion Exchange
   Sulfide Precipitation
B. Regenertion of Ferricyanide Bleach
   Persulfate Regeneration
   Ozone Regeneration
C. Developer Recovery
   Ion Exchange
   Precipitation and Extraction
D. Use of squeegees (to inhibit carry over from one tank to next)
E. Use of Holding Tanks (for slow release rather than dumping)

End-of-Pipe Treatment:

A. Biological Treatment
   Activated Sludge
   Lagoons
B. Physical/Chemical Treatment
   Ozonation
   Activated Carbon Adsorbtion
   Chemical Precipitation
   Reverse Osmosis

In-plant modification costs for a 20,000 gpd flow system which incorporates electrolytic silver recovery, squeegees on photoprocessing machines, and bleach regeneration is approximately $67,000 on an installed basis. These in-plant controls constitute the BPT treatment model.

A summary of costs for the treatment of photographic wastes appears in Table 4.13–1.

TABLE 4.13–1. PHOTOGRAPHIC PROCESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	6.21	14.47	1.24	1.24	1.24
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	4.35	7.91	14.45
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	6.21	14.47	5.59	9.15	15.69
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	6.21	14.47	5.59	9.15	15.69
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	2.35	4.46	10.23	15.29	20.90
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	1.38	3.65	9.58
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	2.35	4.46	11.60	18.94	30.49
O&M					
EXISTING PLANTS					
BPT	2.11	3.99	9.16	13.73	20.60
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	1.23	3.27	8.58
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	2.11	3.99	10.39	17.00	29.18
INDUSTRY TOTAL	4.46	8.45	21.99	35.94	59.67
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	4.46	8.45	21.99	35.94	59.67
ALL ANNUAL COSTS	4.46	8.45	21.99	35.94	59.67

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

4.14. TEXTILES INDUSTRY

Production Characteristics and Capacities

The textile industry includes those establishments which are engaged in the following operations:

- Spinning of natural and synthetic fibers into yarn
- Weaving or knitting the yarn into fabric
- Dyeing and finishing of the woven fabric.

According to the *Census of Manufacturers* in 1972 there were 5,910 establishments engaged in such operations. These establishments are located primarily along the northeastern seaboard and throughout the south. Ninety-three percent of the plants are located in these geographic areas.

The operations are divided into two types of processes: dry (spinning, weaving, and knitting) and wet (known collectively as finishing). The wet processes are the primary producers of waste effluents.

For the purpose of establishing effluent limitations guidelines, the textile industry has been divided into seven subcategories based upon the raw material used and the process employed:

- Wool scouring
- Wool finishing
- Greige mills
- Woven fabric finishing
- Knit fabric finishing
- Carpet mills
- Stock and yarn dyeing and finishing.

Wool scouring is the process of washing the raw wool with detergent or solvent to remove natural grease, soluble salts, and dirt. Wool finishing operations include carbonizing (removing vegetable matter by treating the wool with sulfuric acid at high temperatures), rinsing and neutralization, fulling (chemical treatment followed by washing and mechanical working to produce controlled shrinkage), dyeing and/or whitening or bleaching, and moth-proofing.

Dry processing mills include greige mills (any mill making unfinished fabric) and producers of coated fabrics, laminated fabrics, tire cord fabrics, felts, carpet tufting, and carpet backing.

Woven fabric finishing operations include desizing (acid or enzyme treatment to remove chemicals applied prior to weaving), scouring, bleaching, mercerizing (treatment with sodium hydroxide followed by neutralization and washing to increase dye affinity and add tensile strength), carbonizing, fulling, dyeing, printing, resin treatment, waterproofing, flame proofing, soil repellency, and a number of special finishes.

Knit fabric finishing operations are the same as woven fabric except for the sizing/desizing and mercerizing operations which are not required. Stock and yarn dyeing and finishing require mercerizing but not sizing/desizing. Carpets are made mostly from synthetic yarns. The yarn is looped through a woven mat backing, dyed or printed, and then backed with either latex foam or coated with latex and a burlap-type woven fabric backing put over the latex. The processing operations performed in commission finishing may be any sequence of the operations discussed above.

The basic raw materials used in these manufacturing operations are natural and synthetic fibers. The natural fibers include wool and cotton and the synthetic fibers include rayon, acetate, nylon, acrylic, polyester, polypropylene, and glass fibers. Mill consumption of these fibers is estimated to increase 9.1 percent in 1977 from 1976. Consumption by category is forecast as follows: 67 percent synthetics, 32 percent cotton, and 1 percent wool. On a fiber basis, the largest increase is expected in polyester during the next five years.

The textile industry is anticipating a good business year for 1977. Sales are projected to increase 8–10 percent from 1976. The annual rate of shipment of products is estimated to reach approximately $39 billion, a $3 billion increase over last year. Exports are expected to increase from $2.2 billion in 1976 to $2.4 billion in 1977. However, imports will still outgain exports. Imports are forecast to increase from $4.9 billion in 1976 to $5.2 billion in 1977. Industry growth has been projected to be 4.0 percent annually from the present to 1980. For the period 980 to 1985 the growth rate has been forecast to decline to approximately 2.9 percent annually. This decline is attributed to the expected increase of imports

which could account for 50 percent of all product lines by 1988.

Waste Sources and Pollutants

The textile industry discharges 605.3 billion liters (159.9 billion gallons) of water annually of which 42 percent receives pretreatment. The largest water uses are woven fabric dyeing and finishing and yarn and stock dyeing and finishing.

Water is used in the textile industry for the washing and cleaning of equipment from dry processes and for the processing and finishing of textile fabrics from wet processes. About 80 percent of all the water used in textile wet processing is used for removing foreign material — either that carried on the raw material, or that resulting from processing operations. The waste streams that are generated from these processes contain a wide variety of pollutants such as animal and vegetable wastes, dyes, bleaches, and chemicals.

For the purpose of establishing the effluent guidelines for the textile industry, the following parameters have been defined to be of major polluting significance: total suspended solids, BOD, COD, oil and grease, color, total chromium, sulfide, phenol, fecal coliform, and pH.

Control Technology and Costs

The technologies for control and treatment of waterborne pollutants in the textile industry can be divided into two broad categories: in-process and end-of-pipe. The in-process technologies include:

- Better housekeeping procedures
- Containment of leaks and spills
- Good maintenance practices
- Segregation and treatment of selected concentrated wastewater streams.

The end-of-pipe technologies are biological treatment processes that include:

- Activated sludge
- Biological filtration (trickling filter)
- Rotating biological contactor.

Advanced wastewater treatment methods also applicable to the industry include:

- Phase change processes (distillation and freezing)
- Physical separation processes (filtration, reverse osmosis, ultrafiltration and electrodialysis)
- Sorption systems processes (activated carbon and ion exchange)
- Chemical clarification processes.

BPT guidelines are based on preliminary screening, primary settling, chlorination, better housekeeping procedures, and secondary biological treatment. Processes whose effluents contain grease, latex, and dyes need pretreatment because these pollutants interfere with the biological processes. BAT guidelines include BPT technology plus the use of advanced end-of-pipe treatment methods. NSPS guidelines are the same as BAT.

Control costs are summarized in Table 4.14–1.

TABLE 4.14–1. TEXTILE INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	11.99	42.39	0.43	0.43	0.43
BAT	0.0	0.0	991.99	1322.65	1322.65
NEW PLANTS	8.90	33.71	37.67	56.43	86.96
PRETREATMENT	3.32	11.74	0.12	0.12	0.12
SUBTOTAL	24.21	87.84	1030.21	1379.63	1410.16
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	24.21	87.84	1030.21	1379.63	1410.16
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	5.57	12.27	22.52	33.78	50.66
BAT	0.0	0.0	260.84	608.63	1130.31
NEW PLANTS	4.43	10.88	30.15	52.59	96.09
PRETREATMENT	1.54	3.40	6.24	9.36	14.04
TOTAL	11.55	26.55	319.74	704.36	1291.10
O&M					
EXISTING PLANTS					
BPT	4.38	9.64	17.69	26.53	39.80
BAT	0.0	0.0	678.32	1582.75	2939.40
NEW PLANTS	10.04	24.63	68.25	118.75	216.09
PRETREATMENT	1.45	3.20	5.87	8.80	13.20
TOTAL	15.87	37.47	770.13	1736.84	3208.49
INDUSTRY TOTAL	27.42	64.01	1089.87	2441.19	4499.59
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	27.42	64.01	1089.87	2441.19	4499.59
ALL ANNUAL COSTS	27.42	64.01	1089.87	2441.19	4499.59

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5. METALS INDUSTRIES

For the purpose of this report, the Metals Industries have been defined as those establishments which are primarily engaged in the mining, refining, extracting, processing, fabricating or recovering of ferrous and nonferrous metals, and processes performed by establishments in direct support of these operations. The industries included are the:

Ore Mining & Dressing Industries
Iron & Steel Industries

- Ferroalloys
- Bauxite Refining
- Primary Aluminum
- Secondary Aluminum
- Nonferrous Metals
- Electroplating

Costs associated with the implementation of the FWPCA for the metals industries are summarized in Table 5.-1.

TABLE 5.-1. WATER POLLUTION ABATEMENT COSTS FOR THE METALS INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1972–77	1977–81	1977–86
ORE MINING AND DRESSING INDUSTRY	152.50	389.59	251.00	251.00
IRON & STEEL	660.94	1410.22	1056.48	1692.30
FERROALLOYS	1.33	11.06	1.57	3.26
BAUXITE REFINING	0.0	52.81	0.0	0.0
PRIMARY ALUMINUM	19.51	40.45	29.21	46.95
SECONDARY ALUMINUM	2.23	5.20	3.49	7.82
NON-FERROUS METALS	1.43	3.11	–0.01	0.16
ELECTROPLATING	49.79	264.74	81.55	81.55
TOTAL INVESTMENT	887.73	2177.18	1423.30	2080.04
		ANNUAL COSTS		
	1977	1972–77	1977–81	1977–86
ORE MINING AND DRESSING INDUSTRY	84.58	145.97	603.18	1340.06
IRON & STEEL	407.92	1714.68	2632.10	8245.47
FERROALLOYS	556.66	1984.58	3121.63	8805.44
BAUXITE REFINING	12.58	38.40	50.34	113.26
PRIMARY ALUMINUM	15.31	28.31	82.26	228.45
SECONDARY ALUMINUM	2.49	5.05	14.73	44.52
NON-FERROUS METALS	1.77	3.32	7.29	15.47
ELECTROPLATING	141.74	316.31	751.27	1771.01
TOTAL ANNUAL COSTS	820.64	2538.46	4660.19	12393.75

5.1. ORE MINING AND DRESSING INDUSTRIES

(Some or all of the regulations governing this industry were revoked on May 12, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations).

The Ore Mining and Dressing Industry category is defined as including the mining, milling, and benefication of the following in the U.S.:

1) iron ore
2) copper ore*
3) lead/zinc ore*
4) gold ore*
5) silver ore*
6) bauxite ore
7) ferroalloys ores*
8) uranium, radium, and vanadium ores*
9) titanium ore
10) platinum ore*
11) antimony ore*
12) mercury ore

Those subsectors marked with an asterisk currently have their effluent guidelines reserved, at the time of this analysis, and have not been investigated. Only BPT effluent guidelines had been promulgated for the Ore Mining and Dressing category. Thus, there are no cost estimates for BAT and NSPS.

Production Characteristics and Capacities

The production of ore in the U.S. is closely associated with the rise and fall of the U.S. Gross National Product. Many subsectors have a small production rate in the U.S. due to competition with high grade foreign ores (e.g., ferroalloys) or environmental concerns (e.g., mercury). Gold and silver prospecting activity has increased and, since gold and silver production is allowed to be sold on the open market now, mining activity may increase. For gold, mining in most areas is still not especially profitable.

Iron Ore

There are presently a total of 58 iron ore mining operations (39 of these are major operations) in the United States that mine about 200 million metric tons (200 million long tons) of crude iron ore annually. These operations are located in the states of Wyoming, California, New York, Wisconsin, Alabama, Minnesota, Utah, Pennsylvania, Michigan, Texas, Georgia, Missouri and Colorado. Sixteen of these mines are in Minnesota and five are in Michigan—these account for the major part of the ore produced in the United States. The industry's net production of concentrates in 1976 was 87 million metric tons (87.4 million long tons). The maximum production was 90 million metric tons (90.6 million long tons), occuring in 1973.

Copper Ore

Open pit mines produce 83% of the total copper output with the remainder of U.S. production coming from underground operations. Ten percent of the mined material is treated by dump (heap) and in-situ leaching. Recovery of copper from leach solutions by iron precipitation accounted for 87.5% of the leaching production; recovery of copper by electro-winning amounted to 12.5%. Production for 1974 was down 7% to 245 million metric tons (270 million short tons), due mainly to increased copper prices and labor strikes.

Lead and Zinc Ores

Lead and zinc ores are produced almost exclusively from underground mines. There are some deposits which are amenable to open pit operations; a number of mines during their early stages operated as open-pit mines and then developed into underground mines. The most common lead mineral mined in the U.S. is galena (lead sulfide). This mineral is often associated with zinc, silver, gold, and iron minerals. There are, however, numerous other minerals which contain zinc. The more common include sphalerite (zinc sulfide), zincite (zinc oxide), willemite (zinc silicate), and franklinite (an iron, zinc, manganese oxide complex). Sphalerite is often found in association with sulfides of iron and lead. Other elements often found in association with sphalerite include copper, gold, silver, and cadmium. Raw ore production data are not available from the *Mineral Yearbook*, but the NCWQ Report[1] cites a 1972 production of 16.0 million metric tons (17.6 million short tons) and a 1974 production of 19.4 million metric tons (21.4 million short tons) of raw ore.

Silver Ore

Current domestic production of new silver is derived almost entirely from exploitation of low-grade and complex sulfide ores. Only one-fourth of

this production is derived from ores in which silver is the chief value and lead, zinc, and/or copper are valuable byproducts. About three-fourths of the production is from ores in which lead, zinc, and copper constitute the principal values, and silver is a minor but important byproduct. Free-milling—simple, easily liberated—gold/silver ores, processed by amalgamation and cyanidation now contribute only 1 percent of the domestic silver produced.

Primary recovery of silver is largely from the mineral tetrahedrite, $(Cu, Fe, Zn, Ag)_{12}Sb_4S_{13}$. A tetrahedrite concentrate contains approximately 25 to 32 percent copper in addition to the 25.72 to 44.58 kilograms per metric ton (750 to 1300 troy ounces per short ton) of silver. A low-grade (3.43 kg per metric ton or 100 troy oz. per short ton) silver/pyrite concentrate is produced at one mill. Antimony may comprise up to 18 percent of the tetrahedrite concentrate and may not be extracted prior to shipment to a smelter. Total 1974 production is estimated at 1 million metric tons (1.1 million short tons) of ore.

Gold Ore

The domestic production of gold has been on a downward trend for the last 20 years, largely as a result of the reduction in the average grade of ore being mined, ore depletions at some mines, and a labor strike at the major producer during 1972. However, large increases in the free market price of gold during recent years (from approximately $70 per troy ounce in 1972 to over $200 per troy ounce in 1978) has stimulated a widespread increase in prospecting and exploration activity.

In the United States, this industry is concentrated in eight states: Alaska, Montana, New Mexico, Arizona, Utah, Colorado, Nevada, and South Dakota.

Gold is mined from two types of deposits: placer and lode, or vein, deposits. Placer mining consists of excavating gold-bearing gravel and sands. This is currently done primarily by dredging but, in the past, has included hydraulic mining and drift mining of buried placers too deep to strip. Lode deposits are mined by either underground or open-pit methods, the particular method chosen depending on such factors as the size and shape of the deposit, the ore grade, the physical and mineralogical character of the ore and surrounding rock, and the depth of the deposit.

Bauxite Ore

Bauxite mining, for the eventual production of metallurgical grade alumina, occurs near Bauxite, Arkansas, where two producers mined approximately 1.85 million metric tons (2.05 million short tons) of ore in 1973. Both operations are associated with bauxite refineries, at which purified alumina (Al_2O_3) is produced. Characteristically, only a portion of domestic bauxite is refined for use in metallurgical smelting; one operation reports that only about 10 percent of the alumina it mines is smelted, while the remainder is destined for use as chemical and refractory grade alumina. A gallium byproduct recovery operation occurs in association with one bauxite mining and refining complex.

Ferroalloy Ores

The ferroalloy ore mining and milling category embraces the mining and beneficiation of ores of cobalt, chromium, columbium and tantalum, manganese, molybdenum, nickel, and tungsten. SIC 1061, although presently including few operations and relatively small total production, covers a wide spectrum of the mining and milling industry as a whole. Sulfide, oxide, silicate, carbonate, and anionic ores all are, or have been, mined for the included metals. Open-pit and underground mines are currently being worked; placer deposits have been mined in the past and are included in present reserves. Operations vary widely in scale, from very small mines and mills intermittently worked with total annual production measured in hundreds of tons, to two of the largest mining and milling operations in the nation. Geographically, mines and mills in this category are widely scattered, being found in the southeast, southwest, northwest, north central, and Rocky Mountain regions. These operate under a wide variety of climatic and topographic conditions. Historically, the ferroalloy mining and milling industry production has undergone sharp fluctuations in response to variations of the prices of foreign ores, government policies, and production rates of other metals with which some of the ferroalloy metals in the U.S. are found. Ferroalloy ores in the U.S. are usually of lower grade (or more difficult to concentrate) than foreign ores and consequently are only marginally recoverable or uneconomic at prevailing prices. At present, ferroalloy mining and milling (with the exception of molybdenum) is being conducted at a very low level of production. Increased competition from foreign ores, the depletion of many of the richer deposits, and a shift in government policies from stockpiling materials to selling concentrates from stockpiles have resulted in the closure of most of the mines and mills that were active in the late 1950's. For some of the metals, there is little likelihood of further mining and milling in the foreseeable future; for others, increased production in the next few years is possible.

Uranium Ores

Uranium mining practice is conventional. There were 122 underground mines as of January 1, 1974, with a typical depth of 200 meters (220 feet). Special precautions for the ventilation of underground mines reduce the exposure of miners to radon, a shortlived gaseous radioactive decay product of radium which can deposit daughter decay products in miners' lungs. Because of the small size of pockets of high-grade ore, open-pit mines are characterized by extensive development activity. At present, low-grade ore is being stockpiled for future use. Ore stockpiles on polyethylene sheets are heap-leached at several locations by percolation of dilute sulfuric acid through the ore. In January, 1974, 33 open-pit mines were being worked, and 20 other (e.g., heap leaching) sources were in operation. Because it is uneconomical to transport low-grade uranium ores very far, mines are closely associated with mills that yield a concentrate (yellowcake) containing about 90 percent uranium oxide. This concentrate is shipped to plants that produce compounds of natural and isotopically enriched uranium for the nuclear industry.

Titanium Ores

The principal mineral sources of titanium are ilmenite ($FeTiO_2$) and rutile (TiO_2). The United States is a major producer of ilmenite but not of rutile. Since 1972, however, a new operation in Florida has been producing rutile (5,964 metric tons or 6,575 short tons, in 1974). About 85 percent of the ilmenite produced in the United States during 1972 came from two mines in New York and Florida.

Platinum Ores

The geologic occurrence of the platinum-group metals as lodes or placers dictates that copper, nickel, gold, silver, and chromium will be either byproducts or coproducts in the recovery of platinum metals, and that platinum will be largely a byproduct. With the exception of occurrences in the Stillwater Complex, Montana, and production as a byproduct of copper smelting, virtually all the known platinum-group minerals in the United States come from alluvial deposits in present or ancient stream valleys, terraces, beaches, deltas, and glaciofluvial outwash. The other domestic source of platinum is as a byproduct of refining copper from porphyry and other copper deposits and from lode and placer gold deposits, although the grade is extremely low.

Mercury and Antimony Ores

Mercury and antimony ore are currently produced at two respective mines in the U.S. Antimony production has fallen because of the state of the current market and availability of foreign supplies. Mercury production has increased due to the opening of a large mine in Nevada, currently the only significant mercury mining operation in the U.S.

Emission Sources and Pollutants

Effluents are generally from two distinct sources: mine dewatering, and ore-dressing operations (milling, washing, and separation of ore). The effluent from dressing operations is usually higher in suspended solids. Effluents from this industry are generally high in suspended solids, dissolved metals (depending on the solubility of the specific ores), and small quantities of flotation and flocculation reagents. The suspended solids result from the opening of geological structures to seepage and erosion, and from the milling of the ore for beneficiation.

The wastewaters are generally discharged to a tailings or settling pond in which the suspended solids are allowed to settle. A portion of the water is recycled if possible, and a portion discharged. Raw tailings wastewater contains on the order of 70,000 to 500,000 mg/1 suspended solids. The settling rates of solids in tailing ponds vary. Ninety-eight percent of the solids settle rapidly. However, garillaceous materials present in raw ore and fines produced in grinding operations settle very slowly.

The principal method of water effluent treatment consists of settling ponds. Almost all mines and beneficiation plants use settling ponds and recycle water. The wastewater currently discharged could be treated by further retention to reduce the suspended solids content. The retention times in many of these pond systems, however, are not sufficient to reduce the level of suspended solids adequately, particularly during periods of heavy surface run-off. The basic differences between the operation of present tailings systems and that proposed as BPT are the increased retention time achieved by additional ponds, or clarifiers, coagulation flocculation systems, and the use of lime neutralization. Some cases will require the destruction of cyanides and the selective precipitation of specific metals. Where settling ponds are not sufficient, filters can be used to augment treatment.

Table 5.1-1 contains a summary of BPT compliance costs for all the above categories of ore mining, based on the models and costs identified in the Guidelines Development Document and assuming compliance by July 1,1977.

TABLE 5.1-1. ORE MINING AND DRESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	152.50	389.59	251.00	251.00	251.00
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	152.50	389.59	251.00	251.00	251.00
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	152.50	389.59	251.00	251.00	251.00
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	63.40	124.08	384.13	592.63	844.71
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	63.40	124.08	384.13	592.63	844.71
O&M					
EXISTING PLANTS					
BPT	21.18	21.89	219.05	329.57	495.36
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	21.18	21.89	219.05	329.57	495.36
INDUSTRY TOTAL	84.58	145.97	603.18	922.20	1340.06
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	84.58	145.97	603.18	922.20	1340.06
ALL ANNUAL COSTS	84.58	145.97	603.18	922.20	1340.06

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

REFERENCE

1. "Cost of Implementation and Capabilities of Available Technology to Comply with P.L. 92-500", National Commission on Water Quality, Industry Category 4, July, 1975.

5.2 IRON AND STEEL INDUSTRY

(Some or all of the regulations governing this industry were remanded on November 7, 1975 and on September 14, 1977. The EPA believes that the reasons for these actions were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on costs derived on the basis of published regulations and associated treatment technologies.)

Industry Characteristics.

The iron and steel industry, as defined for the purposes of analyzing water pollution control costs, is comprised of 1,931 establishments engaged in processing iron ores, coke, hot metal, pig iron, scrap, and ferroalloys into finished products such as sheet, pipe, tube, wire, bars, etc., with and without galvanized, tinned, or other finishes. The products of the facilities are included in the Standard Industrial Classification Codes 3312-blast furnaces (including coke ovens), steel works, and rolling mills; 3315-steel wiredrawing and steel nails and spikes; 3316-cold rolled steel sheet, strip, and bars; and 3317-steel pipe and tubes.

The American steel industry historically has been a major employer of industrial workers. The industry has consistently employed 2.6 to 3.7 percent of all persons involved in manufacturing since the end of World War II.

Raw steel production decreased 1.0 percent from 116 million metric tons (128 million short tons) in 1976 to 115 million metric tons (126.7 million short tons) in 1977. As a result of a reduction in producer's inventories, shipments of steel mill products increased 2.9 percent from 81.3 million metric tons in 1976 (89.4 million short tons) to 82.7 million metric tons in 1977 (91 million short tons). In 1974, the top ten steel companies contributed to over 75 percent of total industry shipments. Table 5.2-1 ranks the major steel companies by production levels.

The capacity utilization rate for steel production for 1977 was 77.9 percent. The total capacity was 147.5 million metric tons (162.16 million short tons). This study projects a zero growth rate for the period 1977–1985 for the iron and steel industry. This projection is based on three factors, the primary factor being that the iron and steel industry has failed to modernize its facilities. A second factor which limits the expansion of steel usage is the substitution of aluminum and plastic for steel. Finally, the improvements in the quality and durability of steel have allowed substantial decreases in the tonnage of steel used.

TABLE 5.2-1. Major Steel Companies by Production Levels

Rank	
1	U.S. Steel
2	Bethlehem
3	Armco
4	Republic
5	National Steel
6	Inland
7	Jones & Laughlin
8	Youngstown Sheet and Tube
9	Wheeling Pittsburgh
10	Allegheny Ludlum

Source: Reference(a).

Historically, iron and steel mills have tended to concentrate close to raw materials, transportation, and steel-consuming industries. For these reasons, many plants have been established in the Great Lakes region. Approximately 67 percent of the establishments are located in the Northeast and North Central parts of the United States.

Future changes in raw materials availability are not expected to have much effect on the established geographic concentration patterns. By the late 1950's, because existing high-grade ore supplies (50 percent iron content) were becoming depleted, the industry faced a choice of importing ores, seeking out new ore fields in other geographic areas, or working with the available low-grade ore. The industry chose to retain production facilities in existing locations and transport raw materials from greater distances to production sites. To do so economically, the industry developed a new technology, the concentration of lower-grade ore (25 percent or less iron) to 70 percent iron.

The iron and steel industry has posed some of the nation's most serious water pollution problems, especially where several plants are grouped together, as in the Mahoning River Basin in Ohio. In March, 1976, the EPA issued special effluent

guidelines for eight steel plants in the Mahoning Valley. These plants have been allowed substantially lower abatement requirements than those applied to steel mills in the rest of tha nation. According to the EPA, enforcement of national regulations for these older facilities of U.S. Steel, Republic Steel, and Youngstown Sheet and Tube would cause "severe economic and employment disruptions."

General Description of Iron and Steelmaking Processes

One step in the manufacturing of iron and steel is the production of coke. Coke is produced by two methods. The first method is the by-product or chemical recovery process. This process consists of ovens in which bituminous coal is heated, out of contact with air, to drive off the volatile components. The residue remaining in the oven is coke. The volatile components are recovered and processed in the by-product plant to produce tar, light oils, coke oven gas and other materials of potential value. The second method used to produce coke is the beehive process. In the beehive process, air is admitted to the coking chamber in controlled amounts for the purpose of burning the volatile products distilled from the coal to generate heat for further distillation. The beehive oven produces only coke.

Iron is produced when iron ore, coke, and limestone are charged into a blast furnace. The coke is used to produce carbon monoxide gas which combines with the ore to produce carbon dioxide gas and metallic iron. The limestone is used to form a slag which combines with unwanted impurities in the ore. The molten iron is periodically withdrawn from the bottom of the furnace and the molten slag is skimmed off the top.

The iron is purified into steel in either an open hearth, basic oxygen, or electric furnace. Each method generally uses the same type of basic raw materials to produce steel. The basic raw materials are hot metal or pig iron, steel scrap, limestone, burned lime, dolomite, fluorspar, iron ores, and iron bearing materials such as pellets or mill scale. Depending on the elements added to the basic raw materials either carbon or alloy steel is produced.

Steel is further refined by vacum degassing. This process reduces hydrogen, carbon, and oxygen content, improves steel cleanliness, allows production of very low carbon steel, and improves the mechanical properties of the steel.

Following refinement, the next step is casting of the molten steel. Molten steel is cast by two methods. The first process is continuous casting. In continuous casting billets, blooms, slabs, and other shapes are cast directly from the teeming ladle. The second process is ingot casting. In ingot casting the molten steel is cast into iron ingot molds.

The final step is turning the raw steel into products at finishing mills. Finishing operations include hot forming and shaping, surface preparation and scale removal, cold forming and coating, and alloy and stainless steel pickling and descaling.

For purposes of analyzing water pollution control costs, there are considered to eb 28 different categories of operations in the manufacture of steel products. Operations from the raw materials yard through ingot and continuous casting are considered steelmaking processes and are referred to in this study as "Phase I processes." Steel forming and finishing processes include primary breaking of ingot steel through final end-product finishing and are referred to as "Phase II operations." Table 5.2–2. lists the processes.

The principal source of wastewater pollutants from the iron and steel industry is cooling water. Large amounts of water are used in the steelmaking process to cool furnaces and finished products, and to quench hot coke, slag, etc. Much of this is "once-through" cooling water, although blowdown from recirculating systems and barometric condenser water is also present. Chemical pollution is caused by the addition of chemicals to the cooling water to inhibit vegetation growth on the cooling equipment. Chemical pollution is especially difficult to treat because of the low concentration of chemicals that must be removed from large volumes of cooling water. Water used in "semi-wet" air pollution control systems constitutes the second most important source of wastewater from the iron and steel industry. Other significant sources of wasterwater include excess ammonia liquor and light oil recovery wastes from byproduct coke-making, and gas cleaning water from blast furnace operations. The source of wastewater pollution for Phase I and Phase II operations are listed in Table 5.2–3.

The parameters considered to be of pollutional significance are ammonia, BOD5, cyanide, phenol, oil and grease, suspended solids, and heat.

The treatment technologies available to achieve the BPT, BAT, and NSPS effuent limitations guidelines are summarized in the following listing:

By-product Coking: Lime/Neutralization/Single-State Bioxidation-Areation/Multi State Biological Treatment/Filtration/Recycle.

Blast Furnace: Recycle/Cooling Tower Blowdown — Chlorination/Lime/Neutralization/Filtration/Carbon Adsorption.

Table 5.2-2. Steel Production Processes

Phase I Processes

Raw Materials

- Ore yard
- Coal yard
- Scrap yard
- Sintering
- Coke oven

Ironmaking

- Blast furnace

Steelmaking

- Open hearth
- Basic oxygen furnace
- Electric furnace
- Vacuum degassing

Forming/Casting

- Ingot casting
- Continuous casting—billets
- Continuous casting—slabs

Phase II Operations

Finishing

- Primary breakdown—blooms
- Primary breakdown—billets
- Primary breakdown—slabs
- Heavy structurals
- Bar mill
- Cold finished bars
- Wire mill
- Seamless pipe
- Hot strip mill
- Pickling
- Welded pipe
- Cold reduction
- Galvanizing
- Tin plating
- Plate mill

Source: Reference (1).

Table 5.2-3. Sources of Water Pollutants From Iron and Steel Process Operations Phase I

Phase I Processes

By-product coke	1. Ammonia liquor 2. Final cooling water overflow 3. Light oil recovery wastes 4. Indirect cooling water 5. Coke wharf drainage 6. Coal pile runoff
Beehive coke	1. Quenching water
Sintering plants	1. Waste water from wet scrubbers
Blast furnace	1. Heated furnace cooling water 2. Gas washer water
Basic oxygen furnace	1. Heated furnace cooling water 2. Scrubbing waters
Open hearth furnace	1. Heated furnace cooling water 2. Scrubbing waters
Electric arc furnace	1. Heated furnace cooling water 2. Fume collection cooling water
Vacuum degassing	1. Flange cooling water 2. Barometric condenser cooling water
Continuous casting	1. Cooling water
Ingot casting	1. Minimal sources
Pig casting	1. Minimal sources
Slagging	1. Quenching water

Phase II Processes

Hot forming — primary	1. Heat from furnace cooling water 2. Iron oxide scale 3. Oils and greases 4. Traces of alloying elements
Hot forming — section	1. Heat from furnace cooling water 2. Iron oxide scale 3. Oils and greases 4. Traces of alloying elements
Hot forming — flat Plat mills Hot strip mills	1. Heat from furnace cooling water 2. Iron oxide scale 3. Oils and greases 4. Traces of alloying element
Pipe and tube mills	1. Heat from cooling water 2. Iron oxide scale 3. Oils and greases
Pickling	1. Ferrous salts 2. Spent sulfuric acid 3. Spent hydrochloric acid 4. Rinse water
Cold rolling	1. Oils 2. Heat from roll cooling water
Hot coating— Galvanizing	1. Alkaline cleaning rinses 2. Sulfuric or hydrochloric acid rinses 3. Chromate or phosphate rinses 4. Sulfates, chlorides, phosphates, silicates, zinc, chormium 5. Oils
Terne	1. Alkaline or mineral spirit degreasing solution 2. Sulfuric or hydrochloric acid rinses 3. Oils 4. Sulfates, chlorides, iron, lead, tin
Combination acid pickling	1. Spent nitric-hydrofluoric or nitric acid
Salt bath scale	1. Rinse water containing hexavalent chromium or cyanide

(a) Source: Reference 1

Table 5.2–3. Sources of Water Pollutants From Iron and Steel Process Operations Phase II

Phase I Processes

Electric Arc:	Flocculation/Scrubbing-Blowdown Lime Neutralization/Sedimentation
Basic Oxygen Furnace:	Flocculation/Thickening/Neutralization Settling/Coagulation/Lime Neutralization
Open Hearth:	Chemical Flocculation/Recycle Lime Precipitation/Neutralization/ Sedimentation/Denitrification
Continuous Casting:	Recycle/Bed Filter/ Cooling Tower/Oil Skimming
Basic Oxygen Furnace:	Flocculation/Thickening/Neutralization Settling/Coagulation/Lime Neutralization
Phase II	
Cold Rolling:	Chemical Treatment/Neutralization
Primary Hot Forming:	Clarification/Flocculation/Neutralization Clarification/Flocculation/Filtration
Section Hot Forming:	Recycle/Clarification/ Flocculation/Neutralization Clarification/Flocculation/Filtration
Flat Hot Forming:	Recycle/Clarification/Flocculation Clarification/Flocculation/Filtration
Pipes & Tubes:	Settling/Adsorption Recycle
Hot Coatings:	Equalization/Neutralization/ Precipitation Equalization/Neutralization/ Lime Treatment
Cold Coatings:	Equalization/Neutralization/Precipitation Equalization/Lime Treatment/Filtration
Batch Sulfuric Concentrate:	Equalization/Settling Pond Recover/Reuse
Batch Sulfuric Rinse:	Reuse/Recycle/ Settling Pond/Recover/Reuse
Continuous Sulfuric Concentrate:	Pond Equilization/Settling Recover/Reuse
Continuous Sulfuric Rinse:	Equalization/Settling Pond Recover/Reuse
Batch HC1 Concentrate:	Settling Pond/Hauling Recover/Recycle
Batch HC1 Rinse:	Settling Pond Aeration/Settling Lagoon
Continuous HC1:	Settling Pond/Lime
Continuous HC1 Rinse:	Equalization/Lime/ Adsorption/Clarification Equalization/Lime/Adsorption/Aeration

Costs of Water Pollution Control

The determination of the costs of water pollution control for this large, complex, and highly significant industry involved two separate approaches. The most recently available published document representing extensive economic analysis by a firm under contract to EPA, but utilizing data from numerous sources, was analyzed in terms of water pollution control costs due to Federal regulations. The costs so derived are summarized in Table 5.2–4.

TABLE 5.2-4. IRON AND STEEL INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	487.05	1236.33	451.82	451.82	451.82
BAT	116.18	116.18	373.80	560.70	841.05
NEW PLANTS	57.71	57.71	230.86	346.29	399.43
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	660.94	1410.22	1056.48	1358.81	1692.30
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	660.94	1310.22	1056.48	1358.81	1692.30
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	162.54	283.70	798.60	1242.43	1908.19
BAT	15.27	15.27	183.85	349.63	690.30
NEW PLANTS	7.59	7.59	106.23	204.88	378.20
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	185.40	306.56	1088.78	1796.94	2976.69
O&M					
EXISTING PLANTS					
BPT	365.47	1672.24	1849.96	3007.56	4802.06
BAT	0.0	0.0	103.50	345.00	750.59
NEW PLANTS	5.78	5.78	79.39	154.60	276.10
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	371.26	1678.02	2032.85	3507.16	5828.75
INDUSTRY TOTAL	556.66	1984.58	3121.63	5304.10	8805.44
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	556.66	1984.58	3121.63	5304.10	8805.44
ALL ANNUAL COSTS	556.66	1984.58	3121.63	5304.10	8805.44

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.3 FERROALLOY INDUSTRY

The ferroalloy industry produces most of its products through electric-furnace smelting, exothermic refining, and electrolytic processing.

The products of electric-furnace smelting and/or exothermic refining include such products as ferrosilicon, silicon metal, ferromanganese, silicomanganese, ferromanganese-silicon, ferrochromium, ferrochrome-silicon, calcium-silicon, ferrotitanium, ferrovanadium, ferrocolumbium, and silicomanganese-zirconium. The products of the electrolytic process are primarily manganese, manganese dioxide, and chromium.

Since electric-furnace smelting is also the manufacturing process for calcium carbide, and the largest producers of calcium carbide are ferroalloy companies, calcium carbide is considered within the ferroalloy industry (rather than the inorganic chemicals industry) for pollution abatement considerations. The products of the ferroalloy industry are classified in SIC 3313 (Electrometallurgical Products); calcium carbide appears in SIC 2819 (Industrial Inorganic chemicals, Not Elsewhere Classified).

The total industry consists of 24 companies operating 42 plants, most of which are located east of the Mississippi River. A total of 138 furnaces (22 companies) produce ferroalloys and 7 furnaces (4 companies) produce calcium carbide.

For purposes of establishing water effluent limitation guidelines and standards of performance, the industry has been divided into the following categories:

A. Ferroalloy Smelting and Refining Segment
   1. Open Electric Furnaces with Wet Air Pollution Control Devices
   2. Covered Furnaces and Other Smelting Operations with Wet Air Pollution Control Devices
   3. Slag Processing

B. Calcium Carbide Segment
   1. Covered CaC_2 Furnaces with Wet Air Pollution Control Devices
   2. Other (i.e., Open) Calcium Carbide Furnaces

C. Electrolytic Segment
   1. Electrolytic Manganese
   2. Electrolytic Manganese Dioxide
   3. Electrolytic Chromium

Most of the water usage by this industry is for noncontact cooling purposes. From 700 to 5000 gallons per minute (or 3000 to 11,000 gallons per megawatt-hour) may be used to cool the furnace and components of the electrical systems. The largest source of water-borne pollutants in the ferroalloy smelting and refining segment and the calcium carbide segment related to the use of wet methods (e.g., wet scrubbers and precipitators) to control air pollution. Scrubbers are the principal wet air pollution control device (APCD) presently used in the industry. Scrubber water usage ranges from about 500 to 3500 gallons per megawatt-hour.

The ferroalloy and calcium carbide segments are further divided and categorized based upon the furnace operation being of the open or closed type. In the open furnace operation, the carbon monoxide rich off-gas is combusted at the top of the furnace mix and the burned gases plus excess air are subsequently ducted to the air pollution control device. In the closed-type operation, the furnace is covered to exclude air from the furnace interior. However, as the closed furnace gases to be cleaned are uncombusted, they contain components such as cyanide and phenols, which are not found in appreciable amounts in the open-furnace off-gases. Additional water treatment is required for the effluent from wet pollution control devices (APCD) serving closed furnaces.

Slag processing is an additional source of water pollution in several of the ferroalloy plants. As it represents an additional source of water pollution, slag processing is introduced as a separate subcategory. Thus, in the case of the ferroalloy and calcium carbide smelting and refining segments, the preferred categorization factor for water effluent considerations is the type of furnace equipment (i.e., open or closed furnace, dry or wet APCD) and the auxiliary processing (i.e., slag processing) utilized.

The preferred basis for water effluent characterization and treatment for the electrolytic segment of the industry is by product, i.e., manganese (Mn), manganese dioxide (MnO_2) or chromium(Cr).

It should be noted and appreciated that many of the large ferroalloy plants have concurrent in-plant operations which fall in several of the water effluent categories and subcategories. Thus, as proposed by EPA, the water guidelines and performance standards may be applied to specific plants on the basis of a "building block" or unit operation approach, with the total plant effluent limitations based on the summation of each pollutant in each category. The same approach is taken for costing the required water treatment systems for a multi-operation plant. As expected, the costs associated with the treatment of a particular plant's wastewater are best determined through detailed engineering and cost analysis for the specific plant and operation.

The water pollutants to be controlled for each segment are presented in Table 5.3–1. The achievement of BPT limitations for all segments is based upon physical/chemical treatments, while BAT limitations require physical/chemical treatment plus partial recycle of water.

Table 5.3–1. Ferroalloy Industry Pollutants

Open Electric Furnaces with Air Pollution Control Devices	TSS Chromium Total Chromium VI Mangnese Total
Covered Electric Furnace and other Smelting Operations with Wet Air Pollution Control Devices[a]	TSS Chromium Total Chromium VI Manganese Total Cyanide Total Phenols
Slag Processing	TSS Chromium Total Manganese Total
Closed $CaCO_2$ Furnace	TSS Cyanide
Electrolytic Manganese	TSS Manganese Chromium NH_3-N

Water Pollution Control Costs

The estimate of water pollution control costs reported here were developed on the basis of a plant-by-plant review to determine the type of air pollution control device (wet or dry) in use, and the use of published costs of water pollution control for some specific plants. Where published data were not available, engineering estimates of costs based on cost factors from Guideline Development Documents were applied. The costs listed in Table 5.3–2. are largely involved by that portion of industry using wet air pollution control devices.

TABLE 5.3–2. FERROALLOY INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.33	11.06	0.81	0.81	0.81
BAT	0.0	0.0	0.65	1.94	1.94
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.11	0.34	0.51
SUBTOTAL	1.33	11.06	1.57	3.09	3.26
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1.33	11.06	1.57	3.09	3.26
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	1.67	5.64	7.10	10.65	15.98
BAT	0.0	0.0	0.09	0.51	1.45
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.01	0.09	0.28
TOTAL	1.67	5.64	7.20	11.25	17.70
O&M					
EXISTING PLANTS					
BPT	3.89	10.88	22.29	34.25	52.20
BAT	0.0	0.0	0.0	1.14	5.64
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	3.89	10.88	22.29	35.40	57.84
INDUSTRY TOTAL	5.56	16.52	29.49	46.65	75.54
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	5.56	16.52	29.49	46.65	75.54
ALL ANNUAL COSTS	5.56	16.52	29.49	46.65	75.54

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.4 BAUXITE REFINING INDUSTRY

Production Characteristics and Capacities

There are nine U.S. bauxite refineries owned by five primary aluminum producers. Bauxite refining is done only by these primary aluminum producers, usually in very large-scale installations.

Size range distribution and alumina production capacities of the refineries are classified as: small (less than 500,000 metric tons — 550,000 short tons per year), medium (500,000 to 1,000,000 metric tons — 555,000 to 1,000,000 short tons, per year), and large (> 1,000,000 metric tons — 1,000,000 short tons, per year).

The bauxite refining industry is a subcategory of the aluminum segment of the nonferrous metals industry. Bauxite is the principal ore of aluminum and the only one used commercially in the United States. It consists of aluminum oxide (hydrated) and contains various impurities, such as iron oxide, aluminum silicate, titanium dioxide, quartz, and compounds of phosphorous and vanadium. Two processes are used in alumina refining: the Bayer process and the combination process.

The Bayer process is classicially used in the United States. Impure alumina in the bauxite is dissolved in a hot, strong alkali solution (generally NaOH), to form sodium aluminate. Upon dilution and cooling, the sodium aluminate hydrolyzes, forming a precipitate of aluminum hydroxide which is filtered and calcined (roasting or burning to bring about physical or chemical changes) to alumina (pure).

The combination process is applied to high-silica bauxites. It is similar to the Bayer process but includes an additional extraction step. This is accomplished by mixing the red mud residue from the prior step with limestone and sodium carbonate, and then sintering this mixture at 1100° to 1200°C (2000°F-2200°F). Silica is converted to calcium silicate and residual alumina to sodium aluminate. The sintered products are leached to produce additional sodium aluminate solution, which is either filtered and added to the main stream for precipitation or is precipitated separately. The residual solids (brown mud) are slurried to a waste lake.

The United States produced 1.8 million metric tons (2 million short tons) of bauxite ore in 1975; 1976 production is estimated at 2.0 million metric tons (2.2 million short tons) and will probably remain near this figure. Imports will remain in the range of 12–15 million metric tons (13–17 million short tons) annually, plus an additional 85 thousand metric tons (94 thousand short tons) imported from the Virgin Islands.

Higher taxes and levies on imported bauxite have increased the interest in the possible use of alternative materials located in the United States to produce alumina. Efforts to use domestic sources of raw materials, such as clays, alunite, and anorthosite, are increasing, and a U.S. producer is now using a Soviet process termed successful in refining alumina from alunite.

Waste Sources and Pollutants

The primary waste from a bauxite refinery is the gangue (worthless rock) from the ore, known as red or brown mud, that is produced in large quantities. From about one-third to one ton of red mud or 2 to 2 1/2 tons of brown mud is produced per ton of alumina.

The principal wastewater streams in a bauxite refinery are the following: red mud stream, spent liquor, condensates, barometric condenser cooling water, and storm water runoff.

The major process waste is the mud residue. The Bayer process produces a red mud while the combination process treats this mud and forms a brown mud. However, these differences do not alter the problem of disposal.

Wastewater parameters used for determining effluent guidelines include: alkalinity, pH, total dissolved solids, total suspended solids, and sulfate. Mud residue resulting from process operations is produced on a large scale (500 to nearly 4,000 metric tons or 550 to nearly 4,400 short tons, per day). Use of wastewater recycle systems, along with complete waste retention, will eliminate the discharge of all process wastewater pollutants to receiving waters.

The guidelines for all three levels of control (BPT, BAT and NSPS) are essentially zero discharge of

process wastewaters to navigable waters. To allow for certain climatic conditions, the guidelines permit a bauxite refining plant to discharge an amount of water equal to the amount by which rainfall exceeds the natural evaporation. This amount is applicable to only that rainfall landing directly in impoundment areas, such as active and dormant mud lakes and neutralization lakes.

Control Technology and Costs

Since enormous quantities of aqueous waste suspensions are generated in bauxite refining, no practicable or currently available treatment or control technology for these wastes exists, except for impoundment. In all but two plants, a large diked area for impounding the red mud has been made available. Wastes containing high alkalinity or acidity can be neutralized, but this leads to the creation of dissolved solids. Mud and other pollutants from refining, however, can be impounded in a red mud lake system. Cooling towers may be an alternative for the cooling water supply for barometric condenser effluents.

Two plants are known to be operating currently with no discharge of water. Four other plants have prepared or are implementing plans to achieve a status of no discharge of process waters before the effective date of effluent limitations. Two plants are currently discharging all wastes, but are implementing plans to impound red mud.

TABLE 5.4–1. BAUXITE REFINING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.0	52.81	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.0	52.81	0.0	0.0	0.0
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	52.81	0.0	0.0	0.0
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	6.94	24.30	27.78	41.66	62.49
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	6.94	24.30	27.78	41.66	62.49
O&M					
EXISTING PLANTS					
BPT	5.64	14.10	22.56	33.84	50.76
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	5.64	14.10	22.56	33.84	50.76
INDUSTRY TOTAL	12.58	38.40	50.34	75.51	113.26
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	12.58	38.40	50.34	75.51	113.26
ALL ANNUAL COSTS	12.58	38.40	50.34	75.51	113.26

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.5 PRIMARY ALUMINUM SMELTING INDUSTRY

Production Characteristics and Capacities

The primary aluminum industry has three production stages: bauxite mining, bauxite refining to produce alumina (aluminum oxide), and the reduction of alumina to produce aluminum metal; this last state is commonly known as aluminum smelting.

The reduction of alumina to produce aluminum metal is carried out in electrolytic cells, or pots, that are connected in series to form a potline. The facility containing a number of potlines is referred to as the potroom. The electrolysis takes place in a molten bath composed principally of cryolite, which is a double fluoride of sodium and aluminum. Alumina is added to the bath periodically. As electrolysis proceeds, aluminum is deposited at the cathode, and oxygen is evolved at the carbon anode. The oxygen reacts with the carbon to produce a mixture of carbon monoxide and carbon dioxide while the anode is consumed.

Two methods of replacing the anodes are practiced; these are referred to as the prebaked anode (intermittent replacement) and the Soderberg anode (continuous replacement). For either system, the anode preparation begins in the anode paste plant, where petroleum coke and pitch are hot-blended. For prebaked anodes, the anode paste is pressed in molds, and the anodes are baked in the anode bake plant. The baked anodes are used to replace consumed anodes, and the anode butts are returned to the anode preparation area. In the Soderberg anode system, the anode paste is not baked initially, but is fed continuously through a tublar steel sleeve into the pot. As the paste approaches the hot bath, the paste is baked in place to form the anode. Soderberg anodes are supported in the sleeves by vertical or horizontal studs.

The continuous evolution of gaseous reaction products from the aluminum reduction cell yields a large volume of fumes that require ventilation systems for removal from the potroom. The ventilation air must be scrubbed to minimize air pollution and both dry and wet scrubbing methods are used for this purpose. Water from wet scrubbers, used for air pollution control on potroom ventilation air, is the major source of wastewater in the primary aluminum industry.

The liquid aluminum produced is tapped periodically, and the metal is cast in a separate cast-house facility. The molten metal is degassed before casting by bubbling chlorine or a mixed gas through the melt. The chlorine degassing procedure also produces a fume which must be scrubbed for air pollution control.

A few aluminum smelters have metal fabrication facilities, such as rod mills, rolling mills, etc., on the primary reduction plant site. Since these metal fabrication operations will be covered under separate effluent limitations, they are not covered by this report.

Waste Sources and Pollutants

As mentioned previously, the major source of wastewater in the primary aluminum smelting industry is the water used in air pollution control equipment (scrubbers) that are installed on potline and potroom ventilation air systems. Scrubbers are also used on anode bake furnace flue gas, and on cast-house gases. Other significant sources of wastewater include: cooling water used in casting, rectifiers, and fabrication; boiler blowdown; and storage area run-off, especially water contaminated with fluoride from spent cathodes.

Significant pollutants from the primary aluminum smelting industry for the purposes of establishing effluent limitations guidelines are: fluoride, total suspended solids, and pH. Other wastewater pollutants identifiable with the industry, but not considered significant, include: oil and grease, cyanide, dissolved solids, chloride, sulfate, chemical oxygen demand, temperature, and trace metals.

Control Technology and Costs

The existing technologies for controlling wastewater volume in this industry include dry fume scrubbing, and recycling of water to wet scrubbers after precipitation by lime or alum, absorption on activated alumina or hydroxyapatite, and reverse osmosis. Table 5.5–1 summarizes the present and potential control and treatment technologies for the primary aluminum smelting industry.

Table 5.5–1.
Primary Aluminum Smelting Industry Control Technology

Wastewater Source	Present Practice	Possible Added Control	Possible Added Treatment
Pot (primary) wet scrubber	Discharge without treatment	Convert to dry scrubbing	—
Pot (primary) wet scrubber	Discharge without treatment	Install cryolite or with bleed	Install lime treatment of lime precipitation
Pot (primary) wet scrubber	Lime and settle once —through	Install recycle with bleed	Install alumina adsorption
Pot (primary) wet scrubber	Cryolite or lime precipitation with recycle	—	Install lime treatment of bleed stream
Potroom (secondary) wet scrubber	Discharge without treatment	Install cryolite or lime precipitation plus recycle	—
Potroom (secondary) wet scrubber	Lime and settle once —through	Install recycle adsorption	Install alumina
Cast house wet scrubber	Settle	Convert to alternate degassing	—
Anode bake plant plant wet	Settle	Recycle	Flocculate and aerate
Paste plant wet scrubber	Settle	Recycle	—
Cast house cooling	Discharge without treatment	Close loop	Cooling tower
Rectifier cooling	Discharge without treatment	Convert to air-cooled rectifiers	Cooling tower
Rainfall runoff	Discharge without treatment	Route to cryolite recovery and recycle	—

Reproduced from EPA Development Document; March 1974.

BPT includes the treatment of wet scrubber water and other fluoride-containing effluents to precipitate the fluoride, followed by settling of the precipitate and recycling of the clarified liquor to the wet scrubbers. A holding pond or lagoon might also be necessary to minimize the discharge of suspended solids. Precipitation methods currently available use lime. Alternate control technologies which can be employed to achieve the required effluent levels include dry fume scrubbing, total impoundment, and reuse of effluent water by a companion operation.

The application of the BPT described above results in a relatively low-volume, high-concentration bleed stream from the recycling system. BAT is lime or calcium chloride precipitation treatment of the bleed stream to further reduce the discharge of fluorides. Use of this technology assumes that the volume of fluoride-containing effluent is reduced to approximately 5,000 liters per metric ton (1,200 gallons per short ton) of aluminum. Alternatively, volumes as high as 50,000 liters per metric ton (12,000 gallons per short ton) of aluminum may be possible if the effluent is treated by absorption methods (activated alumina or hydroxyapatite).

NSPS technology assumes the application of dry fume scrubbing systems or, alternatively, wet scrubbing equipment together with total impoundment or total recycling of the scrubber water. The treatment for fluoride and suspended solids removal is essentially the same as for BPT above. The NSPS require the restriction of the discharge volume to 835 liters per metric ton (200 gallons per short ton) of aluminum with a final fluoride concentration of 30 mg per liter; or an equivalent combination of fluoride level and volume. Alternatives for reducing water use and pollutant levels include air-cooled, solid state rectifiers; nonchemical methods of molten metal degassing; and careful cleaning of the anode butts before recycling.

Approximately two-thirds of the primary aluminum smelting plants in the United States are currently operating with discharge levels of pollutants within the July 1977 guidelines.

TABLE 5.5-2. PRIMARY ALUMINUM INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	17.90	35.79	0.75	0.75	0.75
BAT	0.0	0.0	21.34	28.45	28.45
NEW PLANTS	1.61	4.66	7.12	11.13	17.75
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	19.51	40.45	29.21	40.33	46.95
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	19.51	40.45	29.21	40.33	46.95
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	4.71	8.68	19.12	28.72	43.13
BAT	0.0	0.0	5.61	13.09	24.32
NEW PLANTS	0.61	1.21	4.74	8.63	16.57
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	5.32	9.88	29.47	50.44	84.02
O&M					
EXISTING PLANTS					
BPT	9.99	18.42	40.59	60.99	91.59
BAT	0.0	0.0	12.19	28.45	52.84
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	9.99	18.42	52.78	89.44	144.43
INDUSTRY TOTAL	15.31	28.31	82.26	139.89	228.45
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	15.31	28.31	82.26	139.89	228.45
ALL ANNUAL COSTS	15.31	28.31	82.26	139.89	228.45

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.6 SECONDARY ALUMINUM SMELTING INDUSTRY

Production Characteristics and Capacities

The secondary aluminum industry comprises an estimated 54 firms with 66 plants. Other sources list the industry as having more plants, but these numbers include sweaters, scrap dealers, and non-integrated fabricators. For purposes of this report, the number of plants reported excludes these portions of the industry as they do not employ any of the processes included in the effluent limitations guidelines.

The secondary aluminum smelting industry is a subcategory of the aluminum segment of the nonferrous metals manufacturing category. This industry recovers, processes, and remelts various grades of aluminum-bearing scrap to produce metallic aluminum or an aluminum alloy as a product. This product is used primarily to supply the following industries: construction, aircraft, automotive, electrical equipment, beverage cans, and fabricated metal products (which includes a wide variety of home consumer products). The largest user of secondary aluminum ingot is the automotive industry.

Secondary aluminum ingot is produced to specifications; melting to specification is achieved mainly by segregating the incoming scrap into alloy types. The magnesium contained in the scrap is removed, as desired, by a chlorine-gas treatment (demagging) in a reverberatory furnace.

The estimated 1973 capacity was approximately 967,000 metric tons (1.07 million short tons). The top four firms account for about 50 percent of the capacity.

Estimated production of secondary aluminum ingot has increased at the average rate of 5.3 percent annually for the period 1963 to 1971. However, domestic secondary recovery in 1974 was reported by the 1976 U.S. Industrial Outlook to be 1.18 million metric tons (1.30 million short tons) and in 1975 was estimated to increase by 10 percent to about 1.3 million metric tons (1.43 million short tons).

Increased emphasis on recycling should cause more metal to become available to secondary producers. Also, since the decontrol of aluminum scrap in December 1973, increased quantities of waste and scrap have improved the production rate and price structure.

Waste Sources and Pollutants

Wastewaters are generated by the following processes: (1) ingot cooling and shot quenching, (2) scrubbing of furnace fumes during demagging, and (3) wet milling of residues or residue fractions.

The following are the primary wastewater pollutants discharged by the above processes: oil and grease, suspended and dissolved solids, and salts of aluminum and magnesium.

In metal cooling, molten metal in the furnace is usually either cast into ingot or smaller (sow) molds or is quenched into shot. Ingot molds are sprayed while on conveyor belts to solidify the aluminum and allow its ejection from the mold. Shot is solidified by having metal droplets fall into a water bath. The wastewater generated is either vaporized, discharged to municipal sewerage or navigable waters, recycled for some period and discharged (6-month intervals), continuously recycled with no discharge, or discharged to holding ponds.

Fume scrubbing is necessitated when aluminum scrap contains a higher percentage of magnesium than is desired for the alloy produced. Magnesium removal, or "demagging", is done either by passing chlorine through the melt (chlorination) or with aluminum fluoride. When magnesium is extracted, heavy fuming results; this requires passing the fumes through a wet scrubbing system. Water used in scrubbing picks up pollutants, primarily in the scrubbing of chlorine demagging fumes.

Residue processing takes place in the industry since residues are composed of 10 to 30 percent aluminum, with attached aluminum oxide fluxing salts (mostly NaCl and KCl), dirt, and various other chlorides, fluorides, and oxides. The metal is separated from the non-metals by milling and screening (which is performed either wet or dry). In wet milling, the dust problem is minimized but the resulting waste stream is similar in make-up to scrubber waters but more concentrated in dissolved solids. Water is passed into a settling pond before discharge.

The major wastewater parameters stem from two wastewater streams: wet milling of residues and fume scrubbing. Pollutant parameters for wastewater from wet milling of residues include: total suspended solids, fluorides, ammonia, aluminum, copper, COD, and pH. Pollutant parameters for wastewater from fume scrubbing include: total suspended solids, COD, and pH.

Control Technology and Costs

Approximately 10 percent of the industry is currently discharging directly to navigable waters. The majority of the industry discharges effluents to municipal treatment works, usually with some pretreatment.

Currently, some plants are utilizing various control alternatives for each of the three major wastewater sources. The control technologies required to meet BPT and BAT are as follows:

BPT

Metal Cooling

Air cooling or continuous recycling of cooling water with periodic removal, dewatering, and disposal of sludge.

Fume Scrubbing

Chlorine Fume Scrubbing (for magnesium removal using chlorine): pH adjustment and settling. Fluoride fume scrubbing (for magnesium removal using aluminum fluorides): pH adjustment, settling, and total recycling.

Residue Milling

Adjustment of pH with settling and water recycle.

BAT

Metal Cooling

Air cooling, water cooling (for complete evaporation), and total use and recycle of cooling water by use of settling and sludge dewatering.

Fume Scrubbing

Use of aluminum fluoride for magnesium removal, and entrapment of fumes without major use of water, using alternatives such as the Alcoa process,, Derham process or the Tesisorb process.

Residue Milling

Dry milling, and a water recycle, evaporation, and salt reclamation process.

Control costs are summarized in Table 5.6–1.

TABLE 5.6–1. SECONDARY ALUMINUM INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.79	3.59	0.07	0.07	0.07
BAT	0.0	0.0	1.41	1.88	1.88
NEW PLANTS	0.44	1.61	2.00	3.18	5.86
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	2.23	5.20	3.49	5.14	7.82
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	2.23	5.20	3.49	5.14	7.82
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.47	0.87	1.92	2.88	4.32
BAT	0.0	0.0	0.37	0.87	1.61
NEW PLANTS	0.21	0.51	1.49	2.67	5.20
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.68	1.38	3.77	6.41	11.14
O&M					
EXISTING PLANTS					
BPT	1.25	2.31	5.10	7.66	11.50
BAT	0.0	0.0	1.95	4.56	8.46
NEW PLANTS	0.56	1.35	3.91	7.00	13.42
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.81	3.67	10.95	19.22	33.38
INDUSTRY TOTAL	2.49	5.05	14.73	25.63	44.52
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	2.49	5.05	14.73	25.63	44.52
ALL ANNUAL COSTS	2.49	5.05	14.73	25.63	44.52

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.7 OTHER NONFERROUS METALS INDUSTRIES

The categories studied vary in terms of production processes, raw material sources, reagents used, and the treatment necessary for the resultant waste streams. They are, therefore, discussed separately.

Primary Magnesium

Today the primary magnesium industry is located in the states of Texas, Utah, and Washington. In 1973, domestic production of primary magnesium was 111,068 metric tons (122,431 short tons); more recent data have been withheld. Production and consumption of magnesium have increased over the past 8 years. The price has continued to increase during the 1970s.

The primary magnesium industry encompasses four companies with a total rated annual capacity of 195 thousand metric tons (215 thousand short tons). One of these will be using the magnethermic production process (a type of ferrosilicon reduction process) and began production in 1976. Another, after a shutdown in mid-1971 to comply with air quality requirements, has resumed production.

Electrolytic Processes

At this writing, only electrolytic processes are being used to produce magnesium commercially. In the electrolytic processes, magnesium chloride is decomposed by electrolysis to produce elemental magnesium and chlorine. Three magnesium-bearing materials are the raw materials for electrolytic processes in the United States today; seawater, lake brine, and well brine. Various methods for concentration of magnesium, depending on the raw material type, are used in the preparation of feed for the electrolytic cells. Cell-feed makeup is basically chlorides of magnesium, calcium, and sodium. Depending on cell design, small amounts of other chlorides are added to increase conductivity and density and reduce the electrolyte melting point, resulting in higher cell efficiency.

Magnethermic Processes

The magnethermic process, a unique type of ferrosilicon reduction process using dolomite, is employed at one commercial magnesium plant that started production in 1976. The process uses an electric furnace for the heating of a liquid slag made up of dolomite, ferrosilicon, and alumina. Preheated materials are introduced into the furnace in granular or powdered form. Under reduced pressure, magnesium condenses on the walls of a chamber attached to the furnace, and is collected.

Primary Columbium (Niobium) and Tantalum

General

Columbium and tantalum refiners in the United States produce a variety of products, including metal powders and ingots, purified salts, and alloys, from ore concentrates and from alloys containing columbium and tantalum. Essentially all production of the metals, alloys, and salts is from imported raw materials. Columbium, produced as metal, oxide, or ferrocolumbium, is used primarily as an alloying agent in the production of high-strength steels. The dominant use of tantalum is in the electronics industry for the production of capacitors, although usage in chemical equipment, in nonferrous alloys, and in metal cutting tools (as the carbide) is also significant.

Total U.S. columbium shipments for 1975, the last year for which statistics are available, amounted to 482 thousand kg (1,064 thousand pounds) of contained columbium, almost 90 percent of which was in the form of ferrocolumbium. Tantalum shipments totaled 392 thousand kg (865 thousand pounds). Seventy-five percent of that total was tantalum metal in the form of powder, anodes, ingots, and mill products. Production and consumption of both metals is expected to continue to increase through the year 2000, with prices (in constant dollars) remaining fairly stable at about current levels of about $18-$45/pound for columbium and $35-$120 for tantalum products.

Overall Process Technology

U.S. plants processing columbium and tantalum vary widely in raw materials and end products. Representatives of the industry, as listed by the U.S. Bureau of Mines, include producers and users of ferrocolumbium and the three groups below which are considered in this document:

- Producers of metals and salts from concentrates and slags

- Producers of only purified salts from concentrates and slags
- Producers of metals and carbides from purified salts.

Production of columbium and tantalum from concentrates and slags generally proceeds in four basic steps: (1) ore opening, or leaching; (2) separation and purification of the metals in solution; (3) precipitation of purified salts; and (4) reduction of the salts to yield columbium and tantalum metals. The first three steps are always accomplished together. Reduction of the purified salts which result (generally, Cb_3O_5, and/or K_3TaF_3)may be performed at the same site, or the salts may be shipped elsewhere for reduction to metals.

Primary Beryllium

Statistics relative to domestic primary production of beryllium metal are regarded by the industry as proprietary and are, therefore, unavailable. However, the amount of beryl consumed domestically in the production of beryllium metal, alloy, and oxide for ceramics was 3,393 metric tons (3,740 short tons) in 1976. A significant development during 1973 was the discontinuation of primary production at one of the two domestic beryllium metal producers due primarily to a weak market. There are no plans for future production of metal at this plant.

At present, only one U.S. company processes beryllium ore into beryllium. This company is fully integrated, as it owns and operates the single bertrandite mine. It also owns a milling facility, located near the mine, where the beryllium ore is processed by acid leaching and solvent extraction. The beryllium content of the ore is subsequently converted to beryllium hydroxide, which is shipped to a separate plant for processing into metal. In addition to facilities for beryllium metal production, this plant also has manufacturing and fabrication facilities for beryllium/copper master alloy and beryllium oxide ceramics.

The very high reactivity of beryllium when hot makes it impracticable to smelt the ore normally. For this reason, the several methods which have been developed for the extraction of beryllium from beryl all rely on multistage chemical processes for the conversion of beryl to pure beryllium oxide or, more often, hydroxide (which is then used as the starting material for metal preparation).

Germanium

Until the post-war development of the transistor in 1948, there was negligible commercial demand for germanium, but current consumption in the U.S. is well over 20 metric tons (40 thousand pounds) annually. Development and use of germanium transistors revolutionized the electronics industry, although silicon has since made inroads in many semiconductor applications, where germanium has its major use. The decline in germanium consumption in the electronics sector has been partly offset by its use in optics because of its high refractive index and transparency to infrared light. It is used in camera lenses and special glass for spectroscopes and infrared devices. Other applications are in metallurgy, chemotherapy, polymer chemistry, and nuclear radiation devices.

There are two operations capable of primary germanium refining. Of the existing operations, one operation deals entirely with scrap. The latter facility has not processed a concentrate for 8 years, but implementation for this raw material would require only minor adjustments. A proposed refinery will be located near a major electronics producer and will process scrap in addition to its dioxide reduction operation.

Present technology for primary germanium production is based on availability of zinc smelter residues from ores of the Tri-State District. One smelter has a stockpile of roasting residue which contains about 1 percent germanium, and the concentrate is shipped to a nearby germanium refinery. The latter plant also recovers gallium from the concentrate and processes both gallium and germanium scrap.

The basic germanium refining process, regardless of raw material, consists of two phases, which are arbitrarily separated for consideration of water use. The first phase involves chemical conversion of the germanium in the raw material to the tetrachloride, with subsequent transition to the dioxide. The second phase entails pyrometallurgical conversion of the dioxide to zone-refined bars.

Secondary Lead/Antimony

Secondary Lead

The raw material used for production of lead and lead alloys at secondary lead smelters consists of scrap and other lead residues. This feedstock is much different than the ore concentrate used in primary lead smelters. The feedstock to secondary lead smelters consists primarily of used battery storage plates and lead drosses and residues. Other feedstock used in secondary lead smelters in minor amounts includes solder, common babbitt, cable coverings, type metals, soft lead, and antimonial lead. The secondary lead industry performs a valuable environmental service by reclaim-

ing lead from used storage batteries, which otherwise would be directly disposed in dumps or sanitary landfills. It is estimated that approximately 35 million batteries are reclaimed annually by secondary smelters. This represents approximately 95 percent of the 36.5 million replacement batteries produced in 1975.

Estimats of the number of secondary lead smelters in the United States vary widely. The Bureau of Mines has estimated that there are as many as 98 secondary lead smelters in the U.S. The best estimate of the number of smelters, made from trade association and individual company contacts during the course of this study, is 75 to 80. Plants are located principally in urban areas, so as to be close to the supply of waste batteries. Major concentrations of plants are in the Great Lakes states, southeast Texas, and California.

Secondary lead smelters are quite small in comparison to primary lead smelters. Production capacities of individual plants vary from 25 metric tons (27.6 short tons) of lead per year to approximately 36 thousand metric tons (40 thousand short tons) annually. The majority of plants produce between 10 to 30 thousand metric tons (11 to 33 thousand short tons) of lead per year.

The major products recovered from lead scrap are refined soft lead and antimonial lead. Recovered soft lead containing no antimony is used principally to prepare battery lead oxide paste. Antimonial lead containing about 5 percent antimony is used to manufacture battery plate grids. Recovery of soft lead and antimonial lead is estimated to account for over 85 percent of the products recovered. Products recovered in minor amounts include cable lead, solder, lead-base babbitt white metal, and type metal.

Both hard and soft lead are produced by pyrometallurgical processes from battery scrap and other lead scrap. Recovery of lead from discarded storage batteries represents approximately 80 percent of the secondary lead recovered. Reverberatory furnaces and blast furnaces are the major equipment employed at secondary lead smelters. Soft lead (i.e., pure lead) is recovered by reverberatory smelting. The recovered metal is often converted to lead oxide, either by the Barton process or by a melting process. Slag from the reverberatory furnace is then smelted in a blast furnace, using scrap iron as a reducing agent, for recovery of antimonial lead. Alternatively, scrap battery waste may be smelted directly in the blast furnace to produce antimonial lead directly. Both soft lead and antimonial lead are further refined in remelt kettles. At that time, alloying metals, including arsenic and copper, may be added.

Since battery scrap is a major input to secondary lead smelters, used batteries are often processed on site. In this operation, the tops of the batteries are sawed off, and the spent electrolyte (sulfuric acid) is dumped. The battery plates and paste are then removed and stored for input to the smelting furnaces. The battery cases are normally disposed of as solid wastes; however, at some locations, the plastic cases are gound up and the plastic recovered. The spent sulfuric acid electrolyte, mixed with wash water and water used to cool the saw, comprises the major effluent from secondary lead smelters. A number of smelters receive battery scrap which has been processed by scrap dealers and do not generate waste acid.

Secondary Zinc

There are approximately 10 major producers of secondary zinc slab and dust in the United States. These secondary zinc plants are dispersed throughout the country and are generally located close to large urban areas, near sources of scrap material and inexpensive transportation. Two major processes are employed by these companies to produce secondary zinc: sweating (resmelting) and redistillation.

In 1974 71,246 metric tons (78,513 short tons) of secondary redistilled slab zinc and 1,581 metric tons (1,743 short tons) of secondary remelt slab zinc were produced in the U.S. However, 74 percent of the redistilled slab zinc produced was processed at primary zinc smelters. As a result, total zinc slab production at secondary plants actually was only 20,133 metric tons (22,193 short tons). In addition to secondary slab production, 26,376 metric tons (29,075 short tons) of zinc dust was recovered from scrap processed in the U.S. during 1974.

Raw Materials

Raw materials used for secondary zinc production may be classified as either new or old scrap. Drosses from galvanizing and diecasting operations, skimmings, and zinc-base and copper-base alloy scrap from manufacturers are defined as new scrap. Old scrap includes a variety of discarded manufactured items, including diecastings and engravers' plate.

Zinc diecastings are small manufactured items, such as decorative parts on cars and appliances, made of zinc-base alloy. The zinc-base alloy typically contains 3.5–4.3 percent aluminum, up to

1.25 percent copper, and 0.03–0.08 percent magnesium. The primary copper-base alloys are brasses (5 to 45 percent zinc) and bronzes (copper/tin alloys containing up to 4.5 percent zinc).

Products

Zinc-base scrap is recovered in the secondary zinc industry in the form of slab zinc and zinc dust. Product specifications vary depending on raw material, process employed, and customer requirements. However, for a given product line, the materials are generally indistinguishable from those produced at primary smelters and refiners. Byproduct materials are primarily residues containing zinc oxide plus aluminum, copper, ferrous, and nonferrous unmeltable attachments. These residues, which are generated during sweating and distillation operations, are recovered and sent to primary smelters or alloyers for reprocessing.

Scope of Processing

Processing of zinc scrap into slab zinc and zinc dust involves: (1) pretreatment (sorting and segregating scrap materials); (2) sweating or remelting of zinc scrap to produce metal; and (3) redistillation of the zinc metal to produce high-quality slab and dust.

Pertinent Regulations

The recommended effluent limitation guidelines based on the Best Practicable Control Technology Currently Available and Best Available Technology Economically Achievable are summarized in Table 5.7–1. Of the eight subcategories listed for which separate limitations are recommended, it is recommended that facilities in three subcategories achieve a status of no discharge of process wastewater by 1983.

The New Source Performance Standards (NSPS) recommended for operations begun after the proposal of guidelines for the miscellaneous nonferrous metals industry are identical to BPCTCA and BATEA recommended effluent limitations.

Table 5.7-1.
Effluent Limitations For Minor Non-Ferrous Metals Industries
(in kg/metric ton or lb/1000 lb)

	BPT			BAT		
Category	Parameter	30-Day Average	24-Hour Maximum	30-Day Parameter	24-Hour Average	Maximum
Primary Magnesium & Electrolytic	pH	6.0 to 9.0		pH	6.0 to 90	
	TSS	25	100	TSS	25	100
	Free Chlorine		1	22	Free CHlorine	1
Primary Columbium and Tantalum						
Processing of Ore Concentrates & Slags	pH	6.0 to 9.0		pH	6.0 to 9.0	
	TSS	4.2	8.4	TSS	4.2	8.4
	Ammonia[1]	10	20	Ammonia[1]	10	20
	Fluoride	5.9	11.8	Fluoride	2.5	5.0
Processing of Purified Salts	pH	6.0 to 9.0		pH	6.0 to 9.0	
	TSS	3.0	6.0	TSS	3.0	6.0
	Fluoride	4.2	8.4	Fluoride	1.8	3.6
Primary Beryllium	pH	6.0 to 9.0		pH	6.0 to 9.0	
	TSS	14.6	29.2	TSS	8.7	17.4
	Ammonia[1]	17.5	35.2	Ammonia[1]	17.5	35
	Fluoride	14.6	29.2	Fluoride	5.8	11.6
	Chromium	0.03	0.06	Chromium	0.03	0.06
	Beryllium	0.09	0.18	Beryllium	0.9	0.18
Primary/Secondary Germanium		No Discharge				
Secondary Lead/Antimony						
Battery Cracking	pH	6.0 to 9.0		pH	6.0 to 9.0	
	TSS	0.025	0.05	TSS	0.025	0.05
	Lead	0.0005	0.001	Lead	0.0005	0.001
	Arsenic	0.00005	0.0001	Arsenic	0.00005	0.0001
	Cadmium	0.00002	0.00004	Cadmium	0.00002	0.00004
		No Battery Cracking			No Discharge	
Secondary Zinc		No Discharge				

[1] Ammonia as nitrogen.

Wastewater Treatment Technology and Costs

Primary Magnesium

The plants which comprise this industry meet the recommended BPCTCA and BATEA standards. No additional costs for effluent treatment will be incurred by the industry.

Primary Columbium and Tantalum

This industry is divided into two subcategories. Plants assigned to the first subcategory are engaged in processing mineral concentrates or slags to produce the metals or purified salts. The second subcategory encompasses plants processing salts of columbium and/or tantalum to produce the metals.

Subcategory I

Lime precipitation for removal of fluoride is currently practiced at discharging plants in this subcategory. Additional technology required is described below.

BPT — Ammonia steam stripping is the recommended treatment method for plants in Subcategory I.

BAT — Treatment to meet Level B consists of alum addition, at a rate of 300 mg/liter (2.5 lb/1000 gal), and clarification. The clarifier is sized for 16-hour retention.

Subcategory II

Plants in Subcategory II utilize lime neutralization and alum to treat the wastewater.

BPT — Treatment consists of lime neutralization followed by settling in a concrete pit. The pit is designed for 3 days of retention. Lime addition is at a rate of 60 gm/liter (500 lb/1000 gal).

BAT — Treatment to meet BAT regulations consists of alum addition and clarification for Subcategory II plants.

Primary Beryllium

The proposed standard requires the removal of ammonia and fluoride from the wastewater. This activity is in addition to current treatment practices, which include recycling, lime precipitation, settling, and discharge.

Two methods are available for ammonia removal: steam stripping (BPT) and air stripping (BAT), the former being more efficient. Requirements for ammonia stripping systems are very sensitive to specific operating parameters and conditions. The application of this technique in this industry has been very limited. Ammonia air stripping is an accepted sewage treatment process; however, this technology has received only limited application in the metals industry, but has been used in other industry categories.

Fluoride removal — three treatment alternatives are recommended for fluoride removal:

- C — electrochemical
- D — alum fluoride removal
- E — activated alumina adsorption.

Little information is available on the electrochemical process. For fluoride removal by the use of alum, 600 mg/liter (5 lb/1000 gal) of alum are added to the wastewater.

For activated alumina adsorption, the tower packing is regenerated monthly with a 4 percent H_2SO_4 solution.

Germanium

A single plant is the only primary germanium refinery operating at present. The wastewater emanating from the germanium refinery is combined with wastewater from a boron-10 refinery and a gallium refinery, which are colocated. At present, part of the waste stream of 38 thousand liters/day (10 thousand gal/day), flows into a 2.8 hectare (7-acre) containment pond; the remainder into a freshwater pond. The plant is situated in a 13 cm (5-inch) net evaporation area.

The requirements to meet the recommended standards include recycling of the wastewater from the aspirators and further treatment of the wastewater flowing into the containment pond. Several choices appear available for the latter activity.

Three alternatives are considered for resolving the containment pond problem.

- Level A — treat the daily inflow by lime neutralization, and construct a second containment pond in series with the existing pond. The combined surface areas of the two ponds would then be sufficient to evaporate the daily inflow.
- Level B — separate the germanium refinery waste stream, and construct a lined pond with sufficient surface area to evaporate the daily inflow of 1,100 liters (300 gallons).
- Level C — replace the existing containment pond with a new, lined lagoon with sufficient surface area to evaporate the daily inflow of 38 thousand liters (10 thousand gallons).

The costs incurred with two of the alternatives—namely those entailed in the construction of an additional pond and in the replacement of the existing pond—include the treatment of the boron-10 refinery and gallium refinery wastewater, as well as that generated in germanium refining. Additionally, the annual cost of each treatment alternative will be reduced by savings of water costs obtained through the aspirator water recycling operation.

Secondary Lead/Antimony

The major treatment processes for secondary lead smelters are liming, flocculation, settling, and vacuum filtration for the plants discharging to streams, and neutralization with NH_3 and settling for the plants discharging into sewers.

Many smelters engage in battery cracking as a source of raw material. Cracked battery cases are accumulated near the plants. The standards require collection, temporary storage, and subsequent treatment of the runoff from these areas.

Additionally, all plants are required to construct concrete pits for temporary sludge storage prior to land disposal. The pits are sized to hold a 20-day accumulation of sludge.

Secondary Zinc

The plants comprising this industry will incur no additional costs to attain the recommended effluent standards.

Aggregation of Industry Costs

Costs for the control of waterborne pollutants in the Nonferrous Metals industries are summarized in Table 5.7–2.

TABLE 5.7-2. OTHER NONFERROUS METALS INDUSTRIES WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.43	2.96	–0.0	0.36	0.16
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.15	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	1.43	3.11	–0.0	0.36	0.16
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1.43	3.11	–0.0	0.36	0.16
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.39	0.72	1.56	2.44	3.69
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.02	0.04	0.08	0.12	0.18
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.41	0.77	1.64	2.56	3.88
O&M					
EXISTING PLANTS					
BPT	1.32	2.48	5.50	8.03	11.25
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.04	0.08	0.15	0.23	0.34
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.36	2.55	5.65	8.26	11.59
INDUSTRY TOTAL	1.77	3.32	7.29	10.82	15.47
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.77	3.32	7.29	10.82	15.47
ALL ANNUAL COSTS	1.77	3.32	7.29	10.82	15.47

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

5.8 ELECTROPLATING INDUSTRY

(Some or all of the regulations governing this industry were revoked on December 3, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations.)

Industry and Process Description

The Electroplating Point Source Category is a subcategory of the metal finishing industry and includes establishments engaged in applying surface treatments by electrolytic deposition and other methods. These treatments provide corrosion protection, wear or erosion resistance, antifrictional characteristics, lubricity, electrical conductivity, heat and light reflectivity, or other special surface characteristics.

The industry structure and process characteristics each show large ranges of variation and complexity, so that few generalizations are possible for economic analysis.

The industry is principally characterized by a division into independent job shops and captive shops. Independent job shops, which report under SIC's 3471 and 3479, are estimated, to date, to amount to about 3,000 separate installations varying in size from the range of 1–5 employees to more than 150 employees, and offering a range of surface finishes involving from one to 15 technologically different processes. Captive shops are those operated as part of an overall manufacturing process, and are judged to be principally located in manufacturing firms reporting in SIC's 34 through 39, and possibly in other SIC's. The variations in size and processes of captive shops are believed to be similar to those of independent job shops, with the implication of similar water pollution potential. No definitive census of captive shops exists to date. However, the EPA estimates that there are more than 6,000 captive metal finishing operations.

Over 70 percent of the shops have fewer than 20 employees, while the largest shops have more than 150 employees. The area of the products being electroplated varies from less than 10 to more than 1,000 square meters per day (less than 100 to more then 10,000 square feet per day). Products being plated vary in weight from less than 30 grams (less than an ounce) to more than 9,000 kilograms (more than 10 short tons). Most of the plants perform specialized batch operations, but in some plant operations, continuous strip and wire are plated on a 24-hour per day basis. Some companies have capabilities for electroplating 10 or 12 different metals and alloys; others specialize in just one or two.

The range of process variations in this segment of industry may be indicated by a listing of the subcatgories used in the various draft/proposed regulations issued to date:

- A — Electroplating of Common Metals
- B — Electroplating of Precious Metals
- C — Electroplating of Specialty Metals (Reserved)
- D — Anodizing
- E — Coating
- F — Chemical Etching and Milling
- G — Electroless Plating
- H — Making Printed Circuit Boards

Processes

An electroplating process involves cleaning, electroplating, rinsing, and drying. The cleaning operation comprises two or more steps, usually sequential treatments in an alkaline solution and an acid solution, to remove grease, oil, soil, and oxide films from the basic metal surfaces to insure good adhesion. In the electroplating operation, metal ions in either acid, alkaline, or neutral solutions are reduced on the work pieces being plated, which serve as cathodes. Hundreds of different electroplating solutions have been adopted commercially, but only two or three are utilized widely for a single metal or alloy. For example, cyanide solutions are popular for copper, zinc, and cadmium. Acid sulfate solutions and non-cyanide alkaline solutions containing pyrophosphate or another chelating agent are also used. The parts to be plated are usually immersed in the electroplating solutions upon racks, although small parts are allowed to tumble freely in open barrels.

Mechanized systems have been developed for transferring both barrels and racks from cleaning, plating, and rinsing tanks. In some instances, dwell time and transfer periods are programmed on magnetic tape or cards for complete automation.

Waste Sources and Pollutants

Water is used in electroplating operations to accomplish the following tasks:

- Rinsing of parts, racks, and equipment
- Washing equipment and washing away spills
- Washing the air in ventilation ducts
- Preparing operating solutions (with dumping of spent solution)
- Cooling water to cool solutions (usually reused for rinsing).

Approximately 90 percent of the water is used in rinsing operations; this water is used to rinse away the films of processing solutions from the surface of the work pieces. In performing this task, the water is contaminated by the operating solutions and is not directly reusable.

In electroplating facilities the wastes are derived principally from the material plated and the operating solutions. The most important wastes are made potentially toxic by the formation of heavy metal salts and cyanide salts.

For the purpose of establishing effluent limitations guidelines, the major wastewater constituents of polluting significance have been defined to be: cadmium, lead, copper, nickel, hexavalent chromium, total chromium, zinc, silver, cyanide which is amenable to oxidation by chlorine, total cyanide, suspended solids (SS), and pH. Other wastewater constituents of secondary importance that are not the subject of the guidelines include: total dissolved solids, chemical oxygen demand, biochemical oxygen demand, oil and grease, turbidity, color, and temperature.

Control Technology

Pollution control and wastewater treatment technologies for reducing the discharge of pollutants include both in-plant controls and end-of-process treatment system. The most commonly-used treatment in the electroplating industry is a chemical method. The rinse waters are usually segregated into these three streams prior to treatment:

- Those containing hexavalent chromium,
- Those containing cyanide, and
- The remainder containing water from acid dips, alkali cleaners, acid copper, nickel, and zinc baths, etc.

The cyanide is oxidized by chlorine, and the hexavalent chromium is reduced to trivalent chromium with sulfur dioxide or other reducing agents. The three streams are then combined and the metal hydroxides are precipitated by adjusting the pH through chemical addition. The hydroxides are allowed to settle out, often with the help of coagulating agents, and the sludge is hauled to a lagoon or filtered and used as landfill. These chemical facilities may be engineered for batch or continuous operations.

Water conservation can be accomplished by: in-plant process modifications and materials substitutions requiring little capital or new equipment (substituting low concentration electroplating solutions for high concentration baths or the use of noncyanide solutions), good housekeeping practices, reducing the amount of rinse water lost when parts are removed from the solution, and reducing the volume of rinse water used by installing counterflow rinses, adding wetting agents, and installing air or ultrasonic agitation. Significant amounts of water can also be conserved by using advanced treatment methods, such as ion exchange, evaporative recovery, or reverse osmosis to treat and recycle in-process waters. Other more experimental in-process treatment methods include freezing, electrodialysis, ion-flotation, and electrolytic stripping. One system currently in operation has achieved zero discharge of pollutants through the use of reverse osmosis followed by evaporation and distillation of the concentrated waste stream from the reverse osmosis unit.

Proposed BPT for the electroplating industry is based upon the use of chemical methods of treatment of the wastewater at the end of the process and controls to conserve rinse water and reduce the amount of treated water discharged. Proposed NSPS are based upon the above technology plus the utilization of the best multi-tank rinsing practices after each process. Maximum use of combinations of evaporative, reverse osmosis, and ion exchange systems for in-process control are also recommended. Proposed BAT is the use of in-process and end-of-process control and treatment to achieve a statistical no discharge of pollutants.

Regulations

The regulations to be applied to this industry have been developed in increasing depth since the initiation of the study to produce the Development Document for Copper, Nickel, Chromium, and Zinc in 1973. Analysis of the economic impact of regu-

lations has been particularly complex for this segment of industry.

After two previous issues, *Interim Final Limitations and Standards* for subcategories A through F (above) were issued on April 24, 1975 including limitations based on best practicable technology (BPT), best available technology economically achievable (BAT), standards of performance for new sources (NSPS), and pretreatment standards for new sources. These Interim Final Regulations were suspended on December 3, 1976. Subsequently, *Interim Final Regulations; Pretreatment Standards for Existing Sources* were issued on July 12, 1977 (42FR 35813–35834), covering subcategories A through H. These were followed by Proposed Pretreatment Standards for Existing Sources on February 14, 1978 (Fed. Regis., Vol 43, no. 31, pp. 6560–6573). The July and February regulations are the basis for this report.

Costs Under Current Regulations

In brief, the regulations pertinent at the time of this estimate may be denoted in the following terms:

- pretreatment regulations for existing sources discharging to publically-owned treatment works
- regulations covering operations in Subcategories A through H
- a three-year compliance period
- plants in all categories which discharge less than 151,412 liters (40,000 gallons) per day are limited to a 30-day average of 0.08 milligrams per liter of cyanide amenable to destruction by chlorination
- plants in all categories which discharge more than 157,412 liters (40,000 gallons) per day must meet the following 30-day averages:

CN,A <0.08 mg/1
CN,T <0.24 mg/1
Cr,VI <0.09 mg/1
pH 7.5–10.0

where "CN,A" is cyanide amenable to treatment by chlorination, "CN,T" is total cyanide, and "Cr,VI" is hexavalent chromium. The limitations imply, respectively, the application of technologies to destroy cyanide, reduce hexavalent chromium, and neutralize to the indicated pH.

The economic impacts on *independent job shops* of the above regulations are reported as being:

- 38 million dollars in capital investment costs
- 15 million dollars per year in annual costs (including capital charges and operating and maintenance costs)
- 235 possible shop closures representing 5,900 jobs

The estimated possible closures represent eight (8) percent of the independent job shop sector of this industry.

The above estimate of economic impact does not include the *captive shop* sector of the industry, and, of course, being associated with pretreatment regulations, considers only that portion of the industry which discharges to publically owned treatment works.

The above estimate is one published with the promulgation of the subject regulations. This estimate is based on the latest and one of the most detailed cost analysis programs performed to date in association with discharge regulations for this industry category. Although the actual derivation of the cost estimate has not been published, an interim report detailing some of the methodology of costing and estimation of the closure rate has been published.

Estimated abatement costs are summarized in Table 5.8–1. The costs include estimates for all shops for all regulations, including the costs for pretreatment by job shops, as given above.

REFERENCE

1. "Preliminary Economic Analysis of Interim Final Pretreatment Standards for Existing Sources of The Electroplating Point Source Category", EPA-230/3–77–016; June, 1977.

TABLE 5.8-1. ELECTROPLATING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	40.73	255.68	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	9.06	9.06	81.55	81.55	81.55
SUBTOTAL	49.79	264.74	81.55	81.55	81.55
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	49.79	264.74	81.55	81.55	81.55
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	33.62	92.36	134.46	201.69	302.54
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	1.19	1.19	37.53	61.35	97.09
TOTAL	34.81	93.55	171.99	263.05	399.63
O&M					
EXISTING PLANTS					
BPT	106.93	222.76	509.20	763.80	1145.70
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	70.08	132.32	225.68
TOTAL	106.93	222.76	579.28	896.12	1371.38
INDUSTRY TOTAL	141.74	316.31	751.27	1159.16	1771.01
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	141.74	316.31	751.27	1159.16	1771.01
ALL ANNUAL COSTS	141.74	316.31	751.27	1159.16	1771.01

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6. MINERAL BASED MANUFACTURING

For the purpose of this report Mineral-Based Manufacturing Industries are defined as those establishments primarily engaged in the gathering or physical processing of minerals into a form suitable for use by the ultimate consumer. These include the:

- Mineral Mining
- Glass Manufacturing
- Asbestos
- Cement Manufacturing
- Paving and Roofing Industries.

Costs for the reduction of Water Pollution for these industries are summarized in Table 6.-1. These costs and other data are repeated below in the appropriate sections together with the assumptions peculiar to the industry and other details.

TABLE 6.-1. WATER POLLUTION ABATEMENT COSTS FOR THE MINERAL-BASED MANUFACTURING INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1972–77	1977–81	1977–86
MINERAL MINING	28.53	87.96	0.0	0.0
GLASS MANUFACTURING	0.87	2.64	11.97	18.83
INSULATION FIBERGLASS	2.60	6.97	2.72	7.57
ASBESTOS	0.33	1.90	3.13	6.31
CEMENT MANUFACTURING	3.30	20.59	6.93	15.04
PAVING & ROOFING	0.24	1.41	3.37	4.90
TOTAL INVESTMENT	35.87	121.47	28.11	52.64
		ANNUAL COSTS		
	1977	1972–77	1977–81	1977–86
MINERAL MINING	23.02	42.33	110.14	234.60
GLASS MANUFACTURING	0.80	1.75	9.99	37.88
INSULATION FIBERGLASS	2.11	4.41	10.43	29.40
ASBESTOS	0.88	2.03	6.49	22.92
CEMENT MANUFACTURING	5.20	12.58	24.66	62.38
PAVING & ROOFING	1.48	5.62	9.17	26.14
TOTAL ANNUAL COSTS	33.48	68.72	170.87	413.32

6.1. MINERAL MINING AND PROCESSING INDUSTRY

Industry Structure

The mineral mining and processing industry is concerned with the mining, separation, cleaning, and beneficiation of the following minerals:

dimension stone*	potash
crushed stone	trona*
construction sand & gravel	sodium sulfate
industrial sand	mineral pigments*
gypsum	lithium*
asphaltic minerals	bentonite
asbestos & wollastonite	diatomite
lightweight aggregates*	Frasch sulfur
mica*	graphite
barite	jade
fluorospar	magnesite
borates	novaculite
salines	shale & common clay*
tripoli	aplite*
garnet*	attapulgite & montmorillonite*
phosphate rock	rock salt*
talc*	kyanite*
kaolin*	fire clay*
feldspar*	ball clay*

Those sectors bearing asterisks currently have their effluent guidelines reserved, and have not been included here. Only BPT effluent guidelines have been promulgated so far for the Minerals Mining category. Therefore, no cost estimates for BAT or NSPS compliance have been prepared.

Production Characteristics and Capacities

The production of minerals in the U.S. is closely associated with the rise and fall of the U.S. Gross National Product. Many subsectors have a small production rate in the U.S. due to competition with higher grade or cheaper foreign minerals, small demand for selected U.S. minerals, or cheap alternate supplies of minerals, e.g. sulfur, which is a by-product of many chemical and pollution control processes. Production of minerals from year to year is a dynamic phenomenon for the separate sectors, showing great growth and recession.

Crushed Stone

There are currently slightly over 4,800 crushed stone quarries in the United States as reported by the Bureau of Mines. Of these, approximately 2,000 are considered by the Bureau of the Census (SIC's 1422, 1423, and 1429) to be commercial operations primarily concerned with the production of crushed stone. The remaining 2,800 plants consist of quarries operated by federal, state, and local governments; quarries that are part of integrated (cement, lime, etc.) operations; quarries operated on a temporary basis by establishments not concerned primarily with the production of stone (e.g., highway contractors, SIC-1611); and small quarries operated without paid employees, but proprietor-operated. Some of the latter categories enter the market intermittantly. The 4,800 quarries are served by approximately 3,600 plants. The approach used for the impact analysis tends to overstate the adverse economic impact, since the analysis is based on the assumption that there are 4,800 quarry/plant facilities.

The costs considered here are for 1,106 facilities that need some type of control equipment installed.

Sand and Gravel

Sand and gravel are recovered from both wet and dry land-based pit operations and the dredging of rivers, bays or oceans. The mining equipment used varies from small, simple units such as tractor-mounted high-loaders and dump trucks to sophisticated mining systems involving large power shovels, draglines, bucket-wheel excavators, belt conveyors, barges, and other components. Increasingly, mining systems are being designed to provide for efficient and economical land rehabilitation. Sand and gravel is also dredged from river and lake bottoms that are rich in such deposits. Peak annual production has approached 775 million metric tons (850 million short tons).

Industrial Sand

Industrial sands are deposits that have been worked by natural processes into segregated mineral fractions. Such deposits are utilized for their contained quartz (SiO_2). The deposits are found in a broad range of locations and formations, some

as loose and visible as dune sand, others as dense and obscure as the hardest of rocks buried under a variety of surface materials, and in literally all intermediate types of formations. They may be found as low-lying water-bearing sands or as hard-faced bluffs and cliffs—as out-cropped escarpments on a level plain or as a massive ridge or mountain face. It is believed that there is only one operating underground mine. Production in 1974 approached 26 million metric tons (29 million short tons).

Gypsum

Gypsum is mined at 65 sites in the United States. An estimated 57 of these facilities use no contact water in their process. Two known facilities use heavy media separation and washing to beneficiate the crude gypsum ore, resulting in a process effluent.

Asphaltic Minerals

Of the asphaltic minerals, bituminous limestone, oil-impregnated diatomite, and gilsonite, only gilsonite operations currently have any discharge to surface water. The only gilsonite facility is located in Utah.

Asbestos

Asbestos is mined and processed at five locations in the U.S.: two in California, and one each in Vermont, Arizona and North Carolina. One facility in California uses wet processing while the remaining four facilities use a dry process.

Barite

Of the twenty-seven known significant U.S. facilities producing barite ore or ground barite, nine facilities use dry grinding operations, fourteen use log-washing and jigging methods to prepare the ore for grinding, and four use froth flotation techniques. In Missouri, where most of the washing operations are located, tailings ponds are commonly constructed by damming deep valleys. It is customary in lot-washing operations to build the initial pond by conventional earthmoving methods before the facility opens so that process water can be recycled. Afterwards the waste rock is used to construct dikes to increase the pond capacity. This procedure provides a use for the gangue and also provides for storage of more clay and mud tailings. The clay and mud are used to seal the rock and gravel additions. A washing facility located in Nevada also uses tailing ponds with total recycle of wastewater and no discharge of wastewater at any time. Because the recycle facilities are part of the total processing facility already in-place, no pollution control impacts result. Flotation is used on either beneficiated low-grade ore or high-grade ore which is relatively free of sands, clays, and rocks. Therefore, flotation operations produce significantly less solid wastes (tailings) than washing operations, and consequently have less cost for waste treatment. Waste water treatment is similar to that previously described for washing operations: pond settling and storage of tailings followed by recycle. Of the three facilities investigated in this category two are in the East and one in the West. The western facility has achieved a no discharge status; the two eastern facilities have not yet done so.

Fluorspar

The mining of fluorspar, because of its geographical locations, usually has no mine wastewater to be discharged. Beneficiation of mined fluorspar ore is accomplished by heavy media separations and/or flotation operations. Although these technologies are used separately in some instances, generally beneficiation facilities employ both techniques. The primary purpose of heavy media separations is to provide an upgraded and preconcentrated feed for flotation facilities. Five of the six heavy media operations have no wastewater discharge. The sixth facility uses a pond to remove suspended solids and then discharges to surface water.

Brine Extraction

The extraction of several mineral products from lake brines is carried out at two major U.S. locations: Searles Lake in California and the Great Salt Lake in Nevada. Also, lithium carbonate is extracted at Silver Peak, Nevada. The only wastes are depleted brines which are returned to the brine sources.

Borax

The entire U.S. production of borax is carried out in the desert areas of California by two processes: the mining and extraction of borax ore and the trona process. The latter is covered in the section on salines from lake brines. Since the trona process returns all residual brines to the source, there is no need for treatment and there are no treatment costs. The mining and extraction process accounts for about three-fourths of the estimated U.S. production of borax. All wastewater is evaporated in ponds at this facility.

Tripoli

There are several tripoli producers in the United States. The production process is dry both at the facilities and the mines. One small facility has installed a wet scrubber. There is only one facility in this subcategory that has any process wastewater. This is only from a special process producing

10 percent of that facility's production. Therefore, costs are considered to be negligible.

Novaculite

There is only one novaculite producer in the United States. Processing is a dry operation resulting in no discharge of wastewater. A dust scrubber is utilized and the water is recycled after passing through a settling tank. Both present treatment costs and proposed recycle costs are negligible.

Magnesia

There is only one known U.S. facility that produces magnesia from naturally occurring magnesite ore. This facility is located in a dry western climate and has no discharge of wastes to surface water by virtue of a combination evaporation-percolation pond.

Phosphate Rock

"Phosphate rock" is a commercial term for a rock that contains one or more phosphate minerals—usually calcium phosphate—of sufficient grade and suitable composition to permit its use, either directly or after concentration, in manufacturing commercial products. The term "phosphate rock" includes phosphatized limestones, sandstones, shales, and igneous rocks.

Present western phosphate mining operations are open pit. However, most of the western reserve is deep, requiring selective underground mining, which will continue to be economically viable only if future phosphate rock prices are high. The western region accounts for only 13 percent of domestic phosphate rock production. Due to local mineral characteristics and corresponding process practices, and because of the favorable rainfall/evaporation balance existing for the western facilities, all six producers in this region will soon be operating with no discharge of wastewaters. Therefore, they will experience no incremental costs upon implementation of the proposed effluent guidelines. Producers in the eastern district must already comply with effluent guidelines close to those proposed. Only four facilities are known to be exceeding the proposed limits; all four are in Central Florida. As far as is known, the facilities in North Carolina and Tennessee (each state accounting for only about 5 percent of national production) will not be affected.

Potash

Potash is produced in four different locations by four different processes, all of which are in dry climate areas of the western U.S. Two processes, involving lake brines, have no wastewater. Since residual brines are returned to the lake, there are no treatment costs. The third process, at the Carlsbad Operations, consists of dry mining followed by wet processing to separate potash from sodium chloride and other wastes; the operation utilizes evaporation ponds for attaining no discharge of wastewaters.

Sodium Sulfate

Sodium sulfate is produced from natural sources in three different geographical areas by three different processes:

(1) Recovery from the Great Salt Lake
(2) Recovery from Searles Lake brines
(3) Recovery from West Texas brines.

Operations (1) and (2) have no wastewater treatment or treatment costs. All residual brines are returned to the lakes. Operation (3) has wastewater which is percolated and evaporated in existing mud flat lakes. There is no treatment. The wastewater flows to the mud lake by gravity. Costs are negligible.

Bentonite

There is no wastewater from the processing of bentonite. Therefore, there is no treatment cost involved.

Diatomite

Diatomite is mined and processed in the western U.S. Both mining and processing are practically dry operations. Evaporation ponds are used for waste disposal in all cases. The selected technology of partial recycle and chemical treatment is practiced at the better facilities. All facilities are currently employing settling and neutralization, thus there are no additional costs involved.

Graphite

There is only one producer of natural graphite in the United States. For this mine and processing facility, mine drainage, settling pond seepage, and process water are treated for suspended solids, iron removal, and pH level. The pH level and iron precipitation are controlled by lime addition. The precipitated iron and other suspended solids are removed in the settling pond and the treated wastewater discharged. Present treatment costs to meet these regulations are negligible.

Jade

The jade industry is very small and involves very little wastewater. One facility that represents 55 percent of the total U.S. production generates only 190 liters per day (50 gpd) of wastewater. Suspended solids are settled in a small tank. The cleansed overflow water is used to irrigate the

company lawn. Treatment costs are considered to be negligible.

Sulfur

There are two subcategories of sulfur mining:

(1) Anhydrite deposit mining
(2) On-shore salt dome mining.

The industry described by the anhydrite deposit mining subcategory consists of two facilities, 5 and 7 years of age. Both facilities are located in western Texas. There are nine facilities in the U.S. producing sulfur from on-shore salt dome operations. There is only one operational off-shore salt dome facility. Bleedwater is directly discharged without treatment into the Gulf of Mexico. Dissolved methane gas, occurring naturally in the bleedwater, provides initial turbulent mixing of bleedwater and sea water. Dissolved oxygen in the sea water reacts with the sulfides present.

Emission Sources and Pollutants

Effluents from the mineral mining and processing industry are generally high in suspended solids and mineral content, depending on the solubility of the specific ores. Typically, treatment technology consists of settling ponds to remove suspended solids and sometimes lime precipitation to remove metals and adjust pH. For difficult suspended solids, flocculant addition and thickeners can be used. Where settling ponds are not sufficient, filters can be used to augment treatment. Effluents are generally from two distinct sources, mine dewatering and beneficiation operations (milling, washing, and separation of minerals). The effluent from beneficiation operations is usually higher in suspended solids than that from mining operations.

Table 6.1–1 is a summary of compliance costs for the above categories of the mineral mining and processing industry.

TABLE 6.1–1. MINERAL MINING AND PROCESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	28.53	87.96	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	28.53	87.96	0.0	0.0	0.0
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	28.53	87.96	0.0	0.0	0.0
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	14.32	27.53	57.26	85.81	115.63
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	14.32	27.53	57.26	85.81	115.63
O&M					
EXISTING PLANTS					
BPT	8.70	14.79	52.88	79.31	118.97
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	8.70	14.79	52.88	79.31	118.97
INDUSTRY TOTAL	23.02	42.33	110.14	165.12	234.60
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	23.02	42.33	110.14	165.12	234.60
ALL ANNUAL COSTS	23.02	42.33	110.14	165.12	234.60

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.2 GLASS MANUFACTURING INDUSTRY

FLAT GLASS (PHASE I)

Production Characteristics and Capacities

The flat glass industry may be divided into six major subcategories based on the processes employed.

These are:

- Sheet Glass Manufacturing
- Rolled Glass Manufacturing
- Plate (or primary) Glass Manufacturing
- Float Glass Manufacturing
- Automotive Glass Tempering
- Automotive Glass Laminating

The sheet, float and rolled glass manufacturing industries do not contribute a significant wastewater discharge and can be controlled with minimal costs. Thus, they will not be considered for the purposes of this report. The major division within the industry is between primary and automotive glass manufacturers and the processes they use. Automotive glass manufacture is a fabrication process using primary glass.

There were 47 establishments in the flat glass industry in 1972. They produced 222 million square meters (2,390 million square feet) of primary glass and 77 million square meters (830 million square feet) of automotive glass. It is estimated that 34 of the industry's plants generate waste process water. The plants that are contributing to effluent discharge produced 7,400 metric tons per day (8,200 short tons) of primary glass and 172,700 square meters (1,860,000 square feet) per day of automotive glass in 1972.

Glass is produced by combining the following raw materials: sand (silica), sodium carbonate, calcium carbonate, magnesium carbonate, and cullet. Cullet is waste and broken glass; a substantial portion of this can be reused.

In primary glass production, the following processes affect wastewater discharge: (1) washing, (2) batching, and (3) grinding and polishing. In the production of automotive glass, the following processes affect wastewater discharge: (1) seaming, (2) grinding, (3) drilling, (4) cooling, and (5) washing.

The batching process in primary glass manufacturing brings together the raw materials and blends them to a homogeneous mixture for charging to the glass furnace.

Waste Sources and Pollutants

A grinding and polishing process is used for plate and tempered glass. This process uses either a single or twin configuration. (The twin configuration grinds and polishes simultaneously.) The grinding part of the process uses a slurry of sand and water from which a side stream is continuously being blown down in order to be recycled and classified as a progressively finer grinding medium is needed. The polishing process uses a polishing surface of animal felt, and a polishing medium of water and iron oxide or cerium oxide slurry. The glass is reduced in thickness by approximately 15 percent in the combined grinding and polishing process.

The washing process is used for plate glass to remove the slurry, and in float glass to remove the protective chemicals coated on the rollers which prevents the glass from getting marked.

The cooling process utilizes water for cooling in all the melting tanks, the float tanks, and bathing tanks. Water is also used for cooling the rollers for plate glass, for cooling the annealing lehr and the bending lehr, and in the tempering process.

The seaming and drilling processes in automotive glass manufacture are basic fabrication processes that aid in handling and meeting product specifications.

The tempering process includes heating and then rapidly cooling the glass.

Primary glass is specified for almost all architectural and building requirements and is the basic component for fabricated flat glass products. Automotive glass is used primarily for windshields and safety glass.

The number of flat glass plants has increased in recent years but plate glass plants have decreased due to the greater profitability of the float glass process. Flat glass exports by the United States are not significant. There has been a gradual in-

crease in the quantity of imports, with imports comprising about 21 percent of the total consumption in 1975. The demand for tinted or colored glass for reflective architectural uses and for tempered glass for safety applications in buildings is expected to grow. However, the demand for flat glass moves with the level of residential construction and automobile manufacturing and downturns in these industries may adversely affect the growth of the industry.

The major glass manufacturing wastes include: sand, silt, clay, grease, oil, alkalinity, and thermal pollution (4.7° C or 8.5° F over ambient temperature).

The main sources contributing to the total waste load come from the following processes in each segment of the industry:

- Plate—batching grinding and polishing, and washing;
- Tempered—seaming, grinding, drilling, cooling, and washing (wash-water is the major source); and
- Laminated—cooling, seaming, and washing

In order to define waste characteristics, the following pollution parameters were used to develop effluent guidelines for meeting BPT and BAT: total suspended solids, oil, pH, and total phosphorus.

Effluent limitations and standards of performance for new sources are no discharge for the sheet plate glass manufacturing subcategory and the same as best available control technology for the remaining subcategories.

Control Technology and Costs

Waste treatment practices vary in each segment of the flat glass industry. Some use a lagoon system with a polyelectrolyte flocculant or partial recycling of process water. Others require no treatment or have only eliminated detergent in the wash water. Control methods include: filtration alone, filtration and recycling, total recycling with a reverse osmosis unit, coagulation-sedimentation, use of a two-stage lagoon with mixing tank for proper polyelectrolyte dispersion, use of an oil absorbing diatomacous earth filter, and sludge dewatering by centrifugation.

The guidelines for BPT call for control and removal of total suspended solids (TSS), oil, pH, and total phosphorus. BPT calls for the following control methods for each segment of the industry:

- Plate—Two-stage lagoon with a mixing tank for proper polyelectrolyte dispersion.
- Tempered and Laminated—Coagulation/sedimentation.

The BAT guidelines assess the availability of in-process controls, as well as call for additional treatment techniques. The following additional treatment methods under BAT guidelines for each segment of the industry are:

- Plate—Addition of a return of filter backwash to lagoon systems.
- Tempered—Addition of oil-absorptive, diatomacousearth filtration.
- Laminated—Introduction of recycling of post-lamination washing and initial hot water rinse, gravity separation of remaining rinse waters, reduce detergent usage and addition of oil absorptive diatomaceous earth filtration.

GLASS (PHASE II)-PRESSED AND BLOWN GLASS INDUSTRY

Production Characteristics and Capacities

The effluent limitations guidelines for the pressed and blown glass manufacturing industry cover manufacturers of glass containers for commercial packing, bottling, home canning, and the manufacturers of glass and glassware, which is pressed, blown, or shaped from glass produced in the same establishment.

The industry has been divided into the following subcategories, based upon differences in production processes and wastewater characteristics:

- Glass containers
- Machine-pressed and blown glass
- Glass tubing
- Television picture tube envelopes
- Incandescent lamp envelopes-forming/ and frosting
- Hand-pressed and blown glass-leaded and hydrofluoric acid finishing, non-leaded and hydrofluoric acid finishing, and non-hydrofluoric acid finishing.

Four manufacturing steps are common to the entire pressed and blown glass industry: weighing and mixing of raw materials, melting of raw materials, forming of molten glass, and annealing of formed glass products. Further processing (finishing) is required for some products, especially

television tube envelopes, incandescent lamp envelopes, and hand-pressed and blown glass.

Sand (silica) is the major ingredient of glass and accounts for about 70 percent of the raw materials batch. Other ingredients may include soda or soda ash (13–16 percent), potash, lime, lead oxide, boric oxide, alumina, magnesia, and iron or other coloring agents. The usual batch also contains between 10 and 50 percent waste glass (cullet).

Melting is done in three types of units: continuous furnaces, clay pots, or day tanks. Methods used to form glass include blowing, pressing, drawing, and casting. After the glass is formed, annealing is required to relieve stresses that might weaken the glass or cause the product to fail. The entire piece of glass is brought to a uniform temperature that is high enough to permit the release of internal stresses, and then it is cooled at a uniform rate to prevent new stresses from developing; finishing steps include abrasive polishing, acid polishing, spraying with frosting solutions, grinding, cutting, acid etching, and glazing.

In 1972, approximately 300 plants manufactured pressed and blown glass products in the United States, and almost half of these manufactured glass containers. The glass container industry is relatively concentrated, with the eight largest firms producing about 80 percent of the industry's shipments and operating about two-thirds of the individual plants. Because of the special nature of their products, the machine-pressed and blown glass industry is also relatively concentrated, as are the tubing, television picture tube envelope, and incandescent lamp envelope industries. On the other hand, the hand-pressed and blown glass industry is characterized by a large number of family-owned and-operated, single-plant companies. Of the 46 firms in this industry, only four operate more than one plant.

Competition from other types of containers is expected to keep the annual growth rate of glass containers' production down to approximately 1.5 percent per year. This projection may be materially affected by the growing trend towards state and local regulations mandating returnable bottles. The machine-pressed and blown glass and the hand-pressed and blown glass subcategories are expected to grow at about the same annual rate as the GNP.

Waste Sources and Pollutants

Water is used in the pressed and blown glass manufacturing industry for non-contact cooling, cullet quenching, and product rinsing following the various finishing operations. Water may also be added to the raw materials batches for dust suppression. Wet fume scrubbers used in acid polishing areas also contribute wastewater discharge.

For the purposes of establishing effluent limitations guidelines, the following pollution parameters have been designated as significant: fluoride, ammonia, lead, oil, chemical oxygen demand(COD), total suspended solids(TSS), dissolved solids, temperature(heat), and pH. These parameters are not present in the wastewater from every subcategory, and may be more significant in one subcategory than in another. Wastewaters from non-contact cooling, boilers, and water treatment are not considered process wastewaters and are not covered by the guidelines.

Control Technology and Costs

The pressed and blown glass industry is currently treating its wastewaters to reduce or eliminate most of the pollutants. Oil is reduced by using gravity separators. Treating for fluoride and lead involves adding lime, rapid mixing, flocculation, and sedimentation of the resulting reaction products, although some manufacturers of lamp envelopes are switching from fluoride etched products to the soft lights rather than install expensive waste treatment facilities. Several glass container plants recycle non-contact cooling and cullet quench water. Treatment for ammonia removal is presently not practiced in the industry.

Additional treatment systems that are applicable to the industry include chemical or physical methods to reduce oil levels further, (such as high-rate filtration, diatomaceous earth filtration, and chemical addition or coagulation); additional treatment of fluorides by ion-exchange or activated alumina filtration; and ammonia removal by steam or air stripping, selective ion exchange, nitrification/denitrification, or break-point chlorination.

Because current treatment practices in the pressed and blown glass industry provide wastewater pollutant concentrations that are already at low levels, no additional control technologies are proposed for most subcategories to meet BPT guidelines. The major exception is the addition of steam stripping to control ammonia discharges from the incandescent lamp envelope manufacturing subcategory.

Additional technologies required for BAT and NSPS guidelines include segregation of non-contact cooling water from the cullet quench water, recycling of cullet quench water, treatment of cullet quench water blowdown by dissolved air

flotation and diatomaceous earth filtration, and treatment of finishing wastewaters by sand filtration and activated alumina filtration.

Table 6.2–1 summarizes the control technologies recommended for each subcategory; as indicated, most of the plants in the pressed and blown glass industry already have sufficient operating technology to meet BPT guidelines. In addition, only about one-third of the approximately 300 plants covered by these guidelines discharge to surface waters. The remaining plants either have achieved a no discharge status or, in most cases, discharge to municipal systems.

Table 6.2–1.
Pressed and Blown Glass
Industry Pollution Control Technologies

Subcategories	BPT	BAT
Glass Containers	Housekeeping	Recycle, gravity oil separation and filtration
Machine-pressed & blown glass	Housekeeping	Recycle, gravity oil separation and filtration
Glass tubing	Housekeeping	Cooling tower and filtration
TV tube envelopes	Lime addition, coagulation, and sedimentation	Sand filtration, activated alumina filtration
Incandescent lamp envelopes	Steam stripping, lime precipitation and recarbonization	Sand filtration, activated alumina filtration
Hand-pressed & blown glass	Batch lime precipitation, coagulation, sedimentation	Sand filtration, activated alumina filtration

NSPS are the same as BAT for all subcategories.

All costs for all the above categories of the glass industry are summarized in Table 6.2–2.

TABLE 6.2–2. GLASS MANUFACTURING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.52	1.40	0.0	0.0	0.0
BAT	0.0	0.0	10.16	13.55	13.55
NEW PLANTS	0.35	1.23	1.80	3.00	5.28
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.87	2.64	11.97	16.55	18.83
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.87	2.64	11.97	16.55	18.83
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.18	0.38	0.74	1.11	1.11
BAT	0.0	0.0	2.67	6.23	11.58
NEW PLANTS	0.16	0.39	1.21	2.24	4.49
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.35	0.76	4.62	9.59	71.73
O&M					
EXISTING PLANTS					
BPT	0.27	0.54	1.06	1.59	2.39
BAT	0.0	0.0	2.90	6.77	12.57
NEW PLANTS	0.19	0.45	1.40	2.59	5.18
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.45	0.99	5.36	10.95	20.15
INDUSTRY TOTAL	0.80	1.75	9.99	20.54	37.88
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.80	1.75	9.99	20.54	37.88
ALL ANNUAL COSTS	0.80	1.75	9.99	20.54	37.88

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.3 INSULATION FIBERGLASS INDUSTRY

Production Characteristics and Capacities

The insulation fiberglass industry has no subcategories. The raw materials for fiberglass production are 55–73 percent silica and 27–45 percent fluxing oxides (e.g., limestone and borates) to manufacture the fiberglass filaments, and a phenolic resin to bind the filaments together. Four basic types of glass are used: low-alkali lime alumina borosilicate, soda-lime borosilicate, lime-free borosilicate, and soda-lime.

The basic process for fiberglass manufacture is as follows. The raw materials batch is melted to form a homogeneous glass stream. There are two ways that the melting process can be done: direct melting or marble process. The molten glass stream is then fiberized to form a random mat of fibers which are bonded together with a thermosetting phenolic binder or glue. The glass is fiberized by either flame attenuation or rotary spinning. The trend in the industry is toward more direct melting and rotary spinning.

The primary domestic uses for insulation fiberglass are: insulating material, noise insulation products, air filters, and bulk wool products.

There are 19 insulation fiberglass plants owned by three major companies. Ten of these plants currently have BPT equipment in place. The typical plant produces 123 thousand metric tons (136 thousand short tons) per year, and all plants have a wastewater discharge.

In 1972, total fiberglass production amounted to 0.77 million metric tons (0.85 million short tons). Of the $427 million in annual sales, exports amounted to $8.4 million and imports were $0.7 million. Therefore, foreign trade is not a significant portion of total consumption.

Waste Sources and Pollutants

The main sources contributing to total waste load are summarized in Table 6.3–1.

Control Technology and Costs

Because of the large volume of process waters and because the chain wash water often contains phenol, formaldehyde, and other contaminants, total recycling of wastewaters is the most economical treatment alternative for the insulation fiberglass industry. Sample recycling systems consist of

Table 6.3–1.
Insulation Fiberglass Industry Pollutant Sources

Waste Stream	Phenols	BOD_5	COD	DS	SS	Oil & Grease	Ammonia	pH	Color	Turbidity	Temp.	Specific Conductance
Air Scrubbing	X	X	X	X	X	—	—	—	X	X	X	X
Boiler Blowdown	—	—	—	X	X	—	—	—	—	X	X	X
Caustic Blowdown	—	—	—	X	X	—	—	X	—	X	X	X
Chain Spray	X	X	X	X	X	X	X	X	X	X	—	X
Cullet Cooling	—	—	—	X	X	—	—	—	—	—	X	—
Fresh Water Treatment	—	—	—	X	X	—	—	X	—	X	X	X
Hood Spray	X	X	X	X	X	X	X	X	X	X	X	
Noncontact Cooling Water	—	—	—	X	—	—	—	—	—	—	X	X

Source: EPA Development Document, January 1974.

coarse filtration, followed by either fine filtration or flocculation and settling.

Effluent control costs are summerized in Table 6.3-2.

TABLE 6.3-2. INSULATION FIBERGLASS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	2.08	5.14	0.15	0.23	0.30
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.52	1.83	2.57	4.22	7.26
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	2.60	6.97	2.72	4.45	7.57
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	2.60	6.97	2.72	4.45	7.57
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.68	1.34	2.75	4.16	6.30
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.24	0.58	1.77	3.25	6.42
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.92	1.92	4.53	7.41	12.72
O&M					
EXISTING PLANTS					
BPT	0.87	1.74	3.56	5.38	8.16
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.32	0.75	2.34	4.30	8.53
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.19	2.49	5.90	9.69	16.68
INDUSTRY TOTAL	2.11	4.41	10.43	17.10	29.40
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	2.11	4.41	10.43	17.10	29.40
ALL ANNUAL COSTS	2.11	4.41	10.43	17.10	29.40

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.4 ASBESTOS MANUFACTURING INDUSTRY

Asbestos Manufacturing (Phase I)

Production Characteristics and Capacities

There were 68 plants operating in this portion of the asbestos manufacturing industry in 1972. A majority of these asbestos plants generate wastewater during production.

The asbestos manufacturing industry (Phase I) can be subdivided into six parts; these are:

- Cement pipe
- Cement sheet
- Paper
- Millboard
- Roofing materials
- Floor tile

Asbestos cement products manufacturers are the largest overall users of asbestos fibers; cement pipe manufacture is the largest element of this category. Asbestos sheet is used for laboratory table tops and other structural uses. Asbestos paper and millboard have a wide variety of uses, but are particularly used for applications where direct contact with high temperatures occur. Asbestos roofing and floor tiles are fabricated products that take advantage of the unique qualities of asbestos.

With the exception of roofing and floor tile manufacturing, there is a basic similarity in the manufacturing methods of various asbestos products. The asbestos fibers and other raw materials are slurried with water and then formed into sheets. Save-alls (settling tanks) are used in all processes. In roofing manufacture, asphalt or coal tar is soaked into asbestos paper. In floor tile manufacture, asbestos is added to the tiles for its special structural and dimension-holding qualities.

A favorable trade balance may be projected for asbestos products, regardless of any price effects resulting from the effluent standards. However, there has been a recent trend towards an increase in the value of imports, with an increase from $8.8 million in 1969 to $11.3 million in 1972.

Waste Sources and Pollutants

Asbestos manufacturing wastes include: total suspended solids (which include asbestos fibers), BOD_5, COD, pH (alkalinity), high temperature, total dissolved solids, nitrogen, phosphorus, phenols, toxic materials, oil and grease, organic matter, nutrients, color, and turbidity.

The major source of wastewater in the asbestos industry is the machinery that converts slurry into the formed wet product. Water is used as: an ingredient, a carrying medium, for cooling, and for auxilliary uses such as pump seals, wet saws or for pressure-testing the pipes. In most plants, wastewater is combined and discharged into a single sewer. In all subcategories, water is removed during various steps to the save-all system (settling tank). Waste characteristics are defined by the following parameters: total suspended solids (TSS), COD, and pH.

Control Technology and Costs

Waste treatment methods used in the asbestos manufacturing industry are summarized in Table 6.4–1.

Asbestos Industry (Phase II)

Production Characteristics and Capacities

For purposes of establishing water effluent guidelines, the Phase II asbestos industry covers four processes: coating of asbestos textiles, solvent recovery, vapor absorption, and wet scrubbing.

There are a total of 51 asbestos plants in the Phase II portion of the industry. However, only 9 plants have wastewater streams from the processes covered by the guidelines. The majority of products are manufactured by a dry process and this production does not generate process wastewaters.

The primary reasons for the use of asbestos fiber in textile products are its properties of durability and resistance to heat, fire, and acid. Asbestos is the only mineral that can be manufactured into textiles using looms and other textile equipment. Asbestos textile products are primarily used for friction materials, industrial packing, electrical insulation, and thermal insulation.

The manufacture of asbestos textile products involves a variety of processes. The textile plants

receive the asbestos fiber by rail car in 100-lb. bags. The bags are opened, and the fibers passed over a vibrating screen or trommel screen for cleaning. The fibers are lifted from the screen by air suction and graded. After preparation, the fiber is mixed and blended. Chrysolite is the predominant fiber used in textiles. Crocidolite and amosite asbestos fibers may also be added to the chrysolite. Small percentages of cotton, rayon, and other natural or synthetic fibers serve as carriers or supports for the shorter asbestos fibers, and they improve the spinnability of the fiber mixture. Typically, the organic fiber content is between 20 and 25 percent. The blending and mixing operations are primarily done during carding of the fibers, but can also be performed in multi-hopper blending units.

In the carding operation, the fibers are arranged by thousands of needle-pointed wires that cover the cylinders of the carding machine. The fibers are combed by passing between the carding machine main cylinder and the worker cylinders rotating in the opposite direction. The carding machine forms a continuous mat of material. This mat is divided into strips, or slivers, and mechanically compressed between oscillating surfaces into untwisted strands. The strands are wound on spools to form the roving. Roving is the asbestos textile product from which asbestos yarn is produced. The roving is spun into yarn in a manner similar to that employed to manufacture cotton and wool yarn. The strands of roving are converted into a single yarn by the twisting and pulling operations of a spinning machine. The yarn produced in the spinning and twisting operation is the basic component of several other asbestos textile products. Asbestos twine or cord is produced by twisting together two or more yarns on a spinning frame similar to those used to manufacture cotton cord. Braided products are made by a series of yarn-carrying spindles, half traveling in one direction and half in the opposite direction to plait the yarn together and form a braided product.

Asbestos yarn can also be twisted or braided into various shapes to form packing and gaskets. The braided material can be impregnated with different compounds. Graphite is commonly used to impregnate braided packing material; the graphite serves to lower the frictional properties and improve the binding properties of the packing.

Asbestos cloth is woven from yarn on looms that operate in a manner similar to those used for the manufacture of other textile products. The warp yarn is threaded through the heddles and the reed of the loom and the filler yarn is wound on quills and placed in a shuttle. The cloth is woven as the filler yarn in the shuttle interweaves the warp yarn transversely. Following weaving, the asbestos cloth is inspected for strength, weight, and asbestos content.

Asbestos yarn or cloth may be coated for fabrication into friction materials and special textile products. The material is drawn through one or more dip tanks and the coating material is spread by rollers, brushes, or doctor blades. The coated textile product then passes through a drying oven where the solvent is evaporated.

Table 6.4–1.
Asbestos Manufacturing Industry
Waste Treatment Methods

Subcategories	Sedimentation & Neutralization	Complete Recycle
Asbestos Cement Pipe		
BPT	X	—
BAT	—	X
NSPS	X	—
Asbestos Cement Sheet		
BPT	X	—
BAT	—	X
NSPS	—	X
	Sedimentation & Coagulation	Complete Recycle
Asbestos Paper		
BPT	X	—
BAT	—	X
NSPS	—	X
	Sedimentation (Elastrometric binder)	Complete Recycle (Starch binder)
Millboard		
BPT	—	X
BAT	—	X
NSPS	—	X
	Sedimentation & Skimming	Complete Recycle
Roofing		
BPT	X	—
BAT	—	X
NSPS	—	X
Floor Tile		
BPT	X	—
BAT	—	X
NSPS	—	X

Waste Sources and Pollutants

Water is not normally used in an asbestos textile manufacturing plant. Two exceptions are the addition of moisture during weaving or braiding and the coating operation. Wastewater is generated only in the latter process.

The basic parameters used to define wastewater characteristics are: COD, suspended solids, and pH. Two of the nine plants discharge to municipalities, while six of the plants already provide BPT

treatment prior to discharge to surface waters. Only one plant does not have BPT treatment installed on a Phase II wastewater stream. This facility is planning to incorporate total recycling of all waters.

Control Technology and Costs

New plants are expected to be designed for zero effluent discharge. Increased user charges are expected to be negligible since the waste streams for Phase II processes are small. There are no pretreatment standards. It is estimated that the costs for the Phase II guidelines will be zero.

Best practical technology for the Phase II asbestos industries varies from cooling, recycle, sedimentation, and activated sludge. New plants are expected to recycle all processed wastewater and have no discharge.

Best available technology for this industry is carbon absorption treatment or total recycle.

Total asbestos industry water pollution control costs are summarized in Table 6.4–2.

TABLE 6.4–2. ASBESTOS MANUFACTURING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.10	1.12	0.0	0.0	0.0
BAT	0.0	0.0	1.91	2.55	2.55
NEW PLANTS	0.23	0.77	1.22	2.07	3.76
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.33	1.90	3.13	4.61	6.31
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.33	1.90	3.13	4.61	6.31
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.15	0.34	0.59	0.89	1.33
BAT	0.0	0.0	0.50	1.17	2.18
NEW PLANTS	0.10	0.24	0.78	1.47	3.02
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.25	0.58	1.88	3.53	6.53
O&M					
EXISTING PLANTS					
BPT	0.27	0.62	1.09	1.64	2.45
BAT	0.0	0.0	0.80	1.86	3.46
NEW PLANTS	0.35	0.83	2.72	5.11	10.48
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.63	1.45	4.61	8.61	16.40
INDUSTRY TOTAL	0.88	2.03	6.49	12.14	22.92
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.88	2.03	6.49	12.14	22.92
ALL ANNUAL COSTS	0.88	2.03	6.49	12.14	22.92

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.5 CEMENT INDUSTRY

Production Characteristics and Capacities

The cement industry is divided into two basic manufacturing processes: wet and dry.

A facility using the wet process grinds up the raw materials with water and feeds them into the kiln as a slurry.

A facility using the dry process drys the raw materials, grinds and then feeds them into the kiln in a dry state.

In each of these processes, there are three major steps: grinding and blending, clinker production, and finish grinding. Clinker is a material about the size of a large marble which has been through the kiln but has not been fine-ground into finished cement.

The raw materials for cement production include lime (calcium oxide), silica, alumina, iron, and gypsum. Lime, the largest single ingredient, comes from cement rock, oyster shell marl, or chalk.

The cement industry numbered 166 establishments in 1972 with the typical plant production estimated to be 525 thousand metric tons (579 thousand short tons) per year.

In 1973, 80.5 million metric tons (88.7 million short tons) of cement were produced. From 1967 to 1973, production increased at a compound annual average rate of 5.3 percent. Imports have risen to meet demand, growing from 1.0 million metric tons (1.1 million short tons) in 1967 to 6.1 million metric tons (6.7 million short tons) in 1973. Exports have increased to 454 thousand metric tons (500 thousand short tons) in 1974. Shipments in 1975 declined because of the severe drop in overall construction activity. Total shipments dipped about 28 percent below 1974 to about 59 million metric tons (65 million short tons). However, because of higher cement prices, value of industry shipments in 1975 dropped only about 5 percent to $2.1 billion. According to the U.S. Industrial Outlook, an increase was expected in 1976 of about 21 percent in the value of Portland cement industry shipments to $2.5 billion, reflecting the higher prices and higher demand for new housing construction.

Prices have increased due to higher production costs and pollution abatement costs. Fuel cost increases are also expected to affect prices.

Waste Sources and Pollutants

In terms of the generation of water pollutants, the cement industry is divided into three subcategories:

- Leaching plants. The kiln dust comes into direct contact with water in the leaching process for reuse and from the wet scrubbers that control stack emission.
- Non-leaching plants. The contamination of water is not a direct function of the water usage.
- Pile materials. Kiln dust, clinker, coal or other materials that are subject to rainfall runoff.

The main sources contributing to the total waste load come from the following: in-plant leakage, non-contact cooling water, process water, kiln dust pile runoff water, housekeeping water, and effluent from wet scrubbers.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: pH, total dissolved solids, total suspended solids, alkalinity, potassium, sulfate, and temperature (heat).

BPT for plants in the non-leaching subcategory has been defined as no discharge of pollutants from manufacturing except for thermal discharge for which an increase of 3°C (5.5°F) is permitted.

For plants in the leaching subcategory, BPT is the same as for the non-leaching subcategory except for the dust-contact streams where a reduction of pH to 9.0 and of suspended solids to 0.4 kg/metric ton of dust leached is required. For plants subject to the provisions of the Materials Storage Piles Runoff Subcategory, either the runoff should be contained to prevent discharge or the runoff should be treated to neutralize and reduce suspended solids.

BAT for both leaching and non-leaching plants is defined as zero discharge of pollutants. For plants

subject to the provisions of the Materials Storage Piles Runoff Subcategory, the definition of BPT is applied to BAT.

NSPS is the same as BPT except that no discharge is permitted for plants with materials storage pile runoff.

Control Technology and Costs

The main control and treatment methods for the cement industry involve recycle and reuse of wastewater. The devices employed include cooling towers or ponds, settling ponds, containment ponds, and clarifiers.

For leaching plants, additional controls are needed for adequate control of alkalinity, suspended solids, and dissolved solids. Alkalinity is controlled by neutralization, or carbonation; suspended solids by clarification, sometimes with the addition of flocculating agents. Although none of the leaching plants currently use a treatment method to control dissolved solids, several processes that might be employed include, precipitation, ion exchange, reverse osmosis, electrodialysis, and combinations of these followed by total evaporation.

In-plant control methods include good maintenance and operating procedures to minimize solid spillage and to return dry dust to the process. Solids introduced into storm water runoff can be minimized by paving areas for vehicular traffic, providing good ground cover in other open areas, removing accumulations of dust from roofs and buildings, and by building ditches and dikes to control runoff from materials storage piles.

Control costs are summarized in Table 6.5–1.

TABLE 6.5–1. CEMENT INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	3.30	20.59	0.0	0.0	0.0
BAT	0.0	0.0	2.19	2.92	2.92
NEW PLANTS	0.0	0.0	4.73	7.47	12.11
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	3.30	20.59	6.93	10.40	15.04
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	3.30	20.59	6.93	10.40	15.04
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	2.71	6.61	10.83	16.25	24.37
BAT	0.0	0.0	0.58	1.35	2.50
NEW PLANTS	0.0	0.0	1.52	3.30	7.45
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	2.71	6.61	12.93	20.89	34.31
O&M					
EXISTING PLANTS					
BPT	2.49	5.96	11.22	17.04	25.77
BAT	0.0	0.0	0.51	1.19	2.21
NEW PLANTS	0.0	0.0	0.0	0.0	0.08
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	2.49	5.96	11.73	18.23	28.07
INDUSTRY TOTAL	5.20	12.58	24.66	39.12	62.38
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	5.20	12.58	24.66	39.12	62.38
ALL ANNUAL COSTS	5.20	12.58	24.66	39.12	62.38

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

6.6. PAVING AND ROOFING MATERIALS INDUSTRY

Industry Description

Establishments covered under these guidelines include: (1) Asphalt emulsion plants (SIC 2951); (2) Asphalt concrete plants (SIC 2951 and 1611); (3) Asphalt roofing plants (SIC 2952) and (4) Linoleum and asphalt felt flooring (SIC 3996). The regulations for this industry are cited in 40CFR443.

Asphalt Emulsion Plants

About 50 plants produce asphalt emulsions. The chief source of pollutants is water from the wet collection of waste fumes and the runoff of precipitation.

The costs of meeting the regulations for a typical plant of 5,500 metric tons (6,000 short tons) per day have been developed by EPA for the BPT, BAT, and NSPS case, and are applied to the 7 plants not in compliance in 1974, the year the regulations were proposed. Eighteen plants at that time were meeting the BPT standards, of which 8 met BAT standards. (This was industry practice, not anticipation of the regulations.) Twenty-five plants discharge to municipal sewers.

Industry size was static from 1971–75 but is expected to grow at 4 percent per year through 1980 and at 1.65 percent per year from 1981 to 85. These estimates are based on expected highway construction and repair.

Asphalt Paving Plants

Approximately 3,180 plants use wet scrubbers to remove particulates from the air, thereby creating a potential water pollution problem. (The rest of the industry group uses fabric filters.) The BPT, BAT, and NSPS requirements are the same—no discharge of pollutants. This can be easily achieved by the use of an earthen stilling basin or lagoon, or by use of a mechanical sedimentation tank. Costs derived in the EPA development document have been used. No pretreatment costs have been calculated since, according to a recent survey, only one plant discharges to a municipal system. Forty percent of new plants or expansions occuring after 1974 are expected to use wet scrubbing; the balance will use dry air pollution control methods and thus will not incur water pollution control costs. Of the plants using wet scrubbers in 1974, 10 percent (308 plants) were not in compliance with the water regulation. Only 55 percent of these are expected to continue to use water systems. The balance are estimated to have changed to fabric filters to abate air pollution and avoid the costs of upgrading their water clean-up system. Forty percent of future plants are expected to use wet systems. The overall industry growth rate is expected to be the same as for highway construction and repair.

Asphalt Roofing

In 1974, 225 plants produced a variety of asphalt and tar roofing materials including shingles, felts, siding materials, and coatings. The chief pollution problem arises from oil and particulate in the cooling water that is used directly on the material. In addition most plants have a tower for blowing asphalt. The ground adjacent to this unit is usually saturated with asphalt so that precipitation runoff becomes contaminated with oils.

The costs for meeting BPT, BAT, and NSPS for a plant of 450 metric tons per day (500 short tons per day) have been developed by EPA and have been applied to the 21 plants not conforming to BPT regulations and the additional 21 plants meeting BPT but not BAT standards.

Growth of the industry is assumed to be 3.5 percent per year.

Linoleum and Asphalt Felt Flooring

This industry segment of the tar and asphalt products industry is quite small (3 plants estimated) and the costs for conforming to the regulations are small, $6,100 capital investment and $2,570 O&M for a typical plant. For these reasons, the costs have not been tabulated or included.

The total costs for asphalt emulsion plants, asphalt paving plants and asphalt roofing plants are shown in Table 6.6–1.

TABLE 6.6–1. PAVING AND ROOFING MATERIALS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.11	1.09	0.26	0.29	0.35
BAT	0.0	0.0	2.59	3.45	3.45
NEW PLANTS	0.13	0.32	0.53	0.75	1.10
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.24	1.41	3.37	4.49	4.90
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.24	1.41	3.37	4.49	4.90
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.19	0.75	0.89	1.35	2.04
BAT	0.0	0.0	0.68	1.59	2.95
NEW PLANTS	0.04	0.07	0.35	0.61	1.12
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.24	0.82	1.92	3.55	6.11
O&M					
EXISTING PLANTS					
BPT	1.21	4.74	5.52	8.40	12.84
BAT	0.0	0.0	1.04	2.43	4.51
NEW PLANTS	0.03	0.07	0.69	1.35	2.67
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.24	4.80	7.26	12.19	20.02
INDUSTRY TOTAL	1.48	5.62	9.17	15.74	26.14
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.48	5.62	9.17	15.74	26.14
ALL ANNUAL COSTS	1.48	5.62	9.17	15.74	26.14

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7. FOREST PRODUCTS INDUSTRIES

For the purpose of this report, the Forest Products Industries are defined as those establishments engaged in gathering and processing forest products and in the manufacture of consumer goods from these materials. These are the:

- Timber Products Processing Industry
- Timber Products Processing (Furniture)
- Gum and Wood Chemicals Industry
- Pulp, Paper, and Paperboard Manufacturing Industry

Costs for the reduction of Water Pollution for these industrial sectors are summarized in Table 7-1. These costs and other data are repeated below in the appropriate sections together with the assumption peculiar to the industry and other details.

TABLE 7.-1. WATER POLLUTION ABATEMENT COSTS FOR THE FOREST PRODUCTS INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

			INVESTMENT	
INDUSTRY	1977	1972–77	1977–81	1977–86
TIMBER PRODUCTS	10.04	55.05	74.04	99.15
GUM & WOOD CHEMICALS	0.02	3.58	0.20	0.22
PULP PAPER & PAPERBOARD MANUFACTURING	700.00	2178.75	441.25	1511.05
FURNITURE MANUFACTURING	0.0	0.0	2.80	4.80
TOTAL INVESTMENT	710.07	2237.38	518.29	1615.22
			ANNUAL COSTS	
	1977	1972–77	1977–81	1977–86
TIMBER PRODUCTS	42.34	73.92	203.41	548.85
GUM & WOOD CHEMICALS	1.13	4.60	4.74	10.31
PULP PAPER & PAPERBOARD MANUFACTURING	528.53	1146.20	2281.20	6478.66
FURNITURE MANUFACTURING	0.0	0.0	1.37	12.59
TOTAL ANNUAL COSTS	572.01	1224.71	2490.72	7050.41

7.1. TIMBER PRODUCTS PROCESSING INDUSTRY

Production Characteristics and Capacities

The plywood, hardboard, and wood preserving segment of the timber products processing industry is a large and complex conglomerate. For purposes of establishing effluent limitations guidelines, and standards of performance, it has been divided into ten subcategories as follows: (1) barking, (2) veneer, (3) plywood, (4) hardboard — dry process, (5) hardboard — wet process, (6) insulation board (no steam), (7) insulation board with steam or hardboard, (8) wood preserving, (9) wood preserving — steam, and (10) wood preserving — boultonizing.

As of 1974, the industry had over 3600 establishments under the following subsectors:

Plants	Subsectors
2400	Sawmills
382	Plywood mills
338	Veneer plywood mills
390	Wood preserving plants
74	Particle board mills
37	Hardboard mills
17	Insulation board mills

"Barking" includes the operations that remove the bark from logs, either through mechanical abrasion or by hydraulic force. "Veneer" includes converting barked logs or heavy timber into thinner sections of wood, which may be later cut and conditioned to improve the quality of the product. "Plywood" includes operations of laminating layers of veneer to form finished plywood, either softwood from veneers of coniferous or needle bearing trees or hardwood from veneers of deciduous or broad-leaf trees. "Hardboard" includes the operations leading to the production of panels from chips, sawdust, logs, or other raw materials, using either the dry (air) or wet (water) matting processes for forming the board mat. "Insulation board" includes operations producing a low density board from wood particles, chips, and sawdust. "Wood processing" includes all pressure or non-pressure processes employing water-borne salts (copper, chromium, or arsenic), in which steaming or vapor drying is not the predominant method of conditioning. "Wood preserving-steam" includes steam impingement on the wood being conditioned. "Wood preserving-boultonizing" uses a vacuum extraction of water as the conditioning method. Timber products are used primarily for the building and construction industry, commercial uses, and home and decorative purposes.

Waste Sources and Pollutants

Wastewater sources are given for the following segments:

- Barking. Hydraulic barking contributes high suspended solids and BOD, as does drum barking.
- Plywood and veneer. Log conditioning, cleaning of veneer dryers, washing of the glue lines and glue tanks, and cooling water.
- Hardboard and Insulation Board. Wastewater discharge is low for dry processing but can occur due to washing. Sources from wet processing include: raw materials handling, fiber and mat formation, and processing.
- Wood preserving. Pollutants include oils, simple sugars, cooling water, steam condensate, boiler blowdown, and metals salts.

The major pollutant parameters common to all subcategories, but not necessarily present in process water from all the categories for which effluent guidelines and standards are presented, include the following: BOD_5, COD, phenols, oil and grease, pH, high temperature, dissolved solids, total suspended solids, phosphorus, and ammonia.

Wood preserving subcategories may also include the following pollution contributors: copper, chromium, arsenic, zinc, and fluorides. The above pollutants are not always present in process water from all the subcategories, and their presence depends on the processing methods.

Presently achieving a no discharge status are about 50 percent of the veneer and plywood plants, about 40 percent of the hardboard manufacturers and 10 percent of the wood preserving plants.

Control Technology and Costs

Current technology includes the following:

- Barking. Use of Clarifiers.
- Veneer. Reduction in the amount of wastewater by reuse and conservation.
- Plywood. Use of minimal wastewater and effecting a reduction in water use.
- Hardboard — Dry. Oil and water separation and use of waste retention ponds or spray irrigation.
- Hardboard — Wet. Use of water recycling, filtration, sedimentation, coagulation, evaporation, and biological oxidation such as lagoons, aerated lagoons, and activated sludge systems.
- Wood Preserving. Storage of wastes or discharge to sewers, evaporation and incineration, flocculation, and sedimentation.

BPT includes the following:

- Barking. Use of primary screening and settling followed by biological treatment.
- Veneer. Substitution for direct steam conditioning of logs by: hot water spray tunnels, indirect steaming, or modified steaming with the use of steam coils. Land disposal of solid waste.
- Plywood. Use of steam to clean spreaders where applicable and the use of high pressure water for cleaning, use of glue applicators that spray water for glue makeup, and evaporation and spray application of glue water on bark going to the incinerator.
- Hardboard-Dry. Recycling of log wash and chip wash water and disposal of the solids by landfill or use as boiler fuel, operation of the resin system as a closed system with wash water being recycled, and land application of solids.
- Hardboard-Wet, Hardboard, Insulation Board. Recycling of process water as dilution water, utilization of heat exchangers to reduce temperature, use of gravity settling, screening, filtration or flotation to reduce suspended solids, use of primary settling plus screening followed by aerated lagoons or activated sludge or both with pH adjustment, and disposal of sludge by aerobic digestion in sludge lagoons, recycling or as landfill.
- Wood Preserving. Recovery of contaminated water, modifications of existing nonpressure processing equipment, use of oil recovery equipment, biological treatment, neutralization, flocculation, evaporation, and landfill disposal.

BAT consists of the following:

- Barking. Reduction in water use and recycle.
- Veneer. Use of dry veneer dryer cleaning methods or proper land disposal.
- Plywood. Elimination of discharge from gluing operation and dry housekeeping procedures.
- Hardboard-Dry. Same as BPT.
- Hardboard-Wet. Installation of a pre-press and evaporation system, primary treatment followed by biological treatment, and use of recycle of process water.
- Wood Preserving. Implementation of good housekeeping practices, and minimizing water use.

NSPS is the same as BPT for barking, and the same as BAT for the remaining processes in the industry.

Control costs are summarized in Table 7.1–1.

TABLE 7.1-1. TIMBER PRODUCTS PROCESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	4.84	31.85	0.0	0.0	0.0
BAT	5.20	23.20	71.04	112.15	94.15
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	3.00	5.00	5.00
SUBTOTAL	10.04	55.05	74.04	117.15	99.15
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	10.04	55.05	74.04	117.15	99.15
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	4.19	11.06	16.75	25.12	37.69
BAT	3.05	6.73	31.52	65.85	116.08
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.79	1.97	3.94
TOTAL	7.24	17.79	49.06	92.94	157.71
O&M					
EXISTING PLANTS					
BPT	29.59	47.12	128.80	193.20	289.80
BAT	5.52	9.01	24.51	47.85	92.64
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	1.04	3.46	8.71
TOTAL	35.10	56.13	154.35	244.51	391.15
INDUSTRY TOTAL	42.34	73.92	203.41	337.45	548.85
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	42.34	73.92	203.41	337.45	548.85
ALL ANNUAL COSTS	42.34	73.92	203.41	337.45	548.85

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.2 TIMBER PRODUCTS PROCESSING (FURNITURE) INDUSTRY

Production Characteristics and Capacities

This industry segment, covered by the SIC 25 category, includes the following subcategories:

SIC	Sector
2511	Wood household furniture, unupholstered
2512	Wood household furniture, upholstered
2517	Wood television, radio, phonograph, and sewing machine cabinets
2521	Wood office furniture
2531	Public building related-furniture
2534	Kitchen cabinets
2541	Wood partitions, office and store furniture

There are about 6,000 establishments, with no single establishment accounting for more than 3% of industry sales, indicating a diversified and fragmented industry employing on the average, less than 25 people per establishment.

Furniture operations can generally be split into five steps:

(1) raw material handling
(2) machining
(3) wood bending and fitting
(4) assembly and gluing
(5) finishing.

Of these operations, gluing, cleaning, and finishing are the chief sources of effluents. The gluing process effluent is essentially washwater from the cleanup of excess and spilled glues. Cleaning effluent is from the cleaning of wiping rags and protective clothing. Finishing effluents are oils, solvents, resins, pigments, and particulates, and overspray collected typically in spray booths using either water sprayers or filters. The significant effluent descriptors for typical effluent from the furniture industry are:

Primary Significance	Secondary Significance
(1) Chemical Oxygen Demand	(1) Biological Oxygen Demand
(2) Total Suspended Solids	(2) Phenols
(3) Dissolved Solids	(3) Color
(4) pH	(4) Oil and Grease
(5) Temperature	(5) Inorganic Ions

Potential treatment technologies for industry effluents are:

(1) Incineration via spraying or scrap fuel
(2) Evaporation ponds
(3) Spray irrigation
(4) Trucking to landfill
(5) Disposal to municipal systems

Guidelines for the furniture and fixtures industry for both BPT and BAT call for zero discharge of wastewater pollutants to navigable waters, and as of 1974, 95 percent of all furniture and fixtures plants were in compliance with these guidelines. Table 7.2–1 is a summary of compliance costs for the SIC 25 group. It should be noted that SIC 2531 and SIC 2541 encompass the metal fabricated furniture industry, which has negligible gluing effluents and significantly reduced spray booth emissions compared to the wood furniture industry. Only the costs of effluent control in the wood furniture industry are included in Table 7.2–1.

TABLE 7.2-1. TIMBER PRODUCTS PROCESSING (FURNITURE) INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.0	0.0	0.0	0.0	0.0
BAT	0.0	0.0	2.80	4.80	4.80
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.0	0.0	2.80	4.80	4.80
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	2.80	4.80	4.80
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.0	0.0	0.0	0.0	0.0
BAT	0.0	0.0	0.63	1.89	3.79
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.63	1.89	3.79
O&M					
EXISTING PLANTS					
BPT	0.0	0.0	0.0	0.0	0.0
BAT	0.0	0.0	0.74	3.52	8.80
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.74	3.52	8.80
INDUSTRY TOTAL	0.0	0.0	1.37	5.42	12.59
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	1.37	5.42	12.59
ALL ANNUAL COSTS	0.0	0.0	1.37	5.42	12.59

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.3 GUM AND WOOD CHEMICALS INDUSTRY

General Industry Description

The Gum and Wood Chemicals Industry corresponds to SIC's 2861 and 2899 and has been divided, for pollution control purposes, into six categories as follows:

- Char and charcoal
- Gum rosin and turpentine
- Wood rosin, turpentine, and pine oil
- Tall oil rosin, fatty acids, and pitch
- Essential oils
- Rosin derivatives

Twelve major companies have been identified with this industry.

The 1972 Census of Manufacturers reported that the gum and wood chemicals industry included 139 facilities employing 5,900 people with an annual payroll of $47.6 million. Over 50 percent of the establishments are in the South.

The gum and wood chemicals industry produces a variety of products which had a value in excess of $300 million in 1972. These products are used by many different industries. The major products and their primary use are as follows:

Wood Char — Principal uses are in the production of charcoal briquettes for cooking and, to a lesser extent, as an industrial fuel source. Secondary uses are in the manufacture of activated charcoal and the production of carbonaceous chemicals, such as calcium carbide, and certain types of graphite.

Turpentine — Turpentine consists of the volatile hydrocarbon constituents of the oleorosin contained in coniferous trees. It is basically a mixture of $C_1 H_{16}$ hydrocarbons. Primary uses are in the manufacture of synthetic pine oil, insecticides, terpene resins, flavors and perfumes, refined terpenes and derivatives, solvents, and other miscellaneous industrial uses.

Rosin — Rosin is the solid resinous component of the oleoresin contained in the wood of coniferous trees. It is a complex mixture of rosin acids and some extraneous nonacidic compounds. Primary end uses include paper size, applications in the manufacture of synthetic rubber, adhesives, coatings, inks, and resins, and other miscellaneous uses.

Tall Oil Fatty Acids and Other Products From Tall Oil Fractination — The fatty acids from tall oil comprise 31 percent of the U.S. market for fatty acids. These are used to make plasticizers, soap, synthetic detergents, textile treating and finishing compounds, rubber chemicals, cutting oils, stabilizers, emulsifiers, asphalt additives, fungicides, and fuel oil additives.

Pine Oil — Pine oil produced by the distillation of southeastern pine stumps is called natural pine oil. This is used as an ingredient in insecticides, deodorants, polishes, sweeping compounds, and cattle sprays.

Cedarwood oil — Cedarwood oil is obtained from two varieties of trees and is used in soaps, as a fixative for various perfume fragrances, and a perfumant in shoe and furniture polishes.

Processes

A brief description of the manufacturing processes are given below:

Char and Charcoal — Char and charcoal are produced by thermal decomposition of raw wood in a kiln above 270C (520F). Both condensable and noncondensable products are given off and recovered for their fuel value. The char residue may be used as such, or mixed with a binder and made into briquettes.

Gum Rosin and Turpentine — Crude raw gum is collected from scarified longleaf and slash pine trees. This is melted and filtered to remove impurities. The purified gum is then distilled to separate the turpentine.

Wood Rosin, Turpentine and Pine Oil — The raw material for this process is the stumps from cutover pine forests. These are uprooted by bulldozers and delivered on railroad flat cars to an extraction plant. The stumps are cleaned and reduced to chips. These are then extracted in a sequential process to (1) remove water, (2) remove resinous material and (3) remove solvent. The resinous frac-

tion is then distilled to obtain the desired products, and the spent wood chips are burned for fuel.

Tall Oil Rosin, Fatty Acids, and Pitch — These products are produced using very modern distillation techniques starting with crude tall oil as the raw material.

Essential Oils — Essential oils are obtained by the steam distillation of scrap wood fines from comparable wood. For example, cedarwood oil is obtained by distilling cedarwood, etc.

Rosin Derivatives — Rosin is commonly chemically modified to enhance particular properties. Many different types of chemical reactions are involved in the various modifications, none of which can be considered as typical.

The general trend in the gum and wood chemicals industry is toward a decrease in production. This is primarily due to more efficient use of rosin for sizing in the paper industry and a predictable decline of the gum naval stores industry in the United States. Trends in specific products are as follows:

Rosin — The U.S. Department of Agriculture reports that the U.S. consumption of rosin has been decreasing over a period of many years. In 1974, consumption was only 78 percent of 1960 consumption, and the downward trend is expected to continue. A variety of reasons for this have been identified. For example, fortified rosins now used by the paper industry are more effective than rosin itself. A variety of substitute and competitive materials have also been developed which are gradually replacing rosin.

Turpentine and Pine Oil — The apparent consumption of turpentine is parallel to that of rosin. The demand increased until the late 1960's, after which there has been a slow decrease which is expected to continue. By contrast, the demand for pine oil is estimated to be increasing at approximately 5 percent per year. However, the wood chemical industry produces only about one-half the pine oil; the kraft pulping industry produces the remainder.

Tall Oil Fatty Acids — The production of tall oil fatty acids depends upon the availability of crude tall oil which is a by-product of the kraft pulping process. The production of tall oil fatty acids has been distorted because of a shortage of crude tall oil in 1974 and 1975. However, an increase of 3 percent yearly is estimated provided that sufficient crude tall oil is available.

Pollutant Characteristics

The pollutant characteristics for the six categories of gum and wood chemicals are outlined below.

Char and Charcoal

No wastewater discharge has been identified from this process since it involves high temperature kiln distillation. One possible discharge is stormwater runoff which carries suspended solids. This can be controlled, however, by proper materials handling systems that reduce dust and solid materials in the plant area.

Gum and Rosin Turpentine

Three wastwater sources have been identified in this process. These are (1) rosin washing to remove soluble impurities, (2) distillate condensation, and (3) brine used to dehydrate the gum rosin. This waste load is largely generated during washing operations.

Wood Rosin, Turpentine and Pine Oil

Process wastewater includes stripping as well as vacuum and steam condensates from the distillation operation. Another possible source of wastewater is from the washing of stumps for dirt removal. In a properly operated plant, however, this washwater is returned to a settling pond and reused after the solids have settled out. The solids are then periodically removed to a land fill.

Tall Oil Rosin, Pitch and Fatty Acids

This is a highly efficient distillation process, with the primary source of wastewater being an acid wash given to the crude tall oil. Additional wastewater is accumulated during washdowns of process equipment.

Essential Oils

This process generates large amounts of wastewater since it is based primarily on steam distillation and the use of separators to recover the desired oils from the steam condensate. This results both in large amounts of wastewater and a high waste load in the water.

Rosin Derivatives

These processes produce wastewater from a variety of point sources, including water of reaction, spray steam, vacuum jet steam, and condenser cooling water.

Control and Treatment Technology

The Development Document identified 139 facilities in this industry category and found that ap-

proximately one-third used municipal sewage plants and were not covered by the final effluent guidelines. Approximately 20 percent of the plants had treatment ponds with no direct discharge, while 8 percent used the effluent for land irrigation in remote areas. Only approximately four percent had point-source discharges, and of these, eighty percent had no additional requirements to meet the BPCTCA guidelines.

Treatment of wastewater has consisted both of in-plant and end-of-pipe treatment.

In-Plant Treatment

In-plant treatment techniques generally amount to more efficient housekeeping practices such as:

- Separating drainage lines so that effluent not requiring treatment (i.e. storm water) is handled separately.
- Improved efficiency of equipment washing procedures such as the use of several small quantities of rinsewater which can be recycled into the process.
- Use of techniquees such as a squeegee to remove material before rinsing.

End-of-Pipe Treatment

Applicable end-of-pipe treatment processes include the use of primary clarifiers, aerated lagoons, oxidation ponds, dissolved air flotation and combinations of these. Additional improvement in wastewater quality can be obtained through the use of filtration or carbon absorption of the biological treatment plant effluent.

Control Costs

The cost of controlling the waste load in the effluent for 5 categories of the Gum and Wood Chemicals Industry has been estimated at three levels of control (BPCTCA, BADCT, and BATEA). To obtain the estimate, model systems were developed for the various subcategories, and cost estimates made based on end-of-pipe treatment. In-plant costs were not included because of their highly variable nature depending upon the purpose for which the plant was constructed.

To evaluate the economic impact of the control treatments, it was necessary to choose uniform end-of-pipe treatment models which would provide the desired level of treatment. These were chosen as follows:

End-of-Pipe Technology Level	Treatment Model
BPCTCA	Activated sludge
BADCT	Activated sludge plus filtration
BATEA	Activated sludge plus filtration plus carbon absorption

Costs derived for these models are summarized in Table 7.3–1.

TABLE 7.3–1. GUM AND WOOD CHEMICALS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.02	3.58	0.20	0.21	0.22
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.02	3.58	0.20	0.21	0.22
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.02	3.58	0.20	0.21	0.22
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.63	2.56	2.63	3.95	5.85
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.63	2.56	2.63	3.95	5.85
O&M					
EXISTING PLANTS					
BPT	0.50	2.03	2.11	3.09	4.46
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.50	2.03	2.11	3.09	4.46
INDUSTRY TOTAL	1.13	4.60	4.74	7.05	10.31
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.13	4.60	4.74	7.05	10.31
ALL ANNUAL COSTS	1.13	4.60	4.74	7.05	10.31

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

7.4. PULP AND PAPER INDUSTRY

Production Characteristics and Capacities

The Pulp and Paperboard Mill and Converted Paper Products Point Source Category is considered here to include the following subparts:

Unbleached Kraft	Sulfite Pulp
Sodium Based Neutral Sulfite Semi-Chemical	Groundwood-Chemi-Mechanical
Ammonia Base Neutral Sulfite Semi-Chemical	Groundwood-Thermo-Mechanical
Unbleached Kraft-Neutral Sulfite Semi-Chemical	Groundwood-CMN Paper
Paperboard From Waste Paper	Groundwood-Fine Paper
Dissolving Kraft	Soda
Market Bleached Kraft	Deink
BCT Bleached Kraft	NI Fine Paper
Fine Bleached Kraft	NI Tissue Paper
Papergrade Sulfite	NI Tissue (FWP)
Low Alpha Dissolving	High Alpha Dissolving Sulfite Pulp
	Papergrade Sulfite Market Pulp
	Builder's Paper and Roofing Felts

The majority of industry production is from unbleached kraft and cross recovery processes. A description of major process and product use by subcategories follows:

Unbleached Kraft

Pulp is produced without bleaching using a "full cook" process with a high alkaline-sodium hydroxide and sodium sulfide cooking liquor. Unbleached kraft products are used for linerboard, the smooth facing in corrugated boxes, and grocery sacks.

Sodium Base-Neutral Sulfite Semi-Chemical (NSSC)

Pulp production occurs without bleaching, using a neutral sulfite cooking liquor with a sodium base; mechanical fiberizing follows the cooking stage. The main product is the corrugating medium or inner layer in the corrugated box "sandwich."

Ammonia Base-Neutral Sulfite Semi-Chemical (NSSC)

Pulp is produced without bleaching, using a neutral sulfite cooking liquor with an ammonia base. Products are similar to sodium base NSSC.

Unbleached Kraft-Neutral Sulfite Semi-Chemical (cross recovery)

Unbleached kraft and sodium base NSSC processes are in the same mill. NSSC liquor is recovered within the unbleached kraft recovery process. The products are the same as for the unbleached kraft and NSSC subcategories.

Builder's Paper

The raw materials are prepared by cooking, beating, and pulping in a blending chest to reduce them to individual fibers. These fibers are then formed on a paper machine and dried by a steam-heated multidrum dryer. Finishing coats are then applied to protect the fibers; the coatings generally consist of mineral fragments in a bitumen or asphalt medium, depending upon the specifications of individual clients.

All of the processes are similar in their digestion of wood chips with a chemical cooking liquor and the subsequent removal of the spent liquor. Process differences relate primarily to the preparation, use, and recovery of the cooking liquor. In the case of paperboard, no pulping is involved.

Exports are primarily woodpulp and liner board. American producers have a cost advantage because of cheap raw material sources; however, this advantage may be eliminated by the European Economic Community tariff increases scheduled for 1980. (Europe comprises 43 percent of the export market.) Pulp, paper, and paperboard products from Canada are the only significant imports.

Waste Sources and Pollutants

The main sources contributing to the total waste load come from the following processes: wood preparation, pulping processes, and the paper machine.

In order to define waste characteristics, the following basic parameters were selected as guidelines for meeting BPT and BAT guidelines: BOD_5, TSS, pH, and color.

Control Technology and Costs

Waste treatment practices in the pulp, paper and paperboard industry include the following methods.

- Reuse of gland, vacuum pump seal, knot removal shower, wash, and condensate waters

- Internal spill collection: hot stock screening and chemical and dregs recovery
- Land disposal: save-all systems
- Screening and neutralization
- Suspended solids removal through use of mechanical clarifier, earth basin, filtration, and dissolved air flotation
- BOD_5 removal by use of aerated stabilization basins, activated sludge processes, and storage control
- Foam control through the use of chemical and mechanical means
- Color removal through the use of lime treatment, activated carbon, coagulation-alum, and reverse osmosis
- The use of resin adsorption, ultra-filtration, amino treatment and ion flotation.

The control technologies called for in BPT, BAT, and NSPS guidelines are summarized as follows:

Guideline and Area	Technology Suggested
BPT-Internal	
	Hot stock screening, spill and evaporator boil-out storage, use of multi-stage counter-current washers
	Non-polluting spent liquor disposal by (a) partial evaporation/incineration (b) use of fluidized bed reactor
	TSS reduction by the use of earthen basins, mechanical clarification, and sludge removal, and dissolved air flotation
BPT External	
	BOD_5 reduction by: the use of activated sludge, aerated stabilization basins, and storage/oxidation ponds
	Biological solids removal by: the use of mechanical clarifiers, stilling ponds, stilling ponds with aerated stabilization basins, or quiescent zone in aerated stabilization basins beyond the influence of aeration equipment
	Sludge disposal by landfilling or incineration
BPT-Paper Machines	
	Use of water showers
	Segregation of white water
	Press water filtration by vibrating or centrifugal screen
	Use of collection system for vacuum pump seal water
	Reduction in gland water use
BAT-Internal	
	Refuse of fresh water filter backwash
	Control of spills through retention, reuse or separate treatment
	Reduction of pulp wash and extraction water
	Internal reuse of process waters
	Separation of cooling waters from the other wastewater streams and treatment, removal, and reuse of these waters
	Reduction of gland water spillage
BAT-External	
	BOD_5 reduction by: the use of biological oxidation with nutrient addition. TSS reduction by: the use of mixed media filtration and chemical addition and coagulation. Color reduction through the use of minimum lime treatment for cross recovery mills and reverse osmosis for NSSC both sodium and ammonia base mills
NSPS	Coagulation and filtration are not included for any subcategories:, color reduction for both NSSC bases are not included. Otherwise same as BAT, with substantially no process changes but changes to increase efficiency.

Water pollution control costs appear in Table 7.4–1. These costs are derived from an economic analysis document, and costs are grouped accordingly.

TABLE 7.4–1 PULP AND PAPER INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	700.00	2178.75	88.75	93.75	101.05
BAT	0.0	0.0	352.50	1057.50	1410.00
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	700.00	2178.75	441.25	1151.25	1511.05
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	700.00	2178.75	441.25	1151.25	1511.05
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	286.45	621.71	1190.50	1787.72	2685.97
BAT	0.0	0.0	46.34	278.07	834.20
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	286.45	621.71	1236.84	2065.78	3520.17
O&M					
EXISTING PLANTS					
BPT	242.08	524.49	1006.11	1510.83	2269.99
BAT	0.0	0.0	38.25	229.50	688.50
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	242.08	524.49	1044.36	1740.33	2958.49
INDUSTRY TOTAL	528.53	1146.20	2281.20	3806.11	6478.66
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	528.53	1146.20	2281.20	3806.11	6478.66
ALL ANNUAL COSTS	528.53	1146.20	2281.20	3806.11	6478.66

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8. FOODS AND AGRICULTURAL INDUSTRIES

For the purpose of this report the Foods and Agricultural Industries are defined to include those establishments which prepare or process farm or ranch products for delivery to an ultimate consumer. Farms and ranches are specifically excluded; these are discussed in Chapter IX under Nonpoint Sources. The industries covered in this chapter are:

- Grain Mills
- Sugar Processing
- Canned and Preserved Fruits and Vegetables
- Canned and Preserved Seafoods
- Dairy Products Processing
- Feedlots
- Meat Product
- Leather Tanning and Finishing

Costs for the abatement of water pollution for these sectors are summarized in Table 8.-1. These costs and other data are repeated below in the respective sections of this chapter, together with the assumptions peculiar to the industry and other details.

TABLE 8.-1. WATER POLLUTION ABATEMENT COSTS FOR THE FOODS AND AGRICULTURAL INDUSTRIES (IN MILLIONS OF 1977 DOLLARS)

		INVESTMENT		
INDUSTRY	1977	1972–77	1977–81	1977–86
GRAIN MILLS	1.56	3.83	4.41	7.58
SUGAR PROCESSING				
RAW CANE SUGAR PROCESSING	1.18	3.54	2.91	6.03
CANE REFINING SEGMENT	2.84	8.21	14.87	23.86
BEET SUGAR PROCESSING	3.73	9.91	5.13	9.01
CANNED AND PRESERVED FRUITS & VEGETABLES	193.99	636.69	93.94	134.06
CANNED AND PRESERVED SEAFOOD	22.98	43.59	79.44	114.78
DAIRY PRODUCTS PROCESSING	21.27	136.96	20.41	39.52
FEEDLOTS	26.66	97.92	12.06	29.34
MEAT PRODUCTS	9.86	24.82	147.76	211.78
LEATHER TANNING AND FINISHING	10.67	29.36	101.44	135.25
TOTAL INVESTMENT	294.74	994.83	482.39	711.21
		ANNUAL COSTS		
	1977	1972–77	1977–81	1977–86
GRAIN MILLS	0.89	1.73	5.92	19.08
SUGAR PROCESSING				
RAW CANE SUGAR PROCESSING	1.34	3.08	7.72	21.72
CANE REFINING SEGMENT	1.75	3.68	13.07	43.40
BEET SUGAR PROCESSING	1.55	3.05	7.97	21.91
CANNED AND PRESERVED FRUITS & VEGETABLES	843.07	1844.29	3412.54	7760.00
CANNED AND PRESERVED SEAFOOD	9.77	17.62	67.93	211.91
DAIRY PRODUCTS PROCESSING	21.23	57.95	93.98	232.80
FEEDLOTS	27.86	69.65	119.69	290.26
MEAT PRODUCTS	11.22	29.25	173.49	657.09
LEATHER TANNING AND FINISHING	8.01	16.27	83.42	294.73
TOTAL ANNUAL COSTS	926.69	2046.58	3985.74	9552.89

8.1 GRAIN MILLING INDUSTRY

(Some or all of the regulations governing this industry were remanded on May 5, 1975 and revoked on November 11, 1976. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations.)

GRAIN MILLING INDUSTRY (PHASE I)

Production Characteristics and Capacities

For purposes of establishing water effluent guidelines, the grain milling industry is divided into four major subcategories: wet corn milling, dry corn milling, bulgur wheat flour milling, and parboiled rice milling. Two other subcategories, normal wheat flour milling and normal rice milling, have been excluded because they do not use process water.

Wet corn milling comprises three basic process operations: milling, starch production, and syrup manufacturing. The finished products of starch and corn sweeteners are used for paper products, food products, textile manufacturing, building materials, laundries, home uses, and miscellaneous operations.

Dry corn milling processes separate the various fractions of corn, namely the endosperm, hull, and germ. These fractions are later ground and sifted after separation. The final products include: corn meal, grits, flour, oil, and animal feed.

Bulgur wheat flour milling produces parboiled, dried, and partially debranned wheat for use in either cracked or whole grain form. Bulgur is produced primarily for the Federal Government as part of a national effort to utilize surplus wheat for domestic use and for distribution to underdeveloped countries.

Parboiled rice milling utilizes rice that is carefully cleaned, parboiled by soaking in water, and then cooked to gelatinize the starch. After cooking, the water is drained and the parboiled rice is dried before milling. The bran and germ are later separated from the milled rice. The final product has superior nutritive qualities because vitamins from the bran are forced into the endosperm.

According to the USDA, shipments of wet corn milling products have increased at an annual rate of 7.5 percent over the period 1968–1976; this growth rate is expected to continue. The use of dry corn milling products directly in foods has declined significantly over the past 20 years but this decline has been offset by the growing use of the products as ingredients in processed foods. Total production has remained about constant. Consumption of bulgur wheat flour milling products has been increasing in developing nations due to the high nutritional values of bulgur wheat. A 10 percent increase in shipments from 1974 to 1980 is expected. Rice milling including parboiled products are about 60 percent exported and 40 percent used for domestic trade. An increase in rice mill products of 2.3 percent is expected annually from 1976 to 1985.

Waste Sources and Pollutants

Principal wastewater sources in wet corn milling are modified starch washing, condensate from steepwater evaporation, mud separation, syrup evaporation, animal feeds, and corn steeping. Dry corn milling process wastes originate from infrequent car washing and washing of corn. Bulgur wheat flour milling process wastewater stems from steaming and cooking of bulgur, although these quantities are relatively small. Parboiled rice milling process wastewater stems from steeping or cooking operations, and at least one plant uses wet scrubbers for dust control, which generates an additional source of wastewater.

The basic parameters used to define wastewater characteristics are BOD_5, suspended solids, and pH. About one-fourth of the wet corn milling plants discharge directly into surface water. The majority of the plants in the other subcategories discharge into municipal systems.

Control Technology and Costs

Except for wet corn milling, little attention has been focused on either in-plant control or treatment of wastewaters. In many instances, the treatment technologies developed for wet corn milling can be transferred to the other industry subcatego-

ries. Current in-plant control consists of water recycling cooling systems (barometric condensers), and some plants use biological treatment (activated sludge).

Best practicable technology for the four subcategories consists of the following:

- Wet corn milling—Equalization of flows, activated sludge treatment, and stabilization lagoon
- Dry corn milling—Primary sedimentation and activated sludge treatment
- Bulgur wheat flour milling—Activated sludge treatment, and
- Parboiled rice milling—Activated sludge treatment.

The best available technology for the four subcategories is deep bed filtration in addtion to BPT. New source performance technology is the same as BAT.

Since the wet corn milling industry contributes the largest amount of wastewater discharges, control costs for this industry are of primary concern.

Control costs are summarized in Table 8.1–1.

GRAIN MILLING INDUSTRY (PHASE II)

Production Characteristics and Capacities

For purposes of establishing water effluent guidelines, the Phase II segments of the grain milling industry consist of three major subcategories: animal feed, breakfast cereal (ready-to-eat and hot cereal), and wheat gluten and starch. Animal feed and hot cereal mills do not generate any significant process wastewaters.

There are a total of 23 grain milling plants included in the two subcategories that generate wastewater. Of these plants, 17 are ready-to-eat cereal mills, and 6 are wheat gluten and starch mills. The ready-to-eat cereal subcategory has been divided according to average daily production into plant classes consisting of: small (91 metric tons or 100 short tons per day), medium (230 metric tons or 250 short tons per day), and large (540 metric tons or 600 short tons per day). The division of the wheat gluten and starch subcategory daily production values is: small (30 metric tons or 33 short tons per day), medium (45 metric tons or 50 short tons per day), and large (60 metric tons or 66 short tons per day).

The animal feed, breakfast cereal, and wheat gluten and starch industries all utilize products from the basic grain processing mills for raw materials. Grain and grain milling by-products are the chief ingredients in animal feed. The manufacture of breakfast cereals utilizes both milled and whole grain, particularly corn, wheat, oats, and rice. Wheat gluten and starch manufacturing employs wheat flour as its raw material.

Animal feed manufacturing comprises: ingredients mixing, meal production, pelleting, cooling and drying pellets, rolling, and finally, formation of granules. Of all the cereal grains produced in the U.S., only about 15 percent is used directly as food for human consumption. The vast majority of the grain harvest is used to feed poultry and livestock.

Breakfast cereals can be broadly classified as either hot cereals or ready-to-eat cereals. Hot cereals require cooking before serving and are normally made from oats or wheat. Ready-to-eat cereal manufacturing methods vary depending on the type of cereal. Raw materials include whole grain wheat and rice, corn grits, oat flour, sugar, and other minor ingredients. The general processes involved include ingredient mixing, cooking, drying, forming (either flaking or extruding), toasting or puffing, and vitamin addition.

The wheat starch industry may be properly termed the wheat gluten and starch industry, as the gluten presently brings a higher economic return than the starch. Basically, wheat starch manufacturing involves the physical separation and refinements of the starch and gluten (protein) components of wheat flour.

Waste Sources and Pollutants

Animal feed and hot cereals manufacturing plants utilize little or no process water and generate no wastewaters. Water is used quite extensively in ready-to-eat cereal manufacturing plants. The various operations where water is used include: grain tempering, flavor solution makeup, cooking, extrusion, and coating. Water is also used for cooling flaking and forming rolls, extruders, and for wet scrubbers. Most of the unit processes do not result in process wastewaters. Only the cooking operation in shredded cereal manufacturing generates a continuous or semi-continuous waste stream. In wheat starch manufacturing, process water is used for dough making, dough washing, backwashing of screens, and countercurrent washing of centrifuge discharges. Water is also used for plant clean up and for auxiliary systems such as boiler feed water and cooling.

The basic parameters used to define wastewater characteristics are BOD_5, suspended solids, and pH. For all practical purposes, all of the plants in both the ready-to-eat cereal and wheat gluten and starch categories discharge to municipal systems.

Control Technology and Costs

The only costs for the industry categories in this group are increased user charges for plants discharging to municipal sewerage. New plants may be expected to pretreat their process waste before discharging to municipal systems or to provide secondary treatment.

Best practical technology (BPT) for the ready-to-eat cereal subcategory is activated sludge treatment and sedimentation. Activated sludge treatment and equalization is required for wheat gluten and starch plants.

Best available technology (BAT) for these two subcategories is deep bed filtration.

Abatement costs for Phase II of the Grain Milling Industry are included in Table 8.1–1.

TABLE 8.1–1. GRAIN MILLING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.37	3.29	0.41	0.62	0.72
BAT	0.0	0.0	3.13	4.40	4.51
NEW PLANTS	0.18	0.53	0.88	1.41	2.35
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	1.56	3.83	4.41	6.43	7.58
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1.56	3.83	4.41	6.43	7.58
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.43	0.83	1.87	2.88	4.46
BAT	0.0	0.0	0.81	1.95	3.73
NEW PLANTS	0.07	0.16	0.56	1.03	2.05
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.50	0.98	3.23	5.86	10.24
O&M					
EXISTING PLANTS					
BPT	0.31	0.60	1.35	2.08	3.22
BAT	0.0	0.0	0.79	1.90	3.64
NEW PLANTS	0.07	0.15	0.55	1.02	1.98
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.39	0.75	2.69	5.00	8.84
INDUSTRY TOTAL	0.89	1.73	5.92	10.86	19.08
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.89	1.73	5.92	10.86	19.08
ALL ANNUAL COSTS	0.89	1.73	5.92	10.86	19.08

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.2 SUGAR PROCESSING

(Some of the regulations governing this industry were suspended on January 17, 1977. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations.)

CANE SUGAR REFINING INDUSTRY (SUGAR PROCESSING, PHASE I)

Production Characteristics and Capacities

Raw sugar consists primarily of crystals of sucrose with small percentages of dextrose and levulose. Various impurities such as particulates, organic and inorganic salts, and micro-organisms will also be present. A film of molasses is contained on raw sugar. Crystalline raw sugar is washed to remove part of the molasses film, put into solution, taken through various purification steps, and finally recrystallized.

The major processes involved in cane sugar refining are: (1) melting, (2) clarifing, (3) decolorizing, (4) evaporating, (5) crystallizing, and (6) finishing. Melting is the first step in which raw crystals are put into solution by heating; this syrup is then fine screened to remove insoluble materials. In the clarifing step, screened melt liquor which still contains fine suspended and colloidal matter is treated chemically to cause these to precipitate. Decolorizing involves the physical absorption of impurities; bone char is the primary absorbent used to remove color. The object of the evaporating process is a concentration of the decolorized sugar liquor and sweet water (water containing syrup); this is done in continuous evaporators. Crystallizing of the concentrated sugar liquor and sweet waters is done in batch evaporators called vacuum pans. Finishing is a drying or granulation step in which moisture is removed and the crystals are separated and later cooled and fine screened.

The molasses produced as a by-product of cane sugar refining is used as a sweetener, as an ingredient for animal feed, for making alcohol, for organic chemicals, and for other uses.

The cane sugar refining industry consists of two subcategories: (1) crystalline cane sugar refining, and (2) liquid cane sugar refining. Liquid sugar production is essentially the same as crystalline sugar production except that the primary product is not recrystallized.

A total of 29 cane sugar refineries are in the continental United States and Hawaii. Of these, 22 are crystalline, 5 are liquid, and 2 are combination crystalline-liquid refineries. Crystalline cane refineries are classified into two size ranges: 170–500 and 640–3,200 metric tons per day (190–550 and 700–3,500 short tons per day) of melted sugar; there is a single range for liquid cane sugar refineries: 270–770 metric tons per day (300–850 short tons per day) of melted sugar. It is estimated that the total capacity of the cane sugar industry in 1971 was 30,540 metric tons (33,660 short tons) per day of melted sugar. According to the U.S. Industrial Outlook (1976), the value of shipments of cane sugar in 1976 is expected to reach $5.5 billion, 6 percent above 1975 shipments of $5.2 billion. These increases reflect expected higher prices.

Sugar prices were at record levels in November 1974. The 1974 average wholesale price of refined sugar (Northeast) was 34.35 cents a pound. Wholesale prices were adjusted frequently during 1975 and for the first 8 months of the year averaged 36.40 cents a pound. High prices of sugar and sugar-containing products and competition from fructose corn syrup in 1975 resulted in a decline in per capita sugar consumption to an estimated 41 kg (90 pounds), down from 44 kg (97 pounds) in 1974. Prices receded further in 1976 and 1977 to below 20 cents per pound.

Waste Sources and Pollutants

Major process wastewaters from cane sugar refining include char (and activated carbon process water from nonchar refineries) wastewater from decolorization. Most of the waste streams produced in other processes are recovered as low purity sweet water. Wastewater from barometric condenser cooling is usually recirculated and represents a minor waste stream.

Wastewater contaminating pollutants are associated with (1) the water used as an integral part of

the process (primarily the decolorizing steps of either bone char or activated carbon washing), (2) the result of entrainment of sucrose into barometric condenser cooling water, and (3) the water used to slurry the filter cake.

Parameters under effluent guidelines for meeting BPT, BAT, and NSPS include BOD_5, suspended solids, and pH. Additional parameters of significance to the industry include COD, temperature, sucrose, alkalinity, total coliforms, fecal coliforms, total dissolved solids, and nutrients.

Currently, 50 percent of crystalline sugar refineries and 60 percent of liquid cane sugar refineries discharge into municipal systems. On an average 38,400 liters per metric ton (9,200 gallons per short ton) of wastewater is discharged from crystalline sugar refineries; the corresponding figure is 18,800 liters per metric ton (4,500 gallons per short ton) from liquid cane sugar refineries.

Control Technology and Costs

Current technology for control and treatment of cane sugar refinery wastewaters consists primarily of process control (recycling and reuse of water, preventing sucrose entrainment in barometric condenser cooling water and recovering sweet waters), impoundage (land retention), and disposal of process water to municipal sewerage systems.

Best Practicable Technology (BPT) consists of a combination of in-plant changes and end-of-pipe treatment. In-plant changes include: (1) collection and recovery of all floor drainage, (2) use of improved baffling systems, demisters, and/or other control devices in evaporators to minimize sucrose entrainment in barometric condenser cooling water, and (3) dry handling of filter cakes after desweetening, with disposal to sanitary landfills, or complete containment of filter cake slurries. End-of-pipe treatment consists of biological treatment of all wastewater discharges other than uncontaminated (noncontact) cooling water and barometric condenser cooling water.

Best Available Technology (BAT) is essentially the same as BPT but, in addition to BPT, the following are applicable: (1) recycle of barometric condenser cooling water by utilizing either a cooling tower or pond, (2) biological treatment of the (assumed 2 percent) blowdown from the cooling system, and (3) sand filtration of effluent from the biological treatment system. Essentially the same control technology is applicable to both crystalline and liquid cane sugar refineries.

Control costs are detailed in Table 8.2–1.

RAW SUGAR CANE PROCESSING INDUSTRY (SUGAR PROCESSING, PHASE II)

Production Characteristics and Capabilties

Sugar cane milling (SIC 2061) involves the conversion of freshly harvested sugar cane into raw sugar and molasses. Because the quality of the juice drops rapidly after harvest, sugar mills are located close to the fields in which the cane is grown. On the other hand, refineries, which convert raw sugar to refined sugar, are typically located close to the market area. Only a few cane mills are integrated with a refinery. (Pollution problems in sugar cane refining are discussed elsewhere.) The indicated sugar crop to be processed in 1977 is 25.1 million metric tons (27.7 million short tons). Of this, 8.2 million metric tons is from Florida, 9.2 from Hawaii, 6.5 from Louisiana, and 1.1 from Texas (9.0, 10.1, 7.2 and 1.2 million short tons, respectively). In 1976, domestic refiners received 619,000 metric tons (682,000 short tons) of raw sugar from Hawaii, 142,000 metric tons (156,000 short tons) from Puerto Rico, and 924,000 metric tons (1.02 million short tons) of domestically produced raw sugar, a total of 1.685 million metric tons (1.857 million short tons).

The processes carried out in the sugar mill are conceptually rather simple. The cane is hauled into the mill, weighed, and dumped. In areas where collection procedures cause large amounts of dirt and rocks to be included in the material brought to the mill (Hawaii, Louisiana, and Puerto Rico), the cane is usually cleaned by blowing air through it and by washing it with water. Rocks are removed by passing the material over grates. (In some regions of Hawaii, it is not unusual for 50 percent of the gross weight of cane brought to the mill to be rocks, dirt, and field trash such as leaves). The clean cane is then chopped or run through a hammermill and then crushed with rollers that squeeze much of the juice out. This is followed by 4–6 three-roll mills that squeeze out almost all the remaining sugar. Water is added at the last mill to help wash the last of the sugar from the fiber. This juice is then used to wash the fiber in earlier stages so that a countercurrent extraction is achieved. The bagasse from the last mill has about 50 percent moisture and is sent to the boiler or to the bagasse house. The bagasse can be not only used as boiler fuel but also processed to make the chemical furfural or can be used in making wallboard or paper. In some regions where fuel is cheap or where the bagasse exceeds the needs for the boiler and where no by-product industry exists, unwanted bagasse is either landfilled or dumped in the ocean.

TABLE 8.2-1. CANE SUGAR REFINING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	2.75	7.88	1.05	1.57	1.57
BAT	0.0	0.0	10.78	15.19	15.19
NEW PLANTS	0.09	0.33	3.04	4.86	7.09
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	2.84	8.21	14.87	21.63	23.86
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	2.84	8.21	14.87	21.63	23.86
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	1.04	2.16	4.49	6.94	10.67
BAT	0.0	0.0	2.78	6.72	12.71
NEW PLANTS	0.04	0.11	1.14	2.39	5.02
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.08	2.27	8.42	16.05	28.40
O&M					
EXISTING PLANTS					
BPT	0.65	1.36	2.81	4.34	6.66
BAT	0.0	0.0	1.23	2.96	5.60
NEW PLANTS	0.02	0.06	0.62	1.30	2.73
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.67	1.41	4.65	8.60	14.99
INDUSTRY TOTAL	1.75	3.68	13.07	24.65	43.40
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.75	3.68	13.07	24.65	43.40
ALL ANNUAL COSTS	1.75	3.68	13.07	24.65	43.40

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

The fresh cane juice is heated and treated with lime to precipitate impurities. The precipitate, "mud", is separated from the clarified juice by decantation and vacuum filtration of the sludge from the clarifier. The mud, which is mostly inorganic material but which contains sugar, wax, organic salts, and fine bits of bagasse, is frequently a disposal problem. The clarified juice is next evaporated using multiple effect evaporators to reduce its volume and increase the concentration of sugar. After the solution is partly evaporated, it is conveyed to vacuum pans in which it is further concentrated. The final concentrated sugar solution in the vacuum pans is seeded with crystals of pure sugar and, because the solution is supersaturated, the sugar grows around these seeds excluding the water and impurities. The final product is raw sugar, which is centrifuged, washed with hot water, and discharged. It is pure enough to be free-flowing even though it has a light brown color. The centrifugate, which is known as blackstrap molasses, contains roughly 44 percent sugar but also contains dissolved salts and water. It is sold for animal feed or as a starting material for rum or other fermentation products.

Pollution Problems

A number of points in the process can give rise to water pollution. The greatest problem in areas with dirty cane is the handling of the cane washings. In the washing process, some sugar is lost to the washwater and organic particles are suspended in it, each of which give rise to a biological oxygen demand. In addition, there are large amounts of suspended dirt and dissolved inorganic solids. In areas where irrigation is practiced, the cane wash water can be used for irrigation. In other areas, storage in ponds followed by appropriate treatment is needed. The solid trash, rocks, etc., are landfilled.

The mud which is removed from the vacuum filters contains about 75 percent water which has dissolved organic and inorganic material in it. To avoid problems some mills dry the mud, which can then be returned to the fields. In other sugar mills, the filter mud is slurried and discharged to waterways, which can present a significant water problem.

In the final stage of the multiple effect evaporator, and in the vacuum pans, barometric condensers are used; that is, cooling water is mixed directly with the steam to condense it and create a vacuum. This allows sugar particles that are entrained in the steam to become mixed into the condenser water, producing a biological oxygen demand when that water is ultimately discharged. Condenser water can amount to as much as 25 (thousand liters per metric ton thousand gallons per short ton) of cane processed and can have a BOD_5 loading of up to 1.5 kg per metric tons (3 pounds per short ton) of cane processed. When this water is used for irrigation, there is no significant problem. On the other hand, in areas where irrigation is impractical, the water produces a pollution problem if discharged into navigable waterways. Control can be obtained by impoundment followed by biological treatment before discharge. Alternatively, the condenser water can be used in cane washing. If the cane wash water is collected and treated it can be recycled to the condenser.

Minor sources of problems are the water from washing the floors of the sugar mill which contain sugar from the spills and spatters that continually occur in the mill as well as mud tracked in on boots. The boiler systems can also give rise to pollutants. The water in which the ash is slurried for removal from the boiler can cause problems as well as the blowdown water from the boiler itself.

Regulation Control Technology

BPT regulations have been issued (40FR8498, February 27, 1975) and BAT and NSPS regulations proposed (40FR8506, February 27, 1975). The regulations originally proposed for the Hilo Coast of the Island of Hawaii have been suspended (42FR3164, January 17, 1977). It is expected that new regulations will be proposed soon. Note that the regulations do not require any particular technology. The following have been suggested as methods of compliance.

BPT Technology for Louisiana.

Improved controls and practices to reduce pollution such as the reduction of entrainment of sucrose in the barometric condenser cooling water are recommended. The use of settling ponds to remove solids from the wash water and biological treatment for the effluent from settling ponds and all other waste streams except barometric condenser cooler water and excess condensate are recommended.

BAT and NSPS Technology—Louisiana.

Recycling of barometric condenser cooling water and cane wash water and biological treatment of blowdown and miscellaneous waste streams is suggested.

BPT, BAT, and NSPS Technology—Florida and Texas.

The containment of all wastewaters is required except when rainfall causes an overflow from a facility designed to contain wastewaters.

BPT, BAT, and NSPS Technology—State of Hawaii except for Hilo Coast.

These are the same as for Florida and Texas.

BPT, BAT, and NSPS Technologies—Puerto Rico.

These are the same as for Louisana.

Cost for Pollution Abatement

The Economic Analysis Document gives the expected pollution costs for Louisana and for Puerto Rico for the promulgated BPT and proposed BAT and NSPS regulations. These costs were developed through the use of several model plants. The degree of conformance of each of the existing mills to a model plant was evaluated and costs for upgrading each one were developed separately. Current practices in Florida and Texas and in the portions of Hawaii other than the Hilo Coast are such (irrigation or recycle) that there is already a full compliance with BPT and BAT requirements. Therefore there are no costs involved in these regions. Since the regulations for the Hilo Coast of Hawaii are in suspense, no costs have been calculated for this region.

Pretreatment

No limitations have been proposed for pretreatment before discharge to municipal sewage systems. No sugar mills are now known to be discharging to municipal sewers.

Growth Rates

The domestic sugar industry in recent years has not been very profitable with the exception of 1974 when the prices of sugar were very high. Currently, there is very keen competition from foreign sugar producers. Although a price support system has recently been activated, a resurgence of the industry is not expected. Rather, it is be-

lieved that this will protect the industry as it is and will not encourage increased acreage of cane or the building of new sugar mills. As a matter of fact, in a period from 1973 through 1976, three mills closed in Louisana, three in Hawaii, and the rated capacity in Puerto Rico declined. For these reasons, the study used a zero growth rate.

Costs are summarized in Table 8.2–2.

Beet Sugar Industry

Production Characteristics and Capacities

There were 52 beet sugar plants owned by 11 companies in 1973. As three new plants (all large) began operation by 1975, the beet sugar industry now contains 55 plants.

The plant size ranges are classified according to production capacity, small (less than 2,100 metric tons or 2,300 short tons per day), medium (2,100–3,500 metric tons or 2,300–3,900 short tons per day), and large (greater than 3,500 metric tons or 3,900 short tons per day).

Typical plant production is estimated to be 3,200 metric tons (3,600 short tons) of sliced beets per day. The main products from this industry are refined sugar, dried beet pulp (used for animal feed), and molasses.

The beet sugar processing industry is a subcategory of the sugar processing industry. Water is commonly used for six principal purposes: (1) transporting (fluming) of beets to the processing operation, (2) washing beets, (3) processing (extraction of sugar from the beets), (4) transporting beet pulp and lime mud cake waste, (5) condensing vapors from evaporators and crystallization pans, and (6) cooling.

TABLE 8.2–2. RAW CANE SUGAR PROCESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.18	3.54	0.0	0.0	0.0
BAT	0.0	0.0	2.91	5.82	6.03
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	1.18	3.54	2.91	5.82	6.03
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1.18	3.54	2.91	5.82	6.03
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.58	1.22	2.31	3.46	4.54
BAT	0.0	0.0	0.79	2.45	5.80
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.58	1.22	3.10	5.91	10.34
O&M					
EXISTING PLANTS					
BPT	0.76	1.28	4.63	6.94	10.41
BAT	0.0	0.57	0.0	0.55	0.66
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.31
TOTAL	0.76	1.86	4.63	7.48	11.38
INDUSTRY TOTAL	1.34	3.08	7.72	13.39	21.72
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.34	3.08	7.72	13.39	21.72
ALL ANNUAL COSTS	1.34	3.08	7.72	13.39	21.72

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

Beets are transported into the plant by water flowing in a narrow channel (flume) that removes adhered soil. The beets are then lifted from the flume and spray washed. Flume water accounts for about 50 percent of the total plant water consumption.

Process water is associated with the operations of extracting sugar from the beets. Diffusers draw the raw juice from the beets into a solution which contains 10–15 percent sugar. Exhausted beet pulp is later pressed to remove moisture. This exhausted pulp water is usually recycled back to the diffuser.

Lime mud cake waste results when lime is added to the raw juice and the solution is purged with carbon dioxide gas, causing calcium carbonate to precipitate. The sludge formed removes impurities which were suspended in the juice.

Water from barometric condensers is employed in the operation of pan evaporators and crystallizers in the industry. Water is used in large quantities. Condenser water is usually cooled by some device and recycled for use in the plant.

In addition to the above, about 40 percent of the plants employ the Steffen process to recover additional sugar. In the Steffen process, syrup remaining from the above processes is concentrated to form molasses, which is then desugared to recover the sugar. In this step, water is used to dilute the molasses and calcium oxide is added to the solution, causing a precipitate to form. The precipitation process produces the Steffen filtrate and recovered sugar; the filtrate may be directly discharged as a waste or it may be mixed with beet pulp to produce by-products.

The rated 1973 capacity in beets sliced per day was 161,400 metric tons (177,900 short tons). The projected 1980 capacity is estimated to be 183,300 metric tons (202,000 short tons) per day.

According to the U.S. Industrial Outlook, the value of shipments for 1975, 1976, and 1985 are $1.5, $1.6, and $2.8 billion, respectively. These increases reflect an annual increase of 6.4 percent in value of shipments.

Areas of future growth of beet sugar production are expected to be along the Red River between northern Minnesota and North Dakota, and in the Columbia River Basin.

Waste Sources and Pollutants

The major waste sources stem from the primary production processes. These include: (1) beet transporting and washing, (2) processing (extraction of sugar from the beets), (3) carbonating of raw juice, and (4) Steffen processing (for those plants involved in desugaring of molasses). Barometric condensers are also a wastewater source. The primary wastewaters resulting from the beet sugar processing industry are: flume water, lime mud cake from the carbonation process, barometric condenser water, and Steffen process water used to dilute molasses for desugarization.

The basic parameters used in establishing water effluent guidelines to meet BPT are: BOD_5, total suspended solids, pH, and temperature.

Control Technology and Costs

Presently, 14 of the 55 operating plants are achieving no discharge of wastewaters to navigable waters. Five plants discharge flume and/or condenser water to municipal sewerage systems.

Current pollution control technology does not provide a single operation that is completely applicable under all circumstances. The major disposal methods are: reuse of wastes, coagulation, waste retention ponds or lagooning, and irrigation.

BPT and BAT involve extensive recycle and reuse of wastewaters within the processing operation with no discharge or controlled discharge of process wastewater pollutants to navigable waters. To implement these levels of technology, the following actions are necessary:

- For flume waters, recycling with partial or complete land disposal of excess wastewater. This includes: (1) screening, (2) suspended solids removal and control in the recirculating system, and (3) pH control for minimization of odors, bacterial populations, foaming, and corrosive effects.
- For barometric condenser water, recycling for condenser (or other in-plant) uses with land disposal of excess water.
- Land disposal of lime mud slurry and/or reuse or recovery.
- Returning of pulp press water and other process water to the diffuser.
- Using continuous diffusers.
- Using pulp driers.
- Handling all miscellaneous wastes (washwaters) by subsequent treatment and reuse or land disposal.
- Using entrainment control devices on barometric condensers to minimize entrainment.

Note: BAT permits no discharge of wastewaters. One method of accomplishing this is to apply the

wastewaters to the land after BPT steps have been taken. It is possible that after sufficient concentration of wastewaters, only salt-tolerant grasses could be grown. Farm lands may be taken out of production and no credit is taken for the value of crops grown on these lands. It is uncertain how long the soil can remain stable under these conditions.

Control costs are summarized in Table 8.2-3.

TABLE 8.2-3. BEET SUGAR INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	3.67	9.66	0.0	0.0	0.0
BAT	0.0	0.0	3.17	4.23	4.23
NEW PLANTS	0.06	0.24	1.96	3.04	4.78
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	3.73	9.91	5.13	7.27	9.01
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	3.73	9.91	5.13	7.27	9.01
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	1.27	2.48	5.08	7.62	11.44
BAT	0.0	0.0	0.83	1.95	3.61
NEW PLANTS	0.03	0.08	0.76	1.55	3.30
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.30	2.56	6.68	11.12	18.35
O&M					
EXISTING PLANTS					
BPT	0.25	0.48	0.98	1.47	2.21
BAT	0.0	0.0	0.16	0.38	0.70
NEW PLANTS	0.01	0.02	0.15	0.31	0.66
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.25	0.50	1.30	2.16	3.57
INDUSTRY TOTAL	1.55	3.05	7.97	13.28	21.91
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	1.55	3.05	7.97	13.28	21.91
ALL ANNUAL COSTS	1.55	3.05	7.97	13.28	21.91

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.3 CANNED AND PRESERVED FRUITS AND VEGETABLES INDUSTRY

Production Characteristics and Capacities

The fruits and vegetables processing industry includes processors of canned fruits and vegetables, preserves, jams, jellies, dried and dehydrated fruits and vegetables, frozen fruits and vegetables, fruit and vegetable juices, and specialty items. The effluent limitations guidelines issued by the EPA are limited to processors of apple products (except caustic peeled and dehydrated products), citrus products (except pectin and pharmaceutical products), frozen and dehydrated potato products, and specialty fruits and vegetables. The principal items in each group are as follows:

- Apples: slices, sauce, and juice (cider)
- Citrus: juice, segments, oil, dried peel, and molasses
- Potatoes: chips, frozen products, dehydrated products, canned hash, stew, and soup products.
- Specialty fruits and vegetables.

The manufacturing processes employed after harvesting depend on the particular product to be manufactured. Specific processes include receiving, storing, washing and sorting, peeling and coring, sorting, slicing, segmenting or dicing, pressing or extracting (for juice products), cooking, finishing, blanching (for potatoes), juice concentrating, dehydrating, canning, freezing, can rinsing and cooling, and cleaning up. Many processes previously performed by hand, such as peeling and coring, have been automated. Peeling, for example, may be performed mechanically or caustically. In the caustic process the fruit or vegetable is dipped in a hot lye solution to loosen and soften the peel, which is then removed by brushes and water spray.

The fruits and vegetables canning and freezing industry comprises approximately 1,680 plants that are subdivided into 1,038 canned fruits and vegetables plants plus 642 frozen fruits, vegetables, and specialities plants. These plants are further subdivided into canning plants, freezing plants, combination canning and freezing plants, and dehydrating plants. According to the *1976 U. S. Industrial Outlook*, shipments of canned and frozen fruits and vegetables were expected to reach $11 billion in 1976, an increase of 11 percent over 1975. Approximately 70 percent of all these plants are multiproduct producers, although an equivalent percentage confine their operations to either fruits or vegetables.

The canning and freezing industry is characterized by a large number of small, single-plant firms. These firms share a very small segment of the total market and have very little influence on industry prices and total supply. Over the past 20 years, there has been a steady trend in the industry to fewer large plants from many smaller operations. The four largest firms in the canning, freezing, and dehydrating industries account for approximately 20, 25, and 35 percent, respectively, of the total value of industry shipments. Although a large proportion of the plants are relatively old, the industry has generally maintained modern technology through renovation and equipment modernization.

It is likely that the trend toward fewer plants will continue. New large plants will probably continue to replace the production capacity of the small, older plants that will close.

Waste Sources and Pollutants

Water is used extensively in all phases of the food procesing industry; it is used as:

- A cleaning agent to remove dirt and foreign material
- A heat-transfer medium for heating and cooling
- A solvent for removal of undesirable ingredients from the product
- A carrier for the incorporation of additives into the product
- A vehicle for transporting and handling the product.

Although the steps used in processing the various commodities display a general similarity, there are variations in the equipment used and in the amount and character of the wastewaters produced. For example, caustic peeling produces a much higher pollution load than does mechanical peeling. Similarly, water transport adds a great deal to a plant's wastewater flow compared to dry transportation methods.

The pollutant parameters that have been designated by EPA as being of major significance for apple, citrus, and potato processors are BOD, suspended solids, and pH. Minor pollutant parameters include COD, total dissolved solids, ammonia and other nitrogen forms, phosphorus, fecal coliforms, and heat.

Control Technology and Costs

Control technologies applicable to wastewaters from the fruit and vegetable processing industry consist of both in-plant (or in-process) technologies and conventional end-of-pipe waste treatment technologies. In-plant control methods include field washing of crops; substitution of dry transport methods for flumes; replacing conventional hot water and steam blanching methods by fluidized bed, microwave, hot gas, or individual quick blanching methods; using high pressure nozzles and automatic shutoff valves on hoses; reusing process waters in countercurrent flow systems, recirculating of cooling waters, etc.; and minimizing the use of water and detergents in plant clean up.

End-of-pipe treatment technologies used in the fruits and vegatables processing industry generally include preliminary screening, equalization, the use of catch basins for grease removal, sedimentation and clarification, followed by a biological treatment system such as activated sludge and the use of trickling fiters, anaerobic lagoons, or aerated lagoons. Where necessary, neutralization and chlorination are also included. Other technologies that are or may be used by the industry include solids removal by air flotation or centrifugal separation, chemical coagulation and precipitation, biological treatment (through the use of a rotating biological contactor), sand or diatomaceous earth filtration, and other advanced treatment technologies. The liquid portion of cannery wastes can be "completely" treated and discharged through percolation and evaporation lagoons or by spray irrigation.

Because the wastes from fruit and vegetable processing plants are primarily biological, they are compatible with municipal sewage treatment systems, therefore, discharge into municipal systems is also a practicable alternative for fruit and vegetable processors.

BPT guidelines are based upon the average performances of exemplary biological treatment systems. Thus, the technology demanded includes preliminary screening, primary settling (potatoes only), and biological secondary treatment. The use of cooling towers for the recirculation of cooling water is considered a BPT for the citrus industry. In-plant control methods should include good housekeeping and water use practices. No special in-plant modifications are required. Land treatment methods such as spray irrigation are, of course, not excluded from use.

BAT and NSPS guidelines assume the use of BPT, plus additional secondary treatment, such as more aerated lagoons and/or shallow lagoons and/or a sand filter following secondary treatment; disinfection (usually chlorination) is also included. Management controls over housekeeping and water use practices are assumed to be stricter than BPT. Although no additional in-plant controls are required, several modifications may be economically more attractive than additional treatment facilities. These include: recycling raw material wash water, utilizing low water-usage peeling equipment, recirculating of cooling water, and utilizing dry clean up methods. Where suitable land is available, land treatment is not only recommended from the discharge viewpoint, but will usually be more economical than other treatment methods.

Control costs are summarized in Table 8.3–1.

TABLE 8.3–1. CANNED AND PRESERVED FRUITS & VEGETABLES INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	189.46	619.07	0.0	0.0	0.0
BAT	0.0	0.0	82.29	108.86	108.86
NEW PLANTS	4.53	17.62	11.65	18.07	25.20
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	193.99	636.69	93.94	126.93	134.06
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	193.99	636.69	93.94	126.93	134.06
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	81.39	179.59	325.57	488.34	732.52
BAT	0.0	0.0	21.82	50.45	93.38
NEW PLANTS	2.32	5.74	13.04	21.99	37.80
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	83.71	185.33	360.42	560.78	863.77
O&M					
EXISTING PLANTS					
BPT	758.72	1657.40	3029.27	4540.36	6803.84
BAT	0.0	0.0	18.70	43.21	79.24
NEW PLANTS	0.63	1.57	4.14	7.28	13.16
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	759.36	1658.96	3052.12	4590.86	6896.23
INDUSTRY TOTAL	843.07	1844.29	3412.54	5151.64	7760.00
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	843.07	1844.29	3412.54	5151.64	7760.00
ALL ANNUAL COSTS	843.07	1844.29	3412.54	5151.64	7760.00

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.4 CANNED AND PRESERVED SEAFOOD INDUSTRY

Production Characteristics and Capacities

There are approximately 1,800 seafood processors located in the United States, including tuna processing plants located in Puerto Rico and American Samoa. The crab, shrimp, and catfish processors include a large proportion of small producers. Some of these are associated with large national seafoods processors, but there is no significant degree of concentration in these industries. In the crab processing industry, there seems to be an increasing number of multiplant firms and a growing importance of large plants. The catfish processing industry is very small and fragmented. This study's count of 30 plants does not include a number of very small "backyard" operations which are thought to be scattered throughout the South. In general, these segments of the seafood processing industry can be characterized as possessing many small, under-utilized, old plants that in some cases compete with efficient, low-cost foreign producers.

On the other hand, the tuna industry is dominated by five firms that operate 14 large-scale plants which account for over 90 percent of the industry production.

In general, the volume of production is dependent upon the amount of seafood harvested, both domestic and imported. Analyses by the U.S. National Marine Fisheries Service indicate that a 3.1 percent annual compound growth rate can be sustained through 1985 by the extension of the U.S. fisheries jurisdiction to 200 miles, raising additional fish by aquaculture, and by encouraging the catch and sale of presently under-utilized fish species. A fully operational predictive model to forecast the effect of the 200-mile limit is not yet available.

Catfish processors have historically exhibited a low utilization of capacity due to geographically limited demand. Growth has been at 2.0 percent per year in the recent past and is expected to remain at that level in the future unless there is an unanticipated new market sector.

Effluent guidelines have been promulgated by EPA to cover both the Phase I and Phase II segments of the industry.

The effluent limitations guidelines issued for the seafood processing industry by the EPA cover the processing of crab, shrimp, tuna, farmed catfish, fish meal, salmon, bottom fish, sardine, herring, clams, oysters, scallops, and abalone. All methods of preservation, fresh-pack, freezing, canning, or curing, are included.

Processing seafood involves variations of a common sequence of operations: harvest, storage, receiving, preprocessing (washing, thawing, etc.), evisceration, precooking, picking or cleaning, preservation, and packaging. Many of the operations, such as picking, shelling, and cleaning, have been mechanized, but much of the industry still depends on conventional hand operations.

For the purpose of establishing effluent limitations guidelines, the seafood processing industry has been divided into 33 subcategories, as listed in Table 8.4–1. Of these, 14 are in Phase I and 19 are in Phase II. The groupings are based upon the type of product, the degree of mechanization, and the location or remoteness of the processing plant. Remote Alaskan plants have been placed in a separate subcategory because their isolated locations render most wastewater treatment alternatives infeasible because of the high cost of overcoming engineering obstacles and the undependability of access to transportation during extended severe sea or weather conditions.

Waste Sources and Pollutants

Pollution sources in the seafood processing industry include both the fishing boats (mostly their discharged bilge water) and the processing plants themselves. Water uses in the processing plants include: washing the seafood, plants, and equipment; flumes for in-plant transport of product and wastes; live holding tanks; cooling and ice making; cooking; freezing; and brining.

The solids and effluents from all fish and shellfish operations consist of:

- Solid portions consisting of flesh, shell, bone, cartilage, and viscera.
- Hot and cold water (fresh or seawater) solutions containing dissolved materials (proteins and breakdown products).

Table 8.4–1.
Seafood Processing Industry Subcategories

Phase I

(1) Farm Raised Catfish
(2) Conventional Blue Crab
(3) Mechanized Blue Crab
(4) Non-Remote Alaskan Crab Meat
(5) Remote Alaskan Crab Meat
(6) Non-Remote Alaskan Whole Crab and Crab Section
(7) Remote Alaskan Whole Crab and Crab Section
(8) Dungeness and Tanner Crab Processing in the Contiguous States
(9) Non-Remote Alaskan Shrimp
(10) Remote Alaskan Shrimp
(11) Northern Shrimp in the Contiguous States
(12) Southern Non-Breaded Shrimp Processing in the Contiguous States
(13) Breaded Shrimp Processing in the Contiguous States
(14) Tuna

Phase II

(1) Fish Meat
(2) Alaska Hand-Butchered Salmon
(3) Alaska Mechanized Salmon
(4) West Coast Hand Butchered Salmon
(5) West Coast Mechanized Salmon
(6) Alaskan Bottom Fish
(7) Non-Alaskan Conventional Bottom Fish
(8) Non-Alaskan Mechanized Bottom Fish
(9) Hand Shucked Clam
(10) Mechanized Clam
(11) Pacific Coast Hand Shucked Oyster
(12) Pacific Coast, Atlantic and Gulf Coast Hand-Shucked Oyster
(13) Steamed and Canned Oyster
(14) Sardine Processing
(15) Alaskan Scallop Processing
(16) Non-Alaskan Scallop Processing
(17) Alaskan Herring Fillet
(18) Non-Alaskan Herring Fillet
(19) Abalone Processing

- Suspended solids consisting of bone, shell, or flesh.
- Foreign material carried into the plant with the raw material.

The following pollutant parameters are controlled by the effluent limitations guidelines for the seafood processing industry: 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and oil and grease. Pollutants of peripheral or occasional importance that are not specifically controlled by the guidelines include heat (elevated temperatures), phosphorus, coliforms, chloride, chemical oxygen demand, settleable solids, and nitrogen.

Control Technology and Costs

Control technologies applicable to the seafood processing industry include both in-plant changes and end-of-pipe treatment. Basic in-plant changes include:

- Minimizing the use of water by substituting dry handling for flumes, using spring-loaded hose nozzles, etc.
- Recovering dissolved proteins by precipitation from effluent streams, enzymatic hydrolysis, brine-acid extraction, or through the conventional reduction process for converting whole fish or fish waste to fish meal.
- Recovering solid portions for use as edible product or as by-products by mechanical deboning and extruding, and by shellfish waste utilization.

Very few end-of-pipe waste treatment systems are currently installed in the seafood processing industry. However, the essentially biodegradable nature of the wastes allows for the easy application of conventional treatment methods. These include screening and sedimentation to remove suspended solids; air flotation and skimming to remove heavy concentrations of solids, greases, oils, and dissolved organics; biological treatment systems, such as activated sludge, rotating biological contactors, trickling filters, ponds, and lagoons to remove organic wastes; and land disposal methods where land is available.

In general, BPT guidelines call for in-plant "good housekeeping" practices, but do not assume significant equipment changes. End-of-pipe technologies associated with BPT are represented by simple screening and grease trap methods, with dissolved air flotation for tuna plants and grinders or comminutors, followed by discharge to deep water for remote Alaskan processors where adequate flushing is available. BAT and NSPS guidelines place much more emphasis on in-plant changes, including in-process modifications which promote efficient water and wastewater management to reduce water consumption, recycling some water streams, and solids or byproduct recovery where practicable. End-of-pipe technologies associated with BAT and NSPS guidelines include more extensive use of dissolved air flotation, plus the addition of aerated lagoons or activated sludge treatment for tuna processors in 1983.

Control costs and industry operating data are summarized in Table 8.4–2.

TABLE 8.4–2. CANNED AND PRESERVED SEAFOOD INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	20.63	34.04	1.69	1.69	1.69
BAT	0.0	0.0	69.78	93.11	93.11
NEW PLANTS	2.35	9.55	7.97	12.48	19.97
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	22.98	43.59	79.44	107.28	114.78
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	22.98	43.59	79.44	107.28	114.78
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	4.48	7.22	18.79	28.19	42.28
BAT	0.0	0.0	18.35	42.83	79.56
NEW PLANTS	1.26	3.12	7.59	13.08	23.71
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	5.73	10.34	44.73	84.10	145.55
O&M					
EXISTING PLANTS					
BPT	3.25	5.24	13.44	20.02	29.76
BAT	0.0	0.0	4.65	10.80	19.95
NEW PLANTS	0.79	2.05	5.11	8.98	16.65
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	4.04	7.29	23.20	39.79	66.36
INDUSTRY TOTAL	9.77	17.62	67.93	123.89	211.91
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	9.77	17.62	67.93	123.89	211.91
ALL ANNUAL COSTS	9.77	17.62	67.93	123.89	211.91

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.5 DAIRY PRODUCTS PROCESSING INDUSTRY

Production Characteristics and Capacities

In 1970, there were 5,241 dairy plants reported in the United States. By 1972 the number had shrunk to 4,590, a decline of 12 percent. The size of each plant is determined by the number of employees required, where a small operation has 1–19 employees, a medium one has 20–99 employees, and a large plant over 100 employees.

The dairy processing industry comprises 12 product-related subcatagories: (1) receiving stations, (2) fluid products, (3) cultured products, (4) cottage cheese, (5) butter, (6) natural cheese, (7) ice cream, (8) ice cream mix, (9) condensed milk, (10) dry milk, (11) condensed whey, and (12) dry whey.

A great variety of operations are employed in the dairy products industry. For simplification, they are considered to be a chain of operations involving: (1) receiving and storing, (2) clarifying, (3) separating, (4) pasteurizing, and (5) packaging.

Receiving and storing of raw materials is conducted by using bulk carriers, pumps, and refrigerated tanks. Clarifying is the removal of suspended matter by centrifuging. Separating is the removal of cream by centrifuging. Pasteurizing is accomplished by passing the material through a unit where it is rapidly heated then cooled by contact with heated and cooled plates or tubes. Packaging involves the final handling of the finished product prior to storage.

In 1970, a total of 51 billion kilograms (112 billion pounds) of milk was processed. From this total, 36.5 billion kilograms (80.5 billion pounds) of final products were produced. In 1972, output of final products rose slightly to 38.7 billion kilograms (85 billion pounds)). Growth in different subsectors of the industry during the period 1967–1972 was variable with the Natural and Processed Cheese category showing the greatest expansion. This is consistent with earlier trends. Overall industry growth averaged 1.9 percent on an annual basis.

Waste Sources and Pollutants

Materials are lost during direct processing of raw materials into finished products and from ancillary operations. The former group consists of milk, milk products, and nondairy ingredients (sugar, fruits, nuts, etc.), while the latter consists of cleaners and sanitizers used in cleaning equipment and lubricants used in certain handling equipment. All of these contribute to the release of organic materials, which appear as high BOD and suspended solids, in the process water. Phosphorus, nitrogen, chlorides, heat, and dairy fat can also be found.

The major sources of wastes in the dairy products processing industry are the following: (1) the washing and cleaning out of product remaining in tanks and piping which is performed routinely after every processing cycle, (2) the spillage produced by leaks, overflow, freezing-on, boiling-over and careless handling, (3) processing losses, (4) the wastage of spoiled products, returned products, or by-products such as whey, and (5) the detergents used in the washing and sanitizing solutions.

The primary waste materials that are discharged to the waste streams in practically all dairy plants include: (1) milk and milk products received as raw materials, (2) milk products handled in the process and end-products manufacture, (3) lubricants (primarily soap and silicone-based) used in certain handling equipment, and (4) sanitary and domestic sewage from toilets, washrooms, and kitchens. Other products, such as nondairy ingredients (sugar, fruits, flavors, and fruit juices) and milk by-products (whey and buttermilk) are potential waste contributors.

The basic parameters used in establishing effluent guidelines are: BOD_5, suspended solids, and pH. It is recommended that the pH of any final discharge be within a range of 6.0–9.0. Wastes from various dairy industry subcategories contain compatible pollutants as defined by EPA Pretreatment Standards; hence pretreatment is not required. No toxic materials as defined in the EPA Toxic Pollutant Effluent Standards are present in wastes from this industry.

Control Technology and Costs

Dairy wastes are usually subjected to biological breakdown. The standard practice for reducing the concentration of oxygen-demanding materials in the wastewater has been to use secondary or biological treatment consisting of: activated

sludge, trickling filters, aerated lagoons, stabilization ponds, or land disposal. Tertiary treatment (sand filtration, carbon adsorption) is practically nonexistent at the present time.

BPT and BAT consists essentially of the same practices. In-plant control includes improvement of plant maintenance, waste monitoring equipment and quality control improvements. End-of-pipe control includes biological treatment (activated sludge, trickling filters, or aerated lagoons). If in-house controls are not used, end-of-pipe biological treatment must be supplemented by rapid sand filtration. Small dairies may be able to meet BPT through land disposal options. The recommended effluent reductions attainable through the application of BAT assume the use of BPT technology plus the additional step of a polishing pond, sand filter, or other polishing operation. The guidelines for new sources are the same as the BAT limitations for the respective industry subcatagories.

Control costs are summarized in Table 8.5–1.

TABLE 8.5–1. DAIRY PRODUCTS PROCESSING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	19.05	127.76	0.0	0.0	0.0
BAT	0.0	0.0	9.69	12.82	12.82
NEW PLANTS	2.21	9.20	10.72	16.91	26.70
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	21.27	136.96	20.41	29.73	39.52
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	21.27	136.96	20.41	29.73	39.52
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	16.80	46.16	67.19	100.79	151.18
BAT	0.0	0.0	2.56	5.93	10.99
NEW PLANTS	1.21	3.06	8.28	14.73	27.56
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	18.01	49.22	78.03	121.45	189.73
O&M					
EXISTING PLANTS					
BPT	2.89	7.87	10.81	15.85	23.14
BAT	0.0	0.0	2.76	6.42	11.88
NEW PLANTS	0.33	0.87	2.37	4.26	8.06
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	3.22	8.74	15.95	26.53	43.08
INDUSTRY TOTAL	21.23	57.95	93.98	147.98	232.80
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	21.23	57.95	93.98	147.98	232.80
ALL ANNUAL COSTS	21.23	57.95	93.98	147.98	232.80

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.6 FEEDLOTS INDUSTRY

Production Characteristics and Capacities

Feedlots is a term which applies to many different types of facilities used to raise animals in a "high density" situation. For the purpose of establishing effluent limitations guidelines, the term feedlot has been defined by the following three conditions:

- There is a high concentration of animals held in a small area for periods of time in conjunction with the production of meat, milk, eggs, and/or breeding stock; and/or the stabling of horses;
- There is transportation of feed from other areas to the animals for consumption and;
- By virtue of the confinement of animals or poultry, the land or area will neither sustain vegetation nor be available for crop or forage production.

The effluent limitations guidelines issued to date (Phase I) by the EPA cover feedlots for beef cattle, dairy cattle, swine, chickens, turkeys, sheep, ducks, and horses. A variety of facility types are included within the definition of feedlots. These include: open lots, housed lots, barns with stalls, free-stall barns, slotted-floor houses, solid concrete floor houses, a variety of poultry houses, and wet lots containing swimming areas for ducks.

Raw materials used in the feedlots industry are simply feed, water, and in some cases, bedding. The production processes are defined by the type of facilities employed, and consist mostly of delivering supplies to the animals and carrying away manure and litter.

Although most of the feedlots are classified as small, the bulk of production for many animals is accounted for by the very large producers. Only 1.4 percent of the fed-cattle feedlots accounted for over 60 percent of 1972 production. Although this concentration is not so dominant in some of the other animal groups, the trend toward larger units of production is common to all segments of the industry.

Many producers have diversified into grain production for direct marketing and production of other livestock and poultry. Some are involved in feed grain producing, feed-manufacturing, feeder-cattle producing, and/or meat packing.

Ownership of commercial feedlots ranges from sole-proprietorships to corporate farms, including co-operatives. The feedlot operator may own the animals being fed or, (particularly in the case of fed-cattle) may custom-feed animals owned by others.

Projections of production capacity through 1983 for the cattle, dairy, and hog segments of the feedlots industry anticipate that the trend is toward fewer numbers of production units with the very large units continuing to increase their output volume. Similar projections are not available for the remaining segments of the feedlots industry. However, the growth of production of major agricultural commodities for the period 1970–85 has been estimated. The percentage changes are as follows: beef and veal (33 percent); pork (13 percent); milk (2 percent); chicken (36 percent); turkey (44 percent); eggs (10 percent); and lamb and mutton (65 percent). In all segments of the feedlots industry, it is anticipated that the trend toward larger feedlots will continue. No substantive growth projections are available for the duck or horse subcategories.

Waste Sources and Pollutants

Animal feedlots wastewater originates from two principal sources:

- Rainfall runoff
- Flush or washdown water used to clean animal wastes from pens, stalls, milk center areas, houses; runoff from continuous overflow watering systems or similar facilities; spillages; runoff from duck swimming areas; runoff from washing of animals; runoff from dust control; etc.

The amount of wastewater varies considerably, depending upon the way manure, bedding, etc., are stored and handled; in the outdoor feedlots, rainfall and soil characteristics determine wastewater characteristics.

Animal feedlot wastes generally include the following pollutants:

- Bedding or litter (if used) and animal hair or feathers
- Water- and milking-center wastes
- Spilled feed
- Undigested and partially digested food or feed additives
- Digestive juices
- Biological products of metabolism
- Micro-organisms from the digestive tract
- Cells and cell debris from the digestive tract
- Residual soil and sand.

The primary discharge constituents of concern for pollution control can be described as organic solids, nutrients, salts, and bacterial contaminants. The following specific pollutant parameters have been identified as being of particular importance: BOD_5, COD, fecal coliform, total suspended solids, phosphorus, ammonia and other nitrogen forms, and dissolved solids.

With the exception of the duck feedlot subcategory, the EPA has concluded that animal feedlots can achieve a BPT level of waste control which prevents the discharge of any wastes into waterways, except for overflows due to excessive rainfall or similar unusual climatic events (a 10-year, 24-hour storm as defined by the National Weather Service). The effluent limitations for discharges from duck feedlots have been set at 0.9 kilogram (2 pounds) of BOD_5 per day for every 1,000 ducks being fed, and a total viable coliform count less than that recommended by the National Technical Advisory Committee for shellfish-producing waters, which is 400 fecal coliform per 100 milliliters. The effluent limitations guidelines for all subcategories effective July 1, 1983 (BAT), and for all new sources (NSPS) are no discharge of wastewater pollutants, except for overflows due to rainfalls in excess of the 25-year, 24-hour storm (as defined by the National Weather Service).

Control Technology and Costs

In-process technologies used for the control of wastewaters from animal feedlots include: site selection, selection of production methods, water utilization practices, feed formulation and utilization, bedding and litter utilization, and housekeeping procedures. All of these are important in minimizing wastewater flow and pollutants.

The various technologies available for end-of-process treatment may be classified as either partial or complete. Partial technologies are defined as those that produce a product or products which are neither sold or completely utilized on the feedlot. Thus, gasification and incineration of manure are considered partial technologies because each generates a significant quantity of ash that must be disposed of. Lagoons, trickling filters, and other biological systems are classified as partial technologies because the effluent may not be suitable for discharge, and, in all cases sludge disposal is necessary. Complete treatment technologies produce a marketable product or a product that can be entirely reused at the feedlot, and which has no appreciable by-products, residues, or polluted water discharge. The dehydration and sale of manure, for example, is a complete technology. Spreading animal wastes on land for crop fertilization is also a complete control technology.

The 1977 BPT guidelines for all animal feedlots (except those for ducks), the 1983 BAT, and the NSPS guidelines all assume the use of complete control technology. The BPT guidelines are based on the containment of all contaminated liquid runoff and the application of these liquids, as well as the generated solid wastes, to productive cropland at a rate which will provide moisture and nutrients that can be utilized by the crops. Technologies applicable to BAT guidelines include some of the complete technologies, such as wastelage (addition of waste products to feed), oxidation ditch mixed liquor refeed, and the recycling of wet-lot water for ducks, which are not yet fully available for general use. The BPT guidelines for duck feedlots require the equivalent of primary settling, aeration, secondary settling, and chlorination prior to discharge.

Comprehensive and reliable data are not available on the number of feedlots that will require construction of pollution control facilities to meet the effluent limitations guidelines. It is generally accepted that housed (total confinement) and pasture operations can generally meet the guidelines without new investment or operating cost outlays.

Furthermore, open or partially open feedlots may be situated so that they are not point-source dischargers. Finally, some feedlots have already installed control facilities which meet the guidelines' requirements. Recent estimates suggest that only 10 to 40 percent of all feedlots will require additional investment for control facilities.

Control costs are summarized in Table 8.6–1.

TABLE 8.6–1. FEEDLOTS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	21.78	79.87	0.81	0.81	0.81
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	4.88	18.05	11.25	17.68	28.53
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	26.66	97.92	12.06	18.48	29.34
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	26.66	97.92	12.06	18.48	29.34
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	10.50	26.41	42.21	63.43	95.25
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	2.37	5.78	13.11	22.07	38.97
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	12.87	32.19	55.33	85.50	134.22
O&M					
EXISTING PLANTS					
BPT	12.22	30.74	49.13	73.82	110.86
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	2.76	6.73	15.23	25.62	45.18
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	14.98	37.46	64.36	99.44	156.04
INDUSTRY TOTAL	27.86	69.65	119.69	184.94	290.26
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	27.86	69.65	119.69	184.94	290.26
ALL ANNUAL COSTS	27.86	69.65	119.69	184.94	290.26

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.7 MEAT PACKING INDUSTRY

MEAT PACKING (PHASE I)

(Some or all of the regulations governing this industry were remanded on November 27, 1975. The EPA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations.)

Production Characteristics and Capacities

According to the Department of Agriculture, there were 5,991 meat slaughtering plants in the United States on March 1, 1973. Commercial slaughter of beef, hogs, calves, sheep, and lambs totaled 26.9 million metric tons (29.6 million short tons) in 1972 according to the USDA. Of these plants, 84 were large plants (over 91,000 thousand metric tons or 100,000 short tons annual live weight killed (LWK), 309 medium plants (11,300–90,000 metric tons or 12,500–100,000 short tons annual LWK), and the rest were small. Of the small plants, the Development Document estimated 5,200 to be "locker" plants (very small meat packing plants that slaughter animals and may produce processed meat products which are usually stored in frozen form). The other 400 plants are assumed to be plants between 450 and 11,300 metric tons (500 and 12,500 short tons) annual LWK.

A total of 90 percent of the industry's production is accounted for by 15 percent of the plants. Although the total number of plants in the Development Document slaughterhouse and packinghouse categories is only 793, it was assumed that these plants produce 90 percent of the output, and that locker plants account for the remaining 10 percent.

The meat processing industry comprises four subcategories: simple slaughterhouse, complex slaughterhouse, low-processing packinghouse, and high-processing packinghouse. The plants in this industry range from those that carry out only one operation, such as slaughtering, to plants that also carry out commercial meat processing.

Simple slaughterhouses have very limited by-product processing and usually no more than two other operations such as: rendering, paunch and viscera handling, blood processing, or hide processing. Complex slaughterhouses carry out extensive by-product processing with at least three of the aforementioned operations. Low-processing packinghouses process only animals killed at the plant; normally they process less than the total kill. High-processing packinghouses process both animals slaughtered at the site and additional carcasses from outside sources.

Income from meat slaughtering and meat processing plants in 1972 was $23.8 billion. Factors serving to restrain potential growth of the American meat packing industry include higher meat prices, removal of import quotas, and the availability of synthetic (soybean protein) substitutes. The trend is for any new plants to be larger and more specialized (such as large beef or pork slaughterhouses) and to be located closer to the animal supply (movement from urban to rural areas).

Waste Sources and Pollutants

Wastewaters from slaughterhouses and packinghouses contain organic matter including grease, suspended solids, and inorganic materials such as phosphates, nitrates, and salt. These materials enter the waste stream as blood, meat and fatty tissue, meat extracts, paunch contents, bedding, manure, hair, dirt, curing and pickling solutions, preservatives, and alkaline detergents.

Water is a raw material used in the meat processing industry to cleanse products and to remove unwanted material. The primary operations where wastewater originates are: animal holding pen operations (waste from water troughs, washdown, and liquid wastes), slaughtering (killing, blood processing, viscera handling and offal washing, and hide processing), and clean-up.

The basic parameters used to define waste characteristics are BOD_5, suspended solids, grease, and ammonia (NSPS and BAT). The total number of municipal dischargers is 70 percent of the number of plants. The average wastewater flows for simple slaughterhouse, complex slaughterhouse, low-process packinghouse, high-process packing house are 1.17, 4.40, 3.41 and 4.38 million liters (0.31, 1.15, 0.90, 1.2 million gallons, respectively per day). About 70–75 percent of the total wastewater volume is discharged to municipal systems.

Present Control Technology and Costs

Current end-of-pipe treatment for direct dischargers assumes that all plants have in-plant controls for primary treatment, and a secondary treatment system employing anaerobic and aerobic lagoons. Dissolved air flotation is used for primary treatment, either alone or with screens; however, 30 percent of the plants use a catch basin. Since a small percentage of the industry has more advanced secondary treatment systems (such as activated sludge, trickling filters, or spray irrigation) and a small percentage of meat packers have no waste treatment beyond primary treatment, it can be assumed that the typical plant today is characterized by primary treatment plus anaerobic and aerobic lagoons.

Best Practicable Technology consists of end-of-pipe treatment represented by anaerobic-plus-aerated lagoons and aerated lagoons with efficient solid-liquid separation. Disinfection by chlorination is also required. Land disposal, when available, may be an economical option, especially for small plants. End-of-pipe treatment is assumed to be preceded by in-plant controls; these are: reduction of water use through shut-off valves, extensive dry cleaning, use of gravity catch basins, blood recovery and dry dumping of paunch waste. NSPS are the same as BPT with an additional requirement for control of ammonia.

In addition to BPT, Best Available Technology suggests chemical additions prior to dissolved air flotation, nitrification-denitrification (or ammonia stripping), and sand filtration following secondary treatment.

MEAT PRODUCTS (PHASE II)— RED MEAT PRODUCTS INDUSTRY

Production Characteristics and Capacities

In 1972, the *Census of Manufactures* listed a total of 1,311 plants under SIC 2013 — Sausage and Other Prepared Meat Products. Plants have been classified in size according to the production of finished product (FP). A small processor produces less than 2,750 kilograms (6,000 pounds) per day while a large processor produces in excess of that amount. Large processors are further divided into the following product mix categories: (1) meat cutter, (2) sausage and luncheon meat processor, (3) ham processor, and (4) canned meat processor.

Production processes for subcategories in this segment of the red meat industry are varied but most often include: (1) receiving, and storage, (2) boning and sizing, (3) cooking, preserving or other preparing of finished products, (4) packaging, and (5) finished product storing and shipping.

The value of shipments in the meat processing industry from 1967–1972 increased by $1.86 billion, a compound annual increase of 5.1 percent. Growth in terms of product was 1.8 percent annually during the same period. The sausage and luncheon meat subcategory exhibited the most rapid increase—three percent per year.

Waste Sources and Pollutants

Wastewaters from meat processing plants contain organic matter, suspended solids and inorganic materials, such as phosphates, nitrates, nitrites, and salt. These materials enter the wastestream as meat and fatty tissues, grease, meat juices, product spills, curing and pickling solutions, preservatives, and detergents. In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: (1) five-day biochemical oxygen demand (BOD_5), (2) total suspended solids (TSS), (3) oil and grease (O&G), and (4) fecal coliforms.

The wastes from the meat products industry contain compatible pollutants. There is no evidence that toxic pollutants as defined in the EPA toxic pollutant effluent standards are present in the wastewaters from any of the meat products industry subcategories.

Control Technology and Costs

Waste treatment practices in the meat processing industry vary widely according to the age, size, and location of plants. Many now use primary treatment (including screening and catch basins) for waste material recovery. Where secondary wastewater treatment is practiced, anaerobic processes are commonly employed, followed by a trickling filter, aerated lagoon, or activated sludge process. BPT guidelines for large plants discharging to waterways call for a major removal of BOD_5, TSS, and grease through installation of primary treatment (screening, equalization, dissolved air flotation) followed by secondary biological treatment, such as activated sludge or extended aeration combined with a facultative lagoon and disinfection. EPA assumed that BPT investment for existing plants was limited to chlorination equipment. BAT guidelines project a further reduction in BOD_5, TSS, and oil and grease by means of filtration. In-plant controls for reduction in wastewater volumes are also assessed. Septic tanks are considered to provide BPT and BAT for small processors.

Control costs for the Meat Packing (Phase I) and Red Meat Products (Phase II) categories are given in Table 8.7–1.

TABLE 8.7-1. MEAT PACKING AND RED MEAT PRODUCTS INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	3.52	11.47	0.0	0.0	0.0
BAT	4.01	4.01	136.23	179.19	179.19
NEW PLANTS	2.34	9.34	11.53	18.89	32.59
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	9.86	24.82	147.76	198.09	211.78
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	9.86	24.82	147.76	198.09	211.78
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	1.53	3.66	6.11	9.16	13.74
BAT	0.53	0.53	39.09	87.27	159.53
NEW PLANTS	1.23	3.07	8.55	15.47	30.10
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	3.28	7.25	53.75	111.90	203.37
O&M					
EXISTING PLANTS					
BPT	5.58	15.86	21.95	32.74	48.72
BAT	0.0	0.0	80.50	185.52	342.43
NEW PLANTS	2.36	6.13	17.29	31.68	62.57
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	7.94	21.99	119.74	249.94	453.72
INDUSTRY TOTAL	11.22	29.25	173.49	361.83	657.09
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	11.22	29.25	173.49	361.83	657.09
ALL ANNUAL COSTS	11.22	29.25	173.49	361.83	657.09

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

MEAT PROCESSING (PHASE II)— POULTRY PROCESSING

Production Characteristics and Capacities

In 1974, there were 1,846 poultry processing plants in the United States under Federal inspection. Of this total, 1,178 plants processed both red meat and poultry. The size of a model plant is determined by the number of birds processed per day. Large plants may process in excess of 120,000 birds in a single day.

This segment of the meat products industry has been divided into the following subcategories: (1) Chicken processor, (2) Turkey processor, (3) Fowl processor (mature chickens, geese, and capons), (4) Duck processor, and (5) Further processor (no slaughtering).

The production processes for poultry processing include: (1) receiving birds; (2) killing, (3) bleeding, defeathering, including scalding, picking, singeing and washing, (4) eviscerating, including viscera removal, giblet processing, and carcass washing, (5) weighing, grading and packaging, chilling, and (6) shipping. These steps with minor variations, are used in the processing of chickens, turkeys, fowl and ducks.

"Further Processing" includes those poultry plants that conduct further processing of poultry products only, but do no on-site slaughter. Further processing of poultry products (chickens, fowl, turkeys or ducks) includes the following steps: (1) receiving and storage; (2) thawing; (3) cut-up operations; (4) cooking; (5) battering and breading; (6) cooking; (7) freezing and packaging, and (8) cold storing; or alternatively, after (2) thawing; (3) bon-

ing; (4) dicing, grinding, and chopping; (5) mixing and blending; (6) stuffing or canning, (7) cooking; (8) final product preparing; (9) freezing and packaging; and (10) cold storing.

U.S. Department of Agriculture statistics show the following values for poultry production for 1972 in metric tons (short tons in parentheses): chickens, 4,970,000 (5,480,000); fowl (mature chickens) 375,000 (414,000); turkeys 1,034,000 (1,140,000); ducks, 32,370 (35,670); and other poultry 4,280 (4,700); for a total of 6,416,000 (7,070,000). Further processed poultry products of all subcategories totalled 743,000 metric tons (819,000 short tons) for 1972.

The poultry industry has been growing; U.S. per capita consumption of combined turkey plus chicken has approximately doubled in the last two decades, during which period total red meat consumption increased less than 15 percent. Production in Federally inspected poultry plants was in excess of 8.9 billion kilograms (13 billion pounds) in 1971.

The compound annual growth rate over the period 1973 to 1980 has been estimated at between 4.9 and 5.6 percent. However, the 1972 Census of Manufactures indicates a growth of 4.0 percent between 1967 and 1972.

Waste Sources and Pollutants

Materials are generated through direct processing of raw materials into finished products and from ancillary operations. The former group consists of blood, viscera, fat, and flesh scraps, while the latter consists of cleaners and sanitizers used in cleaning equipment and lubricants used in certain handling equipment. All of these contribute to the release of organic materials, which exert a high BOD and elevate the oil, grease and suspended solids levels in the process water. Phosphorus, nitrogen species, and chlorides can also be found.

The most significant single waste source in the poultry products processing industry is blood from the walls of the blood tunnel which is washed into sewers.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT: (1) five-day biochemical oxygen demand (BOD_5), (2) total suspended solids (TSS), (3) oil and grease (O&G), (4) fecal coliforms, and (5) pH. It is recommended that the pH of any final discharge be within a range of 6.0–9.0. Wastes from various poultry industry subcategories contain compatible pollutants as defined by EPA Pretreatment Standards, hence pretreatment is not required. Furthermore, no toxic materials as defined in the Toxic Pollutants Effluent Standards are present in wastes from this industry. In addition, ammonia control is required for BAT.

Control Technology and Costs

Poultry wastes are usually amenable to biological breakdown. A few plants in various subcategories of this industry are currently meeting the BPT limitations promulgated by EPA. Most plants in all subcategories either discharge to municipal treatment systems or utilize some form of secondary biological treatment. Either a three-lagoon system or an activated sludge system, both followed by chlorination, are suitable alternatives for meeting BPT limitations provided that in-plant grease and solids recovery are practiced. Spray irrigation (land application) is practiced by a few plants. The sale of crops grown on the irrigated acreage can help defray the costs of the land.

To meet BAT limitations, most plants in all subcategories will require, in addition to the BPT requirements, in-plant water conservation practices, dissolved air flotation with pH control and chemical flocculation for oil and grease removal, an ammonia control process, and a final sand filter or microstrainer.

Control costs for the poultry products industry included in Table 8.7–2.

MEAT PRODUCTS (PHASE II)—RENDERERS

Production Characteristics and Capacities

The 1972 *Census of Manufactures* lists 511 independent renderers, down 77 from 588 in 1967. According to the National Renderers Association, the number of plants dropped to 450 or less by 1973. Independent rendering resulting in inedible products is distinguished from on-site rendering (slaughterhouse or packinghouse) which produces edible (lard) products.

Independent rendering plants range in size from very small plants having only one to four employees and a value of shipments of about $150,000 to large plants hiring in excess of 100 employees and having annual sales of $12 million. Average size plants, according to EPA, employ 23 persons and have annual sales of about $1.5 million. For purposes of pollution control costing, three categories of plant size are used — one to nine employees, 10–49 employees, and 50 and over employees.

TABLE 8.7-2. POULTRY PROCESSING INDUSTRY WATER POLLUTION COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	1.53	5.44	0.0	0.0	0.0
BAT	0.0	0.0	16.50	21.83	21.83
NEW PLANTS	1.80	7.00	10.93	19.13	36.02
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	3.33	12.43	27.43	40.96	57.87
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	3.33	12.43	27.43	40.96	57.87
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.71	1.74	2.86	4.29	6.43
BAT	0.0	0.0	4.36	10.10	18.72
NEW PLANTS	0.92	2.28	7.03	13.32	27.86
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.63	4.02	14.25	27.71	53.01
O&M					
EXISTING PLANTS					
BPT	0.73	1.77	2.73	4.01	5.84
BAT	0.0	0.0	7.31	16.87	30.95
NEW PLANTS	0.55	1.43	4.47	8.58	18.17
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	1.27	3.21	14.51	29.47	54.95
INDUSTRY TOTAL	2.91	7.22	28.76	57.18	107.96
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	2.91	7.22	28.76	57.18	107.96
ALL ANNUAL COSTS	2.91	7.22	28.76	57.18	107.96

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

A single product-related subcategory has been deemed adequate to represent the activities and the pollutants of this industry.

The production steps in independent inedible rendering are as follows:

- Raw material recovery
- Crushing and grinding
- Cooking and moisture removal
- Liquid-solid separation
- Grease clarifying, storing, and shipping
- Meal grinding and screening
- Blending
- Meal storing and shipping
- Hide curing.

Variations in the overall rendering process occur depending on whether batch or continuous systems are used.

The value of shipments in the industry has climbed from $510.4 million in 1967 to $808.6 million in 1972. Output of final products rose from 2.4 billion kilograms (5.4 billion pounds) of grease and tallow to 2.7 billion kilograms (6.0 billion pounds) during the five year period while production of meat meal and tankage increased from 36.3 million to 37.2 million kilograms (80 million to 82 million pounds) per year. Very few projections of long range growth have been made for this industry.

Waste Sources and Pollutants

Rendering is a process to convert animal products, by heating, into fats, oils, and proteinaceous so-

lids. A variety of waste meat products including fat trimmings, meat scraps, feathers, offal, bone, and whole carcasses are processed continuously or in batches. The raw material is crushed, then cooked under pressure as required. Fats and oils are allowed to drain off, and the solid material remaining is pressed, ground, and screened to provide a protein-bone meal mixture. Tallow and greases are separated. The large amounts of moisture released in cooking are collected by condensation. Plants which process a large number of dead animals may include facilities for hide curing.

The principal operations and processes in rendering plants where wastewater originates are (1) raw material receiving, (2) condensing cooking vapors, (3) plant cleanup, and (4) truck and barrel washing. Wastewaters from rendering plants contain organic matter, suspended solids, and inorganic materials, such as phosphates, nitrates, nitrites, and salt. These materials enter the wastestream as blood, meat and fatty tissue, body fluids, hair, dirt, manure, tallow and grease, meal products, detergents, and hide curing solutions (where used).

The wastes from all subcategories in the meat products industry contain compatible pollutants. There is no evidence that toxic pollutants as defined in the EPA toxic pollutant effluent standards are present in the wastewaters from any of the meat products industry subcategories.

In order to define waste characteristics, the following basic parameters were used to develop guidelines for meeting BPT and BAT: five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), oil and grease (O&G), pH, fecal coliforms, and ammonia.

Control Technology and Costs

Wastes in the independent rendering industry are amenable to biological treatment. Off-site rendering plants are divided nearly evenly between those which discharge to municipal sewer systems and those which treat their wastes. Of the latter group, half achieve no discharge of pollutants by means of spray irrigation or ponding. The treatment technology is essentially the same as for meat processors. BPT guidelines for plants discharging to waterways call for a major removal of BOD_5, TSS, grease and fecal coliform bacteria through installation of primary treatment (equalization, screening, dissolved air flotation and disinfection). Next is secondary biological treatment, such as activated sludge or extended aeration combined with a facultative lagoon and disinfection. BAT criteria call for further reductions in BOD_5, TSS, and grease, to be achieved by sand filtration; ammonia control is also mandated. In-plant controls for reduction in wastewater volume are also assumed. New source performance standards are the same as BPT for existing plants with the addition of ammonia limitations.

Control costs for the Rendering Industry are detailed in Table 8.7–3. Industry in Table VIII-7–4.

TABLE 8.7–3. RENDERING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	0.31	1.01	0.0	0.0	0.0
BAT	0.0	0.0	10.67	14.02	14.02
NEW PLANTS	0.05	0.22	0.22	0.35	0.57
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	0.36	1.22	10.89	14.37	14.59
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	0.36	1.22	10.89	14.37	14.59
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.13	0.31	0.53	0.80	1.19
BAT	0.0	0.0	2.84	6.52	12.05
NEW PLANTS	0.03	0.07	0.19	0.33	0.61
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.16	0.38	3.55	7.65	13.85
O&M					
EXISTING PLANTS					
BPT	0.31	0.72	1.14	1.66	2.38
BAT	0.0	0.0	5.72	12.93	23.11
NEW PLANTS	0.03	0.09	0.23	0.40	0.76
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.34	0.81	7.08	14.99	26.25
INDUSTRY TOTAL	0.50	1.19	10.64	22.64	40.10
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.50	1.19	10.64	22.64	40.10
ALL ANNUAL COSTS	0.50	1.19	10.64	22.64	40.10

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

8.8 LEATHER TANNING AND FINISHING INDUSTRY

(Some or all of the regulations governing this industry were remanded on March 10, 1976. The ERA believes that the reasons for this action were technical in nature and that similar regulations differing only in the pollutant reductions required and incurring similar costs will be promulgated in the future. This discussion, therefore, was based on the costs derived in the support documents for the present regulations.)

Production Characteristics and Capacities

The leather tanning and finishing industry includes those establishments which are engaged in the processes of converting animal skins into leather. The principal hide used by the industry is cattlehide. In 1976 cattlehide leather accounted for 86 percent of the hides tanned. The second largest volume of raw materials used are sheepskins and lambskins followed third by pigskin. Other types of skins or hides processed include goat, kid, hairsheep, and horse. Those skins tanned on a more limited basis include deer, elk, moose, antelope, rabbit, alligator, crocodile, seal, shark, and kangaroo. Currently there is a tight demand on the raw materials for leather production due primarily to the continued expansion of cattlehide exports. According to the *U.S. Industrial Outlook, 1977*, in 1976, exports accounted for 57 percent of the total production of hides.

The processes utilized to convert raw materials to finished leather are: beamhouse; tanhouse; retan, color, and fatliquor; and finishing.

Beamhouse

Beamhouse processes are used exclusively for cattlehide tanning. The hides received have previously been cured green, salted, or brined at the packing house. Therefore, the first step at the beamhouse is siding and trimming. Next the sides are washed and soaked followed by flushing. The final step is removal of the hair either mechanically or chemically. The hair is either saved or pulped.

Tanhouse

Steps at the tanhouse include the degreasing of sheepskins and pigskins and pickling of cattlehides and pigskins. Sheepskins have been pickled prior to arrival at the tanhouse. All pickled hides and skins are then either chrome-tanned or vegetable-tanned. The tanned hide is then split to form a grainside piece and a flush-side layer.

The next step is the retan, color, and fatliquor process. The skins are usually colored with synthetic dyes. Fatliquoring is the operation in which oils are added to replace the natural oils lost in the beamhouse and tanhouse processes and to make the leather pliable. The amount of oil added depends on the end use of the leather.

Finishing

The final process is finishing which includes a number of operations such as drying, wet-in coating, staking or tacking, plating, skiving, carding, clipping, sanding, and buffing.

For the purpose of establishing effluent limitations guidelines and standards of performance, the primary processes employed in the tanning and finishing industry have been divided into major subcategories. These subcategories are listed in Table 8.8–1.

Table 8.8–1.
Leather Tanning and Finishing Subcategories

Subcategory	Beamhouse	Tanning	Leather Finishing
1	Pulp Hair	Chrome	Yes
2	Save Hair	Chrome	Yes
3	Save Hair	Vegetable	Yes
4	Hair previously removed	Previously tanned	Yes
5	Hair previously removed or retained	Chrome	Yes
6	Pulp or Save Hair	Chrome or no tanning	No

Source: Development Document, March, 1974.

Leather tanning and finishing is a declining industry. The number of tanneries has steadily decreased from around 7,500 operating in 1865 to approximately 1,000 in 1900. According to the *U.S. Industrial Outlook, 1977*, the number of establishments has continued to decrease from the turn of the century to approximately 430 in 1976.

The major factors contributing to the decline have been competition from synthetic leathers and increasing international competition. The industry has been severly impacted by international competition from both the large exports of hides and the rising imports of finished leather products. A zero growth rate is being projected for the industry for the period 1972 — 1985. The no growth projection is based on a historical extrapolation of the annual quantity of finished products given in the 1972 *Census of Manufacturers*.

Waste Sources and Pollutants

The leather tanning and finishing industry may be regarded as highly water dependent. Water is a convenient vehicle for removal of large amounts of wastes and a vital ingredient for the chemical formulas involved in virtually all tanning methods. In 1972 a total of 27.6 billion liters (7.3 billion gallons) of wastewater were discharged. Of this amount, 55 percent was discharged to public sewerage utilities and 45 percent was discharged directly to surface waters. The number of plants in the industry which discharge wastewater is only about 190, not the entire industry. The largest quantities of wastewater effluents are generated by the beamhouse and tanhouse processes. The various constituents of these processes are as follows:

Hair	Lime	Sugars and starches
Hide scraps	Soluble proteins	Oils, fats, and grease
Pieces of flesh	Sulfides	Surface active agents
Blood	Amines	Mineral acids
Manure	Chromium salts	Dyes
Dirt	Tannin	Solvents
Salt	Soda ash	

For the purposes of establishing effluent guidelines for the leather tanning and finishing industry, the following parameters have been defined to be of major polluting significance: BOD_5, COD, total suspended solids, total nitrogen, chromium, oil and grease, sulfide, and pH.

Control Technology and Costs

The technologies for control and treatment of waterborne pollutants in the leather tanning and finishing industry can be divided into two broad categories: in-process and end-of-pipe. The in-process technologies include: water conservation; process solution reuse or recovery; and in-plant treatment to remove a waste constituent.

End-of-pipe technologies consist of pretreatment processes and secondary biological treatment processes. Pretreatment is necessary due to the amounts of sulfides, oil and grease, and chromium present in the wastewater.

Advanced end-of-pipe technologies include:

- Deep-bed filtration or microscreening
- Carbon absorption
- Coagulation, flocculation, and settling
- Chlorination
- Biological nitrification-denitrification
- Ammonia stripping
- Ammonia ion exchange
- Freezing
- Evaporation
- Electrodialysis
- Ion exchange
- Reverse osmosis

BPT guidelines call for a major removal of BOD_5 and suspended solids through the installation of preliminary treatment (chromium removal, screening, equalization and primary clarification) and secondary biological treatment (activated sludge, aerobic, or anaerobic lagoons). BAT guidelines include BPT plus reductions in sulfide and nitrogen through use of aeration and mixing with a carbon sorbent to cause denitrifiction, and filtration of the final effluent using deep-bed, mixed-media filters to remove suspended solids. New source performance standards are the same as BPT for existing plants.

Control costs are detailed in Table 8.8–2.

TABLE 8.8–2. LEATHER TANNING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	9.51	26.16	0.0	0.0	0.0
BAT	0.0	0.0	101.44	135.25	135.25
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	1.16	3.19	0.0	0.0	0.0
SUBTOTAL	10.67	29.36	101.44	135.25	135.25
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	10.67	29.36	101.44	135.25	135.25
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	3.44	6.98	13.76	20.64	30.96
BAT	0.0	0.0	26.67	62.24	115.58
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.42	0.85	1.68	2.52	3.78
TOTAL	3.86	7.84	42.11	85.39	150.31
O&M					
EXISTING PLANTS					
BPT	3.57	7.25	14.29	21.43	32.15
BAT	0.0	0.0	24.70	57.64	107.04
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.58	1.18	2.32	3.48	5.22
TOTAL	4.15	8.43	41.31	82.55	144.41
INDUSTRY TOTAL	8.01	16.27	83.42	167.95	294.73
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	8.01	16.27	83.42	167.95	294.73
ALL ANNUAL COSTS	8.01	16.27	83.42	167.95	294.73

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9. OTHER INDUSTRIES

9.1 PHARMACEUTICAL MANUFACTURING INDUSTRY

The pharmaceutical industry produces hundreds of medicinal chemicals by means of many complex manufacturing technologies. There are six basic processing techniques in common use in the pharmaceutical manufacturing industry. These techniques, all distinctly different, are: fermentation, chemical synthesis, formulation, fractionation, natural extraction and the growth and isolation of cultures. The first three of these techniques are by far the most widely used.

Fermentation plants are large water users and the basic process steps used at these facilities are similar throughout the industry. The major wastewater from processing techniques are spent beers from the initial fermentation step.

Chemical synthesis is another major production process in pharmaceutical manufacturing. Hundreds of different products are made each year using chemical synthesis techniques, which include alkylations, carboxylation, esterification, halogenation, sulfonation, etc. Chemical synthesis plants are also large water users.

Formulation is the third major production process in pharmaceutical manufacturing. Formulation plants receive bulk chemical and fermentation products as raw materials and subsequently manufacture the final dosage forms (tablets, liquids, capsules, etc.). Compared to the fermentation and chemical synthesis processes, formulation is a relatively small water user.

Fractionation, natural extraction and biological culture growth and separation processing techniques are used on much smaller production scales than the three previously discussed techniques.

Natural extraction techniques use animal and plant tissues as product raw materials and also consist of various separation and chemical extraction steps.

Cultures are grown under optimum conditions and then go through a series of seeding, isolation, incubation and drying steps. These three processing techniques are generally conducted in laboratories on a bench-top scale and therefore are very small water users.

For the purpose of establishing effluent limitation guidelines and standards of performance, the pharmaceutical manufacturing point source category has been divided (on the basis of manufacturing techniques, product type, raw materials and wastewater characteristics) into five separate subcategories. The five subcategories are:

A. *Fermentation Products.* Most antibiotics and steriods are produced in batch fermentation tanks in the presence of a particular fungus or bacterium and then are isolated by various chemical processes or are simply concentrated or dried.

B. *Biological and Natural Extraction Products.* Biological and natural extraction products include various blood fractions, vaccines, serums, animal bile derivatives and extracts of plant and animal tissues. These products are usually produced in laboratories on a much smaller scale than most pharmaceutical products.

C. *Chemical Synthesis Products.* The production of chemical synthesis products is very similar to fine chemials production. Chemical synthesis reactions generally are batch types which are followed by solvent extraction of the product.

D. *Mixing/Compounding and Formulation.* The manufacturing operations for formulation plants may be either dry or wet. Dry production involves dry mixing, tableting or capsuling and packaging. Process equipment is generally vacuum-cleaned to remove dry solids and then washed down. Wet production includes mixing, filtering and bottling. Process equipment is washed down between production batches.

E. *Microbiological, Biological, and Chemical Research.* Research is another important part of the pharmaceutical industry. Although such facilities may not produce specific marketable products, they do generate wastewaters. These originate primarily

from equipment and vessel washings and small animal cage washwaters. Large-animal research farms produce significant quantities of manure and urine, which may justify future subclassification of research facilities.

Products

The pharmaceutical manufacturing industry is divided into three product areas: Biological Products, Medicinal Chemicals and Botanical Products, and Pharmaceutical Preparations. Within the Medicinal Chemicals and Botanical Products classification, there are three additional major product areas: fermentation products, chemical synthesis products and natural extraction products. Fermentation products are primarily steroids and antibiotics. Chemical synthesis products include intermediates used to produce other chemical compounds as well as hundreds of fine chemical products. Biological products include vaccines, serums, and various plasma derivatives. Natural extractions include such items as animal gland derivatives, animal bile salts and derivatives and herb tissue derivatives. Formulation products are manufactured from the end products of the other manufacturing areas and include the mechandise which is finally marketed to the public.

Raw Materials

The pharmaceutical manufacturing industry draws upon worldwide sources for the myriad quantity of raw matrials it needs to produce medicinal chemicals. Fermentation plants require many raw materials falling into general chemical classifications such as carbohydrates, carbonates, steep liquors, nitrogen and phosphorus compounds, anti-foam agents, and various acids and bases. Hundreds of raw materials are required for the many batch chemical synthesis processes used by the pharmaceutical manufacturing point source category. These include organic and inorganic compounds, and are used in gas, liquid, and solid forms.

Plant and animal tissues are also used by the pharmaceutical manufacturing industry to produce various biological and natural extraction products.

Plant Size

Plant size, measured in terms of production, apparently has no significant effect on the pounds of pollutant per pound of production (Raw Waste Load). Plant size, measured in terms of total gross floor area, is used as the basis for computing raw waste loads for pharmaceutical plants.

Plant Age

Plant age is not a significant factor in determining the characteristics of a plant's wastewater. Both the presence and absence of separate sewer systems for sanitary and process wastewaters have been observed in both old and new plants. The age of a plant is related more to the location of the plant than to the quantity or characteristics of the wastewaters. The older plants tend to be located in urban areas, whereas the newer plants are sited in rural areas. This will affect the cost of treatment facilities because of land costs and land availability.

Plant Location

Plant location does not affect the quality or quantity of the process wastewater streams. Geographical location does affect the management of non-process streams such as non-contact cooling water. Recirculation of cooling water is more common in the warm climate areas (where water conservation is of more concern) than in cooler geographical regions.

Housekeeping

The pharmaceutical industry has been under a form of pollution control for a number of yers. Certain control standards for cleanliness, sanitation, hygiene, and process control are matters of particular importance to the industry because of its concern about product quality. The pharmaceutical industry has for years been subject to certain manufacturing and operational restrictions and inspections pertaining to the regulations of the Federal Food, Drug, and Cosmetic Act. Good manufacturing practice regulations promulgated by the FDA have been in force, with modifications, since 1963. Housekeeping practices are exceptionally good and therefore are not a factor in affecting wastewater quantities and characteristics. Except for the nuclear industry, the pharmaceutical industry places greater emphasis upon the purity of its products than does any other industry.

Nature of Wastes Generated

Various pharmaceutical manufacturing processes have been examined for the types of contact process water usage associated with each. Contact process water is defined as all water which comes in contact with chemicals (including pharmaceutical products) within the pharmaceutical manufacturing process. The type and quantity of contact process water usage are related to the specific unit operations and chemical conversions within a process.

The characteristics of the wastewaters generated by the different manufacturing techniques utilized by the pharmaceutical manufacturing industry vary considerably. The wastewaters from fermentation processes consist of high strength spent fermentation beers, equipment washwaters, floor washwaters, and waste solvents. The many batch operations used in chemical synthesis operations were a cause of highly variable wastewaters containing many constitutents. The wastewater flows from formulation operations are almost exclusively equipment and floor washwaters.

Biological, natural extraction, and research facilities generate much less wastewater than the other manufacturing processes. Their wastewater flows are intermittent and animal wastes are often found in the effluents from research buildings.

Treatability of Wastewaters

The pollutant loading from plants within the different manufacturing areas varied widely and therefore the treatment technologies employed by companies throughout the industry varied from highly sophisticated thermal oxidation plants to small biological package plants.

The wastewaters generated by fermentation and chemical synthesis processes contain much higher pollutant concentrations than those generated from the manufacturing of biological and natural extraction products. Formulation plants generally discharge wastewaters with moderate strength. The lowest strength wastes sampled were those attributed to research facilities.

Pharmaceutical plants operate throughout the year. Production processes are primarily batch operations with significant variations in pollutional characteristics over any typical operating period. The characteristics of wastewaters vary from plant to plant according to the raw matrials used, the processes used, and the products produced. Depending on the product mix and the manufacturing process, variations in wastewater volume and loading may occur as a result of certain batch operations (filter washing, crystallization, solvent extraction, etc.), thus adequate equalization of the waste load may be imperative prior to discharge to a waste treatment system.

Pharmaceutical manufacturing plants use water extensively both in processing and for cooling. The plant wastewater collection systems are often segregated to permit separate collection of process wastewaters and relatively clean non-contact cooling waters. The process wastewaters are usually discharged to a common sewerage system for treatment and disposal.

The major sources of wastewaters in the pharmaceutical manufacturing point source category are spent broths or beers from fermentations, residues of reactants and by-products of chemical syntheses, product washings, extraction and concentration procedures, ion exchange regeneration procedures, equipment washdowns, and floor washdowns.

Existing control and treatment technologies, as practiced by the industry, include in-plant abatement as well as end-of-pipe treatment. Recovery and reuse of expensive solvents and catalysts are widely practiced in the pharmaceutical manufacturing point source category for economic reasons. Current end-of-pipe wastewater treatment technology involves biological treatment, physical/chemical treatment, thermal oxidation, or liquid evaporation. Biological treatment includes activated sludge, trickling filters, biofilters, and aerated lagoon systems.

The effluent limitations and guidelines are based solely on the contaminants in the contact wastewaters. No specific limitations are proposed at this time for pollutants associated with non—contact wastewaters. Effluent limitations and guidelines for specific streams are being developed in a separate set of regulations for the steam and non-contact cooling water industries.

Raw waste loads (RWL) and the related effluent limitations developed for the pharmaceutical manufacturing point source category are based solely on contact process wastewater. Other non-contact wastewaters (including domestic wastes) are not to be included in effluent limitations.

Organic oxygen-demanding material is the major contaminant in wastewaters generated by the pharmaceutical manufacturing point source cateogry. Ammonia, organic nitrogen, and phosphorus are also found in significant quantities. The best approach to control these pollutants appears to be in-plant measures or at-source treatment in those special cases where excessive discharge is encountered.

Because of extensive in-plant recovery and recycle operations, metals and other toxic materials are not found in significant quantities in pharmaceutical plant wastewaters.

Sludge disposal systems generally consist of sludge thickening, aerobic digestion, vacuum filtration, and ultimate disposal via landfill. Effluent diversion basins, effluent polishing ponds, neutralization facilities, and biological treatment systems are generally required in some plants.

The model Best Available Technology (BAT) treatment facility consists of Best Practical Technology (BPT) followed by a trickling filtration, final clarification, and multi-media filtration. BAT effluent limitations guidelines are based on the addition of multi-media filtration to the proposed BPT treatment technology.

The data required to develop effluent limitations for specific cases include the identity of the specific manufacturing process, average daily waste flow, and raw waste load.

Costs are summarized in Table 9.1–1.

TABLE 9.1–1. PHARMACEUTICAL MANUFACTURING INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	14.11	40.44	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	1.41	5.79	15.03	24.21	40.55
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	15.52	46.23	15.03	24.21	40.55
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	15.52	46.23	15.03	24.21	40.55
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	5.32	11.09	21.27	31.90	47.85
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.76	1.92	7.82	15.08	31.11
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	6.08	13.01	29.08	46.98	78.96
O&M					
EXISTING PLANTS					
BPT	4.18	8.72	16.72	25.09	37.63
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.53	1.36	5.66	10.99	22.80
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	4.71	10.09	22.39	36.07	60.43
INDUSTRY TOTAL	10.79	23.09	51.47	83.06	139.39
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	10.79	23.09	51.47	83.06	139.39
ALL ANNUAL COSTS	10.79	23.09	51.47	83.06	139.39

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

9.2 HOSPITAL INDUSTRY

Production Characteristics and Capacities

The U.S. Hospital industry includes over 7,000 hospitals primarily engaged in providing diagnostic services, extensive medical treatment, surgical services, and other hospital services as well as continuous nursing services. Specific hospital types are:

- General medical and surgical hospital
- Psychiatric hospitals
- Specialty hospitals except psychiatric hospitals; childrens hospitals, orthopedic hospitals, chronic disease hospitals, maternity hospitals, geriatric hospitals, eye, ear, nose, and throat hospitals, tuberculosis hospitals.

The vast majority of hospitals are non-profit institutions in which expenses are recovered by charges for hospital services. Most hospitals are located in densely populated areas and discharge into municipal sewers. The Development Document estimated that approximately 90 percent of all hospitals discharge into municipal sewers. Table 9.2–1 presents estimated numbers of hospitals that have their own treatment facilities.

Table 9.2–1.
"Direct Discharger" Hospitals*

Bed Size Category	Total Number of Hospitals	Estimated Number of Hospitals With Own Treatment Facilities
50–99	1,748	175
100–199	1,533	153
200–299	766	77
300–399	444	44
400–499	291	29
500 or more	634	63

*Assumption: Only 10% of all hospitals in each size category will have their own wastewater treatment facilities.

Source: "Hospital Statistics; 1975 Edition".

Waste Sources and Pollutants

The primary sources of wastewater streams from hospitals include sanitary wastewaters, discharges from surgical rooms, laboratories, laundries, X-ray departments, cafeterias, and glassware washings. Wastewaters from hospitals can be characterized as containing BOD_5, COD, and TSS concentrations comparable to normal domestic sewage and readily amenable to biological treatment.

Specific contaminants in hospital wastewater include mercury, silver, barium, beryllium, and boron. Mercury is used in laboratories, silver and boron result from X-ray development. Barium is used in diagnostic injections and beryllium is used in dental clinics.

Control Technology and Costs

The technology for the control and treatment of waterborne pollutants in the hospital industry can be divided into two broad categories: in-plant-control and end-of-pipe control.

Specific in-house control practices that are applicable to the hospital industry include: recovery of silver from spent X-ray developer, prevention of discharge of volatile solvents and toxic chemicals into drains, and restriction of the discharge of mercury-containing compounds into the sinks and drains.

To meet NSPS and BAT limitations, guidelines and new source performance standards, end-of-pipe treatment technologies equivalent to biological treatment followed by multi-media filtration is recommended.

Relatively few hospitals treat their wastewater since most hospitals are located near urban areas. Of the hospitals that treat their own wastewaters, the most prevalent end-of-pipe wastewater treatment system is the trickling filter plant; however some hospitals use activated sludge treatment systems.

Treatment costs are summarized in Table 9.2–2.

TABLE 9.2-2. HOSPITAL INDUSTRY WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972-77	1977-81	1977-83	1977-86
INVESTMENT					
EXISTING PLANTS					
BPT	19.13	50.35	0.0	0.0	0.0
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	5.37	19.42	25.65	41.41	69.56
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	24.50	69.77	25.65	41.41	69.56
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	24.50	69.77	25.65	41.41	69.56
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	6.62	13.30	26.48	39.72	59.57
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	2.55	6.16	18.35	33.27	64.50
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	9.17	19.47	44.83	72.99	124.07
O&M					
EXISTING PLANTS					
BPT	5.30	10.66	21.21	31.82	47.73
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	1.89	4.57	13.60	24.67	47.81
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	7.20	15.23	34.82	56.49	95.54
INDUSTRY TOTAL	16.37	34.69	79.65	129.48	219.62
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	16.37	34.69	79.65	129.48	219.62
ALL ANNUAL COSTS	16.37	34.69	79.65	129.48	219.62

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

10. NONPOINT SOURCES AND TOXIC SUBSTANCES

10.1 NON-POINT SOURCE POLLUTION

Non-point sources (NPS) of pollution are major contributors to water quality problems in the U.S. For the Nation as a whole, about one-third of the river pollution is from non-point sources. Many basin planning studies are reaching similar conclusions regarding the extent of pollution of the Nation's lakes due to non-point sources.

No specific regulations similar to the Federal effluent guidelines have been issued for non-point sources. For this reason, no discrete treatment technologies have been identified which will be required for all non-point sources. The implementation of controls on nonpoint sources will occur most at the State and local level. Initially, implementation has concentrated on solution of readily controllable problems and on laying the basis for subsequent full scale NPS control planning and action, through problem assessment, defining technical and institutional remedial approaches, and developing the planning framework for specific state and local programs. These efforts support a second phase of activities, characterized by the development of state or areawide plans for all areas of the country. The second phase was scheduled to become fully effective in 1978.

Programs will emphasize development of non-structural solutions such as land use, land management and regulatory provisions, with the objective of minimizing reliance on capital intensive remedies.

Non-point source pollution encompasses many categories of activities and many subcategories within each category. Included under the heading of non-point sources are the following activity categories and subcategories:

Agriculture
- Irrigated Agricultural Land*
- Non-irrigated cropland in tillage
- Other cropland
- Pastureland
- Rangeland

Silviculture
- Forest culture
- Logging activity

Urban or urbanizing
- Urban runoff
- Construction

*Added by the 1977 Amendments to the Act

Mining

The mining industries are discussed in other chapters. Cost estimates for mining as a non-point source of acid or sediment have, therefore, not been included in this Chapter. In addition, NPS includes concern for the protection of ground water and pollution sources which are either point sources smaller than the size defined for permit issuance under the NPDES or are non-point-associated but may be defined or treated in a point source control fashion. Following implementation of point source controls, the NPS program will be a major component of the national effort to achieve water quality goals.

Agriculture

Agriculture is the greatest single contributor to non-point pollution. Over 385 million hectares (950 million acres) of land area in the U.S. are devoted to farmland in grass, pasture land, cropland plus farmsteads and roads. Cropland represents about 157 million hectares (387 million acres) or about 41 percent of the total.

Pollutant Sources

The pollutants contributed by agricultural activity to nearby streams and lakes are varied and include sediment, salts, plant nutrients, pesticides, biodegradable organic materials and pathogens. In terms of overall impact, sediment appears to be the most serious contributor to water pollution.

Control of water pollution attributable to soil erosion will also reap additional benefits in the control of other agriculturally related pollutants. Of the five previously listed classes of pollutants, four (plant nutrients, pesticides, biodegradable organics, and pathogens) either interact with or are at least partially physically or chemically-associated with soil particles.

Cost Estimates

The Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS) work closely with landowners to develop conservation plans which are tailored to the needs of an individual's parcel of land. Once a plan has been written by the SCS, the landowner may apply to have the required practices cost-shared by the Federal government through the ASCS.

Once every ten years the SCS compiles a very detailed and thorough summary of rural land use and conservation treatment needs. The most recent data were obtained in 1967 and a new survey is now in progress.

Conservation treatment needed on agricultural land was determined by field inspection of statistically selected sample areas. Decisions were based on local SCS technical guides, the prevailing agricultural operations, and the practical bases ordinarily used in developing resource conservation plans.

Silviculture

About 20 percent of the area of the 50 states is devoted to commercial forests. The potential for generating non-point-source pollution from this 203 million hectares (500 million acres) is very high. Quantities of pollutants actually discharged to streams and lakes depend in large part on the type of management given the forest. Pollution control, as it pertains to silviculture, is not treatment-oriented because of the very large quantities of water which must be dealt with. Rather it involves a total resource management system. The system can be divided into two parts, the first of which involves the method of harvesting of the trees and transport of the log from the felling site to a truck or other means of moving the wood to the mill. This is the subcategory of logging activity. The second subcategory, forest culture, includes growth promotion, forest protection (fire, disease, insects, and weed trees), and reforestation.

Pollutant Sources

Like agricultural land, silvicultural land can contribute a variety of pollutants to waterways. These pollutants include sediment, both organic and inorganic, pesticides, plant nutrients, and fire retardants. In terms of mass, sediment contributes the largest amount of pollution.

Control of soil erosion will also achieve good nutrient recycling and minimize transport of pesticides and fire retardants (which, increasingly, are nutrients themselves).

Cost Estimates

The SCS also includes forested land in the conservation-needs inventory. The type of forest management practiced by SCS is limited to reforestation and stand improvement. Appropriations and time limitations prevented the development of cost information for practices such as alternative harvesting or logging road construction which reduce water pollution from forest land. Attention might be given to this area in future Cost of Clean Water reports.

Urban Runoff

The "1978 Needs Survey, Cost Methodology for Control of Combined Sewer Overflow and Stormwater Discharge" provides the most recent estimate of the cost to control pollution from urban stormwater runoff. The cost to control the current urban stormwater runoff problem is estimated at $45,704 million in 1978. This cost is expected to increase by $694 million per year as a result of the conversion of rural to suburban and suburban to urban land uses. Thus, from the beginning of 1978 to the end of 1983, the added cost to control pollution from urban runoff is expected to increase by $4,164 million. On a per unit basis, the capital cost of control of pollution for urban runoff is equivalent to $473 per resident of the urban area or $1,913 per acre of urbanized area.

Construction Areas

Each year about 590,000 hectares (1.5 million acres) are converted from rural to suburban or urban usage. This includes areas brought into development for housing, highways, shopping centers, schools and so forth. It has been estimated that, on an area basis, construction causes about ten times more solids loss per year than does tillage.

Pollutant Sources

Sediment is one of the greatest pollutants resulting from construction activity. Sediment includes inorganic and organic materials. Nutrients are transposed in and on the soil particles. Sedimentation caused by rainfall and runoff from construction sites is deposited downstream or in other receiving waters such as ponds, reservoirs, and dams. Sediment deposition occurs under some of the following conditions: when runoff carries a sediment load requiring more energy to carry then the runoff can furnish; when the runoff is intercepted by a grassed waterway, slow-flowing stream, or ponds; and when the sediment consists of large soil particles that settle quickly due to the force of gravity.

Petroleum products are the largest group of organic polluting materials consumed in construction activities. Petroleum products consist of oils, grease, fuels, certain solvents, and many others. Pollutants from construction activities may include: crankcase oil wastes, fuels from leaky storage containers, oil solvents, dust control oils, oils from minor spills during transfers and transportation, oil-laden rags, and degreasers.

A majority of these materials float on the surface of the water and spread easily over a wide area. Oils and other petroleum products are readily absorbed by sediment that becomes the main carrier of these materials. Sediment contaminated with oil is carried in runoff to receiving streams. The inherent properties of petroleum products make them extremely difficult to control after entering water bodies.

Cost Estimates

The amount and type of pollutants generated during construction will depend upon the type and time duration of the various construction practices, the location and size of the construction site, the rainfall distribution and frequency, pest control measures, the resistance of the soil or land surface to erosion by gravity, water, and wind, the chemical properties and geology of subsurface soils, and the number of people and machines linked with each construction site.

The costs of pollution control reflect the extent of disturbance at a given site and the amount of planning devoted to mitigating potential impacts before they become a problem. Very few compilations of construction area pollution control costs have been made. However, it seems reasonable to assume that the types of practices that are effective on agricultural land would also be relevant to construction sites.

Summary

Non-point sources of pollution have been categorized as agricultural, silvicultural, or urban in nature. Because standards for the control of non-point sources have not been promulgated, the estimated costs represent an interpretation of the philosophy of FWPCA. In the case of agricultural and silvicultural sources the tremendous land area involved precludes many of the ordinary engineering practices for wastewater treatment. On the other hand, good land management has benefits for long range maintenance of land productivity and water quality. The degree to which the aggregate costs reflect each of these two overall objectives is moot. It has been assumed that at this time, no distinction is possible for two reasons. First, presumably, non-point source controls will be implemented on an "as needed" basis. Some areas of the country may not require the level of control specified by the SCS and some may require a higher level. Second, the agricultural conservation program up to this point has been completely voluntary. While some landowners are quick to recognize the long term advantages of land management, the rapid turnover in ownership of some areas, especially in developing suburban fringes, has reduced the effectiveness of conservation programs. Unless and until mandatory components of programs are introduced the continuity of non-point source pollution control cannot be assured.

Urban non-point sources, although they represent large areas relative to point sources, are concentrated enough to utilize primary treatment for storm water runoff. Since the pollutant wash-off is relatively rapid from impervious areas the volume of water that must be treated is amenable to common wastewater engineering practice.

Costs for non-point source pollution control are summarized in Table 10.1–1. Since these costs reflect the investment need and not the projected actual investment, they have been excluded from the National totals presented in the Introduction (Chapter 1).

Table 10.1–1.
Capital Investment Cost Summary
1978 to 1983
(in millions of 1977 dollars)

Subcategory	Investment
Agriculture	
Non-Structural	1645.
Structural	1301.
Total	2946.
Silviculture	5121.[1]
Urbanized Areas	
Existing in 1978	45704.
Growth, 1978–1983	4164.
Total (excluding structural controls)	56634.
Total (including structural controls)	57935.

[1] Costs include reforestation and stand improvement only.

10.2 TOXIC SUBSTANCES

Following settlement of a suit filed against the Environmental Protection Agency (EPA) by environmentalists who charged that the Agency was shirking its responsibility under the Federal Water Pollution Control Act of 1972, EPA began developing water pollution standards to cover 65 chemicals or classes of chemicals. Late in 1976, EPA set final standards to control water pollution from five toxic chemicals—benzidine, used to make certain dyes, and the pesticides endrin, toxaphene, aldrin-dieldrin, and DDT. It was determined that no costs were involved in the control of benzidine as this chemical was manufactured strictly as an intermediary in the production of certain dyes and control of benzidine effluents was industry practice.

Polychlorinated Biphenyls (PCB's) were subsequently added to this group. The single plant manufacturing PCB's has since discountinued production.

Description of Sector

Pesticide manufacturing is a major sector of the U.S. chemical industry. In 1975, the value of synthetic organic chemical ingredients produced by this industry exceeded $2,160 million at the manufacturer's level. The major market for pesticides in the U.S. is agriculture which consumes more than 90 percent of the pesticides used. The physical volume of pesticide production more than doubled between 1960 and 1974, while the manufacturers' value increased by more than 400 percent. Nearly all domestic production of pesticides falls within three classes—herbicides, fungicides, or insecticides. The largest single component of U.S. pesticide production in terms of value is herbicides, accounting for about 60 percent of total pesticide value while providing less than 40 percent of pesticide weight.

The portion of the pesticide industry covered by standards for toxic pollutants is the manufacture and formulation of toxaphene, DDT, endrin, and aldrin/dieldrin. All of these pesticides are chlorinated organic compounds and all are used as insecticides.

There is a considerable concentration in the pesticide industry with the 10 largest firms accounting for about 75 percent of total U.S. pesticide sales. Furthermore, less than 10 percent of the products are responsible for nearly 70 percent of the total pesticide sales value.

Toxaphene is the most widely used insecticide in the U.S. in terms of total weight. The most significant use of toxaphene has traditionally been in the control of cotton insects. Other important uses are on livestock and various field crops, including soybeans and peanuts. Four companies manufacture toxaphene in the U.S. The four producers supply 100 percent of U.S. and 60 percent of non-U.S. toxaphene demands. In 1974, manufacturers produced approximately 41 million kilograms (90 million pounds) of toxaphene. Toxaphene production dropped significantly in 1975 due to a 30 percent decrease in cotton acreage.

Only one plant manufactures DDT in the U.S. That plant and one other facility are the only U.S. formulators of DDT. All DDT from these plants is exported, since the use of DDT is banned in the U.S. except under special conditions. The single U.S. manufacturer is not a direct discharger and would not be affected by the toxic standards.

Only one facility manufactures endrin in the U.S. It produces about 2,700 metric tons (3,000 short tons) of endrin per year. About two-thirds of the endrin produced is used on cotton; the other major use is on corn. The manufacture discharges into a municipal system.

In 1974, the Environmental Protection Agency (EPA) banned the agricultural use of aldrin/dieldrin. At that time there was only one producer in the U.S.; however, this facility has ceased production of aldrin/dieldrin. There are no other manufacturers that are direct dischargers nor any formulators of aldrin/dieldrin in the U.S.

Description of Pollution

The toxicity of endrin, toxaphene, DDT, and aldrin/dieldrin, their persistence and degradability, and the nature and extent of their effect on organisms in waters are extensively documented. Studies show that aldrin/dieldrin and DDT are extremely toxic, that they are persistent and mobile in the environment, that they bioaccumulate in aquatic organisms, and that they pose substantial risks to human health. Like other chlorinated hydrocarbon pesticides, toxaphene is a per-

sistent chemical and a long-lived environmental contaminant. Like toxaphene, endrin is highly toxic to a wide variety of organisms. Plants, fish, or animals may bioaccumulate endrin. It is toxic to consumers of aquatic life, including humans. In addition to demonstration of the toxicity of benzidine to aquatic life, studies have conclusively identified benzidine as a human carcinogen, primarily including cancer of the bladder.

Regulations

Effluent standards for the manufacturers and formulators of DDT, aldrin/dieldrin, endrin, and toxaphene pesticides covered by the U.S. EPA under the authority of Section 307(a) of the Federal Water Pollution Control Act Amendments of 1972, include limitations on the discharge of the respective pesticides to navigable water, expressed in terms of concentrations (g/1) and mass emissions (g/kg of production) in the effluent stream. For pesticide formulators, the standards specify a prohibition on the discharge of pollutants.

Similar standards are imposed upon benzidine manufacturers and dye applicators. The applicable effluent standards are summarized in Table 10.2–1.

Control Technology and Cost

In the development document[1] four treatment technologies are suggested for treating effluents containing toxaphene: (1) adsorption on activated carbon, (2) adsorption on XAD-4 ion exchange resin, (3) reductive degradation, and (4) adsorption on XAD-4 resin followed by reductive degradation. Cost estimates for adsorption on activated carbon, resin adsorption, reductive degradation, and resin adsorption followed by reductive degradation were considered.

The only DDT plant now in operation does not discharge into a navigable stream; thus, effluent treatment standards apply only to new DDT plants that might be constructed. Solvent extraction followed by a Friedel-Crafts reaction, adsorption on XAD-4 resin, adsorption on activated carbon, or two-stage extraction with monochlorobenzene are possible technologies for treating effluents containing DDT. Any new DDT manufacturing operation would be able to meet the proposed toxic standards using a treatment technology which is less expensive than the technology now being used by the single U.S. manufacturer. The toxic standards would have no economic impact on new manufacturers.

Table 10.2–1.
Toxic Pollutant Effluent Standards

Manufacturer	Ambient Water Quality Criteria, micrograms/l	Effluent Standard: Maximum Allowable Concentration, micrograms/l — Working Day	Effluent Standard: Maximum Allowable Concentration, micrograms/l — Monthly Ave.	Effluent Standard: Monthly Average Daily Loading, g/metric ton
			Existing Sources	
Aldrin/Dieldrin[1]	0.003		No Discharge	
DDT (DDD.DDE)[1]	0.001		No Discharge	
Endrin[1]	0.004	7.5	1.5	0.6
Toxaphene[1]	0.005	7.5	1.5	0.03
Benzidine[2]	0.1	50.	10.	130.
			New Sources	
Aldrin/Dieldrin[1]	—		No Discharge	
DDT (DDD, DDE)[1]	—		No Discharge	
Endrin[1]	—	0.5	0.1	0.04
Toxaphene[1]	—	0.5	0.1	0.002
Benzidine[2]	—	50.	10.	130.

[1] Pesticide formulators — no discharge allowed.
[2] Benzidine dye applicator — allowed 25 and 10 micrograms/l concentration.

Adsorption on XAS-4 resin, reductive degradation, adsorption on XAD-4 resin followed by reductive degradation, or adsorption on activated carbon are possible technologies for treating effluents containing endrin.

Evaporating the effluent stream from an aldrin/dieldrin manufacturing plant is a possible technology for achieving the goals of the regulation.

There are no aldrin/dieldrin manufacturers that are point-source dischargers. Thus, the toxic standards have no economic impact upon any current aldrin/dieldrin manufacturers. If the facility manufacturing aldrin/dieldrin prior to the 1974 ban on the use of this chemical were to resume manufacture, there would be no impact due to the regulations because that facility already meets the standards.

Costs for the control of Toxic Pollutants are summarized in Table 10.2–2.

TABLE 10.2–2. TOXIC POLLUTANT (PESTICIDE) WATER POLLUTION CONTROL COSTS (IN MILLIONS OF 1977 DOLLARS)

		CUMULATIVE PERIODS			
	1977	1972–77	1977–81	1977–83	1977–86
INVESTMENT					
EXISTING PLANTS					
BPT	1.09	1.09	1.09	1.09	1.09
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
SUBTOTAL	1.09	1.09	1.09	1.09	1.09
MUN. RECOVERY	0.0	0.0	0.0	0.0	0.0
TOTAL	1.09	1.09	1.09	1.09	1.09
ANNUALIZED COSTS					
ANNUAL CAPITAL					
EXISTING PLANTS					
BPT	0.14	0.14	1.14	1.72	2.57
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.14	0.14	1.14	1.72	2.57
O&M					
EXISTING PLANTS					
BPT	0.41	0.41	3.29	4.93	7.39
BAT	0.0	0.0	0.0	0.0	0.0
NEW PLANTS	0.0	0.0	0.0	0.0	0.0
PRETREATMENT	0.0	0.0	0.0	0.0	0.0
TOTAL	0.41	0.41	3.29	4.93	7.39
INDUSTRY TOTAL	0.55	0.55	4.43	6.65	9.97
MUNICIPAL CHARGE					
INVEST RECOVERY	0.0	0.0	0.0	0.0	0.0
USER CHARGES	0.0	0.0	0.0	0.0	0.0
TOTAL	0.55	0.55	4.43	6.65	9.97
ALL ANNUAL COSTS	0.55	0.55	4.43	6.65	9.97

NOTE: COSTS SHOWN FOR YEAR SPANS ARE FROM JULY 1ST OF THE FIRST YEAR TO JUNE 30TH OF THE SECOND YEAR LISTED.
NOTE: ANNUAL CAPITAL COSTS ARE THE COMBINATION OF: (1) STRAIGHT-LINE DEPRECIATION AND (2) INTEREST.

REFERENCE

1. Wastewater Treatment Technology Document for Aldrin/Dieldrin, Toxaphene, Endrin, DDT, February 6, 1976.