Group I, Phase II

Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the

POULTRY

Segment of the

MEAT PRODUCT AND RENDERING PROCESS

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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DEVELOPMENT DOCUMENT

for

PROPOSED EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

POULTRY PROCESSING POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the poultry processing industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines, limitations of performance and pretreatment standards for the industry, to implement Sections 301, 304(b) 307 and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

The poultry processing plants included in the study were plants that slaughter, dress and/or further process poultry, including rabbits and other small game; plants that process eggs or manufacture such products as canned soups and TV dinners are excluded from the study. There are five subcategories in the poultry processing industry; four are based on type of bird slaughtered, and one is plants that further process only.

Effluent limitations are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available," and the "Best Available Technology Economically Achievable," which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The proposed recommendations require the best biological treatment technology currently available for discharge into navigable water bodies by July 1, 1977, and for new source performance limitations. This technology is represented by water recirculation in flow away systems, anaerobic plus aerobic lagoons or their equivalent, and chlorination. The cost to the industry to implement the waste treatment to achieve the 1977 limitations is estimated at $13.9 million. New source limitations incorporate the 1977 limitations and an ammonia limitation. The recommendations for July 1, 1983, are for the best biological treatment and in-plant controls, as represented by dry offal handling systems; improved in-plant primary treatment such as dissolved air flotation, and microscreen, sand filter, or equivalent in solids controls; in addition to the waste treatment system required for the 1977 limitations. Ammonia reduction by nitrification or air stripping will be required if the effluent exceeds the ammonia limitations. When sufficient suitable land is available, land disposal by irrigation with no discharge may be the most economical waste treatment option. The cost for the 1983 limitations is estimated at $38.6 million for the poultry industry.

Supportive data and rationale for development of the proposed effluent limitations and limitations of performance are contained in this report.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

TABLES

TABLES (Continued)

FIGURES

SECTION I

CONCLUSIONS

A conclusion of this study is that the poultry processing industry comprises five subcategories:

Chicken processing
Turkey processing
Fowl processing
Duck processing
Further processing only

The primary criteria for establishing these categories were type of raw material, i.e., kind of poultry, and raw waste load as measured by 5-day biochemical oxygen demand (BOD_5) in the plant waste water. The type of production process was an important consideration in establishing a separate category for plants that further process only. Information and data on the type of finished product, on plant parameters such as size, age, and location, and on other pollutants in the waste water and the treatability of those wastes all support the industry categorization.

The wastes from all subcategories are amenable to biological treatment processes, and no materials harmful to municipal waste treatment processes were found.

The 1977 discharge limits for BOD_5, suspended solids, and grease are based on actual performance data for waste treatment systems in the poultry processing industry. These limits are being met by plants in each subcategory having onsite waste treatment systems. These limits plus a fecal coliform limit are proposed for 1977. The same limits plus a limit for ammonia are recommended for new source limitations. It is estimated that the industry will have to invest about $14 million capital to achieve the proposed 1977 limits.

For 1983, effluent limits were determined as the best achievable in the industry for BOD_5, suspended solids, Kjeldahl nitrogen, ammonia, nitrites and nitrates, phosphorus, and fecal coliform. The industry will have to invest about $39 million to achieve the proposed 1983 limits. The latest reported annual capital expenditures by the industry are $60 million for each of the three years, 1970, 1971, and 1972. It is further concluded that where suitable and adequate land is available, land disposal by irrigation with no discharge may be a more economical option for meeting the discharge limits, especially for small plants.

SECTION II

RECOMMENDATIONS

Limitations recommendations for discharge to navigable waters by poultry processing plants for July 1, 1977, are based on the performance of well-operated biological treatment plants in use by the industry. The range in the limitations among the various subcategories, in terms of live/weight killed (LWK) or finished product (FP) as appropriate, are summarized below:

BOD_5: 0.39 to 0.77 kg/kkg LWK and 0.30 kg/kkg FP;

Suspended Solids: 0.57 to 0.90 kg/kkg LWK and 0.35 kg/kkg FP;

Grease: 0.14 to 0.25 kg/kkg LWK and 0.10 kg/kkg FP;

Fecal Coliform: 400 counts/100 ml.

Adjustments in BOD_5, suspended solids, and grease are provided for dressing plants that further process, and/or render; and a method is explained for accounting for duck processors which may discharge to a common sewer with a duck feedlot.

Recommended New Source Standards are the same as the 1977 limitations, with the addition of 0.14 to 0.26 kg ammonia per kkg LWK and 0.1 kg ammonia per kkg FP.

Limitations recommended for the poultry industry for 1983 are considerably more stringent and for BOD_5, suspended solids, and grease are based on the best performance of the treatment systems and in-plant controls now in use in the poultry industry. In addition to limits on the waste parameters included in 1977, limits are set for ammonia. The discharge limits for ammonia are set at the concentration limits achievable by the best available technology, rather than at a limit related to production level. Adjustments are provided for BOD_5, suspended solids, and grease for dressing plants that further process and/or render.

Duck plants with an onsite feedlot are subject to the combined processor regulation and 1983 feedlot regulations of no discharge from the feedlot. Thus the adjustment for processors is provided for only that portion of waste load due to the processing operation.

In cases where suitable and adequate land is available, land disposal by irrigation with no discharge may be a more economical option for meeting the discharge limits, especially for small plants.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act Amendments of 1972 (the "Act") requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly-owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly-owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal limitation of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a limitation permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the poultry dressing and further processing industries subcategory within the meat products source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal limitations of performance for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, limitations of performance applicable to new sources for the source category of plants engaged in the dressing and further processing of poultry, which was included in the list published January 16, 1973.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and limitations of performance proposed herein were developed in the following manner. The point source category was first studied for the purpose of determining whether separate limitations and limitations are appropriate for different segments within a point source category. This analysis included a determination of whether differences in animal type, raw material used, product produced, manufacturing process employed, equipment, age, size, waste water constituents, and other factors require development of separate effluent limitations and limitations for different segments of the point source category. The raw waste characteristics for each segment were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the source of waste and waste waters in the plant; and (2) the constituents (including thermal) of all waste waters, including toxic constituents and other constituents which produce taste, odor, or color in water or aquatic organisms. The constituents of waste waters which should be subject to effluent limitations guidelines and limitations of performance were identified (see Section VI).

The full range of control and treatment technologies existing within the point source category was identified. This included identification of each distinct control and treatment technology, of the amount of constituents (including thermal), and the chemical, physical, and biological characteristics of pollutants, and of the effluent level resulting from the application of each treatment and control technology. The required implementation time was also identified. In addition, the nonwater-quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, and noise, were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology economically achievable," and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent quality achieved, equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, nonwater-quality environmental impact (including energy requirements), and other factors. Once the alternative wastewater treatment systems corresponding to the three levels of technology described above had been determined, limitations on the discharge of pollutants attainable by the technology appropriate to each level were established. The nature and extent of data available for each subcategory determined the precise method by which the effluent limits were developed.

To the extent possible, the limitations for BPCTCA were derived as averages of the actual effluent discharge from the best treatment systems identified in the subcategory. In some cases it was not possible to employ this methodology because of limited data on the performance of treatment systems in a subcategory. In these instances, limits were based on the performance of whatever plants in the category could be considered exemplary. In cases where there were few such plants, limits were then verified by comparison with known pollutant concentrations in effluent from plants in these categories (or other categories with similar wastes and treatment facilities) and the average flow for plants within the category. Where effluent data were not available at all, the effluent limits were derived in the first instance by means of this procedure. Multiple regression analyses were also used to verify the relationship between limitations on different pollutant parameters.

The data for identification and analysis were derived from a number of sources. These sources included Refuse Act Permit Program data; EPA research information; data and information from North Star files and reports; a voluntary questionnaire issued through the National Broiler Council, Poultry Science Association, Poultry and Egg Institute of America, Southeastern Poultry and Egg Association, Poultry Industry Manufacturer's Council, Arkansas Poultry Federation, National Turkey Federation, Pacific Egg and Poultry Processors Association, Mississippi Poultry Improvement Association, and Alabama Poultry and Egg Association; and onsite visits and interviews at several exemplary poultry processing plants in various areas of the United States. All references used in developing the guidelines for effluent limitations and limitations of performance for new sources reported herein are included in Section XIII of this document.

The data base was primarily comprised of data from questionnaires and plant waste water sampling. It included 152 poultry processing plants. There were 92 questionnaire responses from chicken processing plants. Based on the number of birds reportedly slaughtered by each plant per day, these 92 chicken processing plants account for about 63 percent of the total number of chickens slaughtered by Federally inspected plants. There were 34 questionnaire responses from turkey processing plants. These 34 plants slaughter approximately 61 percent of the total number of turkeys slaughtered. There were seven questionnaire responses from fowl processing plants and these seven plants slaughter 37 percent of the total number of fowl slaughtered. The five duck processing plants that returned questionnaires account for 51 percent of the duck slaughter by number. There were five further processing only plants that returned questionnaires.

Questionnaires were also received from nine plants that slaughter more than one category of bird or that process other poultry. The plants include the following: one plant that slaughters chickens and turkeys; one plant that slaughters geese, ducks, and capons; one plant that slaughters and processes ducks, fowl, broilers, and turkeys; one plant that slaughters chickens and Cornish hens (very young chickens, about 5 weeks old); one plant that slaughters Cornish hens only; one plant that slaughters squab; one plant that slaughters ducks and turkeys; one plant that cuts and packages fresh poultry; and two rabbit slaughter plants.

The geographical distribution of the plants responding to the questionnaire is shown in Table 1. As can be seen, the live weight production distribution and the distribution of the questionnaire respondents among the regions of the country are very similar.

Table 1. Comparison of Production and Questionnaire Respondent Distribution among Geographic Regions in the Country*

Region**	Broilers		Fowl		Turkeys	
	Production	Questionnaires	Production	Questionnaires	Production	Questionnaires
North Atlantic	5.5%	3.3%	14.0%	0%	2.7%	2.9%
North Central	2.9	1.1	25.6	28.6	41.8	47.1
South Atlantic	41.9	43.5	23.4	28.6	17.1	11.8
South Central	44.9	48.8	24.7	28.6	15.7	8.8
West	4.8	3.3	12.3	14.2	22.7	29.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*Note: Production figures reported in more detail in Figure 3.

**STATES IN POULTRY REGIONS

North Atlantic	North Central	South Atlantic	South Central	West
Maine	Ohio	Delaware	Kentucky	Idaho
New Hampshire	Indiana	Maryland	Tennessee	Colorado
Vermont	Illinois	Virginia	Alabama	Arizona
Massachusetts	Michigan	West Virginia	Mississippi	Utah
Rhode Island	Wisconsin	North Carolina	Arkansas	Washington
Connecticut	Minnesota	South Carolina	Louisiana	Oregon
New York	Iowa	Georgia	Oklahoma	California
New Jersey	Missouri	Florida	Texas	
Pennsylvania	Nebraska			
	Kansas			

GENERAL DESCRIPTION OF THE INDUSTRY

The poultry processing industry falls within SIC Code 2016, which includes young and mature chickens, turkeys, and other poultry slaughtering, dressing (evisceration), and ice or freeze packing, and that part of SIC Code 2017 dealing only with poultry (e.g., chicken and other poultry canning and freezing or related processing into specialty items). Young chickens include broilers-fryers and other young immature birds such as roasters and capons; mature chickens are fowl from breeder and market egg flocks and stags and cocks; turkeys include fryer-roasters, which are young immature birds, usually under 16 weeks of age, young turkeys grown to a mature market age, usually 5 to 7 months, and old turkeys which are fully matured birds held for egg production, usually over 15 months of age; other poultry includes ducks, geese, guineas, squabs, pigeons, partridge, pheasants, and rabbits and small game. Excluded from this study were those portions of SIC 2017 dealing with egg processing and plants manufacturing such products as canned soups and TV dinners.

Plants within the industry carry out the operations of slaughtering, dressing, and further processing of broilers, chickens, fowl (mature chickens), turkeys, ducks, geese, other birds, and rabbits and other small game. Some plants only slaughter and dress (eviscerate), others slaughter, dress and further process; and still others further process only. Occasionally, poultry slaughterhouses have rendering operations on the same site but housed separately.

The products of slaughtering and eviscerating operations are icepacked or chilled ready-to-cook broilers and chickens, fresh or frozen fowl, turkeys, etc. Further processing following slaughter and dressing operations converts poultry into a variety of cooked, canned, and processed poultry meat items such as pre-cooked breaded parts, roasts, rolls, patties, meat slices in gravy, canned boned chicken, and various sausages. The amount of further processing performed in poultry slaughterhouses varies considerably. Some plants may process only a part of their kill while others may process their own kill plus birds from other plants. Most of the further processing in slaughterhouses is limited to cutting, cooking, batter coating and breading, browning, and freezing. The type and number of operations carried out in plants that further process only vary considerably, resulting in a wide variety of finished products. The usual practice in turkey plants is to slaughter only during seven to nine months of the year. If the plant also further processes, it will usually produce processed products during the entire year.

The poultry industry is typified by vertical integration from hatchery through feed mill, slaughtering, processing, and wholesale marketing under contract. The slaughtering and processing plants are therefore integral parts of a larger system. For example, the typical integrated broiler firm has its own hatchery, feed mill, and processing plant, and depends almost entirely on contract production. The firm may be local, a subsidiary of a national feed company or meat packer, or a part of a large conglomerate. Turkey and duck slaughtering and processing firms tend to follow a similar pattern; however, fowl or mature chickens tend to be a byproduct of commercial egg production. The vast majority of poultry production is in broilers, turkeys and mature chickens (fowl). This can be seen in Table 2 which shows the weights by class in 1970 for slaughtered, cut-up, and further processed poultry in Federally inspected plants. Young chickens (which include broilers) and all turkeys accounted for 93 percent of the total slaughter. Young chickens accounted for over 90 percent of the total cut-up volume; while turkeys, mature chickens, and young chickens accounted for over 93 percent of the total further processed volume. In 1970, plants under Federal inspection slaughtered over 90 percent of the total U. S. production of young chickens, mature chickens and turkeys.

Table 3 shows the numbers and pounds (both live weight and eviscerated or ready-to-cook weight) of Federally inspected poultry by class for 1969 through 1971. From the data in Table 3 on pounds slaughtered by type of bird, the average live weight, eviscerated weight, and yield were calculated for each type. These are given in Table 4.

In 1973, according to the USDA, there were 248 Federally inspected poultry plants that slaughter only, 288 that process only, and 144 that slaughter and process.[2] However, it is believed that a majority of the 288 process-only plants produce products such as canned soups and TV dinners or are otherwise excluded from this point source category. These plants, as previously mentioned, do not fall within the scope of this program and will not be considered in this report. Also plants handling both poultry and red meat are excluded.

Poultry is produced in nearly every State of the United States. However the largest production of broilers and turkeys is highly concentrated by geographic area. Furthermore, poultry production (hatching and growing) is carried out within close proximity to slaughtering and dressing Operations. Table 5 shows the production of broilers, mature chickens and turkeys by region for 1970. This table shows that the South Atlantic and South Central regions account for 86.8 percent of the broiler production; 48.1 percent of the mature chicken production, and 32.8 percent of the turkey production. Table 6 shows the production in live weight for broilers, mature chickens, and turkeys for the leading ten States in 1970. The top ten States in broiler production, which are mainly from the South Atlantic and South Central regions, account for 84 percent of the total U. S. production. The top ten States in turkey production produced 75 percent of the U. S. turkey output in 1970. However, turkey production is not as highly concentrated regionally as broiler production, with the two largest regions--West North Central and West--accounting for 52 percent of the U. S. production in 1970. Production of fowl

Table 2. Federally Inspected Poultry Slaughter, Cut-up, and Further Processed Volume, by Product Class, 1970[1]

Category	Young Chickens *	Mature Chickens **	Turkeys †	Other Poultry ††	Total Poultry
Slaughtered (1,000 pounds live weight)	10,073,725	810,555	1,987,715	81,860	12,953,825
Percentage of total slaughter	77.7	6.3	15.3	0.7	100.0
Cut-up (1,000 pounds ready-to-cook)	1,842,594	8,608	190,713	2,230	2,044,145
Percentage of total cut-up	90.2	0.4	9.3	0.1	100.0
Further processed (1,000 pounds ready-to-cook)	337,292	392,404	479,427	83,274	1,292,397
Percentage of total further processed	26.2	30.3	37.1	6.4	100.0

*Young chickens are commercially grown broilers-fryers and other young immature birds such as roasters and capons.

**Mature chickens are fowl from breeder and market egg flocks and stags and cocks.

†Includes fryer-roasters which are young immature birds, usually under 16 weeks of age; young turkeys grown to a matured market age, usually 5 to 7 months; and old turkeys which are fully matured birds held for egg production, usually over 15 months of age.

††Includes ducks, geese, guineas, squabs, pigeons, partridge, pheasants, and rabbits.

Source: Based on data from Slaughter Under Federal Inspection and Poultry Used in Further Processing, SRS-USDA, Pou 2-1(2-71).

Table 3. Poultry: Slaughtered under Federal Inspection, United States, by Classes, 1969-1971[3]

Class	Number Inspected			Pounds Inspected (Live Weight)		
	1969	1970	1971	1969	1970	1971
	Thousands	*Thousands*	*Thousands*	*Thousands*	*Thousands*	*Thousands*
Young chickens	2,516,287	2,770,178	2,778,971	9,064,962	10,073,724	10,223,510
Mature chickens	153,767	176,116	183,194	710,935	810,554	825,265
Total chickens	2,670,054	2,946,294	2,962,165	9,775,897	10,884,278	11,048,775
Young turkeys	84,476	92,990	98,226	1,693,643	1,860,995	1,949,966
Old turkeys	1,245	1,058	1,199	23,881	20,667	23,496
Fryer-roaster turkeys	9,651	11,501	12,319	89,618	106,053	112,588
Total turkeys	95,372	105,549	111,744	1,807,142	1,987,715	2,086,050
Ducks	11,589	11,883	11,030	72,018	74,042	69,341
Other poultry				6,898	7,789	9,526
Total poultry				11,661,955	12,953,824	13,213,692

Class	Pounds Certified (Ready-to-Cook)		
	1969	1970	1971
	Thousands	*Thousands*	*Thousands*
Young chickens	6,484,117	7,161,141	7,281.021
Mature chickens	454,400	516,336	523,884
Total chickens	6,938,517	7,677,477	7,804,905
Young turkeys	1,344,352	1,468,038	1,536,241
Old turkeys	18,886	16,315	18,353
Fryer-roaster turkeys	69,548	82,157	87,018
Total turkeys	1,432,786	1,566,510	1,641,612
Ducks	51,133	52,617	49,413
Other poultry	4,438	5,023	6,147
Total poultry	8,426,874	9,301,627	9,502,077

Table 4. Average Live and Eviscerated Weights by Type of Poultry

Class	Live Weight kg, (pounds)	Eviscerated Weight, kg, (pounds)	Yield, percent
Young chickens	1.7 (3.7)	1.2 (2.6)	70.0
Mature chickens	2.1 (4.6)	1.3 (2.9)	63.0
Young turkeys	9.1 (20.0)	7.2 (15.8)	79.2
Old turkeys	8.8 (19.4)	6.9 (15.3)	79.0
Fryer-roaster turkey	4.2 (9.2)	3.2 (7.1)	77.2
Ducks	2.8 (6.2)	2.0 (4.4)	71.0

Table 5. Production of Broilers, Mature Chickens, and Turkeys, by Region, 1970[1]

Region*	Broilers	Mature Chickens	Turkeys
North Atlantic	594,356 (5.5)**	167,156 (14.0)	59,828 (2.7)
East North Central	155,086 (1.4)	145,191 (12.1)	273,188 (12.5)
West North Central	161,984 (1.5)	160,664 (13.5)	638,712 (29.3)
South Atlantic	4,528,245 (41.9)	278,502 (23.4)	372,638 (17.1)
South Central	4,855,432 (44.9)	295,965 (24.7)	341,901 (15.7)
West	506,740 (4.8)	147,457 (12.3)	498,186 (22.7)
United States (48)	10,801,843 (100.0)	1,194,935 (100.0)	2,184,453 (100.0)

* STATES IN POULTRY REGIONS

North Atlantic	Western	East North Central
Maine	Idaho	Ohio
New Hampshire	Colorado	Indiana
Vermont	Arizona	Illinois
Massachusetts	Utah	Michigan
Rhode Island	Washington	Wisconsin
Connecticut	Oregon	
New York	California	
New Jersey		
Pennsylvania		

South Atlantic	South Central	West North Central
Delaware	Kentucky	Minnesota
Maryland	Tennessee	Iowa
Virginia	Alabama	Missouri
West Virginia	Mississippi	Nebraska
North Carolina	Arkansas	Kansas
South Carolina	Louisiana	
Georgia	Oklahoma	
Florida	Texas	

** Numbers in parentheses are regional shares of United States total.

Table 6. Leading Ten States in Production of Broilers, Mature Chickens, and Turkeys, 1970[4]

Broilers		Mature Chickens		Turkeys	
State	Production (Live Weight)	State	Production (Live Weight)	State	Production (Live Weight)
	1000 Pounds		*1000 Pounds*		*1000 Pounds*
Georgia	1,577,149	California	102,824	California	302,834
Arkansas	1,539,126	Georgia	100,546	Minnesota	302,677
Alabama	1,313,981	Arkansas	84,582	North Carolina	175,959
North Carolina	1,137,295	North Carolina	72,026	Texas	169,150
Mississippi	892,660	Pennsylvania	63,558	Missouri	158,979
Maryland	722,452	Alabama	61,265	Arkansas	143,081
Texas	662,591	Mississippi	51,006	Iowa	122,015
Delaware	521,535	Texas	46,037	Indiana	93,374
California	338,922	Florida	44,144	Utah	85,294
Maine	321,510	Indiana	42,441	Virginia	77,451
Total	9,027,221	Total	668,429	Total	1,630,814

Source: Based on data from Statistical Reporting Service, USDA.

or mature chickens is less concentrated regionally than is that for either broilers or turkeys, with the top ten States producing only 56 percent of the U. S. production in 1970. Again the South Atlantic and South Central regions are the largest regions in mature chicken production, accounting for 48 percent of the total.

Production of other poultry (and small game), such as geese, ducks, rabbits, squabs, pigeons, partridge, pheasants and guineas appears to be regionally concentrated. Geese production appears to be mainly in Minnesota and the Dakotas; duck production, mainly on Long Island, New York, and around Lake Michigan in Indiana and Wisconsin; and rabbit production in Arkansas and Kansas. Other poultry accounts for only 0.7 percent by live weight of the total poultry processed (see Table 2), and ducks account for about 90 percent of that (see Table 3).

The volume of all poultry slaughtered in Federally inspected poultry plants increased from 8.1 to 13.2 billion pounds live weight between 1961 and 1971--a 62 percent increase. In the same period, the number of slaughtering plants decreased from 532 to about 400. Civilian per capita consumption of poultry has also increased dramatically over the years, as shown in Table 7. Chicken per capita consumption, for example, has increased from 20.6 to 30.0 to 41.4 pounds for the years 1950, 1961, and 1971, respectively. In fact, Table 7 shows that the combined turkey and chicken consumption has increased more rapidly over the years 1950 to 1972 than that for all red meats.

Most poultry processing plants are located in or near urban areas, primarily small towns, where labor and water are readily available. Poultry processing plants--both slaughtering and further processing are labor intensive operations. The slaughtering or dressing plants, as mentioned previously, are located near poultry production areas. However, plants that only further process poultry may be located outside the production areas.

GENERAL PROCESS DESCRIPTION

A general process flowsheet of a typical poultry slaughterhouse is shown in Figure 1; that for further processing of poultry is shown in Figure 2. The processing steps included in Figures 1 and 2 are not intended to be all-inclusive but to represent the typical plant. For example, duck slaughtering includes a wax dip operation not shown in Figure 1. In addition, some operations depicted in Figure 2 may not be used in some plants, while some other, less frequently used, processes are not included in Figure 2. Specific plant processes may also differ in order or arrangement from that shown in Figure 2 for further processing plants.

Some poultry plants that slaughter may also further process. However, the information gathered during this study showed that

Table 7. Civilian Per Capita Consumption (Pound)[4]

	Eggs (No.)	Chickens and Turkeys	All Chickens	Broilers Only	Turkeys	All Red Meats	Beef and Veal	Pork	Lamb and Mutton
1950	389	24.7	20.6	8.7	4.1	145	71.4	69.2	4.0
1955	371	26.3	21.3	13.8	5.0	163	91.4	66.8	4.6
1956	369	29.6	24.4	17.3	5.2	167	94.9	67.3	4.5
1957	362	31.4	25.5	19.1	5.9	159	93.4	61.1	4.2
1958	354	34.0	28.1	22.0	5.9	152	87.2	60.2	4.2
1959	352	35.2	28.9	22.8	6.3	160	87.1	67.6	4.8
1960	335	34.2	28.1	23.4	6.1	161	91.2	64.9	4.8
1961	329	37.4	30.0	25.8	7.4	160	93.4	62.0	5.1
1962	327	37.0	30.0	25.7	7.0	163	94.4	63.5	5.2
1963	318	37.5	30.7	27.0	6.8	170	99.4	65.4	4.9
1964	318	38.5	31.1	27.6	7.4	175	105.1	65.4	4.2
1965	314	40.9	33.4	29.4	7.5	167	104.7	58.7	3.7
1966	313	43.9	36.1	32.3	7.8	171	108.8	58.1	4.0
1967	320	45.8	37.2	32.8	8.6	178	110.3	64.1	3.9
1968	316	45.4	37.4	33.1	8.0	183	113.3	66.2	3.7
1969	310	47.4	39.1	35.2	8.3	182	114.1	65.0	3.4
1970	311	49.7	41.5	37.4	8.2	186	116.6	66.4	3.3
1971	314	49.9	41.4	37.1	8.5	192	115.7	73.0	3.1
1972*	307	52.0	42.9	38.8	9.1	189	118.2	67.4	3.3

*Preliminary

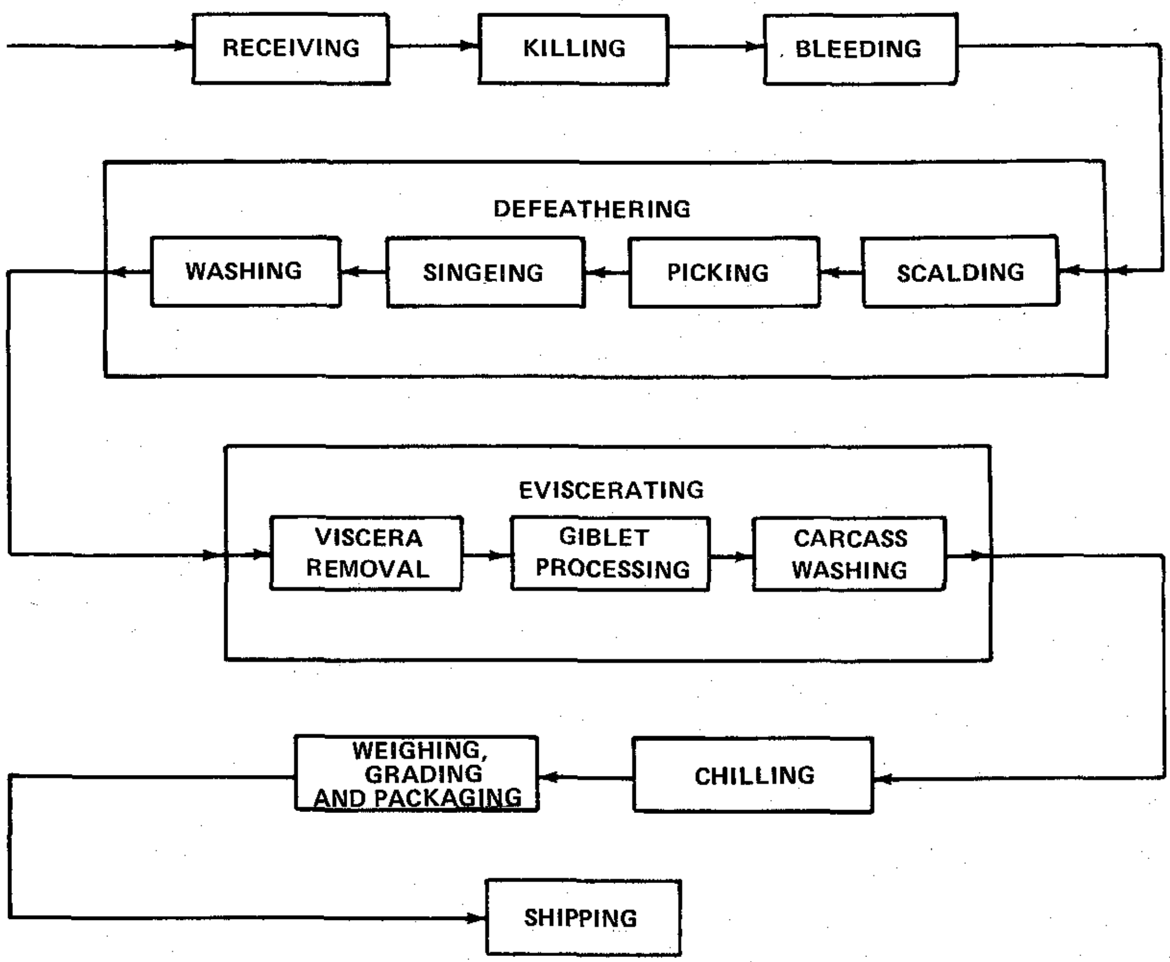

Figure 1. General Process Flowsheet For Poultry Processing

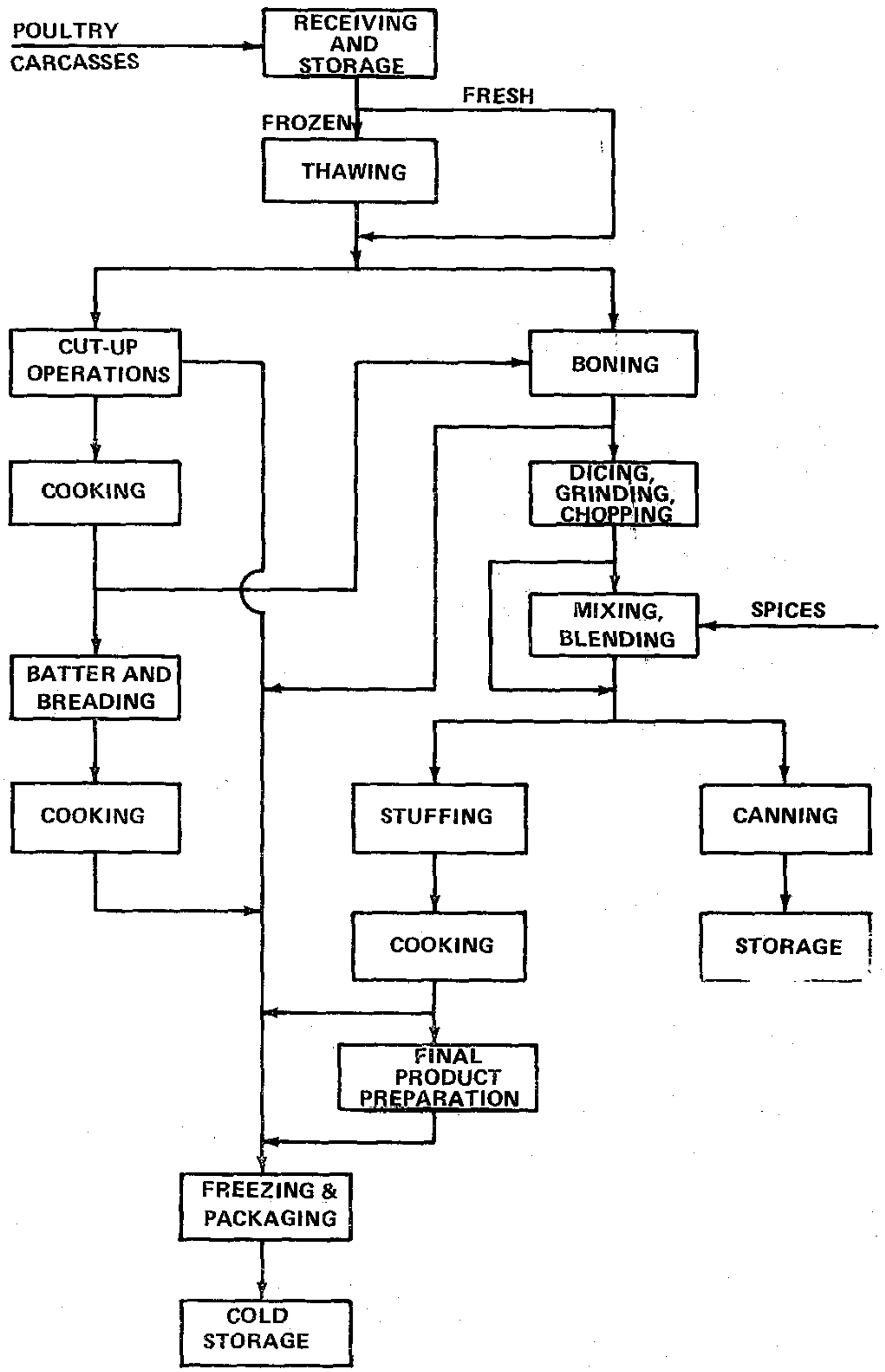

Figure 2. General Process Flowsheet For Poultry Further Processing

in the majority of the plants that do both, the further processing operations usually involved cut-up, cooking, batter and breading, deep frying, and freezing. The specialty products, such as rolls, luncheon meats, patties, etc., are produced primarily in further processing only plants. A few of these plants--usually turkey plants--may slaughter during a specific time of the year and further process for part or for the entire year. The dressed birds can be frozen readily for later processing. Most specialty products are produced for hotels, restaurants, institutions, and fast-food outlets.

POULTRY SLAUGHTER MANUFACTURING PROCESSES

The major limitation manufacturing processes in most modern poultry slaughtering or dressing plants--are receiving, killing, bleeding, defeathering, eviscerating, chilling, and packing (Figure 1). Associated with these processes are the subprocesses of materials recovery and plant cleanup.

Most plants have "flow-away" systems for feathers and offal; in these systems water in flumes is used to carry away the feathers and offal, separately, to byproduct recovery. A few plants do not have flow-away systems for feather and/or offal handling. Kosher processing of poultry, for example, involves dry picking and collecting of feathers. Other plants have replaced the wet offal flow-away system with dry evisceration and offal handling. This is to reduce water use and waste load. Rabbit dressing, of course, includes skinning for pelt removal rather than scalding and defeathering.

Receiving

Live birds are trucked to poultry processing plants in coops on open trucks. The coops hold up to about 20 broiler-size chickens. Normally, the trucking of birds to plants is scheduled so that the birds are held in the receiving area for a minimum amount of time. Holding the birds too long results in increased incidences of death and loss of birds. The greater the holding time, also, the greater the pollution load in the receiving and holding area for manure.

Coops containing the chickens are usually unloaded from the trucks onto a conveyor system. The birds are then conveyed, in the coops, to a hanging area where the birds are removed from the coops and attached by their feet to shackles suspended from an overhead conveyor line. Occasionally coops are permanently attached to the trucks; the birds then are hung as they are removed from the coops. The conveyor system, traveling at a constant speed, now carries the shackled birds into the killing area. Empty coops are returned to the trucks by conveyor, normally without being cleaned. One or more overhead conveying systems may be used in the receiving area or in the processing area, depending on the size of the plant, the plant layout, and the number of birds to be killed that particular day.

Manure, feathers, and dirt are the major pollutants that accumulate on the floor of the receiving area. When live poultry are held for a relatively short time in a receiving area, quantities of pollutants, except nitrogenous nutrients, are minor compared to pollutants from other processes. However, extended holding of poultry can add significant quantities of pollutants. Porges[5] reported that the waste from the storage of chickens was 32 pounds of BOD_5 and 35 pounds of suspended solids per thousand chickens stored each day; Porges and Struzeski[6] reported the values as 36 and 40 pounds, respectively. Porges[5] also reported that the amount of BOD_5 to the sewer is reduced to 5.0 pounds, and the suspended solids to 6.0 pounds per thousand birds stored daily, if dry cleanup is practiced in the receiving area. Waste materials collected by dry cleaning are dumped as refuse or loaded onto the offal truck along with the feathers, offal, and blood, and sent to rendering. Relatively small quantities of water are used in this area, following dry cleanup, to remove residual material.

Killing and Bleeding

In most modern plants, birds are shocked just before or immediately following killing to facilitate bleeding. Slaughtering of poultry is done by either severing the jugular vein or by debraining. Manual and automatic mechanical severance of the jugular vein are the common killing techniques in use today. The killing area is usually a well-contained area with high walls on both sides of the conveyor line to restrict the drainable blood to this area. Such an arrangement is called a "blood tunnel." Data collected show that chickens are held in the tunnel from 45 to 125 seconds for draining the blood, with an average time of 80 seconds; turkeys from 90 to 210 seconds with an average time of 131 seconds.

Most poultry processing plants attempt to recover as much of the free-draining blood as they can. Even under the best conditions and with adequate drainage time--say two minutes--only about 70 percent of the blood in poultry is recovered in the killing area. The blood is usually permitted to congeal on the killing floor and is removed, as a semisolid, from once to several times a day, depending on the cleanup procedures in the plant. A few plants have recently installed troughs just below the bleeding birds to collect blood. The blood is periodically removed from the trough by vacuum, pump, or gravity flow. The blood trough should reduce the waste load due to blood losses to the sewer.

Feathers, dirt, manure, and blood are pollutants that may find their way into the sewer from the killing area; that of the greatest significance is, of course, blood. Congealed blood and other pollutants too difficult to remove by draining and dry scraping are flushed to the sewer during cleanup.

Blood that is collected in the killing area is usually mixed with the feathers on the offal truck. A less common blood handling process, but one that appears to be increasing in use involves loading the blood into receiving tanks that are attached to, or part of, the offal truck. Obviously, the storage of blood in tanks is preferable, since blood dumped onto the feathers in an offal truck can drain from the truck and into a sewer. If the plant has onsite rendering, feathers and blood are frequently handled separately to give higher quality rendered products.

Defeathering

After killing, the birds are scalded in either a scald tank or a spray scald. Tank scalding is by far the most common. The scalding of the bird helps to relax feather follicles for easier feather removal. Water temperature in a scald tank was found in this study to be between 51° and 60°C (124° and 140°F) with an average of 53.3°C (128°F) for chickens, and between 52° and 63°C (135° and 145°F) with an average of 59.5°C (139°F) for turkeys.

The feathers are removed mechanically after scalding. Usually defeathering is accomplished by continuously passing the birds through machines equipped with rubber fingers attached to rotating drums; the fingers flail the birds, removing the feathers. Simultaneously with the feather removal, warm water is sprayed onto the birds as a lubricant, and to flush away feathers as they are removed. In a few cases, mainly small or seasonal operations, batch-type defeathering machines are used. This requires that the birds be removed from the shackles, placed in the machine, defeathered, and then replaced on the conveyor line by hand. This type of defeathering obviously requires more labor. The number and kind of defeathering machines used in a plant depends on the type and size of the birds to be cleaned. Feathers are usually conveyed from the defeathering area by water in a flow-away system.

Following defeathering, the remaining pinfeathers are removed, usually by hand. In duck processing plants, the pinfeathers are removed by wax stripping. In this process, the birds are dipped into molten wax and cooled with a spray of water to harden the wax. Stripping away the hardened wax removes the pinfeathers. The wax is reclaimed and reused. After defeathering, all birds while on the conveyor are passed through a gas flame to singe the remaining fine hairs and pinfeathers, washed, and transported into the evisceration area.

Waste water from the defeathering operations results from the following: continuous overflow from the scald tank; final dump of the scald tank at the end of the operating day; feather flow-away system; continuous water spray in the defeathering machines; carcass washing; and washdown of the floors and equipment during cleanup. The minimum overflow from the scald tank is about 1 liter (1/4 gallon) per bird.

Feathers removed by the defeathering machines and flumed away in the flow-away system contain manure, dirt, and blood. These materials may be dissolved or suspended in the waste waters, thereby contributing to the waste load from the defeathering area. Feathers themselves should not contribute significantly to the waste load because they can be easily removed from the water by screening. Presently, considerable attention is being given to the capture of feathers, since feathers escaping into sewers are a major nuisance in sewage treatment.

Evisceration

The evisceration room is segregated from the killing, bleeding, scalding, and defeathering areas of the plant to insure that eviscerated birds are not exposed to cross-contamination from any of the previous operations. Washing, chilling, packing, and cutting of the eviscerated birds are carried out in the same general plant area as evisceration.

When the birds enter the eviscerating area, their feet are removed, usually with an automatic cutter. The feet are either dry collected or flumed, usually in the feather flow-away system. The birds are then rehung on a different conveyor line to facilitate removal of the viscera and inspection.

On the evisceration line, the oil gland is removed; the peritoneal cavity is opened, the viscera are pulled out and exposed, and the carcass and entrails are inspected; the giblets are recovered, trimmed, and washed; the inedible viscera are discharged, usually to the offal flow-away system; the lungs are removed by vacuum, raking, or by hand; the head is removed; and finally, the neck is removed and washed. Cleaning of the gizzard involves splitting, washing out the contents, peeling the inner liner, and a final wash. The giblets (heart, liver, and gizzard) are conveyed to giblet chillers. The inedible viscera may be carried away by vacuum or mechanical conveying rather than by a flow-away system if dry evisceration is used. The eviscerated birds are thoroughly washed, both inside and outside, and conveyed to chillers.

Potential pollutants from the evisceration process include feet, heads, viscera, crop, windpipes, lungs, grit, sand and gravel, flesh, fat, grease, and blood. Usually these are received by the offal flow-away system which carries them to the screening room. The screening removes the bulk of the suspended material; however, some soluble organic matter, blood, grit, sand, fat, grease, and flesh particles are not removed. The BOD_5 level of the waste water in this stream is only a few hundred mg per liter, but the flow per thousand birds is so high that the total BOD_5 load from the evisceration process is higher than from any other process. It is not uncommon for evisceration to account for 40 to 50 percent of the BOD_5 load in the plant effluent.

The major sources of water from evisceration are the flow-away water, water from the many hand washers located on the eviscerating trough, from the washers in the automatic gizzard splitters, and from carcass washers.

Chilling and Packaging

Before the birds can be packed for shipment, they must be chilled. Removal of the body heat is an important operation because rapid cooling protects the meat flavor and quality and lengthens the market life by preventing bacterial decomposition. Almost all modern poultry processing plants rely on large chilling tanks containing ice water. Several forms of chilling tanks are in operation. One is a large enclosed drum which rotates about a central axis; another is a perforated cylinder mounted within a chilling vat; and still another type is a large open chilling tank containing a mechanical rocker to provide agitation. In all of these, birds cascade forward with the flow of water.

Most poultry plants use several chilling tanks in series, typically two or three. The flow, while carrying the birds through the individual tanks, is countercurrent through the series so the first chilling tank that the birds enter is warmer than the next, and so on. In this arrangement, ice and freshwater are added to the last chiller. The USDA requires one-half gallon per bird overflow in the chillers; the flow typically is about three-fourths of a gallon per bird. The effluent from the first chiller is occasionally used in the offal flow-away system. Normally the carcass of the bird is chilled within 30 to 40 minutes to an ultimate carcass temperature of 1°C (34°F).

A similar, but separate and smaller, chilling system is used for cooling giblets.

After the birds are chilled, they are rehung on a conveyor line to allow the excess moisture to drain off. The birds are then conveyed to an automatic weighing and separating area, and are graded and packed or are routed to further processing.

Old and small plants, which do not use continuous flow and chilling, cool the carcasses in batch tubs of ice and water with bubblers for mixing. Cooled birds are then drained, sized, graded, and packaged manually.

The majority of broilers are ice-packed or packed with dry ice. Turkeys, ducks and exotic fowl are usually frozen; mature chickens, which are used almost exclusively for further processing, are sold either ice-packed or frozen. Freezing of poultry produces no inherent waste water; ice-packing has very little effect on waste water.

Subprocesses

By-Product Recovery

The major byproducts of poultry slaughtering--blood, feathers (skins), and offal--are recovered by nearly all plants. However, grease recovery is not as effectively practiced by poultry slaughtering plants as by meat packing plants. Fortunately, however, grease loads in poultry plants are not as great. Wasting byproducts not only increases the waste load in plant effluents, and hence treatment costs, but also wastes a valuable raw material used by rendering plants in the production of proteinaceous animal feeds. Small amounts of small game skins and feathers are occasionally used in the production of products such as rabbit skins for wearing apparel and feathers for stuffing furniture and bedding items.

A 1970 survey by the USDA found that only 0.6 percent of the plants did not salvage offal. Of the 99.4 percent that recover byproducts, 70.8 percent of the plants sold offal to renderers, 1 percent gave offal to renderers, 26.6 percent rendered offal onsite, and 1 percent dumped or burned the collected offal. The same study revealed that blood was salvaged by 85.8 percent of the plants. It was sold to renderers by 54.6 percent, given away by 7 percent, rendered onsite by 22.4 percent, and dry disposed by 1.8 percent. Feathers were not recovered by 0.4 percent of the plants; they were salvaged and sold by 71.6 percent, given away by 0.8 percent, rendered onsite by 25.9 percent, and burned or dumped by 1.3 percent.[1]

Removal of offal and feathers from flow-away waste water streams is defined as byproduct recovery. Almost all plants use screening equipment for this purpose. The most common equipment arrangement is small mesh (to 200 mesh) rotating or vibrating screens followed by stationary protective screens (1/4- to 1/2-inch openings) to collect any overflow. This arrangement will remove the bulk of the solids.

Gravity separation basins or air flotation systems are usually used following screening to remove grease and suspended solids. This is defined as in-plant primary treatment. (A more detailed description of primary treatment is found in Section VII of this report.)

The byproducts, which are continuously screened from the flow-away systems or are bulk handled in dry evisceration, are loaded into offal trucks for delivery to rendering plants. When the offal is rendered onsite--at the processing plant location but in a separate building the byproduct materials may be conveyed continuously to the rendering system.

Blood, on the other hand, is usually vacuumed or pumped from the blood tunnel to a holding tank. Lungs are frequently mixed with the blood in the holding tank. These byproducts are either dumped onto feathers in the offal truck or tanked for delivery to the rendering plant. The latter is used if the renderer has separate blood processing equipment. Otherwise the blood is mixed with the feathers and they are rendered together.

Plant Cleanup

Normal plant cleanup practice is for a light washdown of the floor during short break periods; for a complete washdown of floors, sometimes including the blood tunnel, and of most of the processing equipment during the lunch break; and for a thorough plant cleanup and general sanitation at the end of the processing day. In addition, the floors and some processing equipment are frequently rinsed just prior to the start of a production day. Spills are cleaned up with water on an as-needed basis.

Maintenance of valves and hoses and use of high-pressure nozzles can help to reduce the volume of water used for plant cleanup. The waste load associated with plant cleanup can be further reduced by dry sweeping and scraping floors and tables prior to washdown. Gross solids collected by dry cleaning should be placed in containers and sent to rendering. Dry cleaning of the blood tunnel is particularly important because of the high pollutional strength of blood.

POULTRY FURTHER PROCESSING MANUFACTURING PROCESS

The major limitation manufacturing processes in plants that further process poultry are receiving and storage; thawing operations; cutting and boning; dicing, grinding, and chopping; cooking; batter and breading; mixing and blending; stuffing; canning; final product preparation; freezing; packaging and shipping. Because of the similar operations and facilities, shipping is grouped with receiving and storage for the discussion below. Associated with these processes are subprocesses of product cooling and plant cleanup.

These manufacturing processes contribute in varying degrees to the raw waste load from further processing operation. It should be noted that the plant raw waste load includes the effect of in-plant primary waste treatment. The source and relative amounts of waste load for each manufacturing process are identified in the following descriptions. Cleanup of equipment and processing areas and the associated waste generated are also described in the following discussions.

Receiving, Storage, and Shipping

Poultry meat used as raw material and nearly all the finished products in a poultry processing plant, except certain canned products, require refrigerated or freezer storage. Poultry-type raw materials are brought into further processing plants as carcasses, cut-up parts, and deboned meat, although the vast majority is whole carcasses. Further processing plants that are an adjunct operation to poultry slaughtering plants usually receive fresh ice-packed poultry meat; plants isolated from raw material sources usually receive frozen poultry meats. Seasonings, spices, and chemicals are usually received in dry form and stored in dry areas convenient to sauce, spice, and batter and breading formulation areas.

The cleaning of storage freezers is mainly a dry process and only on rare occasions, such as defrosting of a freezer, would it generate a waste water load. Refrigerated storage space does require daily wash down, particularly of the floors where meat juices and particles have accumulated from the sorted materials. Although the industry encourages dry cleaning of all floors including storage areas prior to wash down, actual cleanup practices frequently do not include the dry cleanup.

Shipping almost always involves truck transportation. Storage includes the movement in and out of storage facilities within the plant. The primary source of waste from these operations occurs in the transport of raw materials between storage and processing areas within the plant; transport of finished products and other raw materials usually generates lttle or no waste because of the type of packaging used. Further processing raw material transport is largely done in stainless steel carts or vats that must be thoroughly washed and sanitized between uses; this cleaning results in the loss of meat juices and particles into the sewer.

Thawing

Frozen poultry carcasses and raw meat received by further processing plants are thawed by immersion in or by spraying with water, or by thawing in air. The raw material must be adequately protected from cross-contamination. In immersion, poultry is submerged in tanks or vats of lukewarm potable water for the time required to thaw the poultry throughout. At no time should the thawing media in which poultry is immersed exceed 21°C (70°F). Ice or other cooling agents may be utilized if necessary to keep the thawing water within the acceptable range. The vats used for thawing range from pushcarts of 10 to 20 cubic feet in volume to permanently installed tanks up to about 50 feet in length. To enhance thawing, water may be continuously added or flexible air hoses may be inserted to induce agitation. In thawing units which have no freshwater added (no overflow) or where the thawing water leaves the unit for reconditioning prior to returning to the thawing unit, the water is not allowed to exceed 10°C (50°F).

Complete thawing is necessary to permit thorough examination of ready-to-cook poultry prior to any further processing. When the poultry has adequately thawed for reinspection, the product is removed from the water and drained. The practice of placing frozen poultry into cooking kettles, without prior thawing, is permitted only when representative samples of the entire lot have been thawed and found to be in sound and wholesome condition. Thawing may be accomplished in cookers where the water can be heated to enable the cooking process to begin immediately following completion of thawing. It is required that thawing practices and procedures result in no net gain in weight over the frozen weight.

When whole carcasses or parts are thawed for repackaging as parts, USDA regulations prohibit recooling the thawed parts in slush ice. However, they may be held in tanks of crushed ice with the drains open pending further processing or packaging.

Wet thawing of further processing raw materials generates the largest quantity of contaminated waste water. The water used to thaw the poultry is in contact with the meat and thereby extracts water-soluble salts and accumulates particles of meat and fat. The water used in thawing is dumped into the sewer during and/or after thawing is complete. In addition, a waste load results from cleanup of the thawing systems. The waste load generated in dry thawing is from the thawing materials dripped on the floor and the washing of these drippings into the sewer.

Cutting and Boning

Cutting of poultry is normally the first further processing step for fresh ice-packed and just-thawed poultry. Cutting involves disjointing and sawing of poultry into the normal parts such as wings, breasts, and drumsticks. It also may include skinning. The waste load generated from cutting results from the use of water by the personnel involved in the operation during the operating day and from cleanup of the floors and equipment. The waste materials include skin, fat, meat tissue and bone dust. The waste load from cutting does not appear to be large and can be reduced to an insignificant amount by dry cleaning of floors and equipment prior to washdown.

Boning is the separation of meat from bone. This can be done on either raw or cooked poultry. Frequently turkeys, because of their size, are boned raw; chickens and similarly sized poultry are boned either way. The ultimate product use of poultry usually determines whether a product is boned before or after cooking. Raw boning is usually done by hand, whereas boning cooked poultry can be done by hand, by mechanical means, or by a combination of the two methods, providing all bone is removed. The waste load from boning results from frequent washing of knives, cutting boards, pans, and operators' hands during the operation day; from the rinsing of floors and tables during breaks and lunch; and from the dismantling and cleaning of mechanical equipment. The pollutants may include meat juices, and meat and fat tissue. Bones are collected as raw material for rendering.

Grinding, Chopping, and Dicing

Many poultry products, such as patties, rolls, and luncheon meats, require size reduction of boned meat. Grinding, chopping, or dicing vary the degree of size reduction, with grinding producing the greatest degree of size reduction, chopping the next, and dicing the least. These operations are all accomplished by mechanical equipment. In grinding, the meat is forced past a cutting blade and then extruded through orifice plates having holes between 1/8 and 3/8 inch; chopping likewise is usually accomplished by forcing the meat past a cutter and through an orifice plate, but with holes greater than 3/8 inch in diameter. Dicing, on the other hand, is more like a cutting operation in that it makes distinct cuts in the meat to produce square-shaped chunks of meat. Waste loads are generated from these operations by spillage in handling and movement of materials and in cleanup of equipment. These manufacturing operations can be among the major contributors to the waste load in poultry further processing plants as a result of equipment cleanup. Because these processing steps involve size reduction of poultry meats, meat and fat particles tend to coat equipment surfaces and collect in crevices, recesses, and dead spaces within the equipment. Of course, the finer the particle size, the greater the tendency for coating and hanging up of material in the equipment. All of these materials are removed during cleanup and are washed into the sewer. Any piece of equipment that is used in size reduction is cleaned at least once per processing day and may be rinsed off periodically throughout the day, thereby contributing substantially to the waste load.

Cooking

All further processed poultry products are, by definition, cooked at some point in processing. This is done in preparation of a final product or in preparing whole birds for subsequent deboning, the latter applying particularly in processing chickens. Fully cooked poultry products are frequently prepared in further processing operations, especially for the hotel, restaurant, institution, and fast-food outlet market.

Most poultry products are cooked by immersion in water in steam-jacketed open vats. Gas-fired ovens are used for some products and a small number of microwave ovens are also in use in place of immersion cookers. Deep-fat frying is used for breaded products; this is discussed in the following subsection, "Batter and Breading."

Chicken parts, whole birds, and products such as rolls and loaves are cooked by immersion in hot water cookers. Overflow wiers are used in these cookers to collect edible chicken or turkey fat during the actual cooking operation. At the end of the operating day, the cooking vats are dumped to the sewer. The waste water volume is small in comparison to the total water use in dressing plants; it is more significant in plants that further process only. However, the waste load is exceptionally high. A sample of this waste water was found to contain a BOD5 concentration of 17,000 mg/l. Spices and preservatives are added to the cooking water. These additives plus other pollutants accumulate during the cooking of the poultry and contribute substantially to the plant waste load.

The gas-fired ovens require essentially no water in their operating cycle. A small quantity of steam may be added for humidity control, but this is usually vented through the stack system.

The use of microwave ovens frequently requires a preliminary injection of spices and preservatives by means of multiple needle injection equipment such as is used in ham and bacon processing. The pickle solution remaining at the end of the operating day is dumped into the sewer. The quantity of water is small, but again, the strength is very high as a pollutant. A steam atmosphere is used in some microwave ovens; this would produce a small stream of condensate that may be a high-strength pollutant.

All cooked products are cooled before any further processing of the product. The most common cooling technique is by immersion in a cold-water vat which has a continuous overflow. This overflow and the cleanup of the vat at the end of the day generates a waste water stream of significance. Also because of the direct contact between the poultry meat and the water, the pollutant strength of the waste water is substantial.

Cleanup of these cookers requires dumping the liquid contents followed by a thorough washdown of all surfaces exposed to the poultry products. The cleanup after dumping results in a waste water stream and waste load.

Batter and Breading

Fully cooked poultry parts or fresh fabricated products may be battered and breaded to produce a desired finished product. The batter is a water-based pumpable mixture, usually containing milk and egg solids, flour, spices, and preservatives. A new batch of batter is prepared each operating day. The batter is pumped through the application equipment and the excess flows back to the small holding tank. Some of the batter clings to the application equipment and this is cleaned off during the day. At the end of the day, the remaining batter is dumped to the sewer. It is a very small quantity--between 5 and 10 gallons--although it is certainly a high-strength pollutant.

The breading is a mixture of solids which are deposited on the poultry product after the batter is applied to hold the breading on. There is no liquid involved in breading the products, and the residual solids are not disposed of into the sewer.

The breading is "set," "browned," or cooked by frying in deep fat. The breaded products are conveyed through a deep-fat fryer that is either directly gas fired or is heated by the circulation of hot oil from a heater separate from the fryer. This vegetable oil is reused repeatedly. When the rare occasion occurs in which the oil must be disposed of, the oil is shipped to a renderer, rather than dumped to the sewer.

The cleanup of the batter and breading equipment results in some waste water and waste load. However, the relatively small size of the equipment results in a water volume and waste load from cleanup that are relatively minor.

Mixing and Blending

Some of the further processed products include numerous ingredients such as the ground or chopped meat, dry solids, spices, and water. The required intermixing of these ingredients will also vary, depending on the product, from a mild blending action to an intensive high-shear mixing action. Gravies and sauces are also prepared in mixers that usually include steam jacketing. The ingredients are either pumped or manually transported to the mixing equipment for the preparation of the batches of the product mix.

Solid waste materials are generated from these operations by spillage in the handling and movement of materials and in cleanup and preparation of equipment for different types of products.

These manufacturing operations are among the major contributors to the waste load in a poultry further processing only plant as a result of equipment cleanup. Since this processing step involves the intimate mixing of meat and other materials in the preparation of stable mixtures, these materials tend to coat equipment surfaces and collect in crevices, recesses, and dead spaces in equipment. All of these materials are removed during cleanup and washed into the sewer. This is in contrast to larger-size particles that can be readily cleaned from a floor prior to washdown and thereby reduce the raw waste load in the waste water stream. Any piece of equipment that is used in any of these operations is cleaned at least once per processing day and may be rinsed off periodically throughout the day, thereby generating a fairly substantial quantity of waste water and contributing to the raw waste load.

Stuffing and Injecting

Following the preparation of a stable mixture of ingredients for a processed poultry product, the mixture is transported either by pump or in a container to a manufacturing operation where the mixtures are formed into the finished products. Sausage casings are commonly used as containers in this operation. Either natural casings, which are animal intestines, or synthetic casings may be used in producing these kinds of products.

In casing stuffing, a product mixture is placed in a piece of equipment from which the product mixture is either forced by air pressure or is pumped to fill the container uniformly and completely to form the shape of the finished product. Water is used to lubricate casings for use in the stuffing operation.

Whole bird stuffing, primarily with turkeys, involves pumping a stuffing mixture into the body cavity of the dressed bird at a stuffing station, followed by trussing and freezing of the stuffed bird.

Injection of whole birds with edible fats and oils, such as butter, margarine, corn oil, and cottonseed oil, is often done to enhance palatability. Again this is primarily done with turkey carcasses. This is normally accomplished by inserting small perforated needles into the carcass in such a manner as to direct the injected fat or oil between the tissue fibers. It is preferred tc inject longitudinally into the carcass without penetrating the skin of the carcass. Thus the intact overlying skin will retard escape of the injected materials. The injection material can be used one day after preparation, but must be dumped at the end of the second processing day. Most plants minimize or avoid any dumping of this high-cost material by preparing only the quantity that will be needed. When it is dumped, it is discharged into the sewer.

The primary source of waste load and waste water occurs in the cleanup of the equipment used in this operation. The residual mixtures left in the equipment contribute significantly to the waste load because of their propensity to stick to most surfaces that they come in contact with and to fill crevices and voids. All equipment used in this operation is dismantled at least once a day for a thorough cleaning. Between preparation of different products, the equipment may be rinsed off with clear water. The end-of-the-day cleanup is designed to remove all remnants of the mixtures handled by the equipment and this material is washed with the waste water into the sewer, thereby contributing to the waste load.

Some spillage of material occurs in this operation. Spillage occurs during the transport of the material from grinding and mixing to the stuffing operation, and particularly in the stuffing injecting operation when the material being extruded exceeds the capacity of the casing or whole bird, and overflows.

Canning

The containers used to hold the canned poultry food products must be prepared before filling and covering. The cans are thoroughly cleaned and sterilized. The wet cans are transported from the preparation area to the processing area for filling and covering. Water is frequently present all along the can lines from preparation to filling and covering. The cans go through one last steaming just before entering the can filling area. Can filling can be done by hand or mechanically. However, canning of whole birds or disjointed parts necessitates hand filling.

Can filling by machine is a highly mechanized high-speed operation. It requires the moving of the poultry food products to the canning equipment and the automated delivery of those products into a container. The combined high speed and design of the equipment results in an appreciable amount of spillage of product as the cans are filled and conveyed to the covering equipment. At the can covering station a small amount of steam is introduced under the cover or a light vacuum is pulled just before the cover is sealed to create a vacuum within the can when it cools. Steam use also generates a quantity of condensate which drains off the cans and equipment onto the floor. The operation of the filling and covering equipment results in a substantial quantity of waste water containing product spills that is wasted to the sewer. Filling cans by hand does not appear to generate as much spillage. Canning plants that have more than one filling and covering line will have a waste load that is generally proportional to the number of such lines in use.

All of the equipment used in filling and covering cans is washed at least once per day at the end of the processing period. If a can filling machine is to be used for different products during the day, it will usually be cleaned between product runs. Poultry products are frequently canned with gravy-type sauces. This type of canned product results in greater contamination of equipment wash water because of the tendency of the product mixture to coat surfaces it comes in contact with and to fill all dead spaces and crevices in the equipment. Highly mechanized equipment with many moving parts is designed to be cleaned intact rather than being dismantled first, as is much of the grinding and mixing equipment. Cleaning the equipment while it is intact requires a high-velocity water stream or jet of steam to remove all food particles from the equipment. The tendency of operating personnel is to use greater quantities of water than necessary to clean the equipment. This results in large quantities of waste water with substantial waste loads from canning operations.

The equipment used in transporting the meat product to the can filling stations also must be cleaned after it has been used on a specific product, and it is always cleaned at the end of the processing day. The product characteristics that contribute to large waste loads, as described above, also generate large waste loads in cleanup of the transport equipment as well.

Canned poultry food products are stabilized by heat processing to destroy bacteria inside the canned product. This is accomplished by cooking or by retorting, which is the pressurized cooking of canned products. Live steam is used as the heating medium in retorting, and it is common practice to bleed or vent steam from the retort vessels to maintain the cooking pressure. Cooking without pressure is used for cured boneless canned poultry products; the product is considered perishable and must be kept refrigerated. Virtually no waste water or waste load is generated by the retorting or cooking operations unless a can in a particular batch should accidentally open and spill its contents; this requires the wasting of the contents of that can and the cleanup of the cooking vessel. This rarely happens, and the retorts or cooking vessels, as a matter of normal practice, are not cleaned. The cans that are placed in cooking vessels are normally free of any potential source of waste load.

Final Product Preparation

Many of the final products from a poultry plant that includes further processing are ready to serve after heating and are prepared for the hotel, restaurant, and institutional trade. These products are portion controlled, may have gravy or a sauce added, and are packaged in containers of an appropriate size and design for immediate heating and serving. Poultry meat patties, slices of turkey loaf, and chicken parts are examples of the type of meat product prepared in this manner.

Equipment is used to convey, slice, and deposit the meat product into containers. The same equipment delivers and adds the sauce or gravy to the meat in the container, as required for specific products. As the final operation, this equipment closes the individual containers.

All of the equipment surfaces that contact the food products are cleaned at the end of each processing day. A change in the product during the day may require cleaning some components of the equipment. Material spills are cleaned up immediately. All of the materials washed from the equipment are carried to the sewer in the wash water. The volume of water and the waste load from cleanup are relatively small from this processing operation.

Freezing

The first step in the freezing of further processed poultry products is usually accomplished by blast freezing, in which the product is frozen by high-velocity air within the range of $-29°$ to $-40°C$ ($-20°$ to $-40°F$), or by first passing the product through a carbon dioxide or nitrogen tunnel in which the change in phase of carbon dioxide or nitrogen from liquid to gas causes rapid surface freezing. The products are then placed in holding freezers in which the temperature is maintained between $-29°$ and $-18°C$ ($-20°$ and $0°F$). The waste load associated with freezing is normally small or insignificant because packaging isolates the product from contacting any part of the freezing units. IQF (individual quick-frozen) products, however, are usually frozen by conveying, in the unpackaged State, through carbon dioxide or nitrogen freeze tunnels. Product contact with the conveying belt results in material transfer to the belt, requiring that the conveying belt be continuously washed. This washing of the belt can contribute moderately to the raw waste load.

Packaging

A variety of packaging techniques are used in the poultry further processing industry. These techniques include the limitation treated cardboard package, the plastic film sealed under vacuum or the Cry-O-Vac type of package, the bubble enclosure type packages used for sliced luncheon meats, and the boxing of smaller containers or pieces of finished product for shipment. In some techniques of packaging, a substantial amount of product handling is involved. This may result in some wasted finished product. However, the size of the pieces of wasted finished product are such that there is little reason for it to be washed to the sewer. Instead, it should be returned for subsequent use in another processed product or directed to a renderer.

Cleanup of the equipment would be the only time when water would be generated by the packaging operation. Small quantities of water are adequate for cleanup of this equipment, and only small quantities of waste would be generated in cleanup of the packaging equipment.

ANTICIPATED INDUSTRY GROWTH

The estimated value of the poultry products shipped in 1972 was $3.7 billion and was expected to rise to $5.0 billion in 1973. The U. S. Industrial Outlook: 1974[7] estimates a six-percent growth rate for the poultry industry in 1974. However, the growth of dollar volume in the industry has averaged about 9 percent between 1967 and 1973. Therefore it can be expected that the dollar growth rate will be somewhere between 6 and 9 percent over the next several years.

Factors that should contribute to growth can be distinguished from those that act to restrain this growth. A growing population and rising family incomes will continue to maintain consumer demand for poultry products. Per capita consumption of poultry has risen steadily over the past twenty years, as shown earlier in this section. In fact, the per capita consumption by weight of turkey and chicken has risen at an average annual rate of about 3.5 percent over the period of 1962 to 1972 to a value of about 52 pounds in 1972. Rapid growth in the volume of further processed poultry products is anticipated in the coming years. This is based on the fact that both parents are working in many families and as a result will tend to purchase more prepared foods.

The primary restraint to continuing growth of poultry products is high prices. When poultry prices approach those for red meats, their sales dip; however, the net effect of this over a period of time is a lowering in poultry prices. But if all meat prices remain high, consumers reduce their overall consumption of meat products by substituting other foods. The direction and degree of these effects are largely indeterminant at this time.

SECTION IV

INDUSTRY CATEGORIZATION

CATEGORIZATION

In developing effluent limitations guidelines and limitations of performance for the poultry processing industry, a judgment was made as to whether limitations and standards are appropriate for different segments (subcategories) within the industry. To identify any such subcategories, the following factors were considered:

- Type of raw material, i.e., broiler, turkey, small game, etc.;
- Finished product;
- Processing operations;
- Plant size;
- Plant location and age;
- Waste water characteristics and treatability.

After considering all of these factors, it was concluded that the poultry processing industry consists of five subcategories. Four of the subcategories comprise the poultry dressing segment of the industry, the fifth subcategory is for plants that do further processing only. The subcategories are defined as follows:

1. Chicken processor--a chicken dressing plant that primarily slaughters broilers; and may also cut up, further process, and/or render on the same plant site.

2. Turkey processor--a turkey dressing plant that slaughters turkeys, primarily; and may also cut up and further process concurrently or seasonally, and/or render on the same plant site.

3. Fowl processor--a fowl dressing plant that primarily slaughters light or heavy fowl (mature chickens); and may also cut up, further process and/or render on the same plant site. Geese and capon dressing plants are included in this subcategory.

4. Duck processor--a duck dressing plant that slaughters ducks primarily; and on the same plant site may also cut up, further process, and render.

5. Further processing only--a poultry plant that conducts only further processing operations, with any type of bird, but with no onsite slaughtering.

The SIC grouping covered in this study includes rabbit and small game dressing plants. Based on the findings of this study, it is concluded that such plants need not be considered in effluent limitations because the volume of their water use excludes them from the permit program, the plants tend to be small and located within municipal waste water treatment system access, and there are very few such plants in operation. Egg plants and soup or frozen dinner plants are not included in the poultry industry as defined herein.

A schematic drawing depicting the categorization is presented in Figure 3. The industry is basically split between plants that slaughter and those that do not. There is also a reasonable and significant difference in raw waste load between those that do slaughter, based strictly on the type of bird that is handled by the plant.

Those plants that process more than one kind of bird should generally be classified in the subcategory for the bird that accounts for the largest volume. If a multi-product plant handles different types of poultry on a seasonal basis, its assigned subcategory may vary according to the poultry it is processing at any given time. Duck processors operating coincident with a duck feedlot insofar as waste load or treated discharge is concerned, may be best described as "integrated" facilities. Provisions for such facilities are discussed in Section IX.

RATIONALE FOR CATEGORIZATION

Type of Raw Material

The type of raw material used in a poultry dressing plant is an important factor in substantiating the categorization of the industry. The term "raw material," in this context, is synonymous with type of bird or small game animal. The subcategorization is based on the following types of raw material as defined:

1. Chicken--primarily broiler, which is a young chicken usually between seven and nine weeks old and weighing between 3.5 and 4.25 pounds. Chickens that are not classified as mature chickens or fowl are also included in this raw material group.

2. Turkey--a hen or tom turkey of varying age and size.

3. Fowl--a mature chicken larger in average size and older than broilers; used either as a laying or breeding hen. Both light (laying) fowl and heavy (breeding) fowl are included in this group. The small number of geese, capons, roosters, and stags processed are also included here.

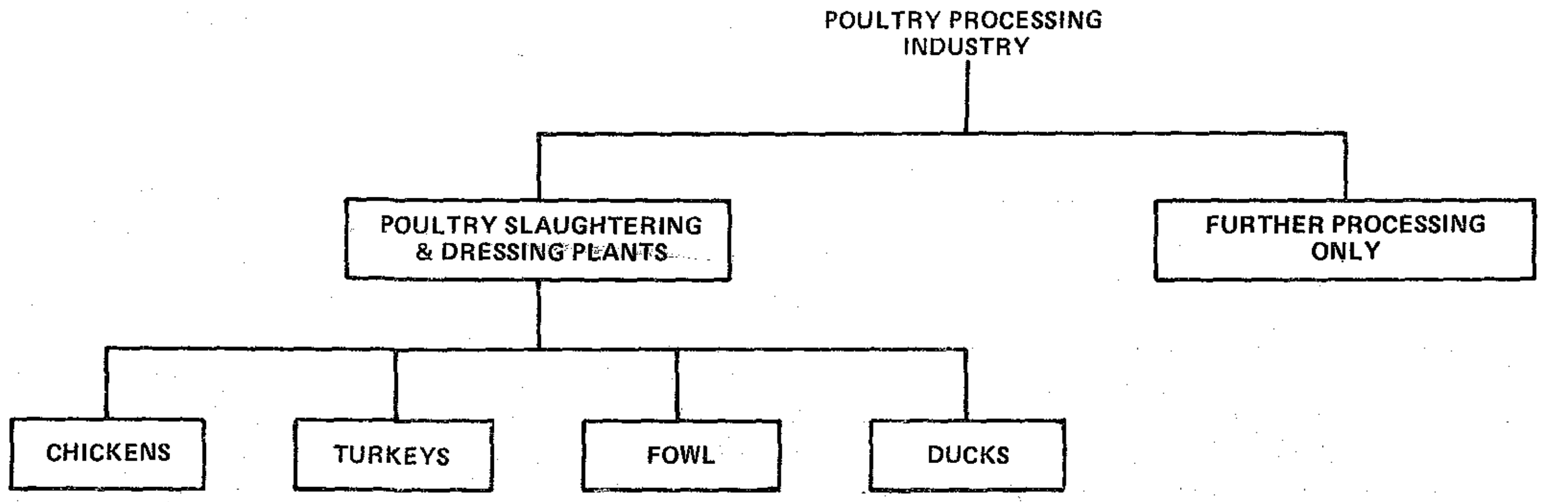

Figure 3. Categorization of Poultry Processing Industry

4. Ducks--all those species of birds classified as ducks usually of domesticated variety raised in feedlots for commercial marketing.

5. Small game--rabbits, pheasants, guineas, squab, and any other small game animals that are slaughtered for commercial use.

The small game portion of this industry represents less than one percent of industry production.[3] The birds in this subcategory are processed in plants handling other raw materials, which would contribute the more significant waste load, or in a very few specialty plants that typically have seasonal operations, small waste water volumes, and are discharging intc municipal treatment systems. While a specific subcategory has not been defined, nor does it appear warranted to do so, data and discussion of these plants will be included wherever appropriate to amplify the discussion of poultry processors.

A clear distinction in subcategories based on raw materials is obtained when the raw waste load basis is weight of BOD_5 per unit weight of LWK. The alternative of BOD_5 weight per number of birds (or animals) killed is less useful because of variations in bird size which would not be accounted for but which would affect the results. The poultry processing industry records both the weight and number of birds processed daily as a matter of routine accounting.

Finished Product

The finished product of a plant is not a factor in categorization of the poultry processing industry and thus confirms the proposed categories. Basically, the poultry industry produces:

- Fresh and frozen whole birds;
- Fresh and frozen parts cut from birds;
- Processed poultry products--frozen, canned, cooked, etc.

The last of the above list includes a myriad of processed products--other than soups and TV dinners which are not included in this industry. They are produced in further processing operations which are found both in dressing plants and in plants that further process only.

The primary finished product distinction is made between dressed birds and processed poultry products. The water use and raw waste load resulting from production of these two different types of product differ substantially. However, dressing plants also may produce processed products. The industry subcategories must be unique, distinct, and separate from one another. There should be no overlap nor commonality among the subcategories. Thus, while the proposed categorization conceptually reflects differences associated with finished products, the actual criterion for categorization is more accurately on in-plant processing operations, rather than finished product, and the categorization is thereby further substantiated.

Processing Operations

In-plant processing operations are the basic distinction and substantiation in categorizing poultry dressing plants as separate from further processing only plants. The descriptive title of each group of plants reflects the predominant type of processing operation in use by the plants. In this context, predominant means the primary water consumer and waste load generator. Dressing plants, as indicated previously, occasionally do include further processing operations. However, the water use and waste load from the dressing operation is several times that from further processing. In fact, the waste load from plants combining both types of operations was found to be very close to that from plants that only slaughter.

The poultry processing industry makes use of the same terms to distinguish the different types of processing operations, i.e., dressing and further processing. This avoids problems of definition or interpretation in assigning plants to subcategories. Thus the categorization based on in-plant processing operations is established as credible, rational, and workable.

Plant Size

Plant size per se is not a factor in categorizing the industry which substantiates the proposed categorization. There is a wide range of size of plants in the various subcategories; however, the range in raw waste load from plants grouped by size was essentially equal for large and small plants. Waste water volume and raw waste load per unit of production were found to be independent of plant size.

Plant Age and Location

Plant age and location do not influence poultry processing plants such as to require consideration in categorization and therefore substantiate the proposed categorization of the industry. Age as a potential factor in categorization at least would have the advantage of quantitative definition. However, industry experience and practice precludes even that utility for the age factor. In-plant processes are continually being updated or improved, so even old buildings may have very current processing equipment. Thus, age is difficult, if not realistically impossible, to define. In addition, a cursory analysis revealed no apparent relationship between reported plant age and raw waste load.

The poultry processing industry, as reported previously, tends to be highly concentrated in a few regions of the country. However, there is no discernible relationship between plant location and raw waste load.

Thus, plant age and location are not relevant factors in categorizing the poultry processing industry, which further confirms the proposed categorization.

Waste Water Characteristics and Treatability

Industrial practices within the poultry processing industry are diverse and produce variable waste loads. It is possible to develop a rational division of the industry, however, on the basis of factors which group plants with similar raw waste characteristics. These raw wastes are amenable to the same treatment techniques. Thus waste characteristics and treatability substantiate the categorization.

The waste water characteristic used as the basis in categorizing the industry is five-day biochemical oxygen demand (BOD_5) in units per 1000 units live weight killed (LWK): kg BOD_5/1000 kg LWK (lb BOD_5/ 1000 lb LWK). BOD_5 provides the best measure of plant operation and treatment effectiveness among the waste water parameters measured, and more data are available for BOD_5 than for any other parameter. Suspended solids data serve to substantiate the conclusions developed from BOD_5, in categorizing the industry.

The major plant waste load is organic and biodegradable; BOD_5, which is a measure of biodegradability, is the best measure of this type of loading entering a waste stream from a plant. Furthermore, because biological waste treatment is a biological process, BOD_5 also provides a useful measure of the treatability of the waste and the effectiveness of the treatment process. Chemical oxygen demand (COD) measures total organic content and some inorganic content. COD is a good indicator of change, but does not relate directly to biodegradation, and thus does not indicate the demand on a biological treatment process or on a stream.

As described in more detail in Section V, differences exist in the average BOD_5 loads for raw wastes for the five distinct groupings of poultry processing operations. As defined above, these groupings (by plant type) are substantiated as subcategories on the basis of waste load. Table 8 presents a summary of average plant operating parameters for each subcategory; the parameters include production, water use, and BOD_5 loading in the raw waste.

A number of additional waste load parameters were also considered. Among these were nitrites and nitrates, Kjeldahl nitrogen, ammonia, total dissolved solids, and phosphorus. In each case, data were insufficient to justify categorizing on the

Table 8. Production, Waste Water Flow, and Raw Waste Loading of Plants in Each Subcategory

	Chicken Processors	Turkey Processors	Fowl Processors	Duck Processors	Further Processing Only
Production					
Average, birds/day	73,000	12,100	34,100	6,600	36,700 kg/day FP (80,500 lb/day FP)
Range, birds/day	15,000 - 220,000	2,000 - 30,000	11,900 - 70,000	1,900 - 15,000	11,400 - 77,600 kg/day FP
Number of Plants in Sample	90	34	8	5	4
Average Live Weight					
Average, kg/bird (lb/bird)	1.74 (3.83)	8.3 (18.2)	2.3 (5.1)	2.9 (6.4)	
Range, kg/bird	1.45 - 1.97	4.1 - 11.4	1.6 - 4.1	2.0 - 3.2	
Number of Plants in Sample	90	34	8	5	
Waste Water Flow					
Average, l/bird (gal/bird)	35.4 (9.3)	118.2 (31.2)	48.9 (12.9)	74.9 (19.8)	12.5 l/kg FP (1.5 gal/lb FP)
Range, l/bird	15.9 - 87.0	36.3 - 270.2	11.0 - 159.0	71.5 - 78.3	2.92 - 21.34 l/kg FP
Number of Plants in Sample	88	34	8	2	4
Raw Waste BOD_5					
Average, kg/kkg LWK	9.89	4.94	15.20	7.06	19.03 kg/kkg FP
Range, kg/kkg LWK	3.26 - 26.1	0.96 - 9.1	11.78 - 23.14	6.59 - 7.52	16.71 - 22.11 kg/kkg FP
Number of Plants in Sample	60	15	4	2	3

basis of the specified parameters; on the other hand, the data on these parameters helped to verify judgments based upon BOD_5.

Judging from biological waste treatment effectiveness and final effluent limits, waste waters from all plants contain the same constituents and are amenable to the same biological treatment techniques. It was anticipated that geographical location, and hence climate, might affect the treatability of the waste to some degree. Climate has occasionally influenced the kind of biological waste treatment used, but has not had an influence on the ultimate treatability of the waste or the treatment effectiveness, given careful operation and maintenance. This is discussed in more detail in Section VII of this document.

Waste water volume and the use of municipal treatment combine as the primary considerations in deleting rabbit and other small game dressing plants from effluent limitations guidelines in this document. Relatively small output and correspondingly small waste water volume are typical of small game plants. These plants also are located in urban areas with access to municipal treatment systems. Thus, there is no need to categorize this type of plant. Data collected on these plants are reported, but no effluent limitations guidelines are proposed.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

WASTE WATER CHARACTERISTICS

Water is used in large quantities in the poultry processing industry; it is used to convey byproduct and unwanted materials from processing areas; to condition, wash, chill, and cook poultry; as an ingredient in some further processed products; and to clean equipment and processing areas. The primary waste water and waste load sources in poultry processing plants are as follows:

- Killing and bleeding;
- Scalding;
- Defeathering;
- Evisceration;
- Chilling;
- Further Processing:
  thaw tanks,
  cooking vats,
  cooling tanks;
- Rendering plant condensate and condensor water.

Waste waters from poultry processing plants contain organic matter including grease, suspended solids, inorganic materials such as phosphates, salt, nitrates and nitrites, and some coliform count. These materials enter the waste water stream as meat and fatty tissue, offal, feathers, body fluids from the birds including blood, losses of materials in process, preservatives and other product ingredients, and caustic or alkaline detergents.

Raw Waste Characteristics

The raw waste load for all subcategories of the poultry processing industry as discussed in the following subsections includes the treatment effects of in-plant primary treatment in devices such as catch basins, skimming tanks, and dissolved air flotation systems. Raw waste is, by definition, that waste water entering the biological waste treatment system.

The parameters used to characterize the raw waste are flow, BOD5, suspended solids (TSS), grease, COD (chemical oxygen demand), chlorides, phosphorus, Kjeldahl nitrogen, ammonia, nitrites and nitrates, total volatile solids, and total dissolved solids. As discussed in Section VI, BOD_5 is considered to be, in general, the most representative measure of the raw waste load. The parameter used to characterize the size of a plant is the live weight kill of birds or, in a further processing only plant, quantity of processed poultry products produced. All values of the waste parameters are expressed as kg/kkg of live weight killed (LWK) or of finished product (FP); this has the same numerical value as lb/ 1000 lb. At times, some waste components in effluents are so dilute that concentration becomes the more significant measure of waste load. In these cases, concentration is reported as mg/l, which is equivalent to parts per million. Production quantities are reported in kg/day and waste water flow is reported in volume (liters and gallons) per bird. Waste water volume is reported on a per bird rather than weight basis because process water use is more directly related to the number of birds than to the weight of the birds; and people in the industry use the per bird frame of reference in describing water use in their plants.

The information used to compute production and waste characteristics data was obtained from questionnaires distributed to their members by the National Broiler Council, Poultry Science Association, Poultry and Egg Institute of America, Southeastern Poultry and Egg Association, Poultry Industry Manufacturer's Council, Arkansas Poultry Federation, National Turkey Federation, Pacific Egg and Poultry Processors Association, Mississippi Poultry Improvement Association, and Alabama Poultry and Egg Association; from waste water sampling by North Star staff at fourteen plants; and from data provided by companies in the industry, by State and municipal pollution control agencies and sewer boards, by the EPA, and by the U. S. Department of Agriculture. Survey questionnaire data were collected on 152 identifiable plants. Data from 83 plants were adequate for use in categorization and in characterization of the raw waste and waste treatment practices. Generally, information found in the open literature was not detailed enough to be included in the data base.

A summary table of production data, waste water volume, and raw waste characteristics is presented for each of the five subcategories in the following subsections. The subcategories of the industry are:

1. Chicken processor;

2. Turkey processor;

3. Fowl processor;

4. Duck processor;

5. Further processing only.

These subcategories are defined in detail in Section IV.

Chicken Processors

These plants typically slaughter broiler-size chickens and package them as ready-to-cook in an ice pack or a cold pack with dry ice. The North Star data includes responses from 92 chicken dressing plants, which account for about 63 percent of the total live weight kill in the country. The largest percentage of these plants reportedly slaughters and cuts up some portion of their production. The chicken processing plants are divided in the sample as follows:

Slaughter only--21 percent

Slaughter plus cut-up--43 percent

Slaughter plus further process--8 percent

Slaughter plus render--5 percent

Slaughter plus cut-up and render--23 percent

The raw waste characteristics reported in Table 9 are averages of data from all of these types of chicken processing plants. The raw waste data includes plants with all combinations of operations in the chicken processing subcategory.

The principle sources of waste water in these plants are the feather and offal flow-away systems, which are part of the typical defeathering and evisceration operations. One of the recent innovations introduced into poultry processing plants is a dry offal handling system. Two chicken processing plants in the North Star sample reported this type of system, and both plants reported lower than average waste water volumes.

Various water circulation systems are also in use by processing plants, including flow-away systems water recirculation to the feather flume, chiller overflow water to the feather flume, and slaughtering plant raw waste water use in rendering plant barometric condensers. The use of these options tends to contribute to the uniformity of the raw waste load for the various types of plants in this subcategory.

Turkey Processors

Most turkey processing plants slaughter turkeys 8 to 10 months of the year. Most of these plants also include further processing operations, which may be used up to 12 months per year. Like the chicken processing plants, the waste water comes primarily from the feather and offal flow-away systems. During that time of the year of further processing only, frozen turkeys are used as the raw material and the water used in the thawing tanks contributes the largest volume of waste waters. The data on the raw waste characteristics of turkey plants are presented in Table 10.

Table 9. Raw Waste Characteristics of Chicken Processors

Parameter	Units	Average	Range	Number of Observations
Production	birds/day	73,000	15,000 - 220,000	90
Average Live Weight	kg/bird (lb/bird)	1.74 (3.83)	1.45 - 1.97	90
Waste Water Flow	l/bird (gal/bird)	34.4 (9.3)	15.9 - 87.0	88
BOD_5	kg/kkg LWK	9.89	3.26 - 19.86	60
SS	kg/kkg LWK	6.91	0.13 - 22.09	53
Grease	kg/kkg LWK	4.21	0.12 - 14.03	39
COD	kg/kkg LWK	19.70	2.04 - 56.81	31
TVS	kg/kkg LWK	13.31	3.48 - 47.17	23
TDS	kg/kkg LWK	11.67	3.52 - 45.8	23
TKN	kg/kkg LWK	1.84	0.15 - 12.16	15
NH_3	kg/kkg LWK	0.23	0.005 - 0.73	19
NO_3	kg/kkg LWK	0.0078	0.0 - 0.14	12
NO_2	kg/kkg LWK	0.0069	0.0 - 0.037	14
Cl	kg/kkg LWK	1.97	0.006 - 9.16	12
TP	kg/kkg LWK	0.39	0.054 - 2.46	22

Table 10. Raw Waste Characteristics of Turkey Processors

Parameter	Units	Average	Range	Number of Observations
Production	birds/day	12,100	2,000 - 20,000	34
Average Live Weight	kg/bird (lb/bird)	8.3 (18.2)	4.1 - 11.4	34
Waste Water Flow	l/bird (gal/bird)	118.2 (31.2)	36.3 - 270.2	34
BOD_5	kg/kkg LWK	4.94	0.96 - 9.1	15
SS	kg/kkg LWK	3.17	0.57 - 10.89	13
Grease	kg/kkg LWK	0.89	0.34 - 1.81	10
COD	kg/kkg LWK	7.39	3.07 - 10.95	5
TVS	kg/kkg LWK	8.36	2.20 - 19.16	6
TDS	kg/kkg LWK	13.53	1.51 - 38.45	5
TKN	kg/kkg LWK	0.94	0.38 - 1.89	5
NH_3	kg/kkg LWK	0.15	0.064 - 0.37	5
NO_3	kg/kkg LWK	0.037	0.005 - 0.092	3
NO_2	kg/kkg LWK	0.0013	0.001 - 0.002	3
Cl	kg/kkg LWK	2.49	0.38 - 5.41	4
TP	kg/kkg LWK	0.098	0.034 - 0.18	4

One turkey plant in the North Star sample of the industry reported having a dry offal handling system. No raw waste data were reported for this plant, however, and the data on waste water volume did not indicate any significant savings.

Fowl Processors

Fowl processing plants are basically similar to chicken processing plants except for the larger average size of the birds. Fowl are usually processed into the further processed types of products either onsite or in a plant at another location. The slaughtering and eviscerating of fowl are the primary sources of the waste water and the raw waste load. The feather and offal flow-away systems are likewise the major waste water sources. In spite of the higher average weight, the average raw waste load of BOD_5 per unit LWK is significantly higher than that for the chicken plants. The data on typical or average production, water use, and raw waste characteristics are presented in Table 11.

Duck Processors

Duck feedlots are located on the same plant site as duck processing plants in all but one plant in the industry, according to the data collected by North Star. This was confirmed by several duck growers and processors. The water flow and waste load from a combined processing plant and feedlot is substantially greater than that from a processing plant alone. However, the processing plant will be dealt with as a single source in this report and the additional load from the feedlot will of course be considered and accounted for.

The slaughtering and evisceration operations in duck processing are basically the same as that for other poultry, with the addition of wax dipping for pinfeather removal. The feather and offal flow-away systems are again the major sources of waste water and raw waste load. The waste water and waste load data presented in Table 12 for two plants represent the processing plant waste load only; feedlot waste water and loading are not included, as described above.

Further Processing Only

Plants that further process only (do no slaughtering) prepare finished poultry products primarily from chickens, fowl, and turkeys. Cooking is involved in all further processing plants, as defined in this study. These plants remove specific parts of the birds, such as wings and legs, and then remove the remaining meat from the skeletal structure of the birds. Cooking may precede or follow this cutting operation. The meat is used in large pieces or reduced in size in special equipment. Various ingredients are mixed with the poultry meat and the numerous

Table 11. Raw Waste Characteristics of Fowl Processors

Parameter	Units	Average	Range	Number of Observations
Production	birds/day	34,100	11,900 - 70,000	8
Average Live Weight	kg/bird (lb/bird)	2.3 (5.1)	1.6 - 4.1	8
Waste Water Flow	l/bird (gal/bird)	48.9 (12.9)	11.0 - 159.0	8
BOD_5	kg/kkg LWK	15.20	11.78 - 23.14	4
SS	kg/kkg LWK	10.09	6.11 - 14.94	4
Grease	kg/kkg LWK	2.32	0.72 - 3.32	3
COD	kg/kkg LWK	41.39	24.26 - 58.52	2
TVS	kg/kkg LWK	18.40	13.10 - 23.71	2
TDS	kg/kkg LWK	24.88	9.14 - 40.62	2
TKN	kg/kkg LWK	0.28	--	1
NH_3	kg/kkg LWK	0.10	--	1
NO_3	kg/kkg LWK	0.0044	--	1
NO_2	kg/kkg LWK	0.00053	--	1
Cl	kg/kkg LWK	3.99	--	1
TP	kg/kkg LWK	0.29	0.27 - 0.31	2

Table 12. Raw Waste Characteristics of Duck Processors

Parameter	Units	Average	Range	Number of Observations
Production	birds/day	6,600	1,900 - 15,000	5
Average Live Weight	kg/bird (lb/bird)	2.9 (6.4)	2.0 - 3.2	5
Waste Water Flow	l/bird (gal/bird)	74.9 (19.8)	71.5 - 78.3	2
BOD_5	kg/kkg LWK	7.06	6.59 - 7.52	2
SS	kg/kkg LWK	4.36	3.47 - 5.24	2
Grease	kg/kkg LWK	1.86	0.66 - 3.05	2
COD	kg/kkg LWK	14.08	13.57 - 14.58	2
TVS	kg/kkg LWK	7.08	6.69 - 7.48	2
TDS	kg/kkg LWK	8.30	3.97 - 12.62	2
TKN	kg/kkg LWK	1.40	0.80 - 2.00	2
NH_3	kg/kkg LWK	0.79	0.062 - 1.52	2
NO_3	kg/kkg LWK	0.030	0.018 - 0.043	2
NO_2	kg/kkg LWK	0.0097	0.0014 - 0.018	2
Cl	kg/kkg LWK	1.44	0.78 - 2.11	2
TP	kg/kkg LWK	0.084	0.073 - 0.096	2

types of finished products are formed, cooked, packaged, and usually frozen.

The waste water and waste load originates primarily in cleanup of further processing equipment and plant facilities. The relative quantities of water and waste load are substantially less in these plants than in slaughtering plants. The data are presented in Table 13 on production, waste water volume, and raw waste characteristics for plants that further process only.

The USDA reports the number of plants in the industry that further process only is 288,[2] but the 1967 Census of Manufacturers indicates only 18 plants fitting that description.[3] Based on the response to the questionnaires and an extensive inquiry of the industry, the number of further processing only plants was judged to be 18 to 20. The USDA figures undoubtedly include plants that are not part of the designated SIC codes for this study.

Discussion of Raw Wastes

The full tabulation of the raw waste characteristics for each subcategory are presented in the preceding tables. Figures 4 and 5 present a graphic comparison of average waste water volume and raw waste loads for the five subcategories. The raw waste parameters of BOD_5, suspended solids, and grease, reported as kg/kkg LWK, were used in the comparison in Figure 5, and waste water volume per bird was the basis for Figure 4. The basis for the data for further processing only plants was output of finished product rather than LWK. The relatively high raw waste loadings for further processing only plants were presumably caused, in part, by the lack of any in-plant primary treatment in three of the four plants.

All four plants in the sample reported using municipal treatment. The differences in the average waste load are apparent. The averages of course represent ranges of values, as reported in the tables of data, and there is overlap in these ranges. The average value of the waste parameters for each subcategory includes those plants that also cut-up, further process, and/or render on the same plant site. Table 14 lists the number of plants in each subcategory in the sample according to what operations are conducted in the plant. The cutting operation is conducted primarily in chicken plants so it is not reported for the other subcategories.

The raw waste load and related quantities of further processed products and rendering raw materials were analyzed to determine whether or not there was any relationship between waste load and further processing or rendering. There was no consistent positive pattern between increasing volumes of further processing or rendering with a corresponding increase in raw waste load. In fact, most of the plants with onsite rendering had lower than average raw waste loads, which may simply indicate a more

Table 13. Raw Waste Characteristics for Further Processing Only

Parameter	Units	Average	Range	Number of Observations
Production	kg/day FP (lb/day FP)	36,700 (80,500)	11,400 - 77,600	4
Waste Water Flow	l/kg FP (gal/lb FP)	12.5 (1.50)	2.92 - 21.34	4
BOD_5	kg/kkg FP	19.03	16.71 - 22.11	3
SS	kg/kkg FP	9.06	2.92 - 14.64	3
Grease	kg/kkg FP	6.36	4.83 - 7.89	3
COD	kg/kkg FP	40.63	--	1
TVS	kg/kkg FP	16.16	11.69 - 20.64	2
TDS	kg/kkg FP	30.01	--	1
TKN	kg/kkg FP	2.04	--	1
NH_3	kg/kkg FP	0.13	0.095 - 0.16	2
NO_3	kg/kkg FP	0.018	--	1
NO_2	kg/kkg FP	0.0019	--	1
Cl	kg/kkg FP	2.25	1.03 - 3.47	1
TP	kg/kkg FP	0.12	--	1

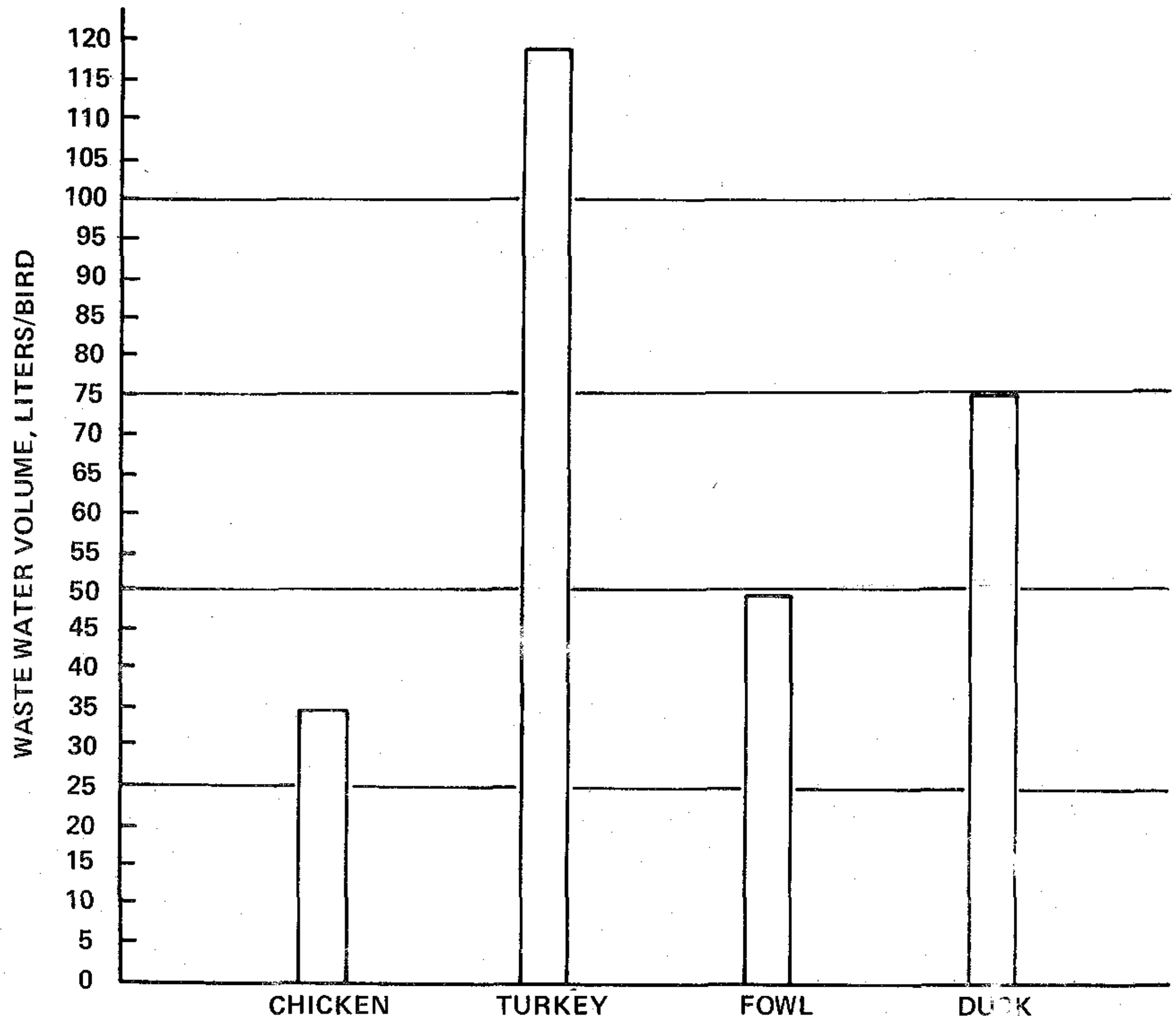

Figure 4. Average Waste Water Volume Generated Per Bird in Processing Plants by Subcategory
[Further Processing Only is 12.5 liters/kg FP (1.5 gal/lb)]

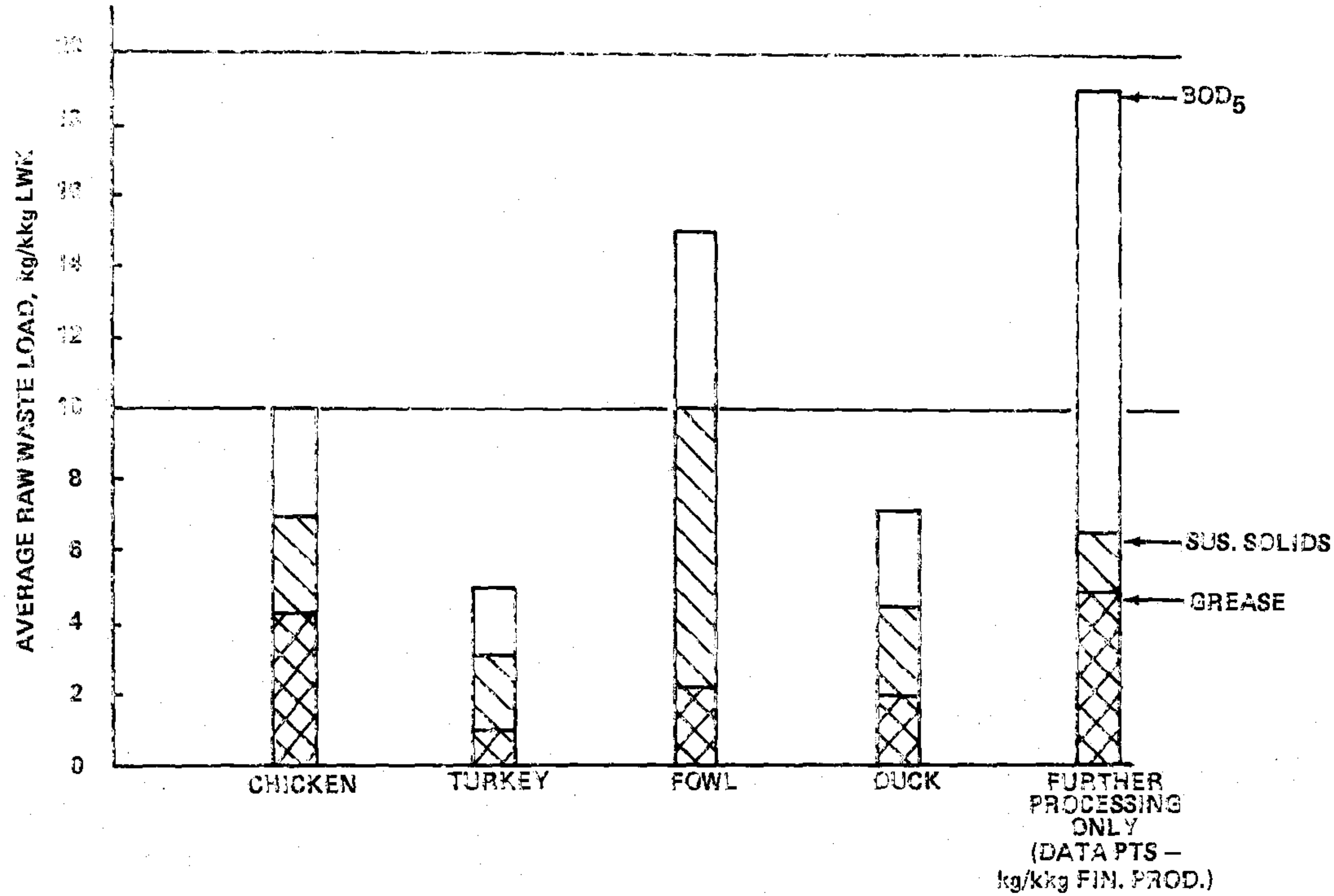

Figure 5. Average Raw Waste Loading of Waste Water From Plants in Each Subcategory

Table 14. The Number of Plants in the Questionnaire Sample Reporting the Use of Various Manufacturing Processes Within Each Subcategory

Manufacturing Process	Chicken	Turkey	Fowl	Duck
Slaughter only	19	21	4	4
Slaughter plus cutting	38	--	--	1
Slaughter plus rendering	5	2	2	--
Slaughter plus further processing	7	11	2	--
Slaughter plus cutting plus rendering	21	--	--	--
Total	90	34	8	5

concerted effort at collecting and retaining byproducts or better byproduct materials handling situations in those plants. There is some indication of increased waste load with increased output of further processed products in poultry slaughtering plants. However, it is not statistically significant. Therefore, the raw waste data are reported for all plants in each subcategory sample and are included in the singular averages for the subcategories. These averages thus include the plants that further process or render in addition to slaughtering.

A regression analysis of the raw BOD5 loading of chicken or turkey plants that slaughter and further process as a function of total output of further processing products yielded an estimate of the increase in raw waste BOD5 of 0.11 kg/kkg LWK per 1000 kg FP (0.05 lb/1000 lb LWK increase in BOD5 per 1000 lb FP). There are four plants in the sample producing 45,000 kg (100,000 lb) FP or more in processing plants. At this level of production of further processed products, the results of the regression analysis suggests that the raw BOD5 waste load would be 5.0 kg/kkg LWK (5.0 lb/1000 lb LWK) higher than if the plant did no further processing, and only slaughtered. This result is not statistically verifiable because of the wide scatter of the data, but the information can be incorporated into the proposed limitations as discussed in Sections IX through XI.

Data on the BOD5 loading of the raw waste water for each month during one or two years were obtained from eight plants. The analysis of these data revealed that in four of the plants the raw waste water loading of BOD5 tended to be more stable and consistent during the months of April through July. A more persistent pattern of variability during the latter months of the year was found in the data from these plants. Generally speaking, a waste loading range equal to two times the typical low value of BOD5 would include about 90 percent of the data points for any given plant throughout the year. There also were two plants with very consistent raw waste loading during the entire year, varying less than 30 percent above the average in one case.

A statistical test was used to determine the existence of mutual relationships between the various pollutant parameters, e.g., BOD5, suspended solids, grease, and the various nutrient sources. Correlation analysis determines if increases in the quantity of one pollutant in a waste water system are accompanied by corresponding increases or decreases of another pollutant. There is a considerable amount of data on broiler plants in the North Star sample; however, the scattering of the data resulted in a finding of no significant correlation or strong relationship between any of the pollutant parameters. The data on turkey plants are far less extensive, however a significant relationship was found between BOD5 and suspended solids in the raw waste. This relationship is one of the expected outcomes of this analysis; that as one increases the other also increases correspondingly. It is wrong to conclude, however, that there is a cause and effect relationship between highly correlated variables such as these pollutant parameters.

Process Waste Water Flow Diagrams

The origin and estimate of relative process waste water quantity is indicated for the two general poultry production processes--dressing and further processing--in Figures 6 and 7. The waste water from cleanup, which is usually the largest and strongest waste load from further processing operations, is not indicated in these figures because cleanup involves virtually the entire processing plant, with the exception of the freezer areas, and the cleanup waste water follows the same path through the plant as a process waste water.

The sources and relative quantities differ for each process. However, byproduct recovery with rotary or vibrating screens followed by a catch basin is typical of dressing plants. The upstream screens are unnecessary in further processing only plants; however, a catch basin is always desirable. Screens were also installed downstream from the catch basin or on a recirculating waste water stream from the catch basin in a few plants.

The other options available to the industry are also indicated in these figures. The plant utilities waste water may by-pass biological treatment. The dilution and increased volume of waste water only serves to inhibit biological treatment effectiveness. The sanitary sewage always enters the waste water downstream from the catch basin.

Liquid waste and wash water from the truck holding and unloading areas is also handled in different ways by processing plants in the industry. Most segregate the entire waste system while others combine the waste water downstream from the in-plant catch basin. Also, most companies do not wash down the live poultry trucks on the plant site.

WATER USE/WASTE LOAD RELATIONSHIPS

Increased water use is usually associated with increased raw waste loading from plants throughout the meat industry. This is generally true for poultry processing plants also, and has been demonstrated in experimental programs in poultry plants.[9] However, this conclusion is not substantiated as statistically significant with the data from the different plants in the sample. There are a small number of poultry plants with high water use and low waste load, and vice versa, and these plants disturb the rigorous statistical test of significance. However, there is a trend that increased water use will generally result in higher raw waste loads, as measured by BOD_5.

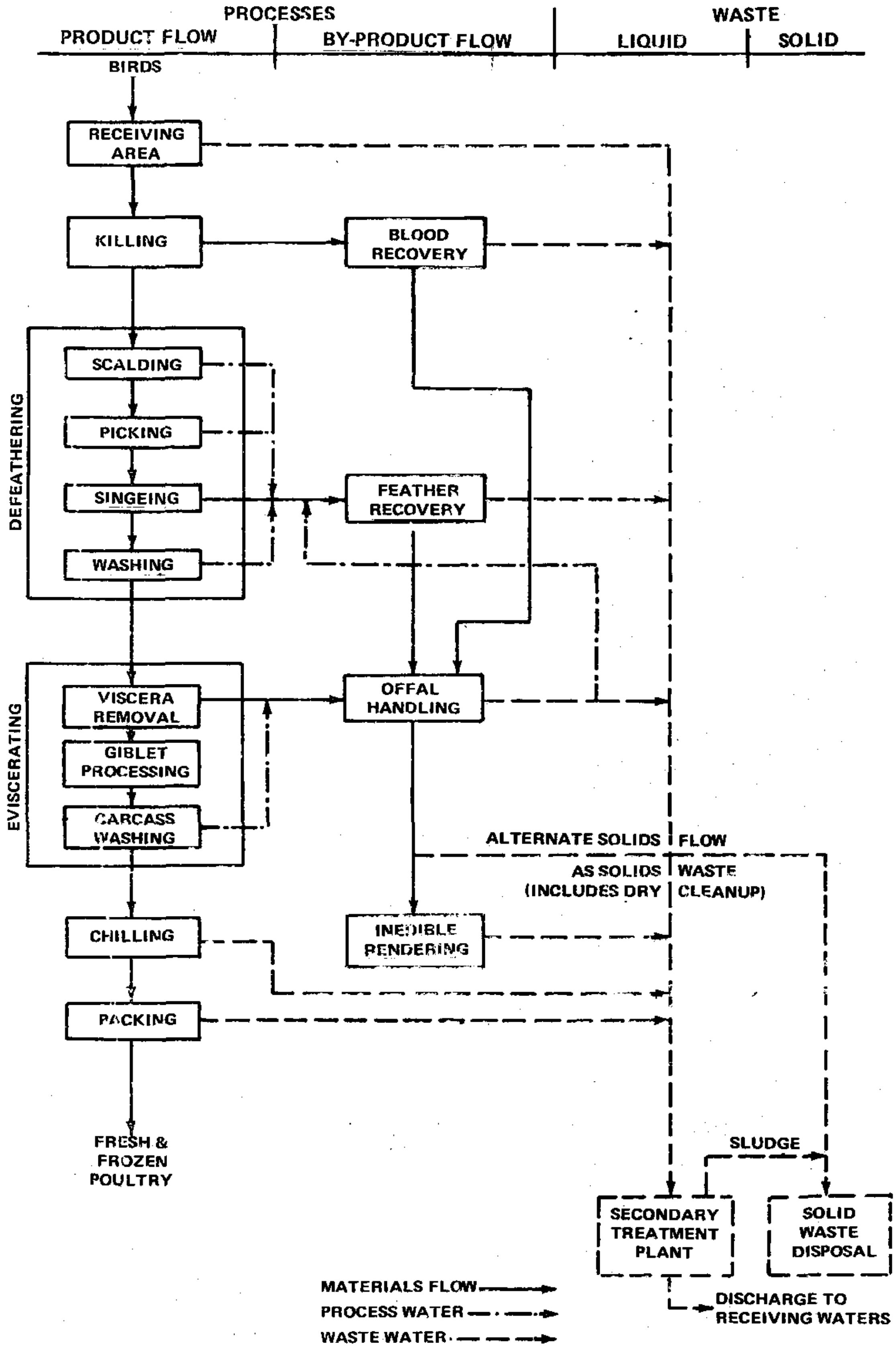

Figure 6. Product and Waste Water Flow for Typical Poultry Processing Plants

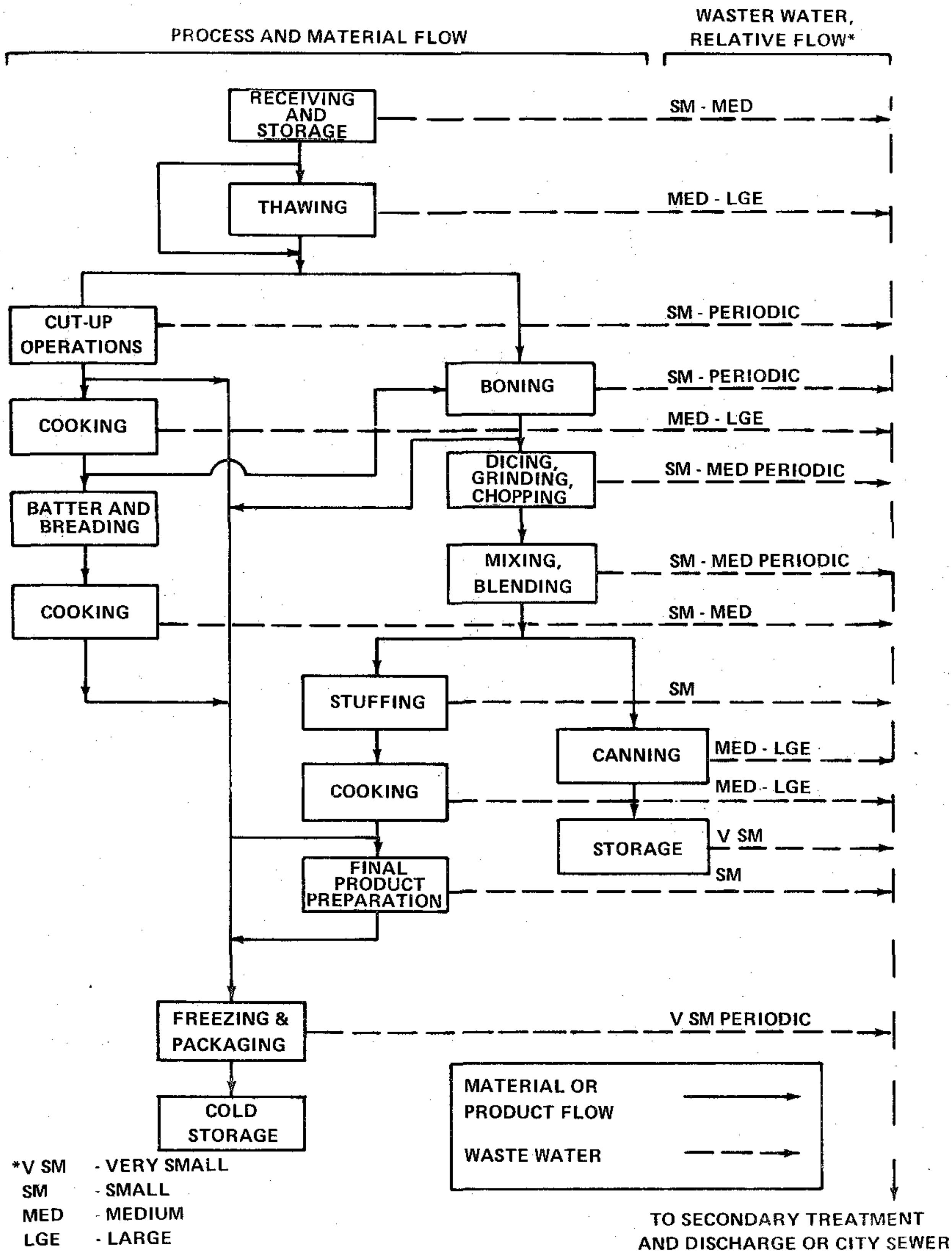

Figure 7. Process and Waste Water Flow For Further Processing

The trend lines of waste load versus waste water volume for chicken and turkey plants are presented in Figure 8. An interpretation of these trend lines suggests that in chicken plants, a 25-percent reduction in water use from, say, 45 to 35 liters per bird (11 to 9 gallons per bird) would result in a 15-percent reduction in the raw BOD_5 waste load. In turkey plants, a 39-percent reduction in water use would reduce the BOD_5 loading by about 15 percent in the raw waste. Each plant probably has its own typical and unique water use/waste load relationship, although it may differ somewhat from Figure 8.

Basically, low water use and the correspondingly low waste load require attentive and concerned management attitudes regarding in-plant water use. Without the active support and intervention of management, water management programs do not succeed; with it, water use can be reduced and the raw waste load will decrease. Waste water treatment systems operate more effectively with reduced hydraulic and waste loads.

SOURCES OF WASTE WATER AND WASTE LOAD

Killing and Bleeding

The strongest single pollutant in a poultry dressing plant is blood. Chicken blood has an approximate BOD_5 of 92,000 mg/l and 1,000 chickens may generate 7.9 kg (17.4 lb) of BOD_5 in recoverable blood.[9] Poultry are manually or mechanically killed by an exterior cut on the neck; ducks may be killed by inserting a knife into the mouth and down the throat, thus avoiding the exterior cut. The common practice is to electrically stun the birds just before killing. Occasionally, stunning follows the kill, and in a few plants other measures are employed such as ultraviolet lighting instead of an electric shock.

The birds are bled while they hang from a moving conveyor. The conveyor is confined to a single room or space usually called the blood tunnel, which is equipped with some means of collecting and handling the blood. A couple of plants have installed a raised metal trough to collect and retain the blood as the birds were conveyed along the length of it. This trough is installed and operated primarily as a byproduct recovery device. It is dry cleaned with a squeegee several times during the day and the blood flows through a vacuum line to a holding tank.

There are three factors that control the quantity of blood that enters the waste water stream: time in the blood tunnel, body movement of the birds in the tunnel, and handling and cleanup procedures for the blood. The residence time of an animal in the blood tunnel is fairly well standardized across the industry today. However, those few plants that were found to maintain shorter bleed times demonstrated unusually high raw waste loads. This presumably results from larger volumes of residual blood draining after removal of the animal from the blood tunnel.

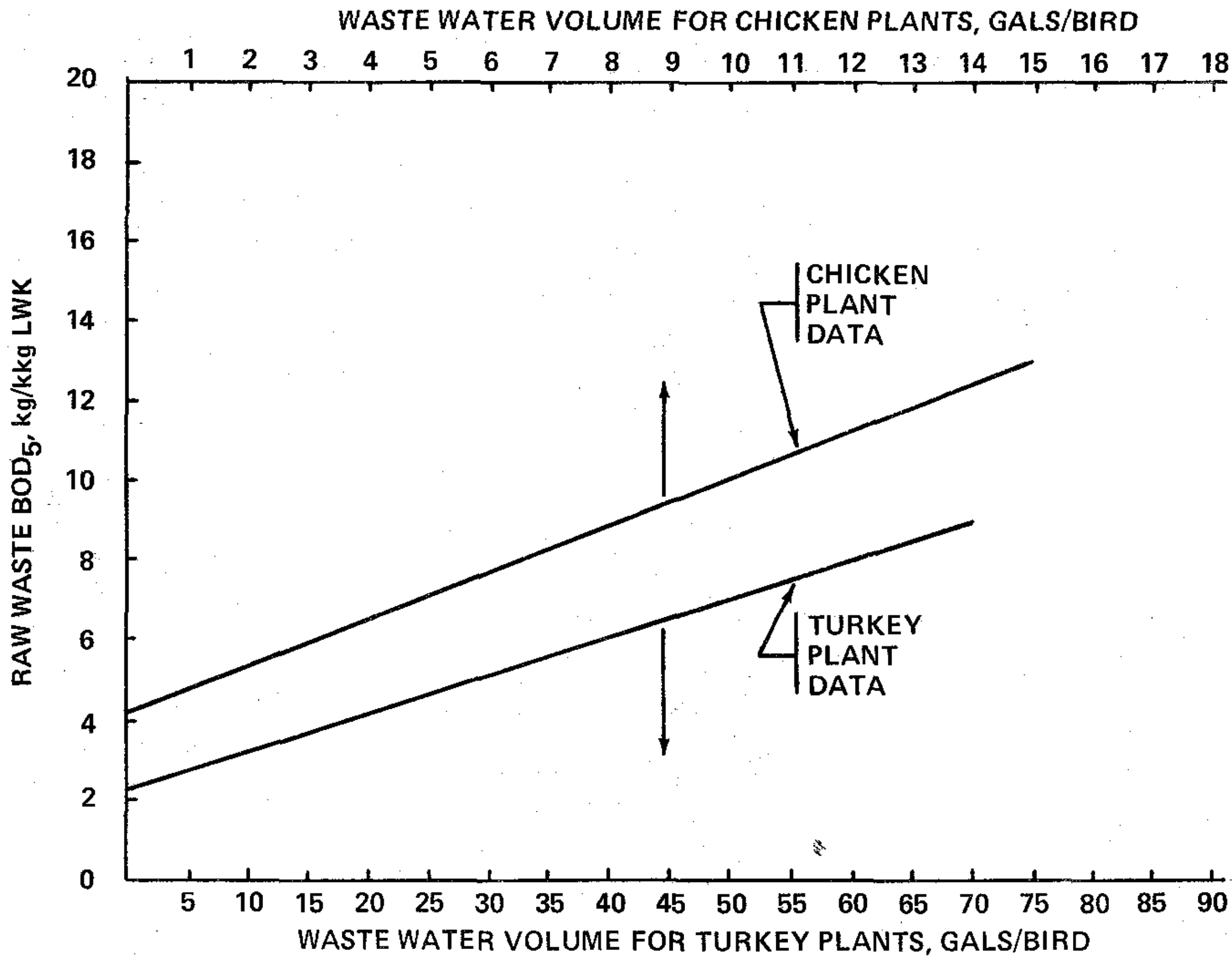

Figure 8. Approximate Relationship Between Raw Waste Loading of BOD_5 and Waste Water Volume Per Bird for Chicken and Turkey Plants

Body movement of the birds as they bleed may scatter the blood onto the feathers of adjacent birds and onto the conveyor and the walls of the blood tunnel. The blood on the feathers will be washed off in the scalder and into the waste water. The blood on the conveyor and walls will be washed off into the sewer during cleanup.

Handling and cleanup procedures can contribute significantly to the quantity of blood that is allowed to enter the sewer. The metal trough described previously was a particularly effective mechanism for confining and handling blood. No plants were found to dump the blood into the sewer. It is a valuable byproduct and is handled as such. However, large bleeding spaces and heavy reliance on water washing in preference to dry cleanup add significantly to the waste load.

Scalding

The scalding operation loosens the body feathers of poultry. It is also the first washing of the carcasses, thus the scalder effluent will contain dirt, feathers, blood, manure, and some dissolved fats and greases. The USDA requires an overflow and freshwater makeup of one-quarter gallon per bird. The BOD5 in a scalder has been measured at 490 mg/l and 1,182 mg/l, suspended solids at 473 and 687 mg/l, and grease at 350 mg/l.[9]

The scalder overflow is usually used to augment the feather flow away water and is dumped directly into the feather flume. The scalder water is maintained at temperatures between 53° and 63°C (128° and 145°F); however, the flow is not sufficient to raise the waste water temperature much above 21°C (70°F). The primary impact of the scalder occurs at the end of the operating day when it is dumped and cleaned. The dumping generates a potential shock load to the waste water handling system. Cleanup requires washing the dirt, blood, and other accumulated debris from the scalder and into the sewer again in relative surges of water.

Defeathering

Large quantities of water are used to move feathers from the defeathering operation to byproduct recovery in flow-away systems. This water use has been estimated to total 10.6 liters (2.8 gallons) per bird in a chicken plant, including 50-percent freshwater and 50 percent reused or recirculated water. Defeathering water will contain dirt and blood and feathers. Screened offal flume water also is sometimes reused in feather flumes. The BOD5 in a feather flume was reported to be 590 mg/l, the suspended solids 512 mg/l, and grease 120 mg/l.[9] The North Star waste water sampling program obtained these results for feather flume waters: 565 mg/l BOD5 and 330 mg/l suspended solids. The feather flume was also reported to be a high source of ammonia, on the order of seven times higher than the offal flume.[10]

A carcass washer follows the defeather process. The water use rate in this washer was found to be 140 liters/min (37 gpm) and the BOD5 of the waste water was reported to be 108 mg/l, with suspended solids of 81 mg/l and grease at 150 mg/l.[9]

Cleanup of the defeathering area occurs periodically during the day and at the end of the day, usually involving the use of large quantities of water to wash the feathers into the flume. The water use was found to be 130 liters/min (34 gpm) during this intermittent cleaning at one plant.[9]

Evisceration

The evisceration process generates a large volume of waste water. Carcass and giblet washing, worker hand washers, side-pan washers in the viscera trough, and viscera flow-away water all contribute to the total evisceration waste water which has been estimated to be 23 liters (6.1 gallons) per bird.[9]

In the evisceration process, the bird is opened up, the viscera are extracted from the peritoneal cavity; after inspection, the giblets are removed from the viscera, then trimmed and washed; and the inedible viscera is dropped into the viscera trough. Heads and feet are removed from the birds and dropped into the feather or offal flumes. The lungs are usually vacuumed to a holding tank, and the windpipe and extraneous tissue are removed and dropped into the trough. A carcass washer is located at the end of the evisceration line to wash both the inside and outside of the birds. In one plant, this washer used 380 liters/min (100 gpm) or about 3 liters (0.8 gallons) per bird.[9]

Much of the eviscerating process is done by hand. The workers and inspector are required to use hand washers to avoid cross-contamination. The quantity of water used in hand washing appears to be discretionary.

The waste water from evisceration will contain tissue and fat solids, grit, grease, blood, and bacteria from the intestinal tract. A BOD5 of 230 mg/l and suspended solids of 302 mg/l are reported in the literature.[9] This BOD5 concentration is equivalent to about 5.4 kg (12 lb) per 1,000 broilers. North Star sampled an offal flume downstream from the offal screening equipment and found a BOD5 of 365 mg/l and suspended solids of 196 mg/l.

Cleanup of the evisceration line also consumes a significant volume of water, although the waste loading is comparatively light. The equipment is washed down at every break and during the lunch hour, and then it is thoroughly cleaned at the end of the day. The cleanup waste load consists primarily of meat and fat particles left clinging to the equipment, the grease coating that accumulates on exposed surfaces, and residual solids that were not conveyed by the flow-away system in the trough.

Chilling

The temperature of the carcass and giblets of poultry must be quickly reduced to 4°C (40°F) after evisceration. The carcasses are usually cooled by immersion in two-stage chillers filled with ice-water. The USDA requires that 1.9 liters (0.5 gal) of freshwater must be added per bird. An overflow, equal to the make-up, plus dragout losses results in about 2.8 liters (0.75 gal) per bird of waste water into the sewer, frequently via the offal flume. Giblets are cooled in smaller but comparable equipment or in heat exchangers which prevent contact between the cooling water and the giblets.

The waste water from carcass chillers was found to be 272 liters/min (72 gpm) for a plant processing 70,000 birds per day and the giblet chillers used 17 liters/min (4.5 gpm).[9] The raw waste load of BOD5 in giblet chilling water was reported to be 2,357 mg/l, with suspended solids at 976 mg/l and grease at 1,320 mg/l.[9] The exceptionally high concentrations may result from the low water volume. The carcass chiller waste load was reported to be 440 mg/l and 320 mg/l of BOD5 from the first and second chillers, respectively. The suspended solids were found to be 250 mg/l and 180 mg/l and grease was 800 mg/l and 250 mg/l for the waste water from the first and second chillers. A North Star sample of chiller water in a turkey plant was analyzed at 180 mg/l BOD5 and 77 mg/l for suspended solids.

Cleanup of the chilling equipment requires dumping the water at the end of each day, which may overload the waste water handling system if dumped over a short period of time. The equipment acquires a conspicuous covering of grease which is washed off during cleanup. This material is wasted to the sewer. Meat and fat particles and blood accumulate in the chiller during the operating day. Any materials remaining in the chiller after it has been dumped are washed out during cleanup.

Byproduct Recovery

The screening equipment for the feather and offal flumes and the byproduct material handling equipment comprise the byproduct recovery area. No appreciable amount of waste water is generated in byproduct recovery other than the screen washing water used during the operating day and the water from cleanup. The water retained by the feathers and offal will drain through the materials handling equipment and from the offal truck which receives and holds these byproducts throughout the day. This drainage enters the waste water stream directly.

The waste load is not generated per se, in byproduct recovery, but results from losses due to inefficiency or ineffectiveness of the recovery equipment. Thus, although the waste water quantity generated in byproduct recovery is small, the waste load may be substantial, depending on the screening effectiveness in removing offal and feathers and the manner in which the blood is handled on the offal truck. If blood is simply dumped on the feathers or the offal, it will drain through and add significantly to the waste load.

Further Processing

Further processing operations use water to thaw frozen raw materials, e.g., turkeys, to cook poultry and finished products, to cool the freshly cooked birds and products, and to clean the plant and equipment.

When frozen birds are used as a source of raw materials, further processing operations thaw the birds in chillers--otherwise used to chill freshly eviscerated birds--or in large portable vats filled with water and agitated by bubbling air through the water. The frozen birds are thawed while wrapped in a protective package such as Cry-O-Vac, or are unwrapped prior to thawing. If the former is used, the water does not contact the birds directly as it would in the latter case, and the waste load from thawing would be relatively little. The direct contact between the birds and water results in a significant waste load in the thawing waters. These waters are dumped after each batch of birds is thawed, with the resulting water and waste load entering the sewer.

Birds and finished products are frequently cooked by immersion in steam-jacketed vats of hot water. Baskets of whole birds and parts or racks of products are immersed in the hot water, which includes spices and preservatives. The grease from cooking is continuously collected as a high-value edible fat. The total volume of waste water is relatively small. It amounted to approximately 0.1 liters (0.03 gallons) per processed bird in one plant sampled by North Star. The waste load in one sample of the cooking waters at the same plant was found to be 4,665 mg/l BOD5, 1,068 mg/l suspended solids, and 514 mg/l grease. These vats are dumped at the end of each processing day and thoroughly cleaned. While the waste water volume is not great, the waste load is a significant one.

Many of the freshly cooked products are immediately cooled by immersion in cold water. Cooling tanks are similar to the cooking vats, but without a steam jacket. A cold water makeup and subsequent overflow is required at between 2 and 4 liters per minute (0.5 and 1 gpm). The cooling water is fresh, clear water without any processing additives. However, the water in the tank comes into immediate contact with the hot products and chicken parts. These cooked products and chicken parts have a substantial surface coating of various pollutants such as grease, cooking water and broth, and spices and preservatives. Most of these materials plus some meat, fat, and skin tissue are washed into the cooling water. The overflow from the cooling tank flows into the sewer during the operating day. At the end of the day, the tank is emptied and cleaned. The volume of water discharged at this time is relatively small; however, the accumulated solids and other pollutants are dumped, simultaneously generating a considerable waste load.

Rendering Plant Condensate and Condenser Water

Some poultry processing plants have onsite rendering plants to produce feed grade materials from the byproducts (feathers, offal, blood, etc.) of the processing plant. A small number of plants have sufficient rendering capacity to bring in byproducts from other dressing plants.

Condensate from cooking and drying the byproducts is a high-strength waste. A previous study of the independent rendering industry provided data indicating BOD_5 concentrations of 1,235 to 1,350 mg/l in undiluted condensate from poultry byproduct rendering. The suspended solids and grease are inconsequential in the condensate. Undiluted condensate would occur only in a closed condenser such as air or shell-and-tube condensers. Barometric condensers will dilute the condensate and lower the concentration, but the total loading of the rendering raw waste is unaffected.

Spills from the rendering equipment and materials handling will contribute to the raw waste load. Cleanup of these spills will add to the waste water volume.

The waste water generated in onsite rendering systems amounts to about 15,800 l/kkg raw material (1,900 gal per 1000 lb RM) based on the data collected by North Star. For chickens, this waste water flow is equivalent to approximately 7.2 liters (1.9 gallons) per bird, and for turkeys it is 27.6 liters (7.3 gallons) per bird, or 20 and 23 percent of the average flow from chicken and turkey dressing plants, respectively.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

SELECTED PARAMETERS

Based on a review of the Corps of Engineers' Permit Applications from poultry processing plants; previous studies on similar waste waters such as from the meat packing, meat processing, and independent rendering plants; industry data; questionnaire data; and data obtained from sampling plant waste waters during this study, the following chemical, physical, and biological constituents constitute pollutants as defined in the Act.

BOD5 (5-day, 20°C biochemical oxygen demand)

COD (chemical oxygen demand)

Suspended solids (TSS)

Total dissolved solids (TDS)

Total volatile solids (TVS)

Grease

Ammonia nitrogen

Kjeldahl nitrogen

Nitrates and nitrites

Phosphorus

Chloride

Bacteriological counts (total and fecal coliform)

pH

Temperature

On the basis of all evidence reviewed, there do not exist any purely hazardous pollutants (such as heavy metals or pesticides) in the waste discharge from poultry processing plants.

RATIONALE FOR SELECTION OF IDENTIFIED PARAMETERS

5-Day Biochemical Oxygen Demand (BOD5)

This parameter is an important measure of the oxygen consumed by microorganisms in the aerobic decomposition of the wastes at 20°C over a five-day period. More simply, it is an indirect measure of the biodegradability of the organic pollutants in the waste.

BOD5 can be related to the depletion of oxygen in the receiving stream or to the requirements for the waste treatment. Values of BOD5 range from 100 to 1500 mg/l in the raw waste, although typical values range from 200 to 700 mg/l.

If the BOD5 of the final effluent of a poultry processing plant into a receiving body is too high, it will reduce the dissolved oxygen level in that stream to below a level that will sustain most fish life; i.e., below about 4 mg/l. Many States currently restrict the BOD5 effluents to below 20 mg/l if the stream is small in comparison with the flow of the effluent. A limitation of 200 to 300 mg/l of BOD5 is often applied for discharge to a municipal sewer, and surcharge rates often apply if the BOD5 is above the designated limit. BOD5 is included in the effluent limitations recommended because its discharge to a stream is harmful to aquatic life since it depletes the oxygen supply.

A 20-day biochemical oxygen demand (BOD20), sometimes called "ultimate" BOD, is usually a better measure of the waste load than BOD5. However, the test for BOD20 requires 20 days to run, so it is an impractical measure for most purposes.

Correlation analysis of the data revealed a high positive correlation between BOD5 and suspended solids, chemical oxygen demand, total volatile solids, Kjeldahl nitrogen, and ammonia nitrogen on both the raw and final effluent. Such correlations are useful in identifying contributing factors in the waste load and relating known changes in the contaminant to predicted changes by another.

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and less able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms, due to the uptake of degraded materials that form the foodstuffs of the algal populations.

Chemical Oxygen Demand (COD)

COD is yet another measure of oxygen demand. It measures the amount of organic (and some inorganic) pollutants under a carefully controlled, direct chemical oxidation by a dichromate-sulfuric acid reagent. COD is a much more rapid measure of oxygen demand than BOD5, and is potentially very useful. However, it does not have the same significance, and at the present time cannot be substituted for BOD5, because COD:BOD5 ratios vary with the types of wastes. The COD measures more than only those materials that will readily biodegrade in a stream and hence deplete the stream's dissolved oxygen supply. The COD range for poultry processing plants is from 100 to 2,800 mg/l in the raw waste.

COD provides a rapid determination of the waste strength. Its measurement will indicate a serious plant or treatment malfunction long before the BOD5 can be run. A given plant or waste treatment system usually has a relatively narrow range of COD:BOD5 ratios, if the waste characteristics are fairly constant, so experience permits a judgment to be made concerning plant operation from COD values. In the poultry processing industry, COD ranges from about 1.0 to 6 times the BOD5 in both the raw and treatment wastes, with typical ratios between 1.5 and 3.0. Although the nature of the impact of COD on receiving waters is the same as the BOD5, BOD5 was chosen for inclusion in the effluent limitations rather than COD because of the industry's frequent use and familiarity with BOD5. COD correlates with BOD5 and suspended solids (TSS) in both the raw and final effluent, although the COD:TSS correlation is not as good in the final as the raw.

Suspended Solids (TSS)

This parameter measures the suspended material that can be removed from the waste waters by laboratory filtration, but does not include coarse or floating matter that can be screened or settled out readily. Suspended solids are a visual and easily determined measure of pollution and also a measure of the material that may settle in tranquil or slow-moving streams. A high level of suspended solids is an indication of high BOD5. Generally, suspended solids range from one-third to three-fourths of the BOD5 values in the raw waste. Suspended solids are also a measure of the effectiveness of solids removal systems such as clarifiers and fine screens.

Suspended solids frequently become a limiting factor in waste treatment when the BOD5 is less than about 20 mg/l. In fact, in highly treated waste, suspended solids usually have a higher value than the BOD5 and in this case, it may be easier to lower the BOD5 even further, perhaps to 5 to 10 mg/l, by filtering out the suspended solids. TSS in the raw waste water from poultry processing plants range from 75 to 1,100 mg/l. Suspended solids in the raw and treated waste waters of poultry processing plants correlate well with BOD5, COD, and total volatile solids.

Suspended solids in receiving waters act as a substrate for bacterial population. The substrate acts as adsorption surface for ionic nutrients, thus resulting in high BOD5 values. Suspended solids also inhibit light penetration and thereby reduce the primary productivity of algae (photosynthesis). Because of the strong impact suspended solids can have on receiving waters, suspended solids were included in the effluent limitations reported in this report.

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, State and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light-absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

Total Dissolved Solids (TDS)

The total dissolved solids in the waste waters of most poultry processing plants contain mainly inorganic salts. The amount of dissolved solids will vary with the type of in-plant operations and the housekeeping practices. Total dissolved solids range from 170 to 2,300 mg/l in the raw waste waters of poultry processing plants. Dissolved solids are of the same order of magnitude and correlate well with the total volatile solids in the raw waste waters, implying that, in general, much of the dissolved solids are volatile. The inorganic dissolved solids are particularly important because they are relatively unaffected by biological treatment processes. Therefore, unless removed, they will accumulate within the water system on total recycle, or reuse, or build up to high levels with partial recycle or reuse of the waste water. Another salt sometimes present in significant quantities is sulfate. This may come from sulfate in the incoming raw water, or perhaps from water conditioning treatment of the water supply. Sulfates become particularly troublesome in causing odor in anaerobic treatment systems, where they are converted to sulfides.

Dissolved solids affect the ionic nature of receiving waters and are usually the nutrients for bacteria and protozoans. Thus, they increase the eutrophication rate of the receiving body of water. Total dissolved solids were not included in the effluent limitations recommended in this report because the organic portion would be limited by BOD_5 limitations and the nutrient portion by the nitrogen and phosphorus limitations.

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese, and other substances.

Many communities in the United States and in other countries use water supplies containing 2,000 to 4,000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4,000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5,000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for freshwater fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of freshwater forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with the purity, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Total Volatile Solids (TVS)

Total volatile solids is a rough measure of the amount of organic matter in the waste water. Actually it is the amount of combustible material in both the total dissolved solids and total suspended solids. Total volatile solids in the raw waste waters of poultry processing plants range from 175 to 2,400 mg/l. Total volatile solids in the raw waste waters of poultry processing plants correlate well with BOD_5, TSS, total dissolved solids and COD; total volatile solids in the final waste waters correlate well with BOD_5 and TSS. Because of these correlations and because total volatile solids is a relatively easy parameter to determine, it could be used as a rapid method to determine a serious plant or treatment system malfunction.

Volatile solids in receiving waters are food for microorganisms, and thus increase eutrophication. Effluent limitations for total volatile solids were not established because TVS will be limited by limitations on other pollutant parameters such as BOD_5 and suspended solids.

Grease

Grease, also called oil and grease, or hexane solubles, is a major pollutant in the raw waste stream of poultry processing plants. Grease forms unsightly films and layers on water, interferes with aquatic life, clogs sewers, disturbs biological processes in sewage treatment plants, and can also become a fire hazard. Hence effluent limitations were established for grease. The concentration of grease in poultry processing raw wastes varies from 100 to 400 mg/l.

Grease may foul municipal treatment facilities, especially trickling filters, and seriously reduce their effectiveness. Thus, it may be of great interest and concern to municipal treatment plants.

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to inhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water-soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water-insoluble components damage the plumage and coats of water animals and fowls. Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water.

Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines

Ammonia Nitrogen

Ammonia nitrogen is just one of many forms of nitrogen in a waste stream. Anaerobic decomposition of protein, which contains organic nitrogen, leads to the formation of ammonia. Thus, anaerobic lagoons or digesters produce high levels of ammonia.

Also, septic (anaerobic) conditions within the plant in traps, basins, etc., may lead to ammonia in the waste water.

Ammonia is oxidized by bacteria into nitrites and nitrates by a process called "nitrification." This may occur in an aerobic treatment process and in a stream. Thus, ammonia will deplete the oxygen supply in a stream; its oxidation products are recognized nutrients for aquatic growth. Also, free ammonia in a stream is known to be harmful to fish.

Typical concentrations in the raw waste range from 1 to 100 mg/l; however, after treatment in an anaerobic system, the concentrations of ammonia can reach 100 to 500 mg/l. Ammonia is limited in drinking water to 0.05 to 0.1 mg/l.[11] In some cases a stream limitation is less than 2 mg/l. Effluent limitations for 1983 were established for ammonia because of the strong impact it can have on receiving waters.

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this State. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Kjeldahl Nitrogen

This parameter measures the amount of ammonia and organic nitrogen; when used in conjunction with the ammonia nitrogen, the organic nitrogen can be determined by the difference. Under septic conditions, organic nitrogen decomposes to form ammonia. Kjeldahl nitrogen is a good indicator of the crude protein in the effluent and, hence, of the value of proteinaceous material being lost in the waste water. The protein content is usually taken as 6.25 times the organic nitrogen. The sources of Kjeldahl nitrogen are basically the same as for ammonia nitrogen, above. The raw waste loading of Kjeldahl nitrogen is extremely variable and is highly affected by blood loss to the waste waters such as by drainage from byproduct trucks. Typical raw waste concentrations of Kjeldahl nitrogen are between 50 and 100 mg/l. Kjeldahl nitrogen has not been a common parameter for regulation and is a much more useful parameter for raw waste than for final effluent. Even so, effluent limitations for 1983 were established for Kjeldahl nitrogen because, in addition to ammonia which has a strong environmental impact on receiving waters, it can be a major source of organic material, which is food for microorganisms in receiving waters.

Nitrates and Nitrites

Nitrates and nitrites, normally reported as N, are the result of oxidation of ammonia and of organic nitrogen. Nitrates as N should not exceed 20 mg/l in water supplies.[12] They are essential nutrients for algae and other aquatic life. For these reasons, effluent limitations for 1983 were established for nitrites-nitrates as N. Nitrites typically range from 0.001 to 2.0 mg/l in the raw wastes and from 0.02 to 1.0 mg/l in the treated wastes; nitrates range from 0.3 to 4.1 mg/l in the raw and from 0.15 to 17.5 mg/l in the treated wastes.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer.

Nitrates and nitrites are important measurements, along with Kjeldahl nitrogen, in that they allow for the calculation of a nitrogen balance on the treatment system. In fact, the field sampling data verified that when there was a substantial nitrogen reduction by the treatment system, it was accompanied by good BOD_5, TSS, and grease reduction.

Phosphorus

Phosphorus, commonly reported as P, is a nutrient for aquatic plant life and can therefore cause an increased eutrophication rate in water courses. The threshold concentration of phosphorus in receiving bodies that can lead to eutrophication is about 0.01 mg/l. The primary sources of phosphorus in raw waste from poultry processing plants are bone meal from cutting, detergents used in cleanup, food additives, and boiler-water additives. Effluent limitations were established for phosphorus for the 1983 limits because of its effect on eutrophication rates.

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by freshwater plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Chloride

Chlorides in concentrations of the order of 5,000 mg/l can be harmful to people and other animal life. High chloride concentrations in waters can be troublesome for certain industrial uses and for reuse or recycling of water. The concentrations in raw waste are extremely variable from plant to plant. Chloride loadings are unaffected by biological treatment systems used by the industry today, and once in the waste waters they are very costly to remove. While high chloride concentrations in biological treatment systems and receiving waters can upset the metabolic rate of organisms, effluent concentrations are probably too low to have a serious impact. Consequently chloride effluent limitations were not established in this report.

Fecal Coliform

The coliform bacterial contamination (total and fecal) of raw waste is substantially reduced in the larger waste treatment systems used in the industry, such as anaerobic lagoons followed by several aerobic lagoons. Chlorination will reduce coliform counts to less than 400 per 100 ml for total, and to less than 100 per 100 ml for fecal. Typically, States require that the total coliform count not exceed 50 to 200 MPN (most probable number) per 100 ml for waste waters discharged into receiving waters. Hence, most final effluents require chlorination to meet State limitations. When waters contain greater than 200 counts of fecal coliform per 100 ml, it is assumed that pathogenic enterobacteriacea, which can cause intestinal infections, are present. Consequently, effluent limitations were established for fecal coliform.

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warmblooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and ba teria.

Many microorganisms, pathogenic to humans and nimals, may be carried in surface water, particularly that deriv d from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, chlorea, vibriosis and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops, and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent.

pH, Acidity, and Alkalinity

pH is of relatively minor importance, although waters with pH outside the 6.0 to 9.0 range can affect the survival of most organisms, particularly invertebrates. The usual pH for raw waste falls between 6.0 to 9.0. This pH range is close enough to neutrality that it does not significantly affect treatment effectiveness or effluent quality. However, some adjustment may be required, particularly if pH adjustment has been used to lower the pH for protein precipitation, or if the pH has been raised for ammonia stripping. The pH of the waste water then should be returned to its normal range before discharge. The effect of chemical additions for pH adjustment should be taken into consideration, as new pollutants could result.

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to waterworks structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the taste of the water. At a low pH, water tastes "sour." The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0, and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Temperature

Because of the long detention time at ambient temperatures associated with typically large biological treatment systems used for treating poultry processing waste water, the temperature of the treatment effluent from most poultry processing plants will be virtually the same as the temperature of the receiving body of water. Therefore, temperature effluent limitations were not established. Temperatures of the raw waste waters are typically about 18°C (65°F).

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases, reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom-associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwater. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open-water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

SUMMARY

The waste load discharged from the poultry processing industry to receiving streams can be reduced to desired levels, including no discharge of pollutants, by conscientious water management, in-plant waste controls, process revisions, and by the use of a primary, biological and advanced waste water treatment. Figure 9 is a schematic of a suggested waste reduction program for the poultry industry to achieve a high quality effluent.

This section describes many of the techniques and technologies that are available or that are being developed to achieve the various levels of waste reduction. In-plant control techniques and waste water management suggestions are described first. Waste treatment technology normally used as a primary treatment is then described. In the case of the poultry processing industry, this "primary" treatment is considered as part of the in-plant system, although many of these systems have been installed to reduce pollution levels as well as to recover byproducts. The effluent from primary treatment is considered the "raw waste." Secondary treatment systems are used in the treatment of the raw waste.

Each treatment process is described, and the specific advantages and disadvantages of each system, and the effectiveness of the specific waste water contaminants found in poultry processing waste are discussed. The advanced treatment systems that are applicable to the waste from typical poultry plants are described in the last part of this section. Some of these advanced treatment systems have not been used on full-scale for poultry processing plant waste; therefore, the development status, reliability, and potential problems are discussed in greater detail than for the primary and biological treatment systems that are in widespread use.

IN-PLANT CONTROL TECHNIQUES

The waste load from a poultry processing plant is composed of a waste water stream containing the various pollutants described in Section VI. The cost and effectiveness of treatment of the waste stream will vary with the quantity of water and the waste load. In-plant control techniques will reduce both water use and waste load. The latter will be reduced by minimizing the entry of raw materials into the waste water stream, and the former by cleanup frequency and procedures and by controlling the water use for high water-use operations and by reusing waste waters.

The in-plant changes that may be made in each plant to reduce water use and waste load will depend upon the particular

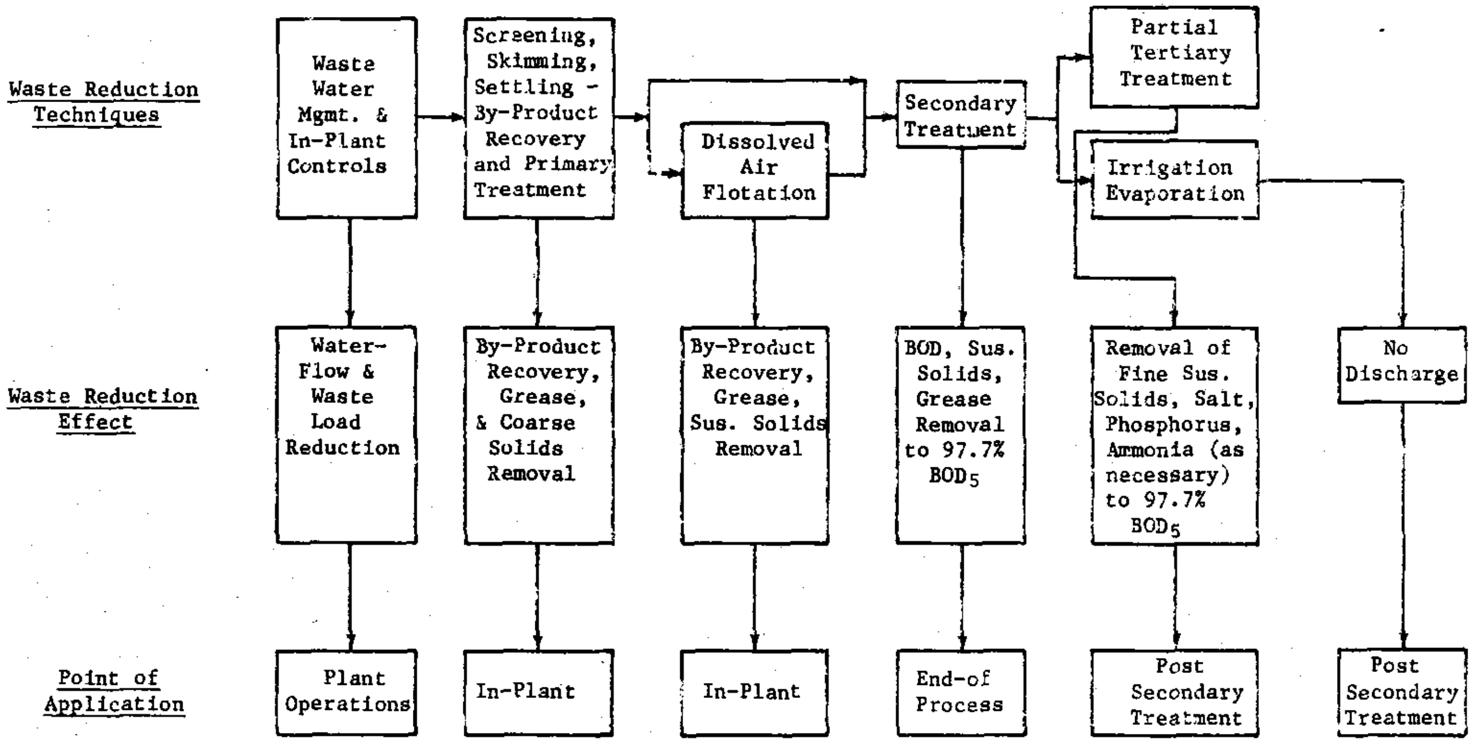

Figure 9. Suggested Poultry Processing Industry Waste Reduction Program

circumstances at that plant. A good understanding of the sources of water use and waste load, however, would be very useful prior to implementation of improved water management practices. Waste water and waste load sources are discussed in detail in Section V. Unfortunately, efforts made by many poultry processing plants to improve the quality of the final treated effluent have been directed at improvements in the treatment system only, and not in in-plant control techniques.

The following is a list of in-plant control techniques which have been used by poultry processing plants or have been shown to be technically feasible in other applications for improving water management practices:

- Appoint a person with specific responsibility for waste and water management. This person should have reasonable powers to enforce improvements, both in the plant and outside.

- Determine or estimate water use and waste load strength from various sources. Install flowmeters and monitor flows in all major water use areas.

- Control and minimize flow of freshwater at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines. On hand washers, this may require installation of press-to-operate valves.

- Stun birds in the killing operation to reduce carcass movement during bleeding.

- Confine bleeding and provide for sufficient bleed time. Recover all collectable blood and ship to rendering in tanks rather than by dumping on top of offal.

- Use minimum USDA-approved quantities of water in the scalder and chillers.

- Shut off all unnecessary water flow during work breaks.

- Consider the reuse of chiller water for makeup water for the scalder. This may require preheating the chiller effluent with the scalder overflow water by using a simple heat exchanger.

- Consider dry offal handling as an alternative to fluming. A number of plants had demonstrated the feasibility of dry offal handling in modern high-production poultry slaughtering operations.

- Control the water use in gizzard machine.

- Provide for regularly scheduled observance of screening and handling systems for offal and feathers. A back-up screen may be required to prevent these materials from entering municipal or private waste treatment systems where they may cause problems.

- Treat offal truck drainage before sewering. One method is to steam sparge the collected drainage and then screen.
- Use dry cleanup prior to washdown on all floors and tables to reduce the waste load. This is particularly important in the bleeding and cutting areas and all other areas where there tends to be spillage of materials.
- Use high-pressure, low-volume spray nozzles or steam-augmented systems for plant washdown.
- Minimize the amount of chemicals and detergents to prevent emulsification or solubilizing of solids in the waste waters. For example, determine the minimum amount of chemicals that will be effective in cleaning the scald tank.
- Control inventories of raw materials used in further processing so that none of these materials are ever wasted to the sewer. Spent raw materials should be routed to rendering.
- Treat separately all overflow of cooking broth for grease and solids recovery.
- Make all employees aware of good water management practices and encourage them to apply these practices.

Byproduct Recovery (Screening)

Byproduct recovery of offal and feathers from flow-away systems in the slaughtering and dressing of poultry is accomplished by various screening techniques. These operations may or may not be followed by in-plant primary treatment such as gravity separation basins or air flotation systems, or even biological screening systems.

Screens vary widely both in mechanical action and in mesh size, which ranges from 0.5-inch openings in stationary screens to 200 mesh in high-speed circular vibratory polishing screens. In some cases the efficiency of screening in the flow-away systems may be sufficient to circumvent biological screening; in others, biological or polishing screening may be warranted. Floor drains not connected to the flow-away systems are usually then discharged to this polishing screen. With no biological screening, the floor drains in the offal room and those adjacent to the flow-away screens and offal conveyors should be pumped back to the flow-away screen influent. These floor drains are frequently the source of serious problems when difficulties arise in the flow-away screen systems or conveyors.

Rotary Screens

Rotary and vibratory screens are the most popular types of screening systems used by the poultry industry for offal and feather recovery from the flow-away systems. One type of barrel or rotary screen, driven by external rollers, receives the waste water at one open end and discharges the solids at the other open end. The screen is inclined toward the exit end to facilitate movement of solids. The liquid passes outward through the screen (usually stainless steel screen cloth or perforated sheet) to a receiver and then to the sewer. To prevent clogging, the screen is usually sprayed continuously by a line of external spray nozzles.[13]

Another rotary screen occasionally used for byproduct recovery or for in-plant primary in the poultry industry, is driven by an external pinion gear. The raw waste water is fed into the interior of the screen, below the longitudinal axis, and solids are removed in a trough-and-screw conveyor mounted lengthwise at the axis (center line) of the barrel. The liquid exits outward through the screen into a tank under the screen. The screen is partially submerged in the liquid in the tank. The screen is usually 40 by 40 mesh, with 0.4 mm (1/64 inch) openings. Perforated lift paddles mounted lengthwise on the inside surface of the screen assist in lifting the solids to the conveyor trough. This type is also generally sprayed externally to reduce blinding. Grease clogging can be reduced by coating the wire cloth with teflon. Solids removal up to 82 percent is reported.[13]

Applications

A broad range of applications exists for screens for both byproduct recovery and for in-plant primary waste water treatment. These include both the plant waste water and waste water discharged from individual sources, especially streams with high solids contents such as offal truck drainage. In one modern poultry treatment facility, a rotary screen equipped with microscreening was successfully used for advanced treatment--the final BOD_5 from this plant was consistently under 15 mg/l.

Vibrating Screens

Vibratory screens are commonly used to recover offal and feathers. The effectiveness of a vibrating screen depends on a rapid motion. Vibrating screens operate between 99 and 1,800 rpm; the motion can be either circular or straight line, varying from 0.08 to 1.27 cm (1/32 to 1/2 inch) total travel. The speed and motion are selected by the screen manufacturer for the particular application.

Of prime importance in the selection of a proper vibrating screen is the application of the proper cloth. The liquid capacities of vibrating screens are based on the percent of open area of the cloth. The cloth is selected with the proper combination of strength of wire and percent of open area. If the waste solids to be handled are heavy and abrasive, wire of greater thickness should be used to assure long life. However, if the material is light or sticky in nature, the durability of the screening surface may be the least consideration. In such a case, a light wire may be desired to provide an increased percent of open area.

Applications

For offal recovery, vibratory screens usually have 20-mesh screening; for feather removal as well as for in-plant primary treatment of combined waste water, a 36- by 40-mesh screen cloth is used. On most applications a double-crimped, square-weave cloth is used because of its inherent strength and resistance to wire shifting. Vibratory screens with straight-line action are largely used for byproduct recovery, while those with circular motion are frequently used for in-plant primary treatment.

Static Screens

The primary function of a static screen is to remove "free" or transporting fluids. This can be accomplished in several ways, and in most older concepts, only gravity drainage is involved. A concavely curved screen design using high-velocity pressure feeding was developed and patented in the 1950's for mineral classification and has been adapted to other uses in the process industries. This design employs bar interference to the slurry which knives off thin layers of the flow over the curved surface.[14]

Beginning in 1969, United States and foreign patents were allowed on a three-slope static screen made of specially coined curved wires. This concept used the Coanda or wall attachment phenomenon to withdraw the fluid from the underlayer of a slurry which is stratified by controlled velocity over the screen. This method of operation has been found to be highly effective in handling slurries containing fatty or sticky fibrous suspended matter.

The specific arrangement and design of transverse wires provides a relatively nonclogging surface for dewatering or screening. The screens are precision-made, usually of 316 stainless steel, and are extremely rugged. Harder, wear-resisting stainless alloys may also be used for special purposes. Openings of 0.025 to 0.15 cm (0.010 to 0.060 inch) meet normal screening needs.

Application

In some plants "follow-up" stationary screens, consisting of two, three, and four units placed vertically in the effluent sewer before discharge to the municipal sewer, have successfully prevented escape of feathers and solids from the drains in the flow-away screen room and other drains on the premises. These stationary "channel" screens are framed and are usually constructed of mesh or perforated stainless steel with 1/4- to 1/2-inch openings. The series arrangement permits removal of a single screen for cleaning and improves efficiency. The three-slope static screen is being used in a few poultry processing plants as primary treatment.

IN-PLANT PRIMARY TREATMENT

In-plant primary treatment in the poultry processing industry is the treatment of waste water after the customary screening out of byproducts from flow-away systems and before discharge to a municipal sewer or private treatment system.

Flow Equalization

Equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations of waste water flow through materials recovery systems. They can be economically advantageous, whether the industry is treating its own wastes or discharging into a city sewer after some pretreatment. The equalizing tank should have sufficient capacity to provide for uniform flow to treatment facilities throughout a 24-hour day. The tank is characterized by a varying flow into the tank and a constant flow out.

The major advantages of equalization are that treatment systems can be smaller since they can be designed for the 24-hour average rather than the peak flows, and many waste treatment systems operate much better when not subjected to shock loads or variations in feed rate. Flow equalization is vital for proper operation of air flotation systems, particularly when chemicals have been added.

Screens

Since so much of the pollutant matter for some waste sources of poultry processing is originally solid (meat and fat particles), interception of the waste material by various types of screens is a natural first step for primary treatment. To assure the best performance on a plant waste water stream, flow equalization may be needed preceding screening equipment.

Unfortunately, when the pollutant materials enter the sewage stream, they are subjected to turbulence, pumping and mechanical screening, and they break down and release soluble BOD_5 into the stream, along with colloidal, suspended, and grease solids. Waste treatment--that is, the removal of soluble, colloidal, and suspended organic matter--is expensive. It usually is far simpler and less expensive to keep the solids out of the sewer.

Static, vibrating, and rotary screens are the primary type used for this step in the in-plant primary treatment. These types of screening systems were previously discussed in this section under byproduct recovery. The main difference between the screening systems used for byproduct recovery and those used for primary treatment, is that the openings in the screening cloth for primary treatment are normally smaller--36 to 200 mesh for primary versus 20 mesh to 1.25 cm openings for byproduct recovery. Whenever possible, pilot-scale studies are warranted before selecting a screen, unless specific operating data are available for the specific use intended, in the same solids concentration range, and under the same operating conditions.

Catch Basins

The catch basin for the separation of grease and solids from poultry processing waste waters are being installed primarily for waste control rather than to recover marketable grease. Unfortunately many catch basins in use today are not equipped with automatic bottom sludge removal equipment. The solids in these basins could often be completely drained to the sewer or are "sludged out" periodically at frequencies such that septic conditions would not cause the sludge to rise. Rising sludge was undesirable because it could affect the color and reduce the market value of the grease. Many wet wells or sumps that receive the screened flow-away waters are considered catch basins by the industry. However the turbulence created as the screened waters fall by gravity into these pits does not permit efficient separation of solids or grease. Furthermore, these basins are not equipped with automatic skimming devices and hence grease must be removed manually, which is normally done once a day.

In the past twenty years, with waste treatment gradually becoming an added economic incentive, catch basin design has been improved in the solids removal area as well. In fact, the low market value of inedible grease and tallow has reduced concern about quality of the skimmings, and now the concern is shifting toward overall effluent quality improvement. Gravity grease recovery systems will remove 20 to 30 percent of the BOD_5, 40 to 50 percent of the suspended solids, and 50 to 60 percent of the grease (hexane solubles).[13]

The majority of the newer gravity grease recovery basins (catch basins) are rectangular. Flow rate is the most important criterion for design; 30 to 40 minutes detention time at one-hour peak flow is a common design sizing factor.[13] The use of an equalizing tank ahead of the catch basin obviously minimizes the size requirement for the basin. A shallow basin-up to 1.8 m (6 feet)--is preferred.

A "skimmer" skims the grease and scum off the top into collecting troughs. A scraper moves the sludge at the bottom into a submerged hopper from which it can be pumped or carries it up and deposits it into a hopper. Both skimmings and sludge can be recycled as a raw material for rendering.

Two identical catch basins, with a common wall, are desirable so operation can continue if one is down for maintenance or repair. Both concrete and steel tanks are used.

Concrete tanks have the inherent advantages of lower overall maintenance and more permanence of structure. However, some plants prefer to be able to modify their operation for future expansion or alterations, or even relocation. All-steel tanks have the advantage of being semiportable, more easily field-erected, and more easily modified than concrete tanks. The all-steel tanks, however, require additional maintenance as a result of wear from abrasion and corrosion.

A tank using all-steel walls and a concrete bottom is probably the best compromise between the all-steel tank and the all-concrete tank. The advantages are the same as for steel; however, the all-steel tank requires a footing underneath and supporting members, whereas the concrete bottom forms the floor and supporting footings for the steel-wall tank.

Dissolved Air Flotation

This system is, by definition, a primary treatment system; thus, the effluent from a dissolved air flotation system is considered raw waste. This system is normally used to remove grease and fine suspended solids. It is a relatively recent technology in the poultry processing industry; therefore, it is not in widespread use, although increasing numbers of plants are installing these systems.

Dissolved air flotation appears to be the single, most effective device currently in commercial use for a plant to use to reduce the pollutant waste load in its raw waste water stream, and is particularly effective when flow equalization tanks precede the flotation unit. It is expected that the use of dissolved air flotation will become more common in the industry, especially as a step in achieving the 1983 limitations.

Technical Description

Air flotation systems are used to remove any suspended material from waste water with a specific gravity close to that of water. The dissolved air system generates a supersaturated solution of waste water and air by pressurizing waste water and introducing compressed air, then mixing the two in a detention tank. This "supersaturated" waste water flows to a large flotation tank where the pressure is released, thereby generating numerous small air bubbles which effect the flotation of the suspended organic material by one of three mechanisms: 1) adhesion of the air bubbles to the particles of matter; 2) trapping of the air bubbles in the floc structures of suspended material as the bubbles rise; and 3) adsorption of the air bubbles as the floc structure is formed from the suspended organic matter.[15] In most cases, bottom sludge removal facilities are also provided.

There are three process alternatives that differ by the proportion of the waste water stream that is pressurized and into which the compressed air is mixed. In the total pressurization process, Figure 10, the entire waste water stream is raised to full pressure for compressed air injection.

In partial pressurization, Figure 11, only a part of the waste water stream is raised to the pressure of the compressed air for subsequent mixing. Alternative A of Figure 11 shows a sidestream of influent entering the detention tank, thus reducing the pumping required in the system shown in Figure 10. In the recycle pressurization process, alternative B of Figure 11, treated effluent from the flotation tank is recycled and pressurized for mixing with the compressed air and then, at the point of pressure release, is mixed with the influent waste water. Operating costs may vary slightly, but performance should be essentially equal among the alternatives. Improved performance of the air flotation system is achieved by coagulation of the suspended matter prior to treatment. This is done by pH adjustment or the addition of coagulant chemicals, or both. Aluminum sulfate, iron sulfate, lime, and polyelectrolytes are used as coagulants at varying concentrations up to 300 to 400 mg/l in the raw waste. These chemicals are essentially totally removed in the dissolved air unit, thereby adding little or no load to the downstream waste treatment systems. However, the resulting float and sludge may become a less desirable raw material for recycling through the rendering process as a result of chemical coagulation addition. Chemical precipitation is also discussed later, particularly in regard to phosphorus removal, under advanced treatment; phosphorus can also be removed at this primary (in-plant) treatment stage. A slow paddle mix will improve coagulation. It has been suggested that the proteinaceous matter in poultry processing plant waste could be removed by reducing the pH of the waste water to the isoelectric point of about 3.5.[15] The proteinaceous material would be coagulated at that point and readily removed as float from the top of the dissolved air unit. This is not being done commercially in the poultry industry in the United States at the present time.

Similarly, the Alwatec process has been developed using a lignosulfonic acid precipitation and dissolved air flotation to recover a high protein product that is valuable as a feed.[16] Nearly instantaneous protein precipitation and hence, nitrogen removal, is achieved when a high protein-containing effluent is acidified to a pH between 3 and 4 with a high molecular weight lignosulfonic acid. BOD_5 reduction is reported to range from 60 to 95 percent. The effluent must be neutralized before further treatment by the addition of milk of lime or some other inexpensive alkali. This process is being evaluated on meat

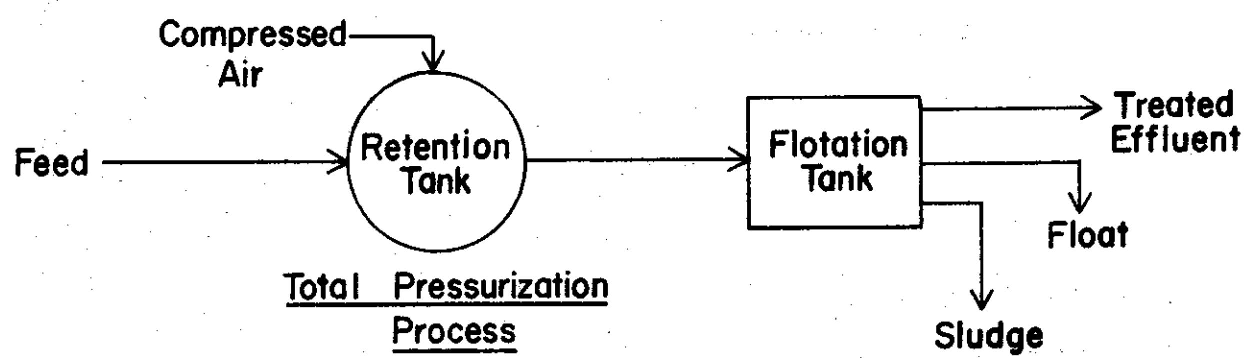

Figure 10. Dissolved Air Flotation

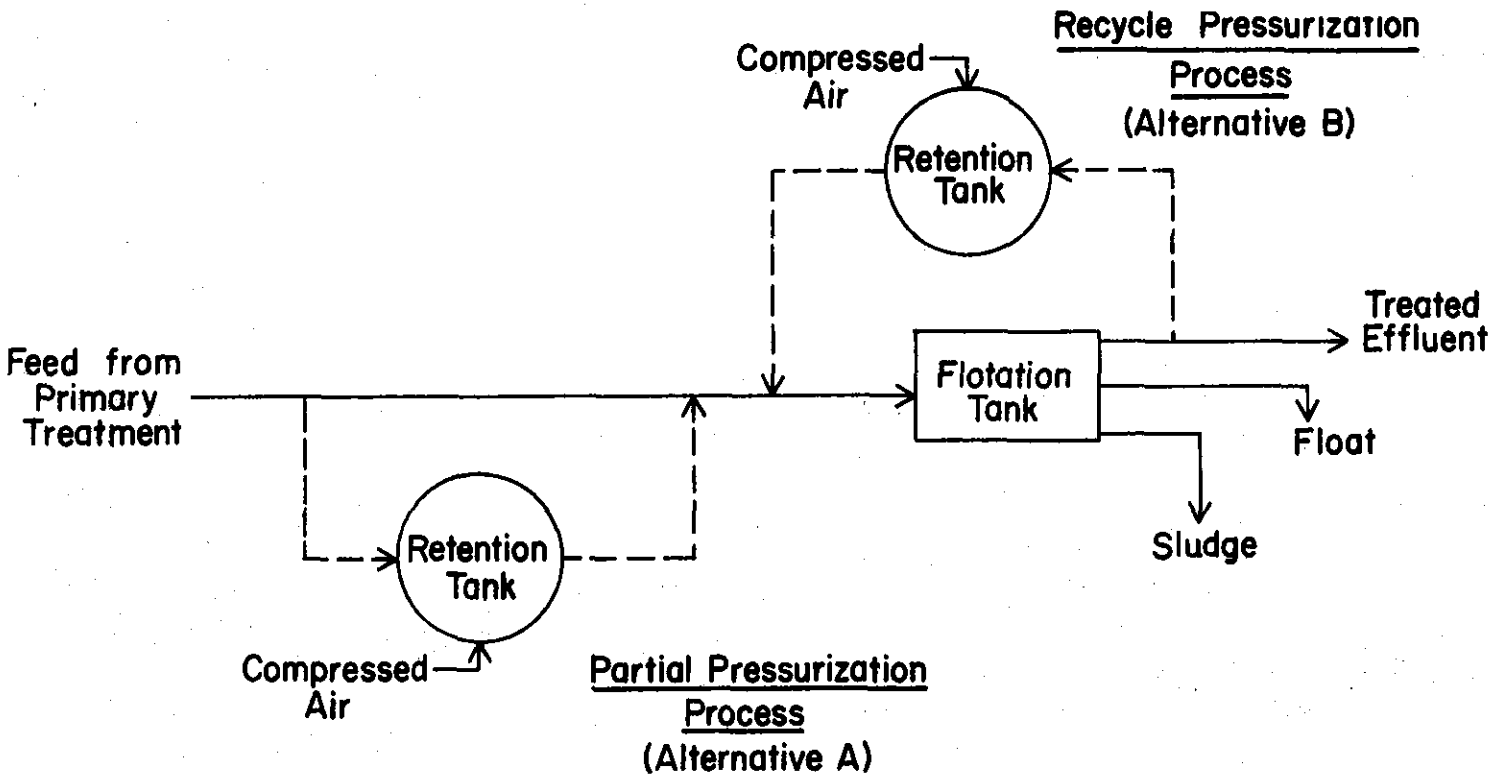

Figure 11. Process Alternatives for Dissolved Air Flotation

packing waste in one plant in the United States at the present time.[17]

One of the manufacturers of dissolved air flotation equipment indicated a 60 percent suspended solids removal and 80-to-90 percent grease removal without the addition of chemicals. With the addition of 300 to 400 mg/l of inorganic coagulants and a slow mix to coagulate the organic matter, the manufacturer says that 90 percent or more of the suspended solids and more than 90 percent of the grease can be removed.[18] Total nitrogen reduction between 35 and 70 percent was found in dissolved air units surveyed in the meat packing industry.[19]

North Star's staff observed the operation of several dissolved air units during the verification sampling program and plant visits of the poultry, rendering, and meat packing industries. One meat packing plant that was visited controlled the feed rate and pH of the waste water and achieved 90-to-95 percent removal of solids and grease; one poultry processing plant consistently obtained about 80-percent BOD_5 reduction with the aid of chemical coagulants. Other plants had relatively good operating success, but some did not achieve the results that should have been attainable. It appeared that they did not fully understand the process chemistry and were using poor operating procedures.

Problems and Reliability

The reliability of the dissolved air flotation process and of the equipment seems to be well established, although it is relatively new technology for the poultry industry. As indicated above, it appears that the use of the dissolved air system is not fully exploited by some of the companies who have installed it for waste water treatment. The potential reliability of the dissolved air process can be realized by proper installation and operation. The feed rate and process conditions must be maintained at the proper levels at all times to assure this reliability. This fact does not seem to be fully understood or of sufficient concern to some companies and thus full benefit is frequently not achieved.

The sludge and float taken from the dissolved air system can both be disposed of with the sludges obtained from biological waste treatment systems. The addition of polyelectrolyte chemicals was reported to create some problems for sludge dewatering. The mechanical equipment involved in the dissolved air flotation system is fairly simple, requiring limited maintenance attention for such things as pumps and mechanical drives.

Electrocoagulation

The concept of electrocoagulation is not new, but only recently has such a system been developed and used to pretreat the raw effluent from the meat products industries. Results reported on treating slaughterhouse effluents[20] show a marked reduction in waste strength when the effects of chemicals plus electric current were added to a catch basin. The waste strength of the effluent from the catch basin alone was 1,213, 465, and 1,108 mg/l for suspended solids, grease, and BOD5, respectively; the respective values for a catch basin plus chemicals plus electric current were 65, 15, and 458 mg/l. Even a greater reduction resulted when pH adjustment was also used. The increased reduction, however, adds to equipment, chemical, and power cost. In the case cited above, the equipment costs were increased by $23,000 to $30,000 and the chemicals and power costs were about $109/day and $5,76/day, respectively.

Technical Discussion

Electrocoagulation provides relatively rapid flotation and compaction of the floc and can be used alone or in conjunction with flocculants. As its name implies, the process electrolytically neutralizes the charge on the foreign particles to aid in forming the floc. The tank acts as the cathode, and a plurality of anodes is placed in the waste water. A direct current, with voltage less than 15 v, is passed through the waste water. Cations formed at the cathode act to neutralize the negative charge on the foreign particles, allowing them to coagulate and form an embryo floc. Microbubbles of oxygen and hydrogen formed during the electrolysis become entrained and occluded in the embryo floc, causing it to rise to the surface. The skimmings have a high solids content (9 to 12 percent, compared to 3 to 5 percent by air flotation). Where the fat loading is high, the solids content can be as high as 50 percent--the fat has a lower density than water, and it is hydrophobic.

Oxidation of constituents that can be oxidized at the operating voltage occurs at the anodes; e.g., if sulfide is present in the wastewater, sulfur will be formed. If chloride is present, chlorine is formed and is effective as a disinfectant, reducing bacteria counts.

There are also indications that the microbubbles themselves carry a positive charge, which helps to neutralize the negative charge on the foreign particles.

The choice of electrode material is important if the process is to be efficient and trouble free. It is important not to use an anode that has an appreciable dissolution rate, and especially important not to use an anode that puts toxic ions into the solution.

The placement of the electrodes is also critical. The electrodes are placed to get the desired field gradient; a higher gradient at the inlet to the tank provides a higher incidence of particle collisions required for coagulation.

WASTE WATER TREATMENT SYSTEMS

The biological treatment methods commonly used for the treatment of poultry processing plant wastes after in-plant primary treatment (solids removal) are the following biological systems: anaerobic processes, aerobic lagoons, and variations of the activated sludge process. Several of these systems are capable of providing up to 97-percent BOD_5 reductions and 95-percent suspended solids reduction, as observed at facilities in all segments of the meat industry. Combinations of these systems can achieve reductions up to 97.7 percent in BOD_5, up to 96.7 percent in grease, and up to 97.7 percent in suspended solids for poultry processing plant waste water. Based on preliminary operating data, the rotating biological contactor also shows potential as a biological treatment system.

The selection of a biological system for treatment of poultry processing plant wastes depends upon a number of important system characteristics. Some of these are waste water volume, waste load concentration, equipment used, pollution reduction effectiveness required, reliability, consistency, and resulting biological pollution problems (e.g., sludge disposal and odor control). The principals governing the design and operation of lagoon systems are the same for any substantially organic waste, i.e.,municipal (domestic) wastes, meat processing wastes, or vegetable processing wastes. Each source, however, possesses somewhat differing characteristics in waste strength which necessitate design adjustments, but all such wastes are highly amenable to biological treatment. Poultry processing wastes are readily degraded by biological processes, thus lagoon systems and other biological treatment are particularly appropriate. Geographical location of the poultry plant has a distinct bearing on the design and operation of such treatment; in turn, design and operation can readily accommodate temperature considerations in any given area.[83] Northern locations may dictate longer hydraulic or solids detention times than in southern areas, whereas southern locations may require more frequent cleanup (by draining lagoons) or lower organic loading rates than in northern areas. Expected reduction in effluent flow relative to raw waste flow (as may be due to evaporation or seepage from lagoons) is also important in design. Some plants have already incorporated a "polishing" clarifier as part of biological treatment. This helps by both removing suspended solids and permitting recycle of sludge for balancing organism activity.

More detailed discussions of the characteristics and performance of each of the above-mentioned biological treatment systems, and also for common combinations of them, are described below. Capital and operating costs are discussed in Section VIII.

Anaerobic Processes

The warm waste water temperatures (20° to 31°C, or 68° to 88°F) and high concentrations of carbohydrates, fats, proteins, and nutrients which characterize most poultry processing plant wastes make these wastes suited to anaerobic treatment. Anaerobic or facultative microorganisms, which function in the absence of dissolved oxygen, break down the organic wastes to intermediates such as organic acids and alcohols. Methane bacteria then convert the intermediates primarily to carbon dioxide and methane. Unfortunately, much of the organic nitrogen present in the influent is converted to ammonia nitrogen. Also, if sulfur compounds are present (such as from high-sulfate raw water--50 to 100 mg/l sulfate), hydrogen sulfide will be generated. Acid conditions are undesirable because methane formation is suppressed and noxious odors develop. Anaerobic processes are economical because they provide high overall removal of BOD5 and suspended solids with no power cost (other than pumping) and with low land requirements. Two types of anaerobic processes are used: anaerobic lagoons and anaerobic contact systems.

Anaerobic Lagoons

Anaerobic lagoons are in common use in the poultry processing industry as the first step in biological treatment or as pretreatment prior to discharge to a municipal system. Reductions of up to 97-percent in BOD5 and up to 95-percent in suspended solids can be achieved with the lagoons; 85-percent reduction is common. Occasionally two anaerobic lagoons are used in parallel and sometimes in series. These lagoons are relatively deep (3 to 5 meters, or about 10 to 17 feet), low surface-area systems with typical waste loadings of 240 to 320 kg BOD5/1000 cubic meters (15 to 20 lb BOD5/1000 cubic feet) and detention times of five to ten days.

Plastic covers of nylon-reinforced Hypalon, polyvinyl chloride and styrofoam have been used on occasion by other industries in place of a scum layer; in fact, some States require this. A scum layer may be used to retard heat loss, to insure anaerobic conditions, and hopefully to retain obnoxious odors. Properly installed covers provide a convenient means for odor control and collection of the byproduct methane gas.

The waste water flow inlet should be located near, but not on, the bottom of the lagoon. In some installations, sludge is recycled to insure adequate anaerobic seed for the influent. The outlet from the lagoon should be located to prevent short circuiting of the flow and carry-over of the scum layer.

For best operation, the pH should be between 7.0 and 8.5. At lower pH, methane-forming bacteria will not survive and the acid formers will take over to produce very noxious odors. At a high pH (above 8.5), acidforming bacteria will be suppressed and lower the lagoon efficiency.

Advantages-Disadvantages

Advantages of an anaerobic lagoon system are initial low cost, ease of operation, and the ability to handle large grease loads and shock waste loads, and yet continue to provide a consistent quality effluent.[21] Disadvantages of an anaerobic lagoon are the hydrogen sulfide generated from sulfate-containing waters and the typically high ammonia concentrations in the effluent of 100 mg/l or more. If acid conditions develop, severe odor problems result. Incidentally, if the gases evolved are contained, it is possible to use iron filings to remove sulfides.

Applications

Anaerobic lagoons used as the first stage in biological treatment are usually followed by aerobic lagoons. Placing a small, mechanically aerated lagoon between the anaerobic and aerobic lagoons is becoming popular. A number of meat packing plants are currently installing extended aeration units following the anaerobic lagoons to obtain nitrification. Anaerobic lagoons are not permitted in some States or areas where the ground water is high or the soil conditions are adverse (e.g., too porous) or because of odor problems.

Aerated Lagoons

Aerated lagoons have been used successfully for many years in a modest number of installations treating meat packing and poultry processing plant wastes. However, with the tightening of effluent limitations, and because aerated lagoons can provide additional treatment and enhance beneficial biological activity in aerobic lagoons (otherwise) receiving an anaerobic influent, the number of installations is increasing.

Aerated lagoons use either fixed mechanical turbine-type aerators, floating propeller-type aerators, or a diffused air system for supplying oxygen to the waste water. The lagoons usually are 2.4 to 4.6 meters (8 to 145 feet) deep, and have a detention time of two to ten days. BOD_5 reductions range from 40 to 60 percent, with little or no reduction in suspended solids. Because of this, aerated lagoons approach conditions similar to extended aeration without sludge recycle (see below).

Advantages-Disadvantages

Advantages of this system are that it can rapidly add dissolved oxygen (DO) to convert anaerobic effluent to an aerobic state; it provides additional BOD_5 reduction; and it requires a relatively small amount of land. Aeration is of particular importance both as a means to assure that aerobic lagoons get a "head start" in aerobic digestion, and as a process which stabilizes fluctuations in performance in anaerobic systems. Disadvantages include the power requirements and the fact that the aerated lagoon, in itself, usually does not reduce BOD_5 and suspended solids adequately to be used as the final stage in a high performance biological system.

Applications

Aerated lagoons are usually the first or second stages of biological treatment, and must be followed by aerobic (shallow) lagoons to reduce suspended solids and to provide the required final treatment.

Aerobic Lagoons

Aerobic lagoons (stabilization lagoons or oxidation ponds) are large surface area, shallow lagoons, usually 1 to 2.3 meters (3 to 8 feet) deep, loaded at a BOD_5 rate of 20 to 50 pounds per acre. Detention times vary from about one month to six or seven months; thus, aerobic lagoons require large areas of land. Use of a series of these lagoons (with or without supplemental aeration) virtually assures sustenance of the bacteriological activity necessary for efficient biological treatment under even the harshest climatic conditions.

Aerobic lagoons serve three main functions in waste reduction:

- Allow solids to settle out;
- Equalize and control flow;
- Permit stabilization of organic matter by aerobic and facultative microorganisms and also by algae.

Actually, if the pond is quite deep, 1.8 to 2.4 meters (6 to 8 feet), the waste water near the bottom may be void of dissolved oxygen and anaerobic organisms may be present. Therefore, settled solids can be decomposed into inert and soluble organic matter by aerobic, anaerobic, or facultative organisms, depending upon the lagoon conditions. The soluble organic matter is also decomposed by microorganisms. It is essential to maintain aerobic conditions in at least the upper six to twelve inches in shallow lagoons, since aerobic microorganisms cause the most complete removal of organic matter. Wind action assists in carrying the upper layer of liquid (aerated by air-water interface and photosynthesis) down into the deeper portions. The anaerobic decomposition generally occurring in the bottom converts solids to liquid organics, which can become nutrients for the aerobic organisms in the upper zone.

Algae growth is common in aerobic lagoons; this may be a drawback when aerobic lagoons are used for final treatment because the algae will appear as suspended solids and contribute BOD_5. Algae added to receiving waters are thus considered a pollutant. Algae in the effluent may be reduced by drawing off the lagoon effluent at least 30 cm (about 14 inches) below the surface where concentrations are usually lower, periodic maintenance cleaning of the lagoon, installation of small clarifier, or a combination of these actions. Algae in the lagoon, however, play an important role in stabilization. They use CO_2, sulfates, nitrates, phosphates, water and sunlight to synthesize their own organic cellular matter and give off oxygen. The oxygen may then be used by other microorganisms for their metabolic processes. However, when algae die they release their organic matter in the lagoon, and either settle out or provide a food source for live microorganisms.

Ammonia disappears without the appearance of an equivalent amount of nitrite and nitrate in aerobic lagoons as evidenced by the data developed in this study. From this, and the fact that aerobic lagoons tend to become anaerobic near the bottom, it appears that considerable denitrification can occur.

Ice and snow cover in winter reduces the overall effectiveness of aerobic lagoons by reducing algae activity, preventing mixing, and preventing reaeration by wind action and diffusion. This cover, if present for an extended period, can result in anaerobic conditions. If necessary, the adverse effects due to this condition can be substantially overcome by supplemental aeration using submerged aerations or similar equipment.[77, 82] When there is no ice and snow cover on large aerobic lagoons, high winds can develop a strong wave action that can damage dikes. Riprap, segmented lagoons, and finger dikes are used to prevent wave damage. Finger dikes, when arranged appropriately, also prevent short circuiting of the waste water through the lagoon. Rodent and weed control, and dike maintenance are all essential for good operation of the lagoons.

Advantages-Disadvantages

Advantages of aerobic lagoons are that they reduce the suspended solids and colloidal matter, and oxidize the organic matter of the influent to the lagoon; they also permit flow control and waste water storage. Disadvantages are reduced effectiveness during winter months that may require extended "no discharge" detention periods (90 days or more), the large land requirements, a possibility for excessive algae for which counter measures may be required, and odor problems for a short time in spring, after the ice melts and before the lagoon becomes aerobic again.

Applications

Aerobic lagoons usually are the last stage in biological treatment and frequently follow anaerobic or anaerobic-plus-aerated lagoons. Large aerobic lagoons allow plants to store waste waters for discharge during periods of high flow in the receiving body of water or to store for irrigation purposes during the summer. These lagoons are particularly popular in rural areas where land is available and relatively inexpensive.

Activated Sludge

The conventional activated sludge process is schematically shown in Figure 12. In this process, recycled, biologically active sludge or floc is mixed in aerated tanks or basins with waste water. The microorganisms in the floc adsorb organic matter from the wastes and convert it by oxidation-enzyme systems to such stable products as carbon dioxide, water, and sometimes nitrates and sulfates. The time required for digestion depends on the type of waste and its concentration, but the average time is six hours. The floc, which is a mixture of microorganisms (bacter, protozoa, and filamentous types), food, and slime material, can assimilate organic matter rapidly when properly activated; hence, the name activated sludge.

From the aeration tank, the mixed sludge and waste water, in which little nitrification has taken place, are discharged to a sedimentation tank. Here the sludge settles out, producing a clear effluent, low in BOD_5, and a biologically active sludge. A portion of the settled sludge, normally about 20 percent, is recycled to serve as an inoculum and to maintain a high mixed liquor suspended solids content. Excess sludge is removed

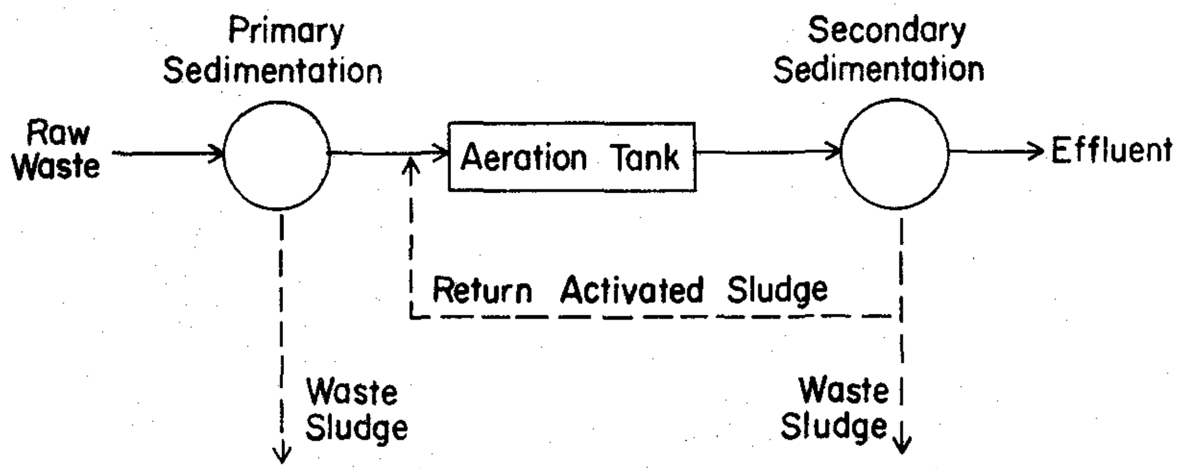

Figure 12. Activated Sludge Process

(wasted) from the system, to thickeners and anaerobic digestion, to chemical treatment and dewatering by filtration or centrifugation, or to land disposal where it is used as fertilizer and soil conditioner to aid biological crop growth.

This conventional activated sludge process can reduce BOD_5 and suspended solids up to 95 percent. However, it cannot readily handle shock loads and widely varying flows and therefore might require upstream flow equalization.

Various modifications of the activated sludge process have been developed, such as the tapered aeration, step aeration, contact stabilization, and extended aeration. Of these, extended aeration processes are most frequently being used for treatment of meat processing, meat packing, poultry processing, and rendering wastes.

Extended Aeration

The extended aeration process is similar to the conventional activated sludge process, except that the mixture of activated sludge and raw materials is maintained in the aeration chamber for longer periods of time. The usual detention time in extended aeration ranges from one to three days, rather than six hours as in the conventional process. During this prolonged contact between the sludge and raw waste, there is ample time for the organic matter to be adsorbed by the sludge and also for the organisms to metabolize the organic matter which they have adsorbed. This allows for a much greater removal of organic matter. In addition, the organisms undergo a considerable amount of endogenous respiration, and therefore oxidize much of the organic matter which has been built up into the protoplasm of the organism. Hence, in addition to high organic removals from the waste waters, up to 75 percent of the organic matter of the microorganisms is decomposed into stable products, and consequently less sludge will have to be handled.

In extended aeration, as in the conventional activated sludge process, it is necessary to have a final sedimentation tank. Some of the solids resulting from extended aeration are rather finely divided and therefore settle slowly, requiring a longer period of settling.

The long detention time in the extended aeration tank makes it possible for nitrification to occur. In nitrification under aerobic conditions, ammonia is converted to nitrites and nitrates by specific groups of nitrifying bacteria. For this to occur, it is necessary to have sludge detention times in excess of ten days.[21] This can be accomplished by regulating the amounts of recycle and wasted sludge. Oxygen-enriched gas could be used in place of air in the aeration tanks to improve overall performance. This would require that the aeration tank be partitioned and covered, and that the air compressor and dispersion system be replaced by a rotating sparger system. When concurrent, staged flow and recirculation of gas back through the liquor are employed, between 90 and 95-percent oxygen use is claimed. Although this modification of extended aeration has not been used in treating poultry processing plant wastes, it is being used successfully for treatment of other wastes.

Advantages-Disadvantages

The advantages of the extended aeration process are that it is immune to shock loading and flow fluctuations because the incoming raw waste load is diluted by the liquid in the system to a much greater extent than in conventional activated sludge. Also, because of the long detention time, high BOD5 reductions can be obtained. Other advantages of the system are the elimination of sludge digestion equipment and the capability to produce a nitrified effluent. Disadvantages are that it is difficult to remove most of the suspended solids from the mixed liquor discharged from the aeration tank; large volume tanks or basins are required to accommodate the long detention times; and operating costs for aeration are high.

Applications

Because of the nitrification process, extended aeration systems are being used by some industries following anaerobic processes or lagoons to produce low BOD5 and low ammonia-nitrogen effluents. They are also being used as the first stage of biological treatment, followed by polishing lagoons.

Rotating Biological Contactor

Process Description

The rotating biological contactor (RBC) consists of a series of closely spaced flat parallel disks which are rotated while partially immersed in the waste waters being treated. A biological growth covering the surface of the disk adsorbs dissolved organic matter present in the waste water. As the biomass on the disk builds up, excess slime is sloughed off periodically and is settled out in sedimentation tanks. The rotation of the disk carries a thin film of waste water into the air where it absorbs the oxygen necessary for the aerobic biological activity of the biomass. The disk rotation also promotes thorough mixing and contact between the biomass and the waste waters. In many ways the RBS system is a compact version of a trickling filter. In the trickling filter, the waste waters flow over the media and thus over the microbial flora; in the RBC system, the biological medium is passed through the waste water.

The system can be staged to enhance overall waste load reduction. Organisms on the disks selectively develop in each stage and are thus particularly adapted to the composition of the waste in that stage. The first stages might be used for removal of dissolved organic matter, while the latter stages might be adapted to nitrification of ammonia.

Development Status

The RBC system was developed independently in Europe and the United States about 1955 for the treatment of domestic waste; it found application only in Europe, where there are an estimated 1,000 domestic installations.[21] However, the use of the RBC for the treatment of poultry processing waste is being evaluated at the present time. One poultry plant[14] is reported to have obtained a 90-percent BOD_5 reduction (from 2,000 to 200 mg/l) when treating the effluent from an air flotation system. Pilot scale operating information is available on its use on meat packing waste. The pilot-plant studies were conducted with a four-stage RBC system with four-foot diameter disks. The system was treating a portion of the effluent from the Austin, Minnesota, anaerobic contact plant used to treat meat packing waste. The results showed a BOD_5 removal in excess of 50 percent, with loadings less than 0.037 kg BOD_5 per square meter on an average BOD_5 influent concentration of approximately 25 mg/l.[22]

Data from Autotrol Corporation, one of the suppliers of RBC systems, revealed ammonia removal of greater than 90 percent by nitrification in a multistage unit. Four to eight stages of disks with maximum hydraulic loadings of 61 liters per day per square meter (1.5 gallons per day per square foot) of disk area are considered normal for ammonia removal.

A large installation was recently completed at the Iowa Beef Processors plant in Dakota City, Nebraska, for the further treatment of the effluent from an anaerobic lagoon.[23] No data are available on this installation, which has been plagued with mechanical problems.

Advantages-Disadvantages

The major advantages of the RBC system are its relatively low first cost; the ability to obtain dissolved organic matter reduction with the potential for removal of ammonia by nitrification; and its good resistance to hydraulic shock loads. Disadvantages are that the system should be housed, if located in cold climates, to maintain high removal efficiencies and to control odors. This system has demonstrated its durability and reliability when used on domestic wastes in Europe, and is currently being tested on poultry processing plant wastes in this country.

Uses

Rotating biological contactors could be used for the entire aerobic biological system. The number of stages required depend on the desired degree of treatment and the influent strength. Typical applications of the rotating biological contactor, however, may be for polishing the effluent from anaerobic processes, and as pretreatment prior to discharging wastes to a municipal system. A BOD_5 reduction of 98 percent is reportedly achievable with a four-stage RBC.[21]

ADVANCED WASTE TREATMENT

Chemical Precipitation

Phosphorus is an excellent nutrient for algae and thus can promote heavy algae blooms. As such, it cannot be discharged into receiving streams, and its concentration should not be allowed to build up in a recycle water stream. However, the presence of phosphorus is particularly useful in spray or flood irrigation systems as a nutrient for plant growth.

The effectiveness of chemical precipitation for removing phosphorus, Figure 13, has been verified in full-scale during the North Star verification sampling program of the meat packing industry.[19] One packing plant operates a dissolved air flotation system as a chemical precipitation unit and achieves 95-percent phosphorus removal, to a concentration of less than 1 mg/l. Chemical precipitation can be used for primary (in-plant) treatment to remove BOD_5, suspended solids, and grease, as discussed earlier in conjunction with dissolved air flotation. Also, it can be used as a final treatment following biological treatment to remove suspended solids in addition to phosphorus.

Technical Description

Phosphorus occurs in waste water streams from poultry processing plants primarily as phosphate salts. Phosphates can be precipitated with trivalent iron and trivalent aluminum salts. It can also be rapidly precipitated by the addition of lime; however, the rate of removal is controlled by the agglomeration of the precipitated colloids and by the settling rate of the agglomerate.[15] Laboratory investigation and experience with in-plant operations have substantially confirmed that phosphate removal is dependent on pH and that this removal tends to be limited by the solubility behavior of the three phosphate salts--calcium, aluminum, and iron. The optimum pH for the iron and aluminum precipitation occurs in the 4 to 6 range, whereas the calcium precipitation occurs on the alkaline side at pH values above 9.5.[15]

Since the removal of phosphorus is a two-step process involving precipitation and then agglomeration, and both are sensitive to pH, controlling the pH level takes on added significance. If a chemical other than lime is used in the precipitation/coagulation process, two levels of pH are required. Precipitation occurs on the acid side and coagulation is best carried out on the alkaline side. The precipitate is removed by sedimentation or by dissolved air flotation.

Polyelectrolytes are polymers that can be used as primary coagulants, flocculation aids, filter aids, or for sludge conditioning. Phosphorus removal may be enhanced by the use of such polyelectrolytes by producing a better floc than might occur without such chemical addition.[24]

The chemically precipitated sludge contains grease and organic matter in addition to the phosphorus, if the system is used in primary treatment. If it is used as a post-biological treatment, the sludge volume will be less and it will contain primarily phosphorus salts. The sludge from either treatment can be landfilled.

Development Status

This process is well established and understood, technically. However, its use on poultry processing plant waste waters, normally as a primary waste treatment system, is limited; although, its use may grow as more stringent effluent limitations are imposed.

Problems and Reliability

As indicated above, the reliability of this process is well established; however, it is a chemical process and as such requires the appropriate control and operating procedures. The problems that can be encountered in operating this process are frequently the result of a lack of understanding or inadequate equipment. Sludge disposal is not expected to be a problem, although the use of polyelectrolytes and their effect on the dewatering properties of the sludge are open to some question at the present time. In addition, the use of the recovered sludge as a raw material for rendering may be less desirable as a result of chemical addition.

Sand Filter

A slow sand filter is a specially prepared bed of sand or other mineral fines on which doses of waste water are intermittently applied and from which effluent is removed by an under-drainage system (Figure 14); it removes solids from the waste water stream. A variety of filters can be used to remove the solids in a treated wastewater: intermittent sand filters, slow sand filters, rapid sand filters, and mixed-media filters. BOD_5 removal occurs primarily as a function of the degree of solids removal. The effluent from the sand filter is of a high quality.

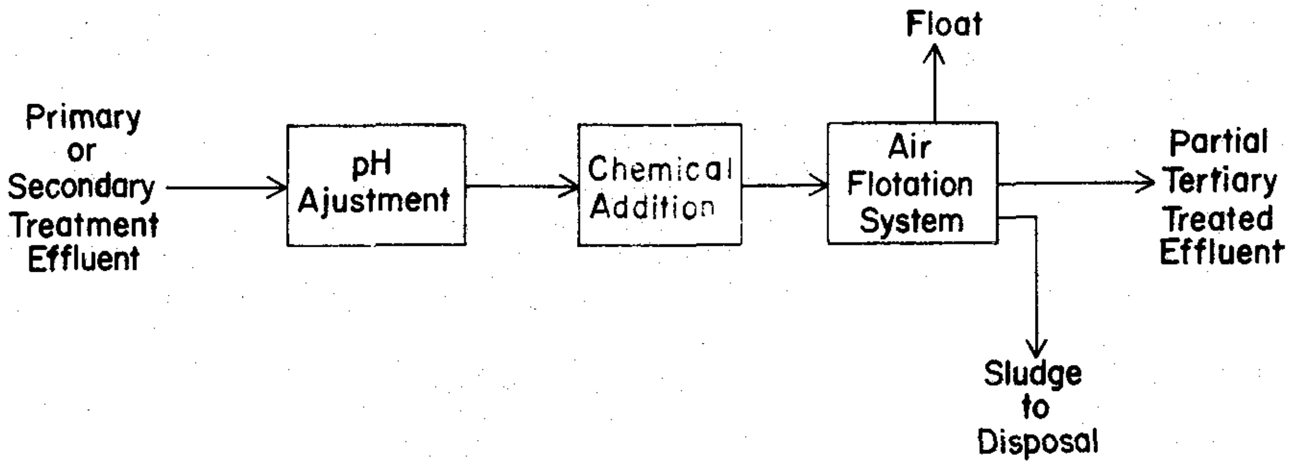

Figure 13. Chemical Precipitation

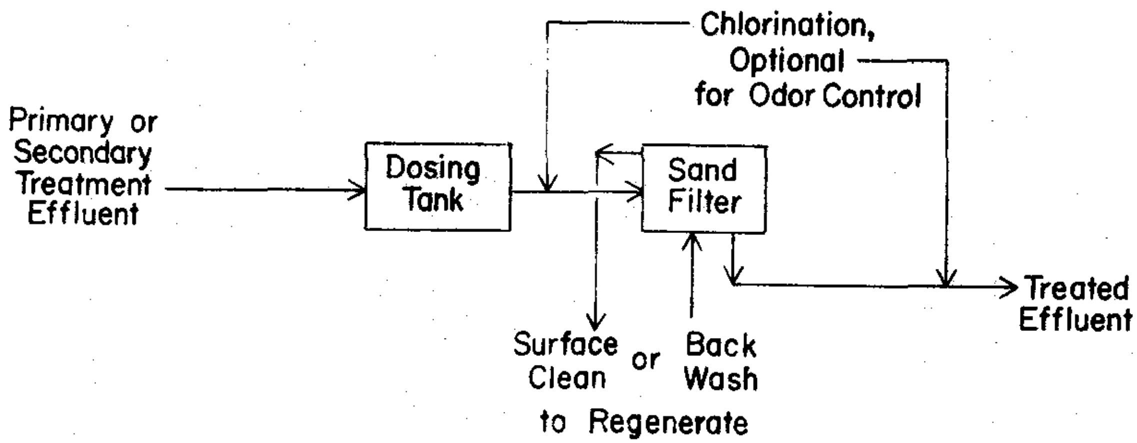

Figure 14. Sand Filter System

A summary of available information indicates that effluent suspended solids concentrations of less than 10 mg/l can be met. Although the performance of a sand filter is well known and documented, it is not in common use in the meat products industry because use of refinements of this type has not been needed to reach current waste water limitations.

A rapid sand filter may operate under pressure in a closed vessel or may be built in open concrete tanks. It is primarily a water treatment device and thus would be used as advanced treatment. Mixed-media filters are special versions of rapid sand filters that permit deeper bed-penetration by gradation of particle sizes in the bed. Up-flow filters are also special cases of rapid filters.

Technical Description

The slow sand filter removes solids primarily at the surface of the filter. The rapid sand filter is operated to allow a deeper penetration of suspended solids into the sand bed and thereby achieve solids removal through a greater cross section of the bed. The rate of filtration of the rapid filter is up to 100 times that of the slow sand filter. Thus, the rapid filter requires substantially less area than the slow filter; however, the cycle time averages about 24 hours in comparison with cycles of up to 30 to 60 days for a slow filter.[26] The larger area required for the latter means a higher first cost. For small plants, the slow sand filter can be used as advanced treatment. The rapid sand filter, on the other hand, can be more generally applied following biological treatment. However, if used as biological treatment it would tend to clog quickly and require frequent backwashing, resulting in a high water use. This wash water would also need treatment prior to discharge particularly if the rapid sand filter were used in biological treatment applications with only conventional solids removal upstream in the plant.

The rapid filters operate essentially unattended with pressure loss controls and piping installed for automatic backwashing. They are contained in concrete structures or in steel tanks.

In a rapid sand filter, as much as 80 percent of the head loss can occur in the upper few inches of the filter. One approach to increase the effective filter depth is the use of more than one media in the filter. Other filter media have included coarse coal, heavy garnet or ilmenite media, and sand.[24] There is no one mixed media design which will be optimum for all wastewater filtration problems. As an example, "removal of small quantities of high-strength biological floc often found in activated sludge effluents may be satisfactorily achieved by a good dual media design. With a weaker floc strength or with an increase in applied solids loading, the benefits of the mixed, tri-media bed become more pronounced."[24]

Although a mixed-media filter can tolerate higher suspended solids loadings than can other filtration processes, it still has an upper limit of applied suspended solids at which economically long runs can be maintained. With activated sludge effluent suspended solids loadings of up to 120 mg/l, filter runs of 15 to 24 hours at 5 gpm/ft^2 have been maintained when operating to a terminal head loss of 15 feet of water.[24]

The effluent quality produced by plain filtration of biological effluents is essentially independent of filter rate within the range of 5 to 15 gpm/ft^2 primarily due to the high strength of the biological floc. The following quality of filter effluents are presented as general guides to the suspended solids concentration which might be achieved when filtering a biological effluent of reasonable quality, without chemical coagulation:[24] high rate trickling filter, 10 to 20 mg/l; two stage trickling filter, 6 to 15 mg/l; contact stabilization, 6 to 15 mg/l; conventional activated sludge plant, 3-10 mg/l; activated sludge plant with a load factor less than 0.15, 1 to 5 mg/l.

Development Status

The slow sand filter has been in use for 50 years and more. It has been particularly well suited to small cities and isolated treatment systems serving hotels, motels, hospitals, etc., where treatment of low flow is required and land and sand are available. Treatment in these applications has been of sanitary- or municipal-type raw waste. The Ohio Environmental Protection Agency is a strong advocate of slow sand filters as biological or advanced treatment for small meat plants, followed by some form of settling or solids removal. As of early 1973, 16 sand filters had been installed and eight were proposed and expected to be installed in Ohio. All 24 of these installations were for waste from meat plants.[27] The land requirements for a slow sand filter are not particularly significant in relation to those required for lagooning purposes in biological treatment processes. However, the quality and quantity of sand is important and may be a constraint in the use of sand filters in some local situations. It should also be recognized that this process requires hand labor for raking the crust that develops on the surface. Frequency of raking may be weekly or monthly, depending upon the quality of pretreatment and the gradation of the sand. Rapid sand filters have received the most attention as the principal method to treat water supplies. More recently, applications as a advanced treatment mode for municipal and joint municipal-industrial wastewater facilities have proven successful. Multi-media filters were developed for general use in the mid 1960's and these filters also have been used for potable water treatment and advanced treatment of wastewater since that time. A summary of results using filtration on a variety of treated effluents is given in Table 14A.

Table 14A. Effluent Quality from Conventional Filtration of Various Biologically Treated Wastewaters*

Influent Source	Filter TYPE	Filter Influent (mg/l)		Filter Effluent (mg/l)		Reference
		BOD	TSS	BOD	TSS	
Activated Sludge	Gravity mixed media	15-20	10-25	4-10	2-5	70
Activated Sludge	multi-media	11-50	28-126	3-8	1-17	70
Extended Aeration plus settling	pressure, multi-media	7-36	30-2180	1-4	1-20	70
Trickling Filter	Gravity, sand	15-130	8-75	2-74	1-27	63, 65
Activated Sludge with Clarifier	multi-media	-	18 (AVE)	-	2.4 (AVE)	67
Contact Stabilization (raw waste includes cannery)	mixed media	-	-	2-4	2-8	68
Miscellaneous	sand (slow and rapid)	10-50	15-75	2-6	3-10	62, 64, 73
Trickling Filter with Nitrification	sand	-	-	9-28	3-7	57

*See also, performance data in references 24, 25, 65, 66, and 69.

Problems and Reliability

The reliability of all principal types of filters seems to be well established by long-term use as a municipal waste treatment system. When the sand filter is operated intermittently there should be little danger of operating mishap with resultant discharge of untreated effluent or poor quality effluent. The need for bed cleaning becomes evident with the reduction in quality of the effluent or in the increased cycle time, both of which are subject to monitoring and control. Operation in cold climates is possible as long as the appropriate adjustment in the surface of the bed has been made to prevent the bed from clogging due to freezing water.

With larger sized slow sand filters, the labor in maintaining and cleaning the surface should receive adequate consideration. Cleanup of the rapid sand filter requires backwashing of the bed of sand with a greater quantity of water than used for the slow sand filter. Backwashing is an effective cleanup procedure and the only constraint is to minimize the washwater required in cleanup, since this must be disposed of in some appropriate manner other than discharging it to a stream. Chlorination, both before and after sand filtering, particularly in the use of rapid filters, may be desirable to minimize or eliminate potential odor problems and slimes that may cause clogging.

The rapid sand filter has been used extensively in water treatment plants and in municipal sewage treatment for advanced treatment; thus, its use in advanced treatment of biological treated effluents from poultry processing plants appears to be a practical method of reducing BOD5 and suspended solids to levels below those expected from conventional biological treatment.

Microscreen-Microstrainer

A microstrainer is a filtering device that uses a fine mesh screen on a partially submerged rotating drum to remove suspended solids and thereby reduce the BOD5 associated with those solids, as shown in Figure 15. The microstrainer is used as a advanced treatment following the removal of most of the solids from the waste water stream, and suspended solids and BOD5 have been reduced to 3 to 5 mg/l in applications on municipal waste.[15] As mentioned earlier, one poultry processing plant using microscreens as advanced treatment consistently achieved a BOD5 in the effluent of less than 15 mg/l and frequently below 5 mg/l. The effluent quality obtained by the microstrainer at the poultry processing plant is consistent with data reported by other situations in which microstrainers have been used to remove solids from biological effluents. The percent removal of suspended solids by a microstrainer are related to the size of the aperture of the screen. Fifty to 60-percent removals can be anticipated with a 23-micron strainer and 40 to 50-percent removals with a 35-micron strainer.[24] The microstrainer effluent quality from a number of studies indicated suspended solids

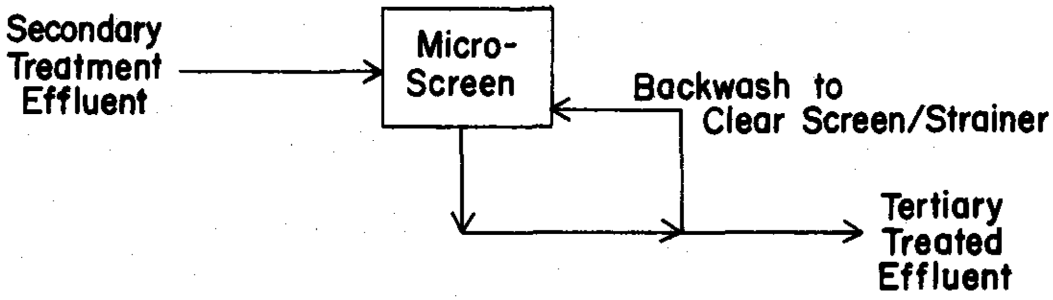

Figure 15. Microscreen/Microstrainer

concentrations of 6 to 8 mg/l when activated sludge effluent was tested, and 15 to 40 mg/l when a trickling filter effluent was treated.[24]

Technical Description

The microstrainer is a filtration device in which a stainless steel microfabric is used as the filtering medium. The steel wire cloth is mounted on the periphery of a drum which is rotated partially submerged in the waste water. Backwash immediately follows the deposition of solids on the fabric, and in one installation, this is followed by ultra-violet light exposure to inhibit microbiological growth. The backwash water containing the solids amounts to about 3 percent of the waste water stream and must be disposed of by recycling to the biological treatment system.[28] The drum is rotated at a minimum of 0.7, and up to a maximum of 4.3 revolutions per minute. The concentration and percentage removal performance for microstrainers on suspended solids and BOD_5 appear to be approximately the same as for sand filters.

Development Status

While application of microscreens for filtration is more recent than that of conventional filters, there is general information available on the performance of microstrainers and on tests involving the use of them. In addition to its use on poultry processing waste, there has been a substantial increase in full-scale applications at municipal facilities. As with conventional filters, the requirements for effluent quality have not necessitated such installations in the past. The economic comparisons between sand filters and microstrainers are inconclusive; the mechanical equipment required for the microstrainer may be a more relevant factor than the space requirement for the sand filter at the present time. Table 14B provides a brief summary of the general performance achieved by microstrainers on biologically treated wastewater.

Problems and Reliability

The reported performance of the microstrainer fairly well establishes the reliability of the device and its ability to remove suspended solids and associated BOD_5. Operating and maintenance problems have not been reported; this is probably because, in large part, of the limited use of the device in full-scale applications. As a mechanical filtration device requiring a drive system, it would have normal maintenance requirements associated with that kind of mechanical equipment. As a device based on microopenings in a fabric, it would be particularly intolerant to any substantial degree of grease loading.

Table 14B. Performance of Microstrainers in Tertiary Treatment of Biologically Treated Wastewater

Influent (mg/l)		Effluent (mg/l)		Reference
BOD	TSS	BOD	TSS	
15-20	20-25	3-5	6-8	24
10-30	10-40	3-8	3-10	73
-	6-54	-	2-14	70*
15-25	15-30	4-5	3-7	poultry plant

*Data from 22 municipal installations including several with wasteload contributions from unidentified industrial sources.

Nitrogen Control

Nitrification

Nitrification is the biological conversion of nitrogen in organic or inorganic compounds from a more reduced to a more oxidized state. In the field of water pollution control, nitrification usually is referred to as the process in which ammonium ions are oxidized to nitrite and nitrate sequentially. When aeration systems are used to treat an industrial wastewater, some nitrification and ammonia stripping can be expected to occur naturally and thus reduce the quantity of ammonia requiring further removal. This "incidental" treatment has been observed for treated effluents from several types of meat products plants where concentrations of about 10 to 50 mg/l of ammonia have been found, while partially treated wastes have concentrations in excess of 100 mg/l. Ammonia removal is becoming more important since it is recommended that the concentration of un-ionized ammonia (NH3) in surface water be no greater than 0.02 mg/l at any time or place. Because ammonia may be indicative of pollution, it is recommended that ammonia nitrogen in public water supply sources not exceed 1.5 mg/l.[42]

Technical Description

Nitrification can be used to reduce the ammonia concentration of wastewaters. Figure 16 is a schematic of the nitrification process. The equations following the figure indicate the nitrification sequence and organisms involved.

Adequate process design and operating control are necessary for consistent results. Factors that affect the nitrification process include concentration of nitrifying organisms, temperature, pH, dissolved oxygen concentration, and the concentration of any inhibiting compounds.[43] The nitrifying organisms of significance in waste management are autotrophic, with Nitrosomes and Nitrobacter being the major bacterial genera that are involved. Nitrifying bacteria are ubiquitous in the soil although they may not be part of untreated wastes.

Nitrifying organisms are aerobic and adequate dissolved oxygen (DO) in the aeration system is necessary. DO concentrations should be above 1 to 2 mg/l to assure consistent nitrification. Nitrification is affected by the temperature of the system. Available information provides conflicting data on the performance of nitrification systems at low temperatures.

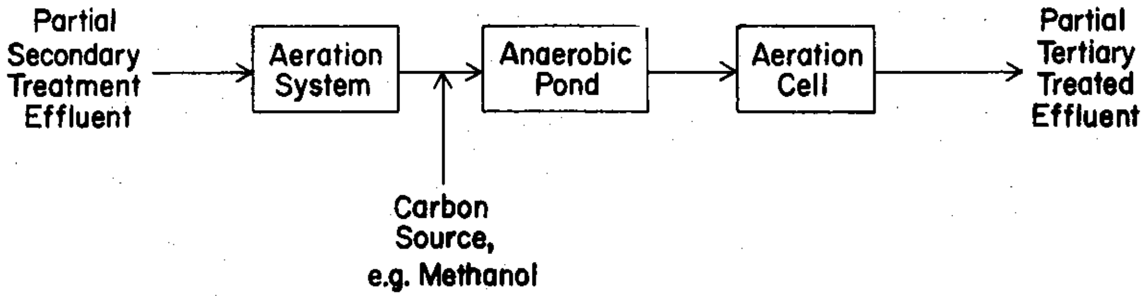

Figure 16. Nitrification/Denitrification

Nitrification:

$NH_3 + O_2 \longrightarrow NO_2^- + H_3O^+$ (Nitrosomonas)

$2NO_2^- + O_2 \longrightarrow 2NO^-$ (Nitrobacter)

Denitrification (using methanol as carbon source)

$6H^+ + 6NO_3^- + 5CH_3OH \longrightarrow 5CO_2 + 3N_2 + 13H_2O$

Small amounts of N_2O and NO are also formed

(Facultative heterotrophs)

Although detailed studies are lacking, it should be possible to achieve nitrification at low temperatures and compensate for slower nitrifying organism growth rates by maintaining a longer solids detention time and hence larger nitrifying active mass in the system.**

The optimum pH for nitrification of municipal sewage has been indicated to be between 7.5 and 8.5. Nitrification can proceed at low pH levels but at less than optimum rates. During nitrification, hydrogen ions are produced and the pH decreases, the magnitude of the decrease being related to the buffer capacity of the system. A decrease in pH is a practical measure of the onset of nitrification.

High concentrations of un-ionized ammonia (NH3) and un-ionized nitrous acid (H NO2) can inhibit nitrification. These compounds can be in the influent wastewater or can be generated as part of the nitrification process. The concentrations of un-ionized ammonia and nitrous acid that are inhibitory; and, the operational approaches to avoid such inhibition have been documented.** Using these approaches, it should be possible to operate nitrification systems that produce consistent results even with wastewaters having high nitrogen concentrations.

Development Status

While research on nitrification has been conducted for a number of years, most pilot and full-scale studies have been initiated since 1970. Even though there has been a relatively short time frame of evaluation, nitrification is already a very readily described process for which treatment system designs can be implemented. Most of the applications have been on municipal effluents, but concentrations of ammonia in these effluents ranged between 20 mg/l and 800 mg/l. Ammonia concentrations in biologically treated effluents from various types of meat and poultry packing and processing plants have been found to range between 10 mg/l and 200 mg/l or more, and thus fall within the limits of the nitrification investigations cited below in Table 14C. Like any other "advanced" level of treatment, nitrification requires more operational attention than has generally been given to simple biological treatment, but the applicability of the process to all types of meat product effluents appears very reasonable.

Problems and Reliability

As discussed above, emphasis on nitrification as a treatment process has been relatively recent. Except for incidental ammonia removal facilities, nitrification processes have not been specifically applied in this industry. A pilot facility may be necessary to derive design and operating requirements before any full-scale installations are constructed. Water temperature, particularly below 10°C, is an apparent constraint for which an increase in sludge age or solids retention time (via sludge recycle) has been shown to compensate. Maintenance of adequate

Table 14C. Selected Results for Nitrogen Control in Effluents

Nitrogen Control[a] Mode	Parameter(s) Measured	Effluent Concentration (mg/l)	Reference
Extented aeration (N)	Total Kjeldahl Nitrogen	0.5-10.0	60
Clarification (DN)	Total nitrogen	5.0	47
Denitrification Tower	Ammonia	0.8-1.2	47
Nitrification	Ammonia	1.7 June- 1.9 January	47
Single Stage (DN)	Total nitrogen	3.8-5.9	47
Submerged Filter (N)	Ammonia	0.3-1.2	59
Rotating Disc (N)	Ammonia	1.6-2.5	58[b]
Trickling Filter Tower (N)	Ammonia	1.2-1.9	57[c]
Aerated sludge and anaerobic reactor (DN)	Ammonia nitrates	0.0-1.5 0.0	53
Breakpoint (N) chlorination	Ammonia	1.0	71
Activated Sludge (N)	Ammonia	0.0-2.7	72

[a] Note (N) refers to nitrification system and (DN) refers to nitrification-denitrification

[b] Influent ammonia concentrations range of 450-800 mg/l

[c] Range of data for 18 month period; test site in Michigan with seasonal data collected for approximately two weeks each season.

dissolved oxygen levels is also important since nitrification activity effectively ceases at DO levels below 1.0 mg/l. The process is relatively delicate and should require attentive operation.

Nitrification/Denitrification

This two-step process of nitrification and denitrification, Figure 16, is of primary importance for removal of the residual ammonia and nitrites-nitrates in biological treatment systems. Removal of the above soluble nitrogen forms is virtually complete, with the nitrogen gas as the end product. This process differs from ammonia stripping and nitrification in that the latter processes convert or remove only the ammonia content of a wastewater. Table 14C shows a summary of results in removing both ammonia and other nitrogen from wastewaters.

Technical Description

As described in an earlier section, nitrification is carried out under controlled process conditions by aerating the wastewater sufficiently to assure the conversion of the nitrogen in the wastewater to the nitrite-nitrate forms. The denitrification process reduces the oxidized nitrogen compounds (nitrites and nitrates) to nitrogen gas and nitrogen oxides thereby reducing the nitrogen content of the wastewater as the gases escape from the liquid.

Denitrification takes place in the absence of dissolved oxygen. Additional important factors affecting denitrification include carbon source, and temperature. Denitrification is brought about by heterotrophic facultative bacteria. Generally, high denitrification rates require the addition of a biodegradable carbon source such as sugar, ethyl alcohol, acetic acid, or methanol. Methanol is the least expensive and performs satisfactorily. Investigators working on this process have found that a 30-percent excess of methanol over the stoichiometric amount is required.[24,30]

Denitrification does not take place until the dissolved oxygen concentration of the wastewater is near or at zero. The organisms responsible for denitrification are ubiquitous and can adapt to pH levels within the range of about 6.0 to 9.0. As with any biochemical process, denitrification exhibits a temperature dependency, although within the range of 20°C to 30°C little effect has been observed. Denitrification activity decreased when the temperature decreased to 10°C. Denitrification can be operated at low temperatures by designing systems with long solids retention times (SRT). For denitrification systems, an SRT of at least 3 to 4 days at 20°C and 30°C and 8 days at 10°C has been recommended.[43] Nitrate reduction efficiency in denitrification can be controlled by adjusting the SRT of the process to assure adequate numbers of denitrifying organisms and adequate denitrification rates as environmental conditions change.

In a sequential nitrification/denitrification process (Figure 16), the wastewater from the denitrification step may be sent to a second aeration basin following denitrification, where the nitrogen and nitrogen oxide are readily stripped from the waste stream as gases. The sludge from each stage is settled and recycled to preserve the organisms required for each step in the process. The processes of nitrification and denitrification can occur simultaneously in aeration systems in which both aerobic and anaerobic portions occur.

Development Status

Nitrification/denitrification has not been applied to poultry processing wastewaters as yet. The process has been evaluated in a number of bench and pilot-scale studies on a variety of wastes. Further demonstration on a plant scale will establish the potential of the process.[43,45] Anaerobic processes evaluated as part of the denitrification sequence have included anaerobic ponds, an anaerobic activated sludge system, and anaerobic filters. Efficient nitrogen removals from agricultural subsurface drainage water were accomplished with an anaerobic filter. In Germany, the successful elimination of nitrogen from sewage and digester supernatant was achieved by first nitrifying the wastes and then denitrifying in a separate vessel. Two and three sludge systems have been shown to be feasible for the nitrification/denitrification process. A pilot model of a three-stage system using this process was developed at the Cincinnati Water Research Laboratory of the EPA and is being built at Manassas, Virginia.[31] Observations of treatment lagoons indicate that the suggested reactions are occurring in present systems. Also, Halvorson[32] reported that Pasveer achieved success in denitrification by carefully controlling the reaction rate in an oxidation ditch, so that dissolved oxygen levels drop to near zero just before the water is reaerated by the next rotor. Denitrification of animal wastes has been evaluated and shown to be feasible.[43 45] Depending upon how a biological system such as an oxidation ditch is operated, the nitrogen loss can range from 30 to about 90 percent.[46]

Problems and Reliability

It would appear that there would be no exceptional maintenance or residual pollution problems associated with this process in view of the mechanisms suggested for its implementation at this time. For some of the newer concepts, i.e., denitrification by fluidized bed reactors, operational difficulties due to biological matting of the carbon filter bed have been encountered in bench scale tests. These difficulties may prove negligible under field conditions, since continuing new inputs of biota would enhance the likelihood of a balance in growth factors. Completely mixed reactors with methanol addition appear to be favored from the standpoints of operational control and long-term reliability in nitrogen removal. However, a final aeration chamber may be required to offset increases in effluent BOD due to methanol leakage from the denitrification reactor. As with nitrification, sludge return has also been shown to assist system stability in the denitrification mode.[47]

Ammonia Stripping

Ammonia stripping is a physical process and amounts to a modification of the simple aeration process for removing gases in water, Figure 17. Following pH adjustment, the waste water is fed to a packed tower and allowed to flow down through the tower with a countercurrent air stream introduced at the bottom of the tower flowing upward to strip the ammonia. Ammonia-nitrogen removals of up to 98 percent and down to concentrations of less than 1 mg/l have been achieved in experimental ammonia stripping towers.

Technical Description

Because of the chemistry of ammonia, the pH of the waste water from a biological treatment system should be adjusted to between 11 and 12 and the waste water is fed to a packed or cooling tower type of stripping tower.[43] As pH is shifted to above 9, the ammonia is present as a soluble gas in the waste water stream, rather than as the ammonium ion. Ammonia-nitrogen removal of 90 percent has been achieved on a municipal effluent with countercurrent air flows between 1.8 and 2.2 cubic meters per liter (250 and 300 cubic feet per gallon) of waste water in an experimental tower with hydraulic loadings between 100 and 125 liters per minute per square meter (2.5 and 3 gallons per minute per square foot). The best performance was achieved with an air rate of 5.9 cubic meters per liter (800 cubic feet per gallon) and a hydraulic loading of 33 liters per minute per square meter (0.8 gallons per minute per square foot); the ammonia concentration was reduced to less than one part per million at 98-percent removal. The high percentage removal of ammonia-nitrogen is achieved only at a substantial cost in terms of air requirements and stripping tower cross-sectional area.[24]

Development Status

The ammonia stripping process (using both steam and air as the stripping medium) has been practiced on "sour water" in the petroleum refinery industry. The only significant difference between the petroleum refinery application and that on poultry processing waste would be the comparatively small size of stripping tower required for poultry plants, compared to the refinery. The air stripping of ammonia from biological effluent is reported primarily on a pilot plant basis using various equipment.[51] Two large-scale installations of ammonia stripping of lime-treated waste water are reported at South Tahoe, California, and Windhoek, South Africa.[15,24] The South Tahoe ammonia stripper was rated at 14.2 M liters per day (3.75 MGD) and was essentially constructed as a cooling tower structure, rather than as a cylindrical steel tower which might be used in smaller sized plants.[74]

Thus, although there is no reported use of ammonia stripping on poultry processing plant waste, the technology is technically well established and implementation, when limitations require it, would be a possible alternative, particularly for well-stabilized biological effluents.

Problems and Reliability

The reliability of this process has been found reasonable in petroleum refinery applications of the process over many years. Although the source of the ammonia may be different and there may be other contaminants in the water stream, this should not affect the established reliability of this process. The experience of other users of the process will have identified potential problems, and, presumably, the solutions for these problems can be found. Among the maintenance requirements would be those normally associated with the mechanical equipment involved in pumping the waste water to the top of the tower where the feed is introduced to the tower, and in maintaining the air blowers. The tower fill would undoubtedly be designed for the kind of service involved in treating a waste water stream that has some potential for fouling. Problems with temperature and tower scaling are also documented. Recent advances in possible anti-scale chemicals appear promising.[50] It has also been observed that efficiency losses due to low temperature can be at least partially overcome by breakpoint chlorination, by housing the stripping tower, or heating the water or air with waste steam. The most recent advance in the process includes an ammonia recovery step and preliminary results indicate that most problems with stripping towers have been overcome.[74]

Breakpoint Chlorination

When wastewater containing ammonia is treated with chlorine, a chemical reaction toward the formation of chloramines is observed. Further chlorination to the "breakpoint" (free chlorine residuals predominate) converts the chloramines to nitrogen gas which is lost to the atmosphere.

Technical Description

A detailed discussion of the chemistry of breakpoint chlorination is readily found in numerous textbooks and references on disinfection.[43,74] In summary, chlorine is added (as a gas or liquid) to wastewaters containing ammonia in amounts sufficient to cause the release of nitrogen gas. For each part of ammonia, about nine parts of chlorine are required to drive the chemical reactions from monochloramines through to nitrogen gas. At proper chlorine feed rates, a contact time of 30 minutes or less is necessary.

Development Status

Breakpoint chlorination is a well-understood and well-documented technology. Applications have centered on advanced treatment of biological municipal wastes, although the concept has been found to be useful as a "polishing" mode in conjunction with ammonia stripping. It appears from the literature that the process offers a viable alternative for ammonia control for ammonia concentrations as are encountered in municipal biological effluents.

Problems and Reliability

Under low pH (less than 6.0) conditions, chlorination of ammonia may produce nitrogen trichloride which is highly odorous. The removal of ammonia is not adversely affected if it becomes necessary to add a base (sodium hydroxide) to overcome acid conditions. Under field conditions described in the literature, the natural alkalinity of the wastewater being treated proved to be sufficient to preclude depression of pH below 6.0. The process operates equally well in the temperature range of 5°C to 40°C; more chlorine may be needed at lower temperatures. Process efficiencies consistently range between 95 and 99 percent and the process is easily adapted to complete automation which helps assure quality and operational control. Excessive use of chlorine can result in substantial relative increases in dissolved solids (choride salts) in effluents.

Spray/Flood Irrigation

A no discharge level for poultry processing waste water can be and is being achieved by the use of spray or flood irrigation on relatively flat land, surrounded by dikes to prevent runoff. A cover crop of grass or other vegetation is maintained on the land. Specific plant situations may preclude the installation of irrigation systems; however, where they are feasible, the economics can be very favorable and serious consideration should be given to them.

Technical Description

Wastes are disposed of in spray or flood irrigation systems by distribution through piping and spray nozzles over relatively flat terrain or by the pumping and disposal through the ridge-and-furrow irrigation systems which allow a certain level of flooding on a given plot of land, Figure 18. Pretreatment for removal of solids is advisable to prevent plugging of the spray nozzles, or deposition in the furrows of the ridge-and-furrow system, or collection of solids on the surface, which may cause odor problems or clog the soil. Therefore, the BOD_5 will usually have already been reduced in preliminary treatment (primary plus some degree of biological treatment) upstream from the distribution system.

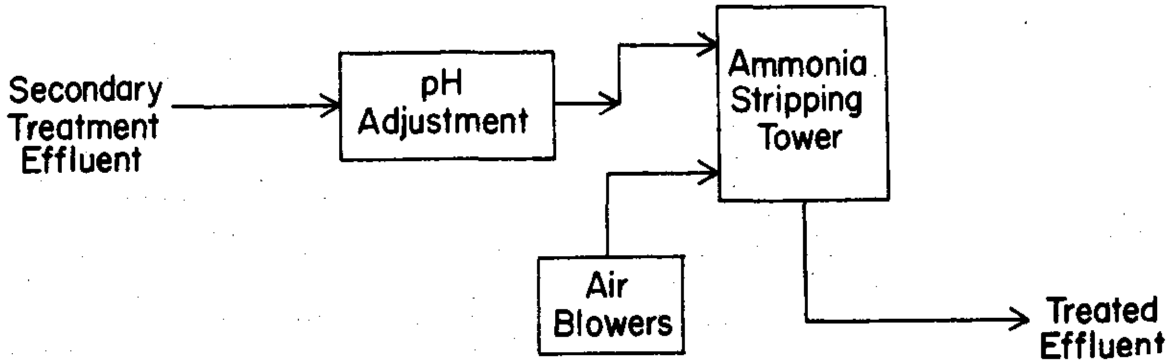

Figure 17. Ammonia Stripping

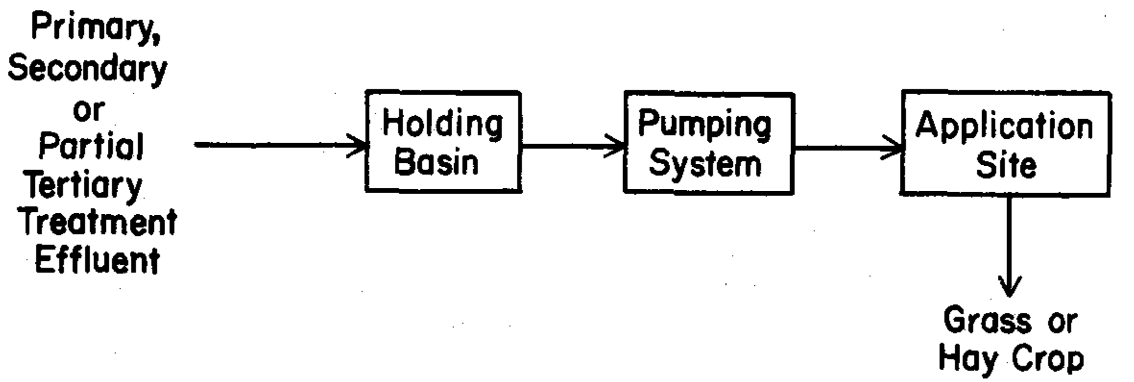

Figure 18. Spray/Flood Irrigation System

In flood irrigation, the waste loading in the effluent would be limited by the waste loading tolerance of the particular crop being grown on the land, or it may be limited by the soil conditions or potential for vermin or odor problems.

Waste water distributed in either manner percolates through the soil and the organic matter in the waste undergoes a biological degradation. The liquid in the waste stream is either stored in the soil or leached to a groundwater aquifer and discharged into the groundwater. Approximately ten percent of the waste flow will be lost by evapotranspiration (the loss caused by evaporation to the atmosphere through the leaves of plants).[29]

Spray runoff irrigation is an alternative technique which has been tested on the waste from a small meat packer[33] and on cannery waste.[29] With this technique, about 50 percent of the waste water applied to the soil is allowed to run off as a discharge rather than no discharge, as discussed here. The runoff or discharge from this type of irrigation system is of higher quality than the waste water as applied, with BOD_5 removal of about 80 percent; total organic carbon and ammonia nitrogen are about 85 percent reduced, and phosphorus is about 65 percent reduced.

The following factors will affect the ability of a particular land area to absorb waste water: 1) character of the soil, 2) stratification of the soil profile, 3) depth to groundwater, 4) initial moisture content, and 5) terrain and ground cover.[29]

The potentially greatest concern in the use of irrigation as a disposal system is the total dissolved solids content and particularly the salt content of the waste water. A maximum salt content of 0.15 percent is suggested in the literature. Some plants may require dilution upstream from the irrigation system to reduce the dissolved solids and the salt content to acceptable levels for continuing application of the waste water on land. However, the average plant should have no problem with salt, since the average salt content of poultry processing waste waters is about a factor of fourteen less than the literature's suggested limit of 0.15 percent.

An application rate of up to 330 liters per minute per hectare (35 gallons per minute per acre) has been suggested in determining the quantity of land required for various waste water flows. This amounts to almost 5 cm (2 inches) of moisture per day, and is relatively low in comparison with application rates reported in the literature for various spray irrigation systems. However, soils vary widely in their percolation properties and experimental irrigation of a small area is recommended before a complete system is built. In this report, land requirements were based on 2.5 cm (1.0 inch) applied per operating day for six months of the year with lagoon storage for six-months' accumulation of waste water.

If poultry processing plant waste waters were being used as the sole nitrogen source for corn growth, the waste waters would probably have to contain 250 to 500 mg/l nitrogen. For lower nitrogen concentrations, the corn crop would probably be damaged by flooding or by heavy overwatering before the corn received sufficient nitrogen from the waste waters. This is based on the assumptions that one bushel of corn requires 454 gm (1 pound) of nitrogen, that the yield is 120 bushels of corn per acre, and that the corn would require from 25 to 75 cm (10 to 30 inches) of water per season.[34] This water rate amounts to 3.1 to 9.5 cm (1.2 to 3.7 inches) of water per two weeks, over a four-month season.

The economic benefit from spray irrigation is estimated on the basis of raising two crops of grass or hay per season with a yield of 13.4 metric tons of dry matter per hectare (six tons per acre) and valued at $22 per metric ton ($20 per ton). These figures are reportedly conservative in terms of the number of crops and the price to be expected from a grass or hay crop. The supply and demand sensitivity as well as transportation problems for moving the crop to a consumer all militate against any more optimistic estimate of economic benefits.[35]

Cold climate uses of spray irrigation may be subject to more constraints and have greater land requirements than plants operating in more temperate climates. However, a meat packer in Illinois reportedly operated an irrigation system successfully. Research indicates that wastes have been successfully disposed of by spray irrigation from a number of other industries.[29] Plants located in cold climates or short growing areas should consider two crops for spray irrigation. One could be a biological crop such as corn and the other a grass crop. The grass crop could tolerate heavier volume loadings without runoff and erosion, and also would extend the irrigation season from early spring to possibly late November. Corn, although a more valuable crop, tolerates irrigation in cold climate areas only during the summer months.

North Star found in its survey of the poultry, meat, and rendering industries that the plants located in the arid regions of the Southwest were most inclined to use spray or flood irrigation systems.

Problems and Reliability

The long-term reliability of spray or flood irrigation systems is a function of the ability of the soil to continue to accept the waste, and thus reliability remains somewhat open to question. Problems in maintenance are primarily in the control of the dissolved solids level and salinity content of the waste water stream and also in climatic limitations that may exist or develop. Many soils may be improved by spray irrigation.

Ion Exchange

Ion exchange, as a advanced waste treatment, is used as a deionization process in which specific ionic species are removed from the waste water stream, Figure 19. Ion exchange could be used to remove salt (sodium chloride) or nutrients (ammonia) from waste waters. Ion exchange resin systems have been developed to remove specific ionic species, to achieve maximum regeneration operating efficiency, and to achieve a desired effluent quality. In the treatment of poultry processing waste, the desired effluent quality would be a waste water with a salt concentration of less than 300 mg/l. Ion exchange systems are available that will remove up to 90 percent of the salt in a water stream.[15] They can also be used to remove nitrogen.[75]

Technical Description

The deionization of water by means of ion exchange resin involves the use of both cation and anion exchange resins in sequence or in combina
tion to remove an electrolyte such as salt.

$$RSO_3H + NaCl \qquad RSO_3Na + HCl$$
$$R\text{-}OH + HCL \qquad R\text{-}Cl + H_2O$$

where R represents the resin.

The normal practice in deionization of water has been to make the first pass through a strong acid column, cation exchange resins, in which the first reaction shown in the equations occurs. Effluent from the first column is passed to a second column of anion exchange resin to remove the acid formed in the first step, as indicated in the second reaction. As indicated in the two reactions, the sodium chloride ions have been removed as ionic species. A great variety of ion exchange resins have been developed over the years for specific deionization objectives for various water quality conditions.

Waste water treatment with ion exchange resins has been investigated and attempted for over 40 years; however, recent process developments in the treatment of biological effluent have been particularly successful in achieving high-quality effluent at reasonable capital and operating costs. One such process is a modification of the Rohm and Hass, Desal process.[15] In this process a weak base ion exchange resin is converted to the bicarbonate form and the biological effluent is treated by the resin to remove the inorganic salts. After this step, the process includes a flocculation/aeration and precipitation step to remove organic matter; however, this should be unnecessary if a sand filter or comparable system is used upstream of the ion exchange system. The effluent from the first ion exchange column is further treated by a weak cation resin to reduce the final dissolved salt content to approximately 5 mg/l. The anion resin in this process is regenerated with aqueous ammonia, and the

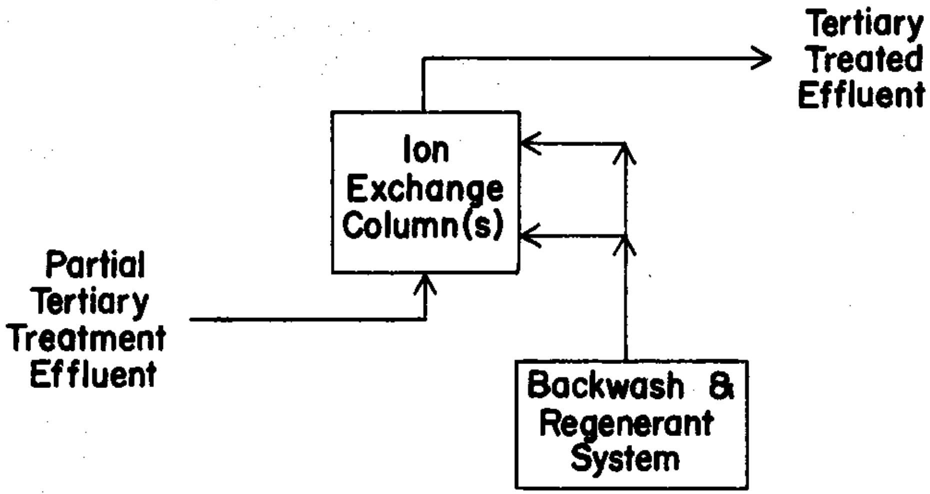

Figure 19. Ion Exchange

cation resin with an aqueous sulfuric acid. The resins did not appear to be susceptible for fouling by the organic constituents of the biological effluent used in this experiment.

Other types of resins are available for ammonia, nitrate, or phosphate removal as well as for color bodies, COD and fine suspended matter.[54] Removal of these various constituents can range from 75 percent to 97 percent, depending on the constituent.[24]

The cycle time on the ion exchange unit will be a function of the time required to block or to take up the ion exchange sites available in the resin contained in the system. Blockage occurs when the resin is fouled by suspended matter and other contaminants. The ion exchange system is ideally located at the end of the waste water processing scheme, thus having the highest quality effluent available as a feedwater.

To achieve a recyclable water quality, it may be assumed that less than 500 mg/l of total dissolved solids would have to be achieved. Of the total dissolved solids, 300 mg/l of salt are assumed to be acceptable. To achieve this final effluent quality, some portion or all of the waste water stream would be subjected to ion exchange treatment.

The residual pollution will be that resulting from regeneration of the ion exchange bed. The resin systems, as indicated earlier, can be tailored to specific ion removal and efficient use of regeneration chemicals, thus minimizing liquid wastes from the regeneration step.

Development Status

Ion exchange as a unit operation is well established and commonly used in a wide range of applications in water treatment and water deionization. Water softening for boiler feed treatment and domestic and commercial use is probably the most widespread use of ion exchange in water treatment. Deionization of water by ion exchange is used to remove carbon dioxide; metal salts such as chlorides, sulfates, nitrates, and phosphates; silica; and alkalinity. Specific resin applications such as in waste water treatment have not been widespread up to the present time, since there has not been a need for such a level of treatment. However, processing development and experimental work have shown the capability of ion exchange systems to achieve the water quality that may be required for irrigation and closed-loop water recycle systems.

Part of the economic success of an ion exchange system in treating poultry processing plant waste will probably depend on a high-quality effluent being available as a feed material. This again, can be provided by an upstream treatment system such as sand filtration to remove a maximum of the particularly bothersome suspended organic material. However, the effect of a low-quality feed would be primarily economical because of shorter cycle times, rather than a reduction in the overall effectiveness of the ion exchange system in removing a specific ionic species such as salt.

Problems and Reliability

The application of the technology in waste treatment has not been tested and therefore the reliability in that application has yet to be established. The problems associated with ion exchange operations would primarily center on the quality of the feed to the ion exchange system and its effect on the cycle time. The operation and control of the deionization-regeneration cycle can be totally automated, which would seem to be the desired approach. Regeneration solution is used periodically to restore the ion exchange resin to its original State for continued use. This solution must be disposed of following its use and that may require special handling or treatment. The relatively small quantity of regenerant solution will facilitate its proper disposal by users of this system.

SECTION VIII

COST, ENERGY, AND NONWATER QUALITY ASPECTS

SUMMARY

The waste water from poultry dressing and processing plants is amenable to treatment in biological and advanced waste treatment systems to achieve low levels of pollutants in the final effluent. In-plant controls, byproduct recovery operations, and strict water management practices can be highly effective in reducing the waste load and waste water flow from any poultry plant. Water management practices will reduce the requisite size of biological and advanced treatment systems and improve their waste reduction effectiveness.

For purposes of estimating waste treatment costs, the subcategories of the poultry processing industry are divided into groups based on size wherever the data indicated such a division as appropriate. The plant size division is based on the number of birds killed within each subcategory, except for plants that further process only, which are grouped by output of finished product. This division of the industry subcategories does not imply the need to categorize according to size: the categorization rationale does not support such a basis for categorizing the industry. Total investment costs and unit operating costs for waste treatment, on the other hand, will vary with plant size. Costs that represent each subcategory situation could not always be determined on the basis of one "typical" plant size, given the wide range of production and waste water flow within most of the subcategories. All costs are reported in 1973 dollars.

Waste water treatment investment cost is primarily a function of waste water flow rate. Cost per unit of production for waste treatment will vary with total investment cost and the production rate. Therefore, the subcategory treatment costs have been estimated on the basis of "typical" plants for each size. A "typical" plant is a hypothetical plant with an average production rate and with a waste water flow rate as indicated by the data in Table 15. The average raw waste load for each subcategory is reported in Sections IV and V of this report. The raw waste load per unit LWK or FP does not vary with plant size within each subcategory.

A capital investment will be required of most plants with treatment systems to upgrade or install waste water treatment to achieve the waste water quality specified for 1977 and 1983. This additional investment required of a "typical" plant for each size in a subcategory to meet the proposed limitations is presented in Table 16. The capital costs will have to be incurred both for the 1977 and the 1983 limitations, as indicated in Table 16.

Table 15. Typical Plant Operating Parameters Used for Estimating Cost of Meeting Effluent Limitations

Plant Type	Production Birds/Day	Waste Water Volume MM liters/day	Waste Water Volume MGD
Chicken			
Small	51,000	1.794	0.474
Medium	95,000	3.38	0.893
Large	207,000	7.80	2.05
Turkey	12,000	1.30	0.342
Fowl			
Small	26,400	0.964	0.255
Large	65,000	2.37	0.627
Duck			
Small	3,000	0.272	0.072
Large	12,000	1.10	0.288
Further Processing Only	kg (lb) FP/Day		
Small	21,000 (47,000)	0.265	0.070
Large	77,000 (170,000)	0.965	0.255

Table 16. Additional Investment Cost for "Typical" Plants in Each Subcategory to Implement Each Indicated Level of Treatment, No Previous Expenditure Included

Plant Type	1977 Limitations	1983 Limitations	New Source Standards	Irrigation
Chicken				
Small	$ 137,000	$ 428,000	$470,000	$183,000
Medium	172,000	542,000	640,000	323,000
Large	244,000	892,000	950,000	687,000
Turkey	126,000	366,000	400,000	138,000
Fowl				
Small	119,000	346,000	364,000	105,000
Large	154,000	458,000	539,000	235,000
Duck				
Small	89,000	259,000	227,000	35,000
Large	124,000	354,000	385,000	118,000
Further Processing Only				
Small	88,000	256,000	225,000	34,000
Large	119,000	346,000	364,000	105,000
Total Industry Cost	$13,874,000	$38,642,000	--	--

The estimated investment cost to achieve the 1977 limitations is based on an analysis of the treatment systems in use in the poultry process industry and their effectiveness on poultry plant waste water. The costs for a "typical" plant to implement waste treatment to achieve the 1977 limitations are based on the following:

- o Add an anaerobic lagoon or the equivalent, or expend the same dollars on revisions of present treatment systems by adding lagoon capacity, mechanical aeration, final clarifier or similar option.

- o Install chlorination for the final effluent.

The following provide the basis for estimating the cost for the "typical" plant to implement waste treatment to achieve the proposed 1983 waste water limitations:

- o 50 percent of the plants with waste treatment will have to add dry offal handling systems.

- o 50 percent of the plants will have to install improved primary treatment such as dissolved air flotation.

- o Install a microscreen or sand filter or equivalent, as a advanced treatment.

- o Install a nitrification system or ammonia stripping equipment or the equivalent, as a advanced treatment.

The cost of the irrigation option is presented to demonstrate the economic attraction of a waste treatment system that produces no discharge. Irrigation by the small plant may be particularly attractive from an economic viewpoint.

The cost for new point sources of waste water includes a basic treatment system such as an anaerobic, aerated, aerobic lagoon system plus dissolved air flotation. The costs are based on the average waste water flow for each type of plant.

The total cost to the industry is estimated at $13.9 million for the 1977 limitations and $38.6 million for 1983. These are cost estimates that include the 50-percent factor based on the need of only half of the plants with waste treatment to add a dry offal handling system, and 50 percent to make significant improvements in primary treatment facilities.

The investment in additional waste treatment facilities involves the 26 percent of the industry with onsite treatment, less those plants that already meet the limitations. The investment cost per total number of birds killed per year varies from 0.5¢ to 6¢ for 1977 and 1.7¢ to 18¢ for 1983 among the various plants in the industry. This does not include the small-size duck processor whose costs for treating feedlot wastes will probably greatly exceed the treatment costs for the duck processing plant waste water. The plants that further process only will have a capital investment per annual unit of production of 0.3¢/kg (0.75¢/lb) for 1977 and 1¢/kg (2.2¢/lb) to meet 1983 limitations.

The additions to plant operating cost and total annual cost for plants to achieve the indicated level of treatment are listed in total dollars and per unit of production in Tables 17 and 18. The wide range in addition to unit costs is the result of the small duck plant. It should also be noted that the unit annual costs amount to between two and three times the unit operating costs because of the high investment cost of the treatment systems and the method of computing annual cost, using both 10-percent depreciation and 10-percent cost of capital as add-ons.

Generally speaking, neither the capital requirements nor the additions to the operating and total annual costs appear to exceed the capabilities of plants in the industry to raise the capital or to compete effectively and profitably and to earn a satisfactory return. Capital expenditures by the industry are reported to have been about $60 million per year for 1970, 1971, and 1972.[36] Waste treatment will require a higher share of these expenditures as the limitations are implemented.

The total energy consumption in waste water treatment by the poultry processing industry is of little consequence in comparison to the present total power consumption of gas and electricity. The waste treatment power consumption to achieve 1983 limitations amounts to 2.2 percent of the total consumption of fuel and electricity by poultry plants. Waste treatment power consumption amounts to about 12 percent of the electrical power consumption in poultry plants.

With the implementation of the proposed limitations, land becomes the primary waste sink instead of air and water. The waste to be landfilled can improve soils with nutrients and soil conditions contained in the waste. Odor problems can be avoided or eliminated in all treatment systems.

"TYPICAL" PLANT

The waste treatment systems applicable to waste water from the poultry processing industry can be used by all plants in the subcategories of the industry. A hypothetical "typical" plant was constructed for each size in each subcategory as the basis for estimating investment cost and total annual cost for the application of each waste treatment system. The costs were estimated and, in addition, effluent reduction, energy requirements, and nonwater quality aspects of the treatment systems were determined.

The waste treatment systems are applied on the basis of the plant constructs for each subcategory, as indicated previously in Table 15.

Table 17. Addition to the Total Annual Cost and Operating* Cost for a Plant in Each Subcategory to Operate Treatment System as Described

Plant Type	1977		1983		New Source		Irrigation	
	Operating	Annual	Operating	Annual	Operating	Annual	Operating	Annual
Chicken								
Small	$22,450	$49,850	$ 70,650	$183,650	$54,000	$148,000	$29,800	$66,400
Medium	26,800	61,200	95,100	237,900	67,100	195,100	35,000	99,600
Large	35,200	84,000	161,400	388,600	90,400	280,400	46,000	183,400
Turkey	20,700	45,900	60,900	159,300	48,300	128,300	27,700	55,300
Fowl								
Small	19,800	43,600	56,000	149,000	45,400	118,200	26,250	47,250
Large	24,600	55,400	79,300	201,700	59,700	167,500	32,000	79,000
Duck								
Small	16,450	34,250	41,860	57,600	35,300	80,700	22,900	29,900
Large	20,000	44,800	111,460	153,200	46,400	123,400	26,600	50,200
Further Processing Only								
Small	16,400	34,000	41,550	110,350	35,100	80,100	22,900	29,700
Large	19,800	43,600	55,900	148,900	45,400	118,200	26,200	47,200

*Total annual cost includes operating cost plus capital cost and depreciation in dollars per year. Total operating cost includes manpower and burden, supplies, chemicals, power, taxes, and insurance in dollars per year.

Table 18. Additions to the Annual Cost and Operating Cost Per Unit of Production for a Plant in Each Subcategory to Operate Treatment System as Described

Plant Type	1977		1983		New Source		Irrigation	
	Operating	Annual	Operating	Annual	Operating	Annual	Operating	Annual
Chicken, ¢/bird								
Small	0.18	0.39	0.55	1.44	0.42	1.16	0.23	0.52
Medium	0.11	0.26	0.4	1.0	0.28	0.82	0.15	0.42
Large	0.07	0.16	0.3	0.75	0.18	0.54	0.09	0.35
Turkey, ¢/bird	1.0	2.25	3.0	7.8	2.4	6.3	1.36	2.7
Fowl, ¢/bird								
Small	0.3	0.66	0.85	2.26	0.69	1.8	0.40	0.72
Large	0.15	0.34	0.49	1.24	0.37	1.03	0.20	0.49
Duck, ¢/bird								
Small	3.2	6.7	8.2	21.8	6.9	15.8	4.5	5.9
Large	1.0	2.2	2.8	7.5	2.3	6.0	1.3	2.5
Further Processing Only								
Small, ¢/kg (¢/lb)	0.31 (0.14)	0.64 (0.29)	0.78 (0.35)	2.10 (0.94)	0.65 (0.30)	1.50 (0.68)	0.43 (0.20)	0.56 (0.25)
Large, ¢/kg (¢/lb)	0.10 (0.05)	0.23 (0.10)	0.29 (0.13)	0.77 (0.35)	0.24 (0.11)	0.61 (0.28)	0.14 (0.06)	0.24 (0.11)

WASTE TREATMENT SYSTEMS

The waste treatment systems included in this report as appropriate for use on poultry processing plant waste water streams can be used, subject to specific operation constraints or limitations as described later, by most plants in the industry. The use of some treatment systems may be precluded from consideration by technical, physical, or economic impracticality for some plants.

The waste treatment systems, their uses, and typical range of effluent reduction associated with each are listed in Table 19.

The dissolved air flotation system can be used upstream of any biological treatment system. The use of chemicals will increase the quantity of grease removed from the waste water system, as indicated in Table 19.

The biological treatment systems are generally land intensive because of the long retention time required in natural biological processes. Mechanically assisted systems have reduced the land requirements, but increased the energy consumption and cost of equipment to achieve comparable levels of waste reduction. Some of the advanced systems are interchangeable. They can be used at the end of any of the biological treatment systems, as required, to achieve a specific effluent quality. Chlorination is included as a disinfection treatment.

The most feasible system for poultry processors to achieve no discharge at this time is flood or spray irrigation. Closing the loop to a total water recycle or reuse system may be technically feasible, but far too costly for consideration. The irrigation option does require large plots of accessible land--roughly 2.0 hectares/million liters (18 acres/thousand gallons) of waste water per day--and limited concentrations of dissolved solids. More detailed descriptions of each treatment system and its effectiveness are presented in Section VII--Control and Treatment Technology.

A study conducted by the Economic Research Service of the USDA reported the type of waste water treatment employed by 386 poultry plants.[1] The distribution between private onsite treatment and municipal treatment reported in this USDA study provided the basis for the data presented in Table 20 on industry waste water treatment practice by subcategory and plant size. The distribution among subcategories and sizes is based on North Star survey questionnaire data covering about 140 plants. The total number of 390 plants is based on an average of the number reported in three different sources and on information collected from the industry during this research program.[1,2,36]

There is a dominant waste treatment pattern among duck processors who almost always treat their own waste water; except for one plant, duck processing plants apparently include a duck feedlot

Table 19. Waste Treatment Systems, Their Use and Effectiveness

Treatment System	Use	Effluent Reduction
Dissolved air flotation (DAF)	Primary treatment or by-product recovery	Grease, 60% removal, to 100 to 200 mg/1 BOD_5, 30% removal SS, 30% removal
DAF with pH control and flocculants added	Primary treatment or by-product recovery	Grease, 95-99% removal BOD_5, 90% removal SS, 98% removal
Anaerobic + aerobic lagoons	Secondary treatment	BOD_5, 95% removal
Anaerobic contact process	Secondary treatment	BOD_5, 90-95% removal
Activated sludge	Secondary treatment	BOD_5, 90-95% removal
Extended aeration	Secondary treatment	BOD_5, 95% removal
Anaerobic lagoons + rotating biological contactor	Secondary treatment	BOD_5, 90-95% removal
Chlorination	Finished and disinfection	--
Sand filter	Tertiary treatment & secondary treatment	BOD_5, to 5-10 mg/1 SS, to 3-8 mg/1
Microstrainer	Tertiary treatment	BOD_5, to 10-20 mg/1 SS, to 10-15 mg/1
Ammonia stripping	Tertiary treatment	90-95% removal
Chemical precipitation	Tertiary treatment	Phosphorus, 85-95% removal, to 0.5 mg/1 or less
Spray irrigation	No discharge	Total
Flood irrigation	No discharge	Total
Ponding and evaporation	No discharge	Total
Nitrification and denitrification	Tertiary treatment	N, 85% removal

Table 20. Industry Breakdown by Subcategory, Size, and Type of Waste Treatment

Plant Type	Total Number of Plants	Private, On-Site Treatment		Municipal Treatment		No Treatment	
		Number of Plants	Percent of Subcategory	Number of Plants	Percent of Subcategory	Number of Plants	Percent of Subcategory
Chickens	222	64	29	153	69	5	2
Small	133	39		91		3	
Medium	82	23		57		2	
Large	7	2		5		0	
Turkey	112	22	20	89	79	1	1
Fowl	26	5	19	20	76	1	5
Small	18	3		14		1	
Large	8	2		6		0	
Ducks	10	9	91	1	9	0	0
Small	4	4		0			
Large	6	5		1			
Further Processing Only	20	2	10	18	90	0	0
Small	16	2		14			
Large	4	0					
Total	390	102	26.2	281	72.0	7	1.8

and its waste water. Likewise, a poultry plant that further processes only is almost always on municipal treatment. In fact, North Star found no further processing only plant with an onsite treatment system. Among the subcategories other than ducks and further processing only, between 20 and 30 percent of the plants apparently have onsite treatment. The number of plants indicated in Table 20 with no treatment and a waste water discharge to a stream is based on the data in the USDA study previously mentioned.

Irrigation of waste water was reported by one plant located in an arid region of the Western United States and by another in the East North Central region of the country. A microstrainer was observed in use as a final treatment device in one plant. It was found to be very effective in the removal of suspended solids. Seventeen plants reported using dissolved air flotation as a primary treatment. Chlorination was reportedly used as a finishing treatment by 14 plants among the respondents to the survey questionnaire.

TREATMENT AND CONTROL COSTS

In-Plant Control Costs

The cost of installation of in-plant controls is primarily a function of the specific plant situations. Building layout and construction design will largely dictate what can be done, how, and at what cost in regard to in-plant waste control techniques. The in-plant control costs included in the investment cost estimates are for water recirculation to the feather flow-away system for 1977 and dry offal handling and improved primary treatment for 1983.

Investment Costs Assumptions

The waste treatment system costs are based on the plant production, waste water flow and BOD_5 figures listed previously for "typical," but hypothetical, plants in each subcategory. Investment costs for specific waste treatment systems are largely dependent on the waste water flow or hydraulic load. Most of the lagoon systems are designed on BOD_5 loading, which has been shown to increase with increased water use, however, cost estimates based on flow are adequate for the purposes of this study.

Cost effectiveness data are presented in Figures 20 and 21, as the investment cost required to achieve the indicated BOD_5 removal with two different waste treatment systems at two levels of waste water flow. The low flow (Figure 20) is typical for the average size plants in the industry. The high flow (Figure 21) is more typical of the large plants in the industry. The raw waste reduction is based on the construct of idealized waste treatment systems with the incremental waste reduction achieved by adding treatment components to the system as indicated in

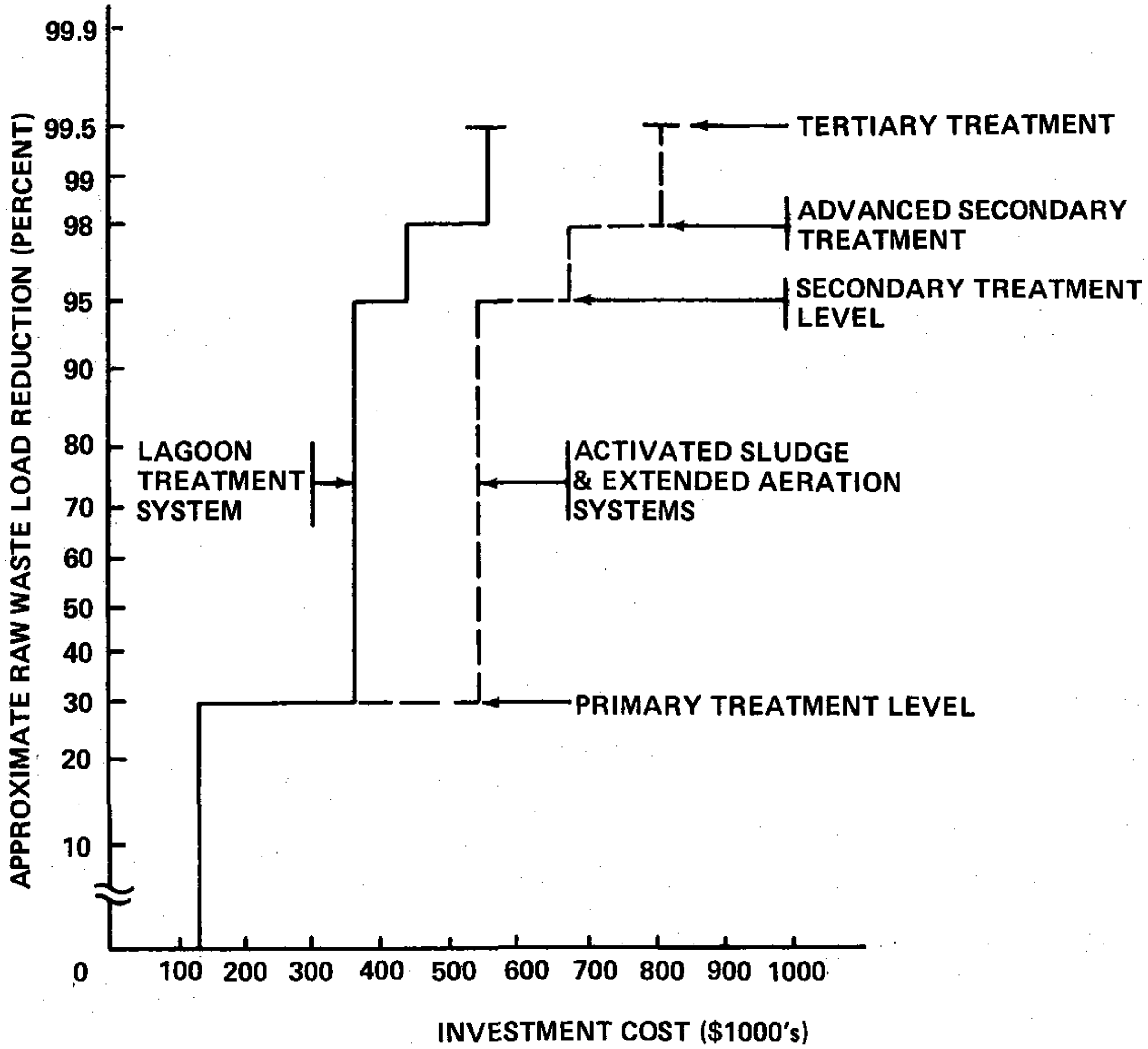

Figure 20. Waste Treatment Cost Effectiveness at Flow of 1.14 Million Liters/Day (0.300 MGPD)

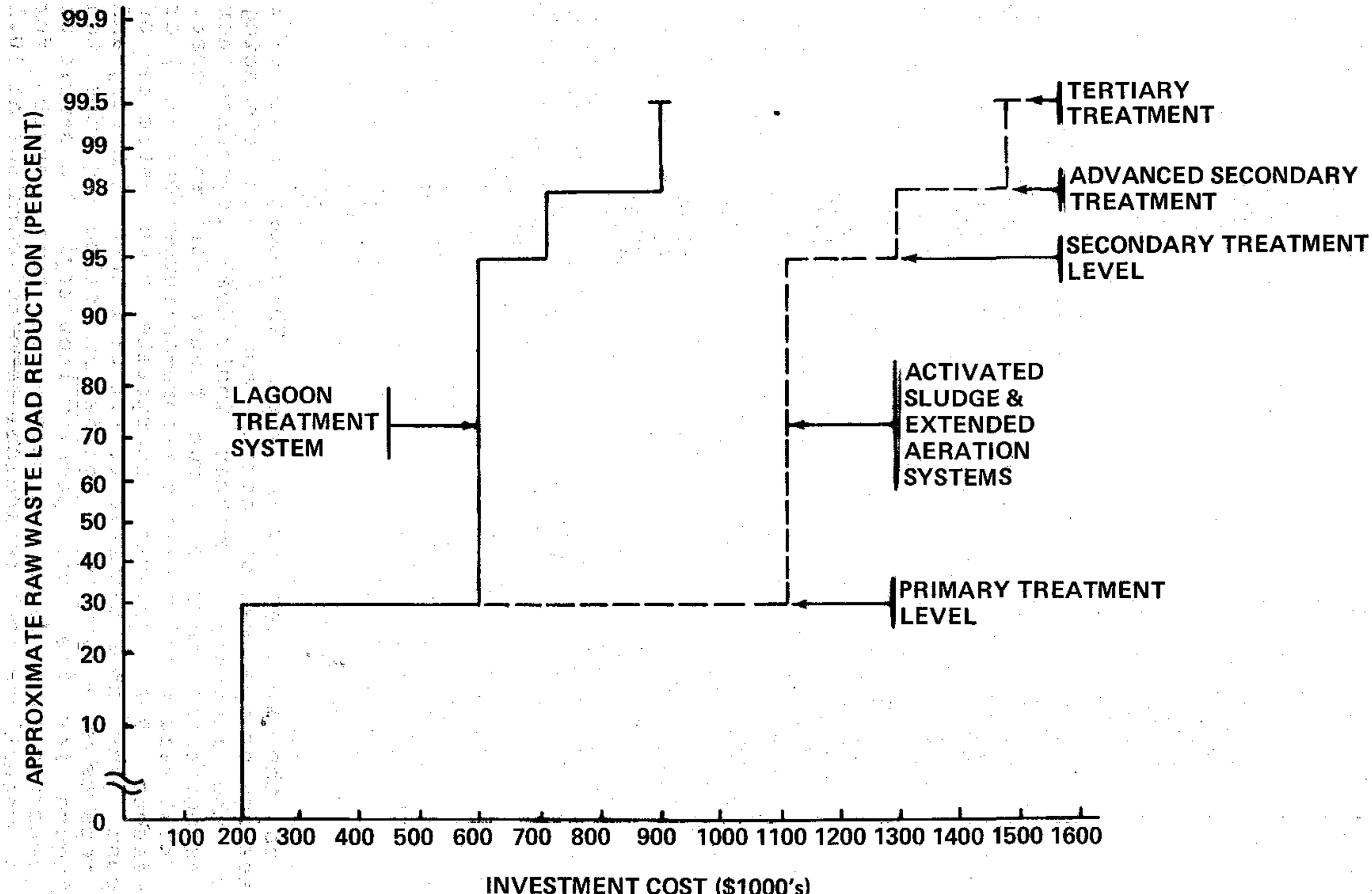

Figure 21. Waste Treatment Cost Effectiveness at Flow of 3 Million Liters/Day (0.800 MGPD)

Table 21. Waste Treatment System Configurations for Cost Effectiveness Curves

Low Cost System	High Cost System	Total Raw Waste Reduction BOD_5 (%)
Catch basin	Catch basin	0
+ Dissolved air flotation	+ Dissolved air flotation	30
+ Anaerobic and aerobic lagoons	+ Activated sludge	95
+ Aerated lagoon	+ Extended aeration	98
+ Sand filter	+ Sand filter	99+

for new ventures. The ten percent figure is probably conservative and thus tends to contribute to a high estimate of total annual cost. Operating cost includes all the components of total annual cost except capital cost and depreciation, wherever it is reported.

The depreciation component of annual cost was estimated on a straight-line basis, with no salvage value and a ten-year life for all investment costs, except land cost which was not depreciated.

The operating and maintenance costs for the 1983 systems include the cost of one man-year at $4.20 per hour plus 50 percent for burden, supervision, etc. A licensed waste treatment operator would add another $5,000 to operating costs per year. One-half man-year was used for the annual cost for the 1977 limitations plus the 50-percent burden, etc. General and maintenance supplies, taxes, insurance, and miscellaneous operating costs were estimated at five percent of the total investment cost per year. Specific chemical-use costs were added when such materials were consumed in the waste treatment system. By-product income, relative to waste treatment, was credited only in the irrigation system for 13,400 kg (29,480 lb)of dry matter (hay or grass) per hectare, at $22 per 100 kg of hay, with two crops per year. This is equivalent to a yield of six tons per acre valued at $20 per ton of dry hay.

Costs per unit of production were based on 250 operating days per year at the average daily production rate for plants in the chicken, fowl, and further processing only subcategories. Turkey and duck processors were assumed to slaughter only 170 days, or about 2/3 of the year, and at the average daily production for each subcategory.

ENERGY REQUIREMENTS

The electrical energy consumption by the poultry processing industry was reported for 1971 at 1.2 million KWH and total heat and power consumption at 6.4 million KWH.[8] The poultry processing industry consumes relatively small quantities of electrical energy, but large quantities of fuel for cooking and heating. The waste treatment systems require power primarily for pumping and aeration. The aeration horsepower is a function of the waste load, and that for pumping depends on waste water flow rate.

Total power consumption for current waste treatment, which will be essentially the same for 1977 limitations, is estimated to be about 50 million KWH per year for the poultry processing industry. This amounts to about 4.2 percent of the industry's electrical energy consumption and less than 1.0 percent of total energy consumption reported for 1971. An additional power consumption increment of 50 to 60 million KWH is estimated to be required to achieve 1983 limitations. Again, using the 1971 consumption levels as a baseline, this amounts to 8.5 percent of electrical energy and 2.2 percent of total energy. This nominal increase does not appear to raise serious power supply or cost questions for the industry. However, the widespread use of chlorine as a disinfectant may pose some energy problems in the future, or, conversely, the future supply of chlorine may be seriously affected by the developing energy situation in which event alternative disinfection procedures may be required.

Waste treatment systems impose no significant addition to the thermal energy requirements of plants. Waste water can be reused in various services in poultry processing plants. Heated waste waters improve the effectiveness of anaerobic ponds, which are best maintained at 32°C (90°F) or higher. Improved water use and thermal efficiencies are possible within a plant when waste water reuse is maximized.

Waste water treatment costs and effectiveness can be improved by the use of energy and power conservation practices and techniques in the processing plant. The waste load tends to increase with increased water use. Reduced water use therefore reduces the waste load, pumping costs, and heating costs, the last of which can be further reduced by water reuse, as suggested previously.

NONWATER POLLUTION BY WASTE TREATMENT SYSTEMS

Solid Wastes

Solid wastes are the most significant nonwater pollutants associated with the waste treatment systems applicable to the poultry processing industry. Screening devices of various design and operating principles are used primarily for removal of large solids from waste water. These solids may have some economic value as inedible rendering material, or they may be landfilled or spread with other solid wastes.

The solids materials separated from the waste water stream which contain organic and inorganic matter, and the chemicals added to aid solids separation are called sludge. Typically, sludge contains 95 - to 98-percent water before dewatering or drying. Both primary and biological treatment systems generate some quantity of sludge; the quantity will vary by the type of system and is roughly estimated in Table 22.

Table 22. Sludge Volume Generation by Waste Treatment Systems

Treatment System	Sludge Volume as Percent of Raw Waste Water Volume
Dissolved air flotation	Up to 10%
Anaerobic lagoon Aerobic and aerated lagoons	Sludge accumulation in these lagoons is usually not sufficient to require removal at any time.
Activated sludge	10 to 15%
Extended aeration	5 to 10%
Anaerobic contact process	Approximately 2%
Rotating biological contactor	Unknown

The raw sludge can be concentrated, digested, dewatered, dried, incinerated, landfilled on site, or spread in sludge holding ponds. The sludge from any of the treatment systems, except air flotation with polyelectrolyte chemicals added, is amenable to any of these sludge handling processes.

The sludge from air flotation with chemicals addition has been found to be difficult to dewater. A dewatered sludge is an acceptable landfill material. Sludge from biological treatment systems is normally ponded by industry plants on their own land or dewatered or digested sufficiently for hauling and deposition in public landfills. The final dried sludge material can be safely used as an effective soil builder. Prevention of runoff is a critical factor in plant-site sludge holding ponds. Costs of typical sludge handling techniques for each biological treatment system generating sufficient quantities of sludge to require handling equipment are included in the costs for these treatment systems.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to insure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to insure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located.

Air Pollution

Odors are the only significant air pollution problem associated with waste treatment in the poultry processing industry. Malodorous conditions usually occur in anaerobic waste treatment processes or localized anaerobic environments within aerobic systems. However, it is generally agreed that anaerobic ponds will not create serious odor problems unless the process water has a sulfate content; then they most assuredly will.

Sulfate waters are definitely a localized condition, varying even from well to well within a specific plant. In northern climates, the change in weather in the spring may be accompanied by a period of noticeable odors. In some cases, a cover or collector of the off-gas from the pond is an effective odor control device. The off-gas is burned in a flare.

Odors have been generated by some air flotation systems which are sometimes housed in a building, thus localizing, but intensifying the problem. Minimizing the unnecessary holdup of any skimmings or grease-containing solids has been suggested as a remedy.

Odors can best be controlled by elimination at the source, rather than resorting to treatment for odor control, which remains largely unproven at this time.

Noise

The only material increase in noise within a processing plant caused by waste treatment is that caused by the installation of an air flotation system or aerated lagoons with air blowers. Large pumps and an air compressor are part of an air flotation system. When such a system is housed in a low-cost building, the noise generated by an air flotation system is confined within the building, but the noise may be amplified to high levels in the building by such installation practices. All air compressors, air blowers, and large pumps in use on intensively aerated treatment systems, and other treatment systems as well, may produce noise levels in excess of the Occupational Safety and Health Administration limitations. The industry must consider these limitations in solving its waste problems.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE--EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The Agency, in establishing effluent limitations which must be achieved by July 1, 1977, is to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. This technology is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category and/or subcategory. This average was not based upon a broad range of plants within the poultry processing industry, but based upon performance levels achieved by exemplary plants.

Consideration was also given to:

- o The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
- o The size and age of equipment and facilities involved;
- o The processes employed;
- o The engineering aspects of the application of various types of control techniques;
- o Process changes;
- o Nonwater quality environmental impact (including energy requirements).

While Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process, it includes waste water control measures within the process itself which are considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of start of construction of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based on the information contained in Sections III through VIII of this report, a determination has been made that the quality of effluent attainable through the application of the Best Practicable Control Technology Currently Available is as listed in Table 23. In the industry study summarized herein, ten of the plants in the chicken category, two plants in the turkey category, and one plant in the duck processing category meet the proposed BOD_5 limitations. All plants in the sample representing the fowl and further processing only subcategories were found to discharge to municipal treatment systems. Therefore, no final effluent data were available in these subcategories.

Plants with onsite rendering or further processing (not including cut-up only operations), in addition to slaughtering, require adjustments in the BOD_5, TSS, and Grease limitations. An adjustment in effluent limitations is also warranted for duck processing plants that have an adjunct feedlot operation. The adjustments for further processing are the values for further processing only given in Table 23; the adjustments for onsite rendering are the values developed for the independent rendering industry.[39] These adjustment factors are presented in Table 24. Adjustments for further processing are permitted only for the production from further processing that includes cooking and processing activity encompassed as part of cooking such as breading, spicing, canning, etc. This excludes cut-up only operations. The reason for this is that the raw waste loads for plants with only slaughtering operations are not distinctively different from plants with slaughter plus cut-up operations (see Section IV).

It appears that the circumstances of several duck processors associated with feedlots are somewhat different than processors operating alone. As a result, it is apparent that any effluent restrictions should be so derived as to properly account for waste load contributions from both the feedlot and the processor. While the small number of operations affected does not appear to warrant a specific separate regulation or new subcategory , the Agency has concluded that the effluent limitation for a combined feedlot/processor should be developed on an additive basis. Thus, in the event that waste streams from the feedlot and processor are combined for treatment or discharge, the quantity of each pollutant or pollutant property controlled for each separate component or waste source shall not exceed the specified limitation for that waste source. For parameters regulated by only one of the potentially applicable regulations, the ultimate limitation should be derived on a flow-proportioned basis. For example, the pollutant "total suspended solids" is not controlled by an effluent limit for a duck feedlot, but is specified for a duck processor. In this instance, the portion (determined by respective flow volume) of suspended solids attributable to the processor in the combined effluent must not exceed the limitation specified for a duck processor in Table 23.

Table 23. Recommended Effluent Limitations for July 1, 1977

Industry Subcategory	Effluent Parameters			
	BOD_5, kg/kkg LWK*	SS, kg/kkg LWK	Grease, kg/kkg LWK	Fecal Coliform, Max. Count/100 ml
Chickens	0.46	0.62	0.20	400
Turkeys	0.39	0.57	0.14	400
Fowl	0.61	0.72	0.15	400
Ducks	0.77	0.90	0.26	400
Further Processing Only	0.30 kg/kkg FP	0.35 kg/kkg FP	0.10 kg/kkg FP	400

*kg/kkg LWK is equivalent to lb/1000 lb LWK plants as well. The further processing adjustment factors become significant when a plant further processes the majority of its kill.

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best Practicable Control Technology Currently Available for the poultry processing industry involves biological waste treatment following in-plant primary treatment for grease and solids recovery. By definition, in-plant byproduct recovery of blood, feathers, and offal is not considered as in-plant primary treatment. To assure that the biological treatment system will successfully achieve the limits specified, plant operators should consider reduction of the raw waste load entering the treatment system by employing one or more of the following housekeeping and management measures, all of which are currently practiced at some plants in the industry:

- Appoint a person with specific responsibility for water management. This person should have reasonable powers to enforce improvements in water and waste management.
- Determine or estimate water use and waste load strength from principal sources. Install and monitor flowmeters in all major water use areas.
- Control and minimize flow of freshwater at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines.
- Shut off all unnecessary water flow during work breaks.
- In-plant primary systems--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water.
- Avoid overfilling cookers in rendering operation.
- Provide and maintain traps in the cooking vapor lines of rendering operations to prevent overflow to the condensers. This is particularly important when the cookers are used to hydrolyze feathers.
- Provide frequent and regularly scheduled maintenance attention for byproduct screening and handling systems throughout the operating day.
- Dry clean all floors and tables prior to washdown to reduce the waste load. This is particularly important in the bleeding, cutting, and further processing areas and all other areas where materials tend to be spilled.

- o Use high-pressure, low-volume spray nozzles or steam augmented systems for plant washdown.

- o Control inventories of raw materials used in further processing so that none of these materials are wasted to the sewer. Spent raw materials should be routed to rendering.

- o Make all employees aware of good water management practices and encourage them to apply these practices.

The above practices can readily help in waste control by reducing raw waste loads. Other actions such as minimizing the amount of chemicals and detergents used, keeping at USDA-approved water use rates in scalders and chillers, installing "demand" valves on all freshwater outlets, or practicing dry offal handling are other potentially useful waste control options which need not necessarily be instituted. Available information indicates that a number of plants are practicing the principles encompassed in the above waste control activities. Even if these control activities are not fully implemented, well-operated treatment processes currently used by the industry and listed below will permit the recommended limits to be achieved.

1. Anaerobic lagoon + aerobic (shallow) lagoons;

2. Activated sludge (or extended aeration) + aerobic (shallow) lagoons;

3. Aerated lagoons + aerobic (shallow) lagoons;

4. Anaerobic + aerated + aerobic (shallow) lagoons.

Plants with higher-than-average raw waste loads or undersized treatment systems may require an additional solids removal stage (e.g., clarifier). Chlorination usually will be required as the final treatment process.

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The rationale used in developing the effluent limitations presented in Table 23 was based upon actual performance data of plants having complete biological waste treatment or upon raw waste characteristics and transfer of waste treatment technology. A complete biological treatment system would include any properly sized system mentioned in the preceding subsection.

SIZE, AGE, PROCESSES EMPLOYED, LOCATION OF FACILITIES

The processes employed in small and large poultry slaughtering plants and further processing plants are basically similar. Furthermore, the factors of size, age, and processes employed did not appear to affect the pollution control techniques used. Hence these factors were not directly employed in establishing effluent limitations. Also, the location of facilities was not a major factor, although it may contribute slightly to seasonal variations in waste load and final effluent.

TOTAL COST OF APPLICATION IN RELATION TO EFFLUENT REDUCTION BENEFITS

Based on information contained in Section VIII of this report, the total investment cost to the poultry industry to implement the waste treatment to achieve the 1977 effluent limitations is estimated to be $13.9 million. This amounts to 23 percent of total capital expenditures of $60 million by the industry in each of the three years 1970, 1971, and 1972.

Moreover, this level of expenditure is associated with a substantial reduction in pollution discharged directly to navigable waters. Using BOD_5 as a basis for calculations, it is estimated that the poultry processors (with a direct stream discharge) are discharging about 13 million pounds of BOD_5 to streams each year at present levels of pollution control. Full implementation of the effluent limitations for BOD_5 by these plants is estimated to provide a reduction of 75 percent in BOD_5, to a level of about 3.5 million pounds per year. The investment cost versus pollution load reduction relationship amounts to about $1.50 per pound of BOD_5 removed for the time period during which the 1977 limitations are applicable.

The additional operating cost associated with achieving 1977 limitations for chicken, turkey, and fowl processors varies from 0.07¢/bird to 1¢/bird, and for duck processors from 1.0¢/bird to 3.2¢/bird. Plants that further process only will incur additional operating costs from 0.1¢ to 0.3¢/kg FP (0.05 to 0.14¢/lb FP). The total annual cost increase per unit of production to achieve 1977 limitations varies from 2.2 to 2.4 times the operating cost increase. The large plants in the industry will experience the lower cost increase per unit of production.

DATA PRESENTATION

Table 25 presents the data for 13 exemplary chicken processing plants. Included in Table 25 are the plant size (thousands of birds per day); effluent flow; raw and final waste loads for BOD_5, TSS, and grease; fecal coliform counts in the final treated

Table 25. Waste Treatment Data For Exemplary Chicken, Turkey, and Duck Plants

Plant Number	Flow liters/bird (gal/bird)	Production 1000 birds/day	BOD_5, kg/kkg LWK* Raw	BOD_5, kg/kkg LWK* Final	SS, kg/kkg LWK* Raw	SS, kg/kkg LWK* Final	Grease, kg/kkg LWK* Raw	Grease, kg/kkg LWK* Final	Final Fecal Coliforms**, Counts/100 ml	Waste Treatment System
Chickens										
1	29.1 (7.7)	65	7.12	0.47	6.06	0.14	--	--	1100	anaerobic, 3 aerobic
2	24.2 (6.4)	55	6.98	0.39	5.00	0.44	5.39	0.45	--	2 aerated, 2 aerobic†
3	30.3 (8.0)	36	5.88	0.66	5.77	0.23	1.67	0.19	--	2 anaerobic, aerobic
4	37.8 (10.0)	65	--	0.26	--	0.52	--	--	<100(CL)	3 anaerobic, aerated, aerobic
5††	51.5 (13.6)	70	10.54	0.24	5.01	0.19	4.03	0.34	<100(CL)	activated sludge, microstrainer†
6	40.9 (10.8)	140	13.00	0.51	5.11	0.12	2.91	0.14	3300(CL)	anaerobic, aerated, aerobic
7	23.5 (6.2)	45	6.30	0.50	10.30	1.40	6.10	0.20	--	aerated
8	23.8 (6.3)	84	4.32	0.39	2.38	0.43	--	--	--	extended aeration, aerobic†
9	15.5 (4.1)	22	6.29	0.45	5.32	0.59	--	--	<100	aerated, 2 aerobic
10	33.3 (8.8)	200	13.48	0.64	5.47	0.46	--	--	--	3 aerated, 2 aerobic†
11	17.4 (4.6)	60	4.46	0.40	3.97	0.50	--	--	--	anaerobic, aerated, aerobic†
12	35.6 (9.4)	85	4.36	0.32	3.51	0.22	--	--	--	extended aeration, aerobic
Turkeys										
13	113.9 (30.1)	9.4	4.69	1.25	3.55	0.62	1.46	0.025	100	activated sludge, aerobic
14	61.3 (16.2)	21	2.70	0.18	1.52	0.57	0.44	0.13	--	3 aerated
15	170.3 (45)	6	3.22	0.59	2.41	1.18	0.88	0.067	<100(CL)	aerated, 2 aerobic†
16	135.1 (35.7)	4.2	0.96	0.49	0.99	0.50	0.35	0.076	1700	anaerobic, aerobic
17	132.5 (35)	20	--	0.41	--	0.63	--	--	--	aerated, aerobic
Ducks										
18	71.5 (18.9)	10	7.52	0.54	3.47	0.81	3.05	0.13	<100(CL)	activated sludge, aerobic
19	78.3 (20.7)	15	6.59	1.32	5.24	1.61	0.66	0.073	<100(CL)	3 aerated, 2 aerobic

*kg/kkg LWK = lb/1000 lb LWK.
**(CL) indicates chlorination of final effluent.
†indicates air flotation primary treatment.
††The performance of the treatment system for Plant 5 was used to establish 1983 effluent limitations.

effluent; and the type of biological waste treatment systems used.

Table 25 also includes the same information for exemplary turkey and duck processing plants. Similar data for fowl processing and for further processing only plants are not available because all of these plants that responded to the questionnaire indicated discharged their raw waste water to municipal treatment systems.

Chickens

Data for three of the chicken processing plants represent information obtained from our field sampling survey; data for two plants were provided directly by the companies; and data for eight plants were obtained from questionnaire information.

The BOD5 effluent limitation of 0.46 kg/kkg LWK is the average of all final BOD5 values except for Plant No. 5 presented under chickens in Table 25. The value for Plant No. 5 was excluded because its waste treatment system includes advanced waste treatment. Seven of the twelve plants listed in Table 25 meet this effluent limitation; eight of thirty-two plants for which final data were available meet the limitation. Using the average of all flow values (excluding Plant No. 5) of 28.3 liters (7.5 gal)/bird, and an average bird weight of 1.74 kg (3.8 lb), the corresponding final BOD5 effluent concentration is 28 mg/l. This concentration is considered to be attainable using the best practicable control technology currently available.

The suspended solids (TSS) effluent limitation of 0.62 kg TSS/kkg LWK is the average of the values listed in Table 25 for Plants 2, 4, 7, 8, 9, 10, and 11. The TSS value for Plant 5 was not included because this plant had advanced waste treatment; values for Plants 1, 3, and 6 were excluded because these values were unusually low relative to the corresponding BOD5 values for each plant. A regression equation was developed from an analysis of treated effluent values for BOD5 and TSS from 30 plants. This equation predicts, with a high correlation, that the final TSS value should be greater than the final BOD5 value. In addition, this regression equation predicts a TSS value of 0.65 kg/kkg, using the BOD5 effluent limitation value of 0.46 kg/kkg LWK. This predicted value for TSS agrees well with the recommended effluent limitation value. Again using the flow value of 28.3 l (7.5 gal) per bird and an average bird weight of 1.74 kg (3.8 lb), this effluent limitation value corresponds to a concentration of 38 mg/l. Eleven of the twelve plants with TSS data listed in Table 25 and eleven of the thirty-two plants for which data were available meet which TSS effluent limitation.

The grease effluent limitation of 0.20 kg grease/kkg LWK is based upon a limiting effluent grease concentration of 10 mg/l and the average water flow per unit of LWK for all chicken processing plants of 35 l (9.3 gal) per bird (see Section V). Of the five plants listed in Table 25, three meet this limitation; of the twenty chicken processing plants for which final grease data were available, nine meet the limitation. The limiting concentration for grease of 10 mg/l was also found to be limiting for the red meat processing industry,[19] even though the wastes from this industry typically have higher raw grease concentrations than do those from the poultry industry.

Turkey

The BOD5 effluent limitation for turkeys of 0.39 kg/kkg LWK is slightly higher than the average of the lowest three values listed in Table 25 for turkey plants. Using the average waste water flow for turkey processors of 118 l (31.2 gal) per bird and an average turkey weight of 8.3 kg (18.2 lb), this corresponds to a final BOD5 concentration of about 28 mg/l.

The suspended solids effluent limitation for turkeys of 0.57 kg TSS/ kkg LWK is the average of the three lowest values for TSS listed in Table 25 for turkey plants. Using the average flow per unit LWK for turkeys, this limitation corresponds to a final TSS concentration of 40 mg/l.

The grease effluent limitation for turkey processing of 0.14 kg grease/ kkg LWK was calculated using the average water flow per unit LWK and the limiting grease concentration of 10 mg/l. Four of the five turkey plants listed in Table 25 meet this effluent limitation and the fifth comes very close with a value of 0.17 kg grease/kkg LWK. These five turkey processing plants were the only ones included in the study for which data on final grease loads were available.

Fowl

The BOD5 effluent limitation for fowl processing of 0.61 kg BOD5/kkg LWK was obtained by applying to a typical BOD5 raw waste load of 12.2 kg BOD5/ kkg LWK a waste reduction of 95 percent. Unfortunately, a comparison with actual performance data is not possible because no fowl processing plants discharging directly to surface waters could be located. However, based on the similarity between fowl and chicken processing in waste water flows, bird size, and processes employed, this effluent limitation appears reasonable.

The suspended solids effluent limitation of 0.72 was obtained by using the regression equation between BOD5 and TSS developed with data for chicken processing and the BOD5 limitation for fowl of 0.61 kg BOD5/kkg LWK. The grease effluent limitation of 0.15 was calculated using an average flow of 32.9 l (8.7 gal) per bird, an average bird weight of 2.2 kg (4.8 lb), and a limiting grease concentration of 10 mg/l. Again, no actual performance data for TSS and grease were available for comparison.

Ducks

The BOD_5 effluent limitation for ducks of 0.77 was calculated using the average waste water flow per unit LWK and a limiting final BOD_5 concentration of 30 mg/l. The TSS effluent limitation was calculated using the BOD_5-TSS regression equation developed from waste water data on chicken processing plants and the duck processing BOD_5 limitation of 0.77 kg BOD_5/kkg LWK. The grease effluent limitation of 0.26 kg grease/ kkg LWK was calculated from the average waste water flow per unit LWK and a grease limiting concentration of 10 mg/l. One of two duck processing plants for which treatment effluent data were available meets all three of these effluent limitations. This plant meets the effluent limitations in spite of the fact that the final effluent included the waste water from an onsite duck feedlot.

Further Processing Only

Since slaughtering processes are not involved, the regression procedures were not directly applied to this subcategory. The effluent limitations for further processing plants were based upon the average waste water flow and final effluent concentrations of 30, 35, and 10 mg/l for BOD_5, TSS, and grease, respectively. The BOD_5 concentrations are considered attainable with current technology based on BOD_5 reduction demonstrated in other subcategories with similar raw waste characteristics. The grease is a limiting value, and a check of validity showed the TSS concentration corresponds to a value predicted from the BOD_5-TSS regression equation developed from final effluent data for chicken processing plants using the BOD_5 concentration of 30 mg/l. In addition, all three of these effluent limitation values are close to those recommended for those segments of the meat processing industry having operations similar to those of a poultry further processing only plant.[40]

ENGINEERING ASPECTS OF CONTROL TECHNIQUE APPLICATIONS

The specific level of control technology, in-plant primary plus biological treatment, is practicable because it is currently being practiced by plants representing a wide range of plant sizes and types. However, if additional treatment is needed, such as sand filters, mixed-media filter beds, or microstrainers, this technology is practical as evidenced by its use in other industries,[19] in municipalities, and in the poultry industry.

PROCESS CHANGES

Significant in-plant changes will not be needed by the vast majority of plants to meet the limitations specified. Many plants will have to improve plant cleanup and housekeeping practices, both of which are responsive to good plant management control. This can best be achieved by minimizing spills, containing and collecting materials, and the use of dry cleaning prior to washdown. Some plants may find it necessary to pretreat offal holding truck drainage before mixing it with other waste waters for recycle, after screening, through the feather flume, and to keep blood segregated from feathers and offal. Some plants may also find it necessary to use improved gravity separation systems, such as air flotation with chemical additions for in-plant primary treatment.

NONWATER QUALITY ENVIRONMENTAL IMPACT

The major impact on the environment will be disposal of the sludge from an activated sludge type of treatment system or from chemical precipitation in in-plant primary treatment. Nearby land for sludge disposal may be necessary; in some cases a sludge digester (stabilizer) may offer a solution. Properly operated activated sludge-type systems should produce well conditioned sludge acceptable for placement in small nearby soil plots for drying without great difficulty. It was concluded that the odor emitted periodically from anaerobic lagoons is not a major impact.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE-- EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved no later than July 1, 1983, are not based on an average of the best performance within an industrial category, but are determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, or by one industry where it is readily transferable to another. A specific finding must be made as to the availability of control measures and the practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration was given to:

- The age of the equipment and facilities involved;
- The process employed;
- The engineering aspects of the application of various types of control techniques;
- Process changes;
- The cost of achieving the effluent reduction resulting from application of the technology;
- Nonwater quality environmental impact (including energy requirements).

Best Available Technology Economically Achievable emphasizes in-process controls as well as control or additional treatment techniques employed at the end of the production process.

This level of technology considers those plant processes and control technologies which, at the pilot-plant, semi-works, and other levels, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities. It is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant-scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs of this level of control are intended to be the top-of-the-line of current technology, subject to limitation imposed by economic and engineering feasibility. However, there may be some technical risk with respect to performance and with respect to certainty of costs. Therefore, some industrially sponsored development work may be needed prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based on the information contained in this section and in Sections III through VIII of this report, a determination has been made that the quality of effluent attainable through the application of the Best Available Technology Economically Achievable is as listed in Table 26. The technology to achieve these goals is generally available, and has been used by at least one poultry processing plant on a full-scale. Plants with onsite rendering and further processing (but not including cut-up only operations) in addition to slaughtering require an adjustment in the BOD_5, TSS, and grease limitations. The adjustment for further processing is the value for further processing only given in Table 26; the adjustment for onsite rendering includes the values developed for the off-site rendering industry.[39] These adjustment factors are presented in Table 27. Adjustments for further processing are only permitted for that part of further processing that includes cooking. This excludes cut-up operations. The reason for this is that the raw effluent waste loads for plants with only slaughtering operations are not distinctively different from the waste loads of plants with slaughter plus cut-up operations (see Section IV). Adjustment factors for duck feedlots are not included for duck processors who also raise ducks, because the feedlot industry limitations require no discharge from duck feedlots by 1983.[41]

Adjustment factors do not have a material effect on the limitations, unless the amount of further processing or rendering relative to the live weight killed is significant. For example, if a broiler slaughter operation kills birds of an average weight of 1.7 kg (3.8 lb) and renders onsite all of the offal from the slaughtering operation at the rate of 0.45 kg (1 lb) offal per bird, the adjustment factors (AF) are:

$$AF(BOD_5) = \frac{0.07 \times 0.45}{1.7} = 0.018 \text{ kg/kkg LWK or } 0.018 \text{ lb/1000 lb LWK}$$

$$AF(TSS) = \frac{0.10 \times 0.45}{1.7} = 0.026 \text{ kg/kkg LWK or } 0.026 \text{ lb/1000 lb LWK}$$

$$AF(Grease) = \frac{0.05 \times 0.45}{1.7} = 0.013 \text{ kg/kkg LWK or } 0.013 \text{ lb/1000 lb LWK}$$

The adjusted effluent limitations for this plant are the corresponding limitations from Table 26 added to those AF(s) above, which are 0.30 + 0.018 or 0.318 kg BOD_5/kkg LWK; 0.34 + 0.026 or 0.366 kg TSS/kkg LWK; and 0.20 + 0.013 or 0.213 kg grease/kkg LWK.

Table 26. Recommended Effluent Limitation Guidelines for July 1, 1983

Industry Subcategory	BOD_5 kg/kkg LWK*	SS kg/kkg LWK	Grease kg/kkg LWK	NH_3 mg/l	Fecal Coliforms counts/100 ml
Chickens	0.30	0.34	0.20	4	400
Turkeys	0.21	0.24	0.14	4	400
Fowl	0.23	0.27	0.15	4	400
Ducks	0.39	0.46	0.26	4	400
Further Processing Only	0.15	0.18	0.10	4	400

*kg/kkg LWK is equivalent to lb/1000 lb LWK.

Table 27. Effluent Limitation Adjustment Factors for On-Site Rendering and Further Processing*

Effluent Parameters	Adjustment Factors	
	For On-Site Rendering**	For Further Processing
BOD_5	$\frac{0.07 \text{ kg } BOD_5}{\text{kkg RM}} \times \frac{\text{(kkg RM)}}{\text{(kkg LWK)}}$	$\frac{0.15 \text{ kg } BOD_5}{\text{kkg FP}} \times \frac{\text{(kkg FP)}}{\text{(kkg LWK)}}$
Suspended Solids (SS)	$\frac{0.10 \text{ kg SS}}{\text{kkg RM}} \times \frac{\text{(kkg RM)}}{\text{(kkg LWK)}}$	$\frac{0.18 \text{ kg SS}}{\text{kkg FP}} \times \frac{\text{(kkg FP)}}{\text{(kkg LWK)}}$
Grease	$\frac{0.05 \text{ kg grease}}{\text{kkg RM}} \times \frac{\text{(kkg RM)}}{\text{(kkg LWK)}}$	$\frac{0.10 \text{ kg grease}}{\text{kkg FP}} \times \frac{\text{(kkg FP)}}{\text{(kkg LWK)}}$

*For processes including a cooking step, but not for cut-up only operations.

**RM--Raw Materials Rendered.

Similarly, the adjustment factors for a broiler operation that slaughters 73,000 birds per day at an average weight of 1.7 kg (3.8 lb) per bird and further processes 25,000 birds per day with an average product yield per bird of 0.76 kg (1.7 lb) FP are:

$$AF(BOD\underline{5}) = 0.15 \times \frac{25,000 \times 0.76}{73,000 \times 1.74} = 0.022 \text{ kg/kkg LWK}$$

or 0.022 lb/1000 lb LWK

$$AF(SS) = 0.18 \times \frac{25,000 \times 0.76}{73,000 \times 1.74} = 0.027 \text{ kg/kkg LWK}$$

or 0.027 lb/1000 lb LWK

$$AF(Grease) = 0.10 \times \frac{25,000 \times 0.76}{73,000 \times 1.74} = 0.015 \text{ kg/kkg LWK}$$

or 0.015 lb/1000 lb LWK

The adjusted effluent limitations for this plant would be: 0.30 + 0.022 or 0.322 kg BOD5/kkg LWK; 0.34 + 0.027 or 0.367 kg TSS/kkg LWK; and 0.20 + 0.015 = 0.215 kg grease/kkg LWK.

In general then, for onsite rendering the adjustment in effluent limitations is only significant when a plant renders raw material from other plants in addition to its own. This practice occurs occasionally in the poultry processing industry. For further processing adjustment factors to be significant, a plant would have to further process the majority of its LWK.

IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The Best Available Technology Economically Achievable includes the biological treatment systems listed under the Best Practicable Control Technology Currently Available (Section IX), and "polishing" by means of a sand filter, microstrainer, or equivalent following biological treatment. In addition, some plants will require improved pretreatment, such as dissolved air flotation with pH control and chemical flocculation, and many will require ammonia control by nitrification, nitrification/denitrification or stripping.

In-plant controls and modifications may also be required to achieve the specified levels. These include the following:

- o Appoint a person with specific responsibility for water management. This person should have reasonable powers to enforce improvement in water and waste management, both in-plant and for treatment systems.

- o Determine or estimate water use and waste load strength from principle sources. Install and monitor flowmeters in all major water use areas.

- o Control and minimize flow of freshwater at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines. On hand washers, this may require installation of press-to-operate valves. This also implies that screened waste water is recycled for feather fluming.

- o Stun birds in the killing operation to reduce carcass movement during bleeding.

- o Confine bleeding and provide for sufficient bleed time. Recover all collectable blood and transport to rendering in tanks rather than by dumping on top of feathers or offal.

- o Use minimum USDA approved quantities of water in the scalder and chillers.

- o Shut off all unnecessary water flow during work breaks.

- o Consider the reuse of chiller water for makeup water for the scalder. This may require preheating the chiller water with the scalder overflow water by using a simple heat exchanger.

- o Use pretreated poultry processing waste waters for condensing all cooking vapors in onsite rendering operations.

- o In-plant primary systems--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water.

- Avoid over-filling cookers in rendering operations.
- Provide and maintain traps in the cooking vapor lines of rendering operations to prevent overflow to the condensers. This is particularly important when the cookers are used to hydrolyze feathers.
- Provide by-pass controls in rendering operations for controlling pressure reduction rates of cookers after feather hydrolysis. Cooker agitation may have to be stopped also, during cooker pressure bleed-down to prevent or minimize materials carry-over.
- Consider dry offal handling as an alternative to fluming. A number of plants have demonstrated the feasibility of dry offal handling in modern high-production poultry slaughtering operations.
- Consider steam scalding as an alternative to immersion scalding.
- Control water use in gizzard splitting and washing equipment.
- Provide for regular and frequent maintenance attention to by-product screening and handling systems. A back-up screen may be required to prevent byproduct from entering municipal or private waste treatment systems.
- Treat offal truck drainage before sewering. One method is to steam sparge the collected drainage and then screen.
- Dry clean all floors and tables prior to washdown to reduce the waste load. This is particularly important in the bleeding, cutting, and further processing areas and all other areas where there tends to be material spills.
- Use high-pressure, low-volume spray nozzles or steam augmented systems for plant washdown.
- Minimize the amount of chemicals and detergents to prevent emulsification or solubilizing of solids in the waste waters. For example, determine the minimum effective amount of chemical for use in the scald tank.
- Control inventories of raw materials used in further processing so that none of these materials are ever wasted to the sewer. Spent raw materials should be routed to rendering.
- Separately treat all overflow of cooking broth for grease and solids recovery.
- Reduce the waste water from thawing operations.
- Make all employees aware of good water management practices and encourage them to apply these practices.

If suitable land is available, land disposal is the best technology; it is no discharge. However, biological treatment may still be required before disposal of waste waters to soil, although the degree of treatment need not be the same as that required to meet the 1977 limitations (Section IX). Any of the systems mentioned in Section IX are suitable.

RATIONALE FOR SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The rationale used in developing the BOD_5, suspended solids and grease effluent limitations presented in Table 26 were based upon actual performance data of a poultry processing waste treatment system and upon the average raw waste water flows for each subcategory. The particular system whose performance was used to establish these limitations included flow equalization, dissolved air flotation with chemical addition, activated sludge, microstrainers, and a chlorination basin. This system was able to produce an effluent of 15, 18, and 10 mg/l of BOD_5, TSS, and grease, respectively. Other systems, but without advanced waste treatment, were also able to achieve some of these concentrations, but never all three for any one system.

The Kjeldahl nitrogen, ammonia nitrogen, total phosphorus, and nitrite-nitrate effluent limitations are based upon transfer of waste treatment technology from the red meat industry[19] and from the off-site rendering industry.[39] These industries, which have similar raw waste characteristics, were able to reach limiting concentration values for these waste parameters using similar waste treatment systems. These limiting concentrations are the effluent limitation values shown in Table 26. A number of poultry processing plants were able to achieve these limiting concentrations. However, the ammonia and Kjeldahl nitrogen limiting concentrations appear to be the most difficult to meet.

The fecal coliform effluent limitations of 400 counts/100 ml was established because all plants having adequate chlorination were within this limit.

Because of the rationale used to establish the 1983 effluent limitation, two major approaches to reducing the final effluent waste load can be used by the industry. The first and most economical approach is to reduce the waste water flow rate to a value well below the averages found in this study (see Section V) by the use of in-plant controls and conscientious waste management. The second is to improve the waste treatment systems to achieve a greater reduction in waste strength. The most practical approach however will undoubtedly be a combination of the two.

AGE OF EQUIPMENT AND FACILITIES

The age of plants and equipment does not affect the end-of-process pollution control effectiveness. Although in-plant control can be managed quite effectively in older plants, some of the methods capable of reducing the raw waste loads to realistically low levels may be more costly to install in older plants.

TOTAL COST OF APPLICATION

Based on information contained in Section VIII of this report, the incremental investment cost above 1977 costs to the poultry industry to implement the waste treatment to achieve the 1983 effluent limitations is estimated to be $38.6 million. This amounts to 64 percent of total capital expenditures of $60 million by the industry in each of the three years 1970, 1971, and 1972.

The additional operating cost associated with achieving 1983 limitations for chicken, turkey, and fowl processors varies from 0.3¢/bird to 3¢/bird and for duck processors from 2.8¢/bird to 8.2¢/bird. Plants that further process only will incur additional operating costs from 0.29 to 0.78¢/kg FP (0.13 to 0.35¢/lb FP). The total annual cost increase per unit of production to achieve 1983 limitations varies between 2.5 and 2.6 times the operating cost increase. The large plants in the industry will experience the lower cost increase per unit of production.

ENGINEERING ASPECTS OF CONTROL TECHNIQUE APPLICATION

The specific level of effluent is achievable. Several plants are currently meeting a number of the 1983 effluent limitations. One plant (which includes a microstrainer for advanced removal of suspended solids) is currently achieving or nearly achieving all limitations. However, nitrification has been achieved in pilot- and full-scale units. Denitrification has been explored with some success in laboratory and pilot-scales. Field sampling surveys of rendering plants revealed that nitrification/denitrification was occurring in large lagoon systems if they were not overloaded.[39] Ammonia stripping may require pH adjustment and later neutralization; recent advances in the operation of the process make it feasible for possible utilization.

Each of the identified technologies, except ammonia removal and nitrification/denitrification, is currently being practiced in the poultry products industry. They need to be combined, however, to achieve the limits specified.

Two poultry plants in our sample are irrigating with their waste water. Technology for land disposal by irrigation is being used by rendering plants and by meat processing and meat packing plants, primarily in the Southwest and California. It has also been used successfully in northern Iowa by rendering plants and it is being planned for a packing plant in Iowa. Other industries, e.g., potato processing, are using it extensively. Secondary treatment and large holding ponds may be required in the north for land disposal during about one-half of the year. Application of technology to reduce in-plant water use will facilitate land disposal alternatives.

PROCESS CHANGES

In-plant changes will be necessary or will be found to be advantageous, for most plants to meet the limits specified. These were outlined in the "Identification of the Best Available Technology Economically Achievable," previously.

NONWATER QUALITY IMPACT

None of the additional technology required to meet the 1983 limitations is energy intensive. The primary energy consumption occurs in pumping the waste water and the other material streams in the treatment processes. Electrical energy usage is expected to increase about 60 million KWH per year above current (and projected 1977) levels. This amounts to only about 1.0% of total power consumption for the industry.

The major impact will occur when the land disposal option is chosen. The potential long-term effect on the soil caused by irrigation of processing plant wastes is unknown. On the other hand, the wastes are among the most amenable to land disposal and irrigation has been done successfully by one California meat processing plant for over 30 years. The impact will probably depend on location, soil conditions, waste strength, climate and other factors.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

The effluent limitations that must be achieved by new sources are termed performance limitations. The New Source Performance Standards apply to any source for which construction starts after the promulgation and publication of the proposed regulations as Standards. The Standards are determined by adding to the considerations underlying the identification of the Best Practicable Control Technology Currently Available, a determination of what higher levels of pollution control are available through the use of improved production processes, and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, New Source Performance Standards are based on an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods, or other alternatives are considered. However, the end result of the analysis is to identify effluent limitations which reflect levels of control achievable through the use of improved production processes and practices (as well as control technology) rather than prescribing a particular type of process or technology which must be employed. A further determination is made whether a limitation permitting no discharge of pollutants is practicable.

Consideration must also be given to:

- o Operating methods;
- o Batch, as opposed to continuous, operations;
- o Use of dry rather than wet processes or expanded reuse of water by cascading through the plant;
- o Recovery of pollutants as byproducts.

EFFLUENT REDUCTION ATTAINABLE FOR NEW SOURCES

The effluent limitations for new sources are the same as those for the Best Practicable Control Technology Currently Available (see Section IX). In addition, ammonia effluent limitations are required. The ammonia limitation is based on an ammonia nitrogen concentration of 10 mg/l and the same waste water flow rates per unit LWK as used in Section IX. The new source ammonia effluent limitations for the five categories are:

Category	Ammonia as N Effluent Limitation, Kg/kkg LWK, (lb/1000 lb LWK)
Chickens	0.20
Turkeys	0.14
Fowl	0.15
Ducks	0.26
Further Processing Only	0.10

The effluent limitations for ammonia are readily achievable in newly constructed plants as demonstrated by the fact that a number of existing well-operated plants are meeting them. However, the limitations for the Best Available Technology Economically Achievable should be kept in mind; it may be a more practical approach to design a plant which approaches the 1983 limitations. Consideration should also be given to land disposal, which would be no discharge. In some situations this will be the most attractive and economical option. Estimates of capital investment cost, operating cost, and total annual cost for waste treatment by new point sources are listed for each subcategory in Table 28.

IDENTIFICATION OF NEW SOURCE CONTROL TECHNOLOGY

The technology is the same as that identified as the Best Practicable Control Technology Currently Available (see Section IX). However, certain steps that will be necessary to meet the 1983 guidelines should be considered and, where possible, incorporated. These include:

In-Plant Controls

- o Control and minimize flow of freshwater at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines. Hand washers may require installation of press-to-operate valves. This also implies that screened waste waters are recycled for feather fluming.
- o Stun birds in the killing operation to reduce carcass movement during bleeding.
- o Confine bleeding and provide for sufficient bleed time. Recover all collectable blood and transport to rendering in tanks rather than by dumping on top of feathers or offal.
- o Use minimum USDA-approved quantities of water in the scalder and chillers.

Table 28. Capital Investment, Operating and Total Annual Costs for New Point Sources

Plant Type	Capital Investment	Operating Cost per Year	Total Annual Cost per Year
Chicken			
Small	$470,000	$54,000	$148,000
Medium	640,000	67,100	195,100
Large	950,000	90,400	280,400
Turkey	400,000	48,300	128,300
Fowl			
Small	364,000	45,400	118,200
Large	529,000	59,700	167,500
Duck			
Small	227,000	35,300	80,700
Large	385,000	46,400	123,400
Further Processing Only			
Small	225,000	35,100	80,100
Large	364,000	45,400	118,200

- Shut off all unnecessary water flow during work breaks.

- Consider the reuse of chiller water as makeup water for the scalder. This may require preheating the chiller water with the scalder overflow water by using a simple heat exchanger.

- Use pretreated poultry processing waste waters for condensing all cooking vapors in onsite rendering operations.

- Consider dry offal handling as an alternative to fluming. A number of plants have demonstrated the feasibility of dry offal handling in modern high-production poultry slaughtering operations.

- Consider steam scalding as an alternative to immersion scalding.

- Control water use in gizzard splitting and washing equipment.

- Provide for frequent and regular maintenance attention to by-product screening and handling systems. A back-up screen may be required to prevent byproduct from entering municipal or private waste treatment systems.

- Dry clean all floors and tables prior to washdown to reduce the waste load. This is particularly important in the bleeding, cutting, and further processing areas and all other areas where there tend to be material spills.

- Use high-pressure, low-volume spray nozzles or steam-augmented systems for plant washdown.

- Minimize the amount of chemicals and detergents to prevent emulsification or solubilizing of solids in the waste waters. For example, determine the minimum effective amount of chemical for use in the scald tank.

- Control inventories of raw materials used in further processing so that none of these materials are ever wasted to the sewer. Spent raw materials should be routed to rendering.

- Treat separately all overflow of cooking broth for grease and solids recovery.

- Reduce the waste water from thawing operations.

- Make all employees aware of good water management practices and encourage them to apply these practices.

- Treat offal truck drainage before sewering. One method is to steam sparge the collected drainage and then screen.

- In-plant primary systems--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water. Frequent, regular maintenance attention should be provided.

End-of-Process Treatment

- o Land disposal by irrigation should be a primary consideration wherever possible.
- o Sand filter or microscreen following biological treatment of effluent.
- o Solid waste drying, composting, and upgrading of protein content.

PRETREATMENT REQUIREMENTS

No constituents of the effluent discharged from a plant within the poultry processing industry have been found which would interfere with, pass through, or otherwise be incompatible with a well-designed and operated, publicly-owned activated sludge or trickling filter waste water treatment plant. The effluent, however, should have passed through byproduct recovery and in-plant primary treatment in the plant to remove settleable solids and most of the grease. The concentration of pollutants acceptable to the municipal treatment plant is dependent on the relative sizes of the treatment facility and the poultry processing plant, and must be established by the treatment facility. It is possible that grease remaining in the plant effluent may cause difficulty in the treatment system; trickling filters appear to be particularly sensitive. A concentration of 100 mg/l is often cited as a limit, and this may require an effective air flotation system in addition to a catch basin. If the waste strength, in terms of BOD_5, must be further reduced, any of the various components of biological treatment systems can be used, such as anaerobic contact, trickling filter, aerated lagoons, etc., as pretreatment.

SECTION XII

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SECTION XIV

GLOSSARY

"Act": The Federal Water Pollution Control Act Amendments of 1972.

Activated Sludge Process: Aerated basin in which waste waters are mixed with recycled biologically active sludge for periods of about 6 hours.

Aerated: The introduction and intimate contacting of air and a liquid by mechanical means such as stirring, spraying, or bubbling.

Aerobic: Living or occurring only in the presence of dissolved or molecular oxygen.

Algae: Major group of lower plants, single and multi-celled, usually aquatic and capable of synthesizing their foodstuff by photosynthesis.

Ammonia Stripping: Ammonia removal from a liquid, usually by intimate contacting with an ammonia-free gas such as air.

Anaerobic: Living or active only in the absence of free oxygen.

Bacteria: Primitive plants, generally free of pigment, which reproduce by dividing in one, two, or three plants. They occur as single cells, chains, filaments, well-oriented groups or amorphous masses.

Biodegradable: The condition of a substance which indicates that the energy content of the substance can be lowered by the action of biological agents (bacteria) through chemical reactions that simplify the molecular structure of the substance.

Biological Oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable matter.

Biological Stabilization: Reduction in the net energy level of organic matter as a result of the metabolic activity of organisms, so that further biodegradation is very slow.

Biological Treatment: Organic waste treatment in which bacteria and/or biochemical action are intensified under controlled conditions.

Blinding: The plugging of the openings in the screen or metal fabric that is part of a process screening device.

Blowdown: A discharge of water from a system to prevent a build up of dissolved solids, e.g., in a boiler.

BOD_5: A measure of the oxygen consumption by aerobic organisms over a five day test period at 20°C. It is an indirect measure of the concentration of biologically degradable material present in organic wastes contained in a water stream.

Broiler: A young chicken typically eight to nine weeks old with an average market live weight of 1.74 kg (3.8 lb).

By-Products: The feathers, offal, and blood that are recovered and used as rendering raw materials.

Category and Subcategory: Divisions of a particular industry which possess different traits that affect raw waste water quality.

Chemical Precipitation: A waste treatment process whereby substances dissolved in the waste water stream are rendered insoluble and form a solid phase that settles out or can be removed by flotation techniques.

Chicken: Often a catch-all classification of both young and mature fowl including domestic fowl, broilers, fryers, roasters, and stewing hens; in this report, a specific subcategory of the industry excluding mature chickens or fowl.

Chilling: In the poultry processing industry, chilling refers to the processing of rapid cooling of carcasses in ice water following the evisceration process.

CIP System: "Clean-in-place" equipment and plant cleaning system using a spray-on detergent that remains in place wherever it is sprayed until it is rinsed off.

Clarification: Process of removing undissolved materials from a liquid, specifically, removal of solids either by settling or filtration.

Clarifier: A settling basin for separating settleable solids from waste waters.

cm: Centimeter.

Coagulant: A material, which when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that absorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric sulfate and alum.

Coanda Phenomenon: Tendency of a flowing fluid to adhere to a curved surface.

COD-Chemical Oxygen Demand: An indirect measure of the biochemical load imposed on the oxygen resource of a body of water when organic wastes are introduced into the water. A chemical test is used to determine COD of waste water.

Comminuted Products: Processed meat products prepared with meat and fat pieces that have been reduced to minute particle size; e.g., luncheon meats.

Condensables: Rendering vapors capable of being condensed.

Condensate: The liquid produced by condensing rendering cooking vapors.

Contamination: A general term signifying the introduction into water of microorganisms, chemical, organic or inorganic wastes, or sewage, which renders the water unfit for its intended use.

Curing: A process, method, or treatment involving aging, seasoning, washing, drying, injecting, heating, smoking, or otherwise treating a product, especially meat, to preserve, perfect, or ready it for use.

Defeathering: Process of removing feathers from birds.

Denitrification: The process involving the facultative conversion by anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

Digestion: Though "aerobic" digestion is used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols, and subsequently converted to such gases as methane and carbon dioxide. Complete destruction of organic solid materials by bacterial action alone is never accomplished.

Dissolved Air Flotation: A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact. The process is particularly effective for grease removal.

Dissolved Oxygen: The oxygen dissolved in sewage, water, or other liquid, usually expressed as milligrams per liter or as percent of saturation.

Duck: A type of domestic water fowl with a typical market live weight of 1.8 to 3.2 kg (4 to 7 lb).

Edible: Products that can be used for human consumption.

Effluent: Liquid which flows from a containing space or process unit.

Microstrainer/Microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

mm: Millimeter = 0.001 meter.

Municipal Treatment: A city- or community-owned waste treatment plant for municipal and possibly industrial waste treatment.

New Source: Any building, structure, facility, or installation from which there is or may be a discharge of pollutants and whose construction is commenced after the publication of the proposed regulations.

Nitrate, Nitrite: Chemical compounds that include the NO_3^- (nitrate) and NO_2^- (nitrite) ions. They are composed of nitrogen and oxygen, are nutrients for growth of algae and other plant life, and contribute to eutrophication.

Nitrification: The process of oxidizing ammonia by bacteria into nitrites and nitrates.

No Discharge: No discharge of effluents to a water course. A system of land disposal with no runoff or total recycle of the waste water may be used to achieve it.

Nonwater Quality: Thermal, air, noise and all other environmental parameters except water.

Offal: In the poultry processing industry, the inedible parts of poultry (head, feet, and viscera) removed in eviscerating and trimming that may be used in production of inedible rendered products.

Off-Gas: The gaseous products of a process that are collected for use or more typically vented directly, or through a flare, into the atmosphere.

Organic Content: Synonymous with volatile solids except for small traces of some inorganic materials such as calcium carbonate which will lose weight at temperatures used in determining volatile solids.

Oxidation Lagoon: Synonymous with aerobic or aerated lagoon.

Oxidation Pond: Synonymous with aerobic lagoon.

pH: A measure of the relative acidity or alkalinity of water. A pH of 7.0 indicates a neutral condition. A greater pH indicates alkalinity and a lower pH indicates acidity. A one unit change in pH indicates a ten fold change in concentration of hydrogen ion concentration.

Point Source: Regarding waste water, a single plant with a waste water stream discharging into a receiving body of water.

Polishing: Final treatment stage before discharge of effluent to a water course. Carried out in a shallow, aerobic lagoon or pond, mainly to remove fine suspended solids that settle very slowly. Some aerobic microbiological activity also occurs.

Pollutant: A substance which taints, fouls, or otherwise renders impure or unclean the recipient system.

Pollution: The presence of pollutants in a system sufficient to degrade the quality of the system.

Polyelectrolyte Chemicals: High molecular weight substances which dissociate into ions when in solution; the ions either being bound to the molecular structure or free to diffuse throughout the solvent, depending on the sign of the ionic charge and the type of electrolyte. They are often used as flocculating agents in waste water treatment, particularly along with dissolved air flotation.

Ponding: A waste treatment technique involving the actual holdup of all waste waters in a confined space.

ppm: Parts per million, a measure of concentration usually expressed currently as mg/l.

Pretreatment: Waste water treatment located on the plant site and upstream from the discharge to a municipal treatment system.

Primary (In-Plant) Waste Treatment: In-plant materials (grease and solids) recovery and waste water treatment involving physical separation and recovery devices such as catch basins, screens, and dissolved air flotation.

Raw Waste: The waste water effluent from the in-plant primary waste treatment system.

Recycle: The return of a quantity of effluent from a specific unit or process to the feed stream of that same unit including the return of treated plant waste water for several plant uses.

Rendering: Separation of fats and water from poultry offal by heat or physical energy. "Rendering" operations in the poultry processing industry also include such operations as feather hydrolysis and blood processing for animal feeds.

Return on Assets (ROA): A measure of potential or realized profit as a percent of the total assets (or fixed assets) used to generate the profit.

Return on Investment (ROI): A measure of potential or realized profit as a percentage of the investment required to generate the profit.

Reuse: Referring to waste reuse. The subsequent use of water following an earlier use without restoring it to the original quality.

Riprap: A foundation or sustaining wall, usually of stones and brush, so placed on an embankment or a lagoon to prevent erosion.

RM: Referring to the raw material used in the rendering process.

Rotating Biological Contactor: A waste treatment device involving closely spaced light-weight disks which are rotated through the waste water allowing aerobic microflora to accumulate on each disk and thereby achieving a reduction in the waste content.

Sand Filter: A filter device incorporating a bed of sand that, depending on design, can be used in biological or advanced waste treatment.

Secondary Treatment: The waste treatment following primary in-plant treatment. Typically involving biological waste reduction systems.

Sedimentation Tank: A tank or basin in which a liquid (water, sewage, liquid manure) containing settleable suspended solids is retained for a sufficient time so part of the suspended solids settle out by gravity. The time interval that the liquid is retained in the tank is called "detention period." In sewage treatment, the detention period is short enough to avoid putrefaction.

Settling Tank: Synonymous with "Sedimentation Tank."

Sewage: Water after it has been fouled by various uses. From the standpoint of source it may be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions, together with those from industrial and agricultural establishments, and with such groundwater, surface water, and storm water as may be present.

Shock Load: A quantity of waste water or pollutant that greatly exceeds the normal discharged into a treatment system, usually occurring over a limited period of time.

Skimmings: Fats and floatable solids recovered from waste waters by catch basins, skimming tanks, and air flotation devices.

Sludge: The accumulated settled solids deposited from sewage or other wastes, raw or treated, in tanks or basins, and containing more or less water to form a semiliquid mass.

Slurry: A solids-water mixture, with sufficient water content to impact fluid handling characteristics to the mixture.

Small Game: Includes rabbits, pheasants, partridge, pigeons, squabs and guineas, and is often referred to as other poultry by the industry.

Stoichoimetric Amount: The amount of a substance involved in a specific chemical reaction, either as a reactant or as a reaction product.

Surface Waters: The waters of the United States including the territorial seas.

Suspended Solids (TSS): Solids that either float on the surface of, or are in suspension, in water; and which are largely removable by laboratory filtering as in the analytical determinant of TSS content of waste water.

Tertiary Waste Treatment: Waste treatment systems used to treat biological treatment effluent; and typically use physical-chemical technologies to effect waste reduction. Synonymous with "Advanced Waste Treatment."

Total Dissolved Solids (TDS): The solids content of waste water that is soluble and is measured as total solids content minus the suspended solids.

Turkey: A type of poultry with an average market live weight of about 8.2 kg (19 lb). Market live weight varies, however, from about 3.6 kg (8 lb) for fryer-roaster (young) turkeys to about 9.0 kg (20 lb) for mature turkeys.

Viscera: All internal organs of poultry removed during evisceration.

Zero Discharge: The discharge of no pollutants in the waste water stream of a plant that is discharging into a receiving body of water.

TABLE

METRIC TABLE

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier