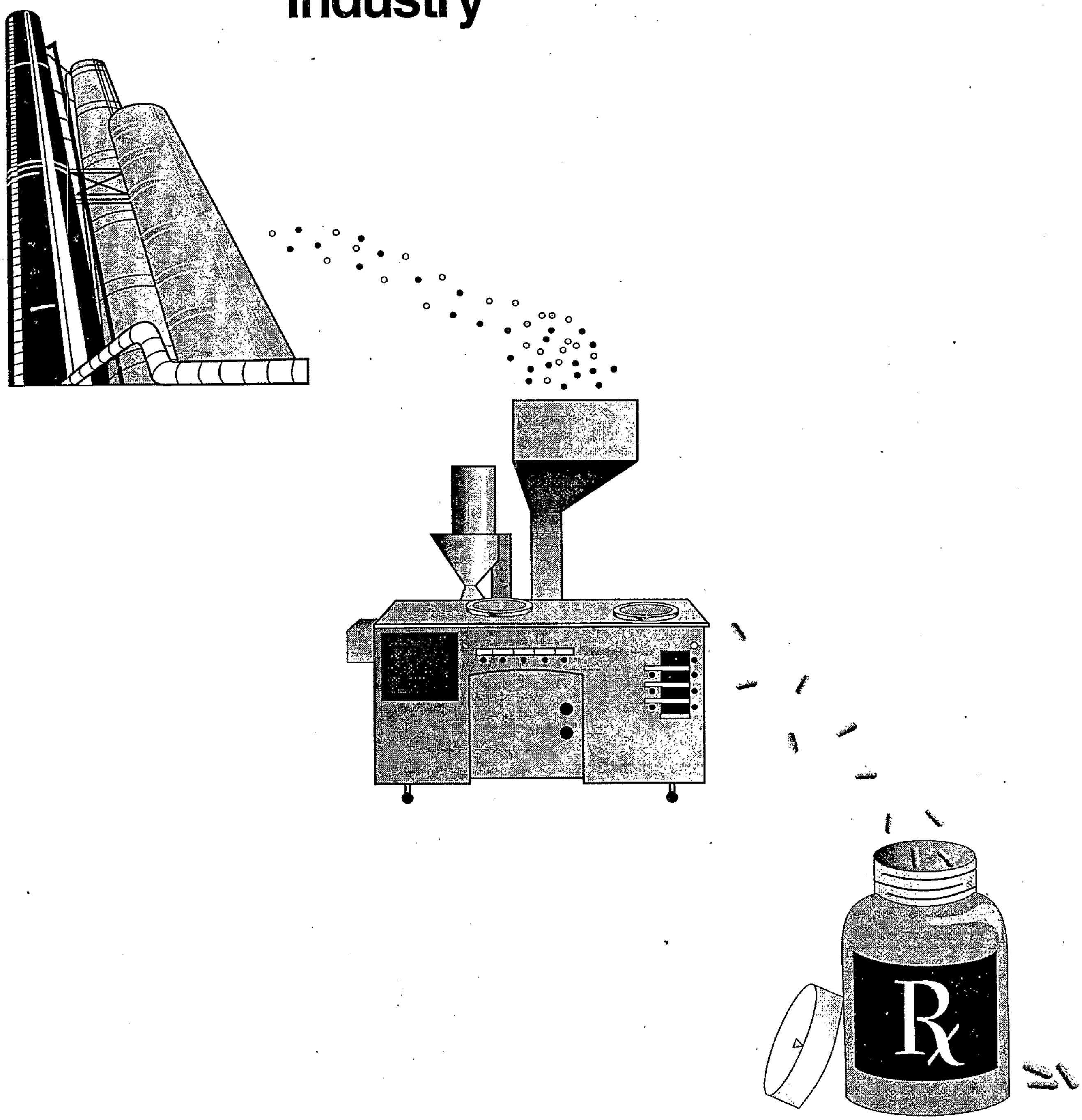
United States
Environmental Protection
Agency

Office of Water
4303

EPA 821-B-98-010
July 1998

Cost-Effective Analysis Of Final Effluent Limitations Guidelines And Standards For The Pharmaceutical Manufacturing Industry



COST-EFFECTIVENESS ANALYSIS OF FINAL EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS FOR THE PHARMACEUTICAL MANUFACTURING INDUSTRY

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SECTION ONE

INTRODUCTION

This analysis is submitted in support of the effluent limitations guidelines and standards for the pharmaceutical manufacturing industry. The report analyzes the cost effectiveness of six regulatory options organized into four regulatory groupings. This document compares the total annualized cost incurred for each of the regulatory options within each grouping to the corresponding effectiveness of that option in reducing the discharge of pollutants. The effectiveness measure used is pounds of pollutant removed weighted by an estimate of the relative toxicity of the pollutant. The rationale for this measure, referred to as "pounds-equivalent (PE) removed," is described later in this document.

Section Two discusses EPA's cost-effectiveness methodology and identifies the pollutants included in the analysis. This section also presents EPA's toxic weighting factors (TWFs) for each pollutant and considers the removal efficiency of each option. Section Three presents the results of the cost-effectiveness analysis. In Section Four, the cost-effectiveness values for the proposed regulatory options are compared to cost-effectiveness values for other proposed and promulgated rules. Appendix A presents data on pollutants and pollutant removals, and Appendix B presents data on annualized costs for each of the regulatory options.

SECTION TWO

BACKGROUND AND METHODOLOGY

Cost effectiveness (CE) is evaluated as the incremental and average annualized cost of a pollution control option in an industry or industry subcategory per incremental and total pounds-equivalent of pollutant (i.e., pound of pollutant adjusted for toxicity) removed by that control option. The cost-effectiveness analysis primarily enables EPA to compare the removal efficiencies of regulatory options under consideration for a rule. A secondary use is to compare the cost effectiveness of proposed options for the Final Pharmaceutical Industry Effluent Guidelines to that of pretreatment standards for other industries.

In each regulatory grouping, EPA ranks options in order of increasing pounds-equivalent removed to identify the point at which increased removal of pollutants is no longer cost-effective. Generally, EPA determines this to be where costs (per pound-equivalent removed) increase sharply, that is, where relatively few incremental pounds are removed for steady increases in cost. The accompanying figure (Figure 2-1) shows this point as Point A, where the cost-effectiveness curve becomes nearly vertical. Increases in removals beyond this point come only at relatively high unit costs, which, in many cases, EPA will determine exceed the benefit of the increased removals to society.

A number of steps must be undertaken before a cost-effectiveness analysis can be performed. There are five steps that define the analysis or generate data for use in the cost-effectiveness calculation:

- Determine the wastewater pollutants of concern (priority and other pollutants).
- Estimate the relative toxic weights (the adjustments to pounds of pollutants to reflect toxicity) of the pollutants of concern.
- Define the regulatory pollution control options.
- Calculate pollutant removals for each pollution control option.
- Determine the annualized cost of each pollution control option.

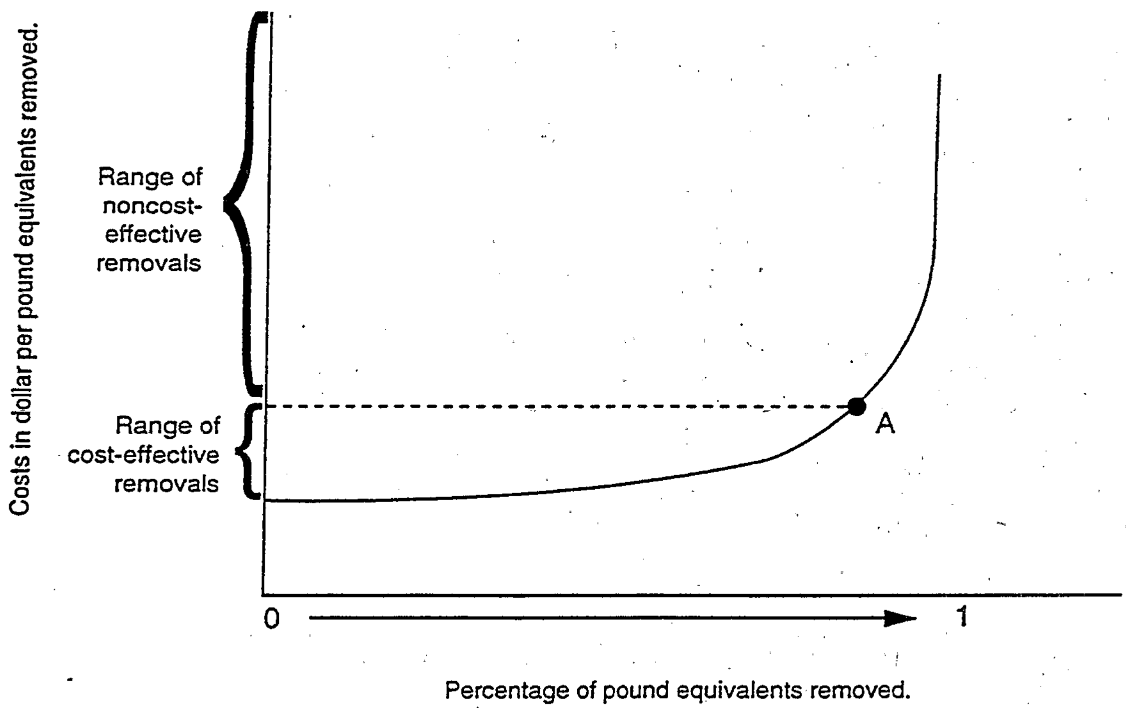

Figure 2-1. Cost effectiveness

All of these factors are used in the calculation of the cost-effectiveness values, which can then be compared for each regulatory option under consideration. The following sections discuss the five preliminary steps and the cost-effectiveness calculation and comparison methodologies.

2.1 POLLUTANTS OF CONCERN

Under the Final Pharmaceutical Industry Effluent Guidelines, a number of priority and other nonconventional pollutants are regulated. Some of the factors considered in selecting pollutants for regulation include toxicity, frequency of occurrence in wastestream effluent, and amount of pollutant in the wastestream. The list of pollutants for all regulatory options is presented in Table 2-1.

2.2 TOXIC WEIGHTING FACTORS

TWFs are used to calculate copper-based pounds-equivalent, and are derived from chronic aquatic life criteria (or toxic effect levels) and human health criteria (or toxic effect levels) established for the consumption of fish. For carcinogenic substances, the human health risk level is set at 10^{-5} (i.e., protective to a level allowing 1 in 100,000 excess lifetime cancer cases over background). These toxicity levels are related to a benchmark value, or toxicity level associated with a single pollutant. Copper, a toxic metal commonly detected and removed from industrial effluent, was selected as the benchmark pollutant (i.e., the basis to which others are compared). EPA used copper previously in TWF calculations for the cost-effectiveness analysis of effluent guidelines. Although the water quality criterion for copper was revised in 1984 (to 12.0μg/L), the TWF method uses the former criterion (5.6 μg/L) to facilitate comparisons with cost-effectiveness values calculated for other regulations. The former criterion for copper (5.6 μg/L) was reported in the 1980 *Ambient Water Quality Criteria for Copper* document.[1]

Two types of TWFs are used for this industry—TWF_{nonvol}, which is used for nonvolatile pollutants and TWF_{vol}, which is used for volatile pollutants. In the TWF_{nonvol} method, a TWF for aquatic life effects and a TWF for human health effects are added for pollutants of concern. The calculation is performed by

[1] U.S. EPA, 1980. *Ambient Water Quality Criteria for Copper.*

Table 2-1

Toxic Weighting Factors and Removal Efficiencies for Regulated Pollutants

Pollutant Code	Pollutant Name	Toxic Weighting Factor	Pollutant Weighting Factor	POTW Removal Efficiency
CN-	Cyanide	1.08E+00	1.90E-01	50%
CHEM3	Acentonitrile	8.50E-05	4.80E-03	0%
CHEM9	Ammonia-N (aqueous)	2.70E-03	4.90E-04	82%
CHEM10	N-Amyl Acetate	8.60E-04	1.50E-04	83%
CHEM11	Amyl Alcohol (1-Pentanol)	1.60E-04	2.80E-05	83%
CHEM12	Aniline	1.50E+00	2.50E-01	80%
CHEM15	Benzene	4.80E-01	8.40E-01	19%
CHEM25	2-Butanone (MEK)	2.90E-04	4.80E-05	83%
CHEM26	N-Butyl Acetate	3.10E-03	5.60E-04	83%
CHEM27	N-Butyl Alcohol (1-Butanol)	1.70E-03	2.90E-04	80%
CHEM29	tert-Butyl Alcohol	3.20E-05	5.60E-06	81%
CHEM35	Chlorobenzene	1.10E-02	1.50E-03	18%
CHEM37	Chloroform	1.00E-01	1.80E-01	1%
CHEM39	Chloromethane	2.08E-01	3.70E-01	0%
CHEM43	Cyclohexane	9.00E-03	1.60E-03	0%
CHEM48	o-Dichlorobenzene	1.20E-02	1.80E-03	78%
CHEM51	1,2-Dichloroethane	1.50E+00	2.60E+00	77%
CHEM55	Diethylamine	2.80E-04	5.00E-05	67%
CHEM58	Diethyl ether	8.82E-04	1.40E-04	0%
CHEM60	N,N-Dimethylacetamide	2.09E-06	3.70E-07	79%
CHEM61	Dimethylamine	6.22E-04	1.10E-04	0%
CHEM62	N,N-Dimethylaniline	8.30E-02	1.50E-02	83%
CHEM64	N,N-Dimethylformamide	2.40E-06	2.90E-04	79%
CHEM66	Dimethyl sulfoxide	1.65E-06	2.90E-07	95%
CHEM67	1,4-Dioxane	1.80E-01	3.10E-01	75%
CHEM70	Ethanol	5.80E-04	1.00E-04	89%
CHEM71	Ethyl acetate	7.60E-04	1.00E-04	83%
CHEM77	Ethylene glycol	8.40E-05	1.50E-05	96%
CHEM79	Formaldehyde	2.30E-03	4.10E-04	85%
CHEM80	Formamide	0.00E+00	0.00E+00	67%
CHEM82	Furfural	6.70E-02	9.60E-03	0%

Table 2-1 (continued)

	Pollutant Name	Toxic Weighting Factor	Pollutant Weighting Factor	POTW Removal Efficiency
CHEM84	N-Heptane	6.20E-02	1.10E-02	37%
CHEM87	N-Hexane	3.10E-02	4.40E-03	37%
CHEM 93	Isobutyraldehyde (2-Methyl propanal)	2.10E-03	3.80E-04	73%
CHEM94	Isopropanol (2-propanol)	5.60E-03	1.00E-03	81%
CHEM95	Isopropyl Acetate	6.90E-05	1.20E-05	83%
CHEM96	Isopropyl Ether	6.10E-04	1.10E-04	83%
CHEM 97	Methanol	3.30E-04	5.80E-05	80%
CHEM99	Methylamine	3.44E-04	6.10E-05	0%
CHEM101	Methyl Cellosolve (2-Methoxyethanol)	1.60E-01	2.90E-02	15%
CHEM102	Methylene Chloride (Dichloromethane)	1.20E-01	2.10E-01	15%
CHEM103	Methyl Formate	8.90E-06	1.60E-06	83%
CHEM105	Methyl Isobutyl Ketone (MIBK)	2.10E-03	3.60E-04	81%
CHEM106	2-Methyl Pyridine (2-Picoline)	1.36E-04	2.40E-05	0%
CHEM113	Petroleum Naphtha	6.70E-02	1.20E-02	80%
CHEM114	Phenol	2.83E-02	5.00E-03	95%
CHEM115	Polyethylene Glycol 600	5.60E-05	1.00E-05	96%
CHEM117	N-Proponal (1-Proponal)	2.70E-05	4.90E-06	88%
CHEM118	Acetone	1.60E-03	2.90E-04	83%
CHEM124	Pyridine	1.60E-01	2.90E-02	0%
CHEM129	Tetrahydrofuran	7.00E-03	1.30E-03	83%
CHEM130	Toluene	6.40E-03	1.00E-03	36%
CHEM134	Trichlorofluoromethane	1.49E-03	1.60E-04	0%
CHEM136	Triethylamine	1.50E-04	2.60E-05	83%
CHEM139	Xylenes	4.30E-03	7.50E-04	20%

Source: U.S. EPA, 1998. *Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.*

dividing aqautic life and human health criteria (or toxic effect levels) for each pollutant, expressed as a concentration in micrograms per liter (μg/L), into the former copper criterion of 5.6 μg/L:

$$TWF_{nonvol} = 5.6/AQ + 5.6/HHOO$$

where:

TWF_{nonvol}	=	Toxic weighting factor for nonvolatile pollutants
AQ	=	Chronic aquatic life value (μg/L)
HHOO	=	Human health (ingesting organisms only) value (μg/L)

Reductions in volatile organic compounds (VOCs) are also included in this cost-effectiveness analysis. The equation to calculate TWFs for volatiles follows the same method used in the *Cost-Effectiveness Analysis for the Organic Chemicals, Plastics, and Synthetic Fibers Industry.*[2] This equation was constructed to include in TWFs all exposure to humans associated with the presence of volatile toxic pollutants in the industry's wastewater. This modification applies only to the volatile pollutants; the calculation of the TWFs for nonvolatile pollutants is as described above.

As discussed in the *Cost-Effectiveness Analysis for the Organic Chemicals, Plastics, and Synthetic Fibers Industry,*[3] VOCs have the potential to volatize from wastewater effluent into the atmosphere during wastewater treatment. Although removed from the final wastewater discharge, the subsequent air load can increase the exposure of humans to pollutants through the inhalation pathway of exposure. Ideally, a weighting factor for VOCs would incorporate both air and water criteria or toxic effect levels. This approach is not readily feasible, however, because the criteria are expressed in different units (μg/m^3 versus μg/L). Therefore, proxy criteria for air are developed by: (1) substituting the average quantity of water ingested (2 L/day) for the average amount of air inhaled (20 m^3/day) and (2) using oral cancer slope potency factors and oral reference doses to represent toxicity from inhalation. With these modifications, the proxy criteria for air become equivalent to the calculated water quality criteria for ingesting water and organisms (as represented by the term HHWO). The equation used here to calculate TWFs is the same as above, except

[2] U.S. EPA, 1987. *Cost-Effectiveness Analysis for the Organic Chemicals, Plastics, and Synthetic Fibers Industry.*

[3] *Ibid.*

that HHOO is replaced with HHWO in consideration of the additional human health risk from the potential presence of VOCs in the air:

$$TWF_{vol} = 5.6/AQ + 5.6/HHWO$$

where:

TWF_{vol}	=	Toxic weighting factor for volatile pollutants
AQ	=	Chronic aquatic life value (μg/L)
HHWO	=	Human health (ingesting water and organisms) value (μg/L)

The similarities and differences between TWF_{vol} and TWF_{nonvol} are summarized in Table 2-2.

2.3 POLLUTION CONTROL OPTIONS

The pollution control options investigated are divided into those for direct dischargers and those for indirect dischargers. Within each type of discharger, additional distinctions are made. First, all technology options are divided between industry subcategories, with A and C industry subcategories (representing facilities that use fermentation or chemical synthesis processes) being distinguished from B and D industry subcategories (representing facilities that use biological and natural extraction processes or that are formulators of pharmaceutical products). For direct dischargers, the technologies are then further broken down into BPT, BCT, BAT, and NSPS options, of which only the BAT options are considered in the cost-effectiveness analysis; for indirect dischargers, PSES technology options are examined. NSPS and PSNS options are identical to the BAT and PSES options for each group of facilities. Thus the relative cost-effectiveness of these options will be similar to that for the equivalent options in each regulatory grouping.

Table 2-3 presents the regulatory options addressed in this analysis and defines the technologies associated with each option.

Table 2-2

Differences Between TWF_{nonvol} and TWF_{vol}

Feature	TWF_{nonvol}	TWF_{vol}
Benchmark Value (numerator)	5.6 (former freshwater chronic criterion for copper)	5.6 (former freshwater chronic criterion for copper)
Carcinogenic Risk Level	10^{-5} (1 in 100,000 excess cancer cases)	10^{-5} (1 in 100,000 excess cancer cases)
Human Health Exposure	Fish consumption only	Drinking water and fish consumption
Aquatic Life Effects vs. Human Health Effects	Effects are added	Effects are added

Source: U.S. EPA, 1987. *Cost-Effectiveness Analysis for the Organic Chemicals, Plastics, and Synthetic Fibers Industry.*

Table 2-3

Summary of Regulatory Options Considered in the Cost-Effectiveness Analysis

Regulation	Short Option Description	Option	Type of Treatment
BAT	BAT-A/C	Add organics, ammonia, and COD and modify cyanide	Advanced biological treatment with nitrification
	BAT-B/D	Add COD and withdraw cyanide	Advanced biological treatment
PSES	PSES-A/C	Add organics, ammonia,and modify cyanide	In-plant steam stripping for organic compounds and ammonia
	PSES-B/D	Add organics and withdraw cyanide	In-plant steam stripping for organic compounds

[a] COD = chemical oxygen demand.

Source: U.S. EPA, 1998. *Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.*

2.4 POLLUTANT REMOVALS

The pollutant loadings have been calculated for each facility under each regulatory option for comparison with baseline loadings. The postregulatory removals under each regulatory option are presented in Appendix A.

Pollutant removals are calculated directly as the difference between current and posttreatment discharges. Removals are then weighted using the TWFs and are reported in pounds-equivalent (see Appendix A for pound-equivalent removals for all pollutants by pollutant and option). Total removals for each option are then calculated by summing the removals for all pollutants under each option.

One additional step is undertaken to calculate final reductions in *nonvolatile* pollutant loadings for indirect dischargers because of the ability of POTWs to remove pollutants. Thus water removals for indirect dischargers take into account POTW removal efficiencies for nonvolatiles. Volatile pollutants are not removed by POTWs since they are volatized before reaching POTWs. Significant emission of these compounds to the air is expected from conveyance systems or open primary treatment units prior to reaching a POTW's biological treatment unit. Table 2-1 presents the POTW removal efficiencies for 50 pollutants. The POTW removal efficiencies are used as follows. If a facility is discharging 100 pounds of cadmium in its effluent stream to a POTW and the POTW has a removal efficiency for cadmium of 38 percent, then the cadmium discharged to surface waters is only 62 pounds. If the regulation results in a reduction of cadmium in the effluent stream such that total cadmium discharged to the POTW is 50 pounds, then the amount discharged to surface waters is calculated as 50 pounds multiplied by the POTW removal efficiency factor (1 - 0.38 or 0.62 times 50 pounds equals 31 pounds). The cost-effectiveness calculations then reflect the fact that the actual reduction of pollutant discharged to surface water is not 50 pounds (the change in the amount discharged to the POTW), but 31 pounds (the change in the amount actually discharged to surface water). Pollutant removals calculated in this way are presented in Table 2-4.

Table 2-4

Total Pollutant Removals by Regulatory Option

Option	Pounds Removed	Pounds-Equivalent Removed
BAT-A/C	2,160,048	9,780
BAT-B/D	22,339	87
PSES-A/C	10,653,427	282,614
PSES-B/D	3,346,808	80,807

Source: See Tables A-1 through A-6.

2.5 ANNUALIZED COSTS OF COMPLIANCE

Under each regulatory option, annualized costs of compliance have been developed.[4] The derivation of these costs is summarized briefly below.

Two groups of costs were derived for each of the affected facilities under each of the regulatory options: capital costs, which include capital equipment, delivery and installation of equipment including site work, site work prior to installation, engineering and necessary ancillary equipment and activities (piping, painting, electrical hookups, etc.); and recurring operating and maintenance costs (O&M) which include O&M labor and materials, chemical use, and sludge handling and disposal, if applicable, and electricity usage costs. The capital costs are then amortized over the lifetime of the equipment, to produce an annual cost.[5] Unlike annual costs derived in the Economic Assessment Report, where tax shields were incorporated when estimating impacts on industry, annual costs in this cost-effectiveness analysis are derived using no tax shields and the 7 percent discount rate suggested by the Office of Management and Budget (OMB) as an appropriate discount rate.[6] These annualized capital costs are added to the recurring costs to produce a total annual compliance cost for each facility affected under each regulatory option. Aggregate annual costs for each regulatory option are used in the calculation of the cost-effectiveness values. The total BAT/PSES aggregate annual costs by option are presented in Table 2-5. Appendix B presents the calculations used to arrive at the aggregate annual cost figures presented in Table 2-5.

2.6 CALCULATION OF THE COST-EFFECTIVENESS VALUES

Cost-effectiveness values are calculated separately for each regulatory option. Options first are ranked in ascending order of pounds-equivalent of pollutants removed. The incremental cost-effectiveness value for a particular control option is calculated as the ratio of the incremental annual cost to the incremental

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[4] See U.S. EPA, 1998. *Technical Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category* and U.S. EPA, 1998. *Economic Analysis for Final Effluent Limitations Guidelines and Standards for Existing and New Sources for the Pharmaceutical Industry.*

[5] These annualized costs are pretax to approximate the total cost to society of these options.

[6] OMB, 1996. *Economic Analysis of Federal Regulations under Executive Order 12866.* January 11.

Table 2-5

Aggregate Annual Cost by Regulatory Option

Option	Cost ($1990)	Cost ($1981)
BAT-A/C	$2,926,352	$2,186,106
BAT-B/D	$333,318	$249,003
PSES-A/C	$36,130,524	$26,990,998
PSES-B/D	$7,166,657	$5,353,790

Source: See Table B-1

pounds-equivalent removed. Average cost-effectiveness values for each option are calculated as total dollars for the option divided by total pounds-equivalent removed by the option. The incremental effectiveness values are viewed incrementally in comparison to the baseline (zero costs/zero removals) for BAT-B/D and to the preceding regulatory option (for all subsequent options). Cost-effectiveness values are reported in units of dollars per pound equivalent of pollutant removed.

For the purpose of comparing cost-effectiveness values of options under review to those of other promulgated rules, compliance costs used in the cost-effectiveness analysis (which are in 1990 dollars) are adjusted to 1981 dollars using *Engineering News Record*'s Construction Cost Index (CCI) (see Table 2-4 for compliance costs in 1981 dollars).[7] This adjustment factor is calculated as follows:

Adjustment factor = 1981 CCI/1990 CCI = 3,535/4,732 = 0.7470

The equation used to calculate incremental cost effectiveness is:

$$CE_k = \frac{ATC_k - ATC_{k-1}}{PE_k - PE_{k-1}}$$

where:

Ce_k	=	Cost-effectiveness of Option k
ATC_k	=	Total annualized treatment cost under Option k
Pe_k	=	Pound equivalents removed by Option k

The numerator of the equation, ATC_k minus ATC_{k-1}, is simply the incremental annualized treatment cost in going from Option k-1 (an option that removes fewer pounds-equivalent of pollutants) to Option k (an option that removes more pounds-equivalent of pollutants). The denominator is similarly the incremental removals achieved in going from Option k-1 to k. Thus, cost effectiveness measures the incremental unit cost of pollutant removal of Option k (in pound equivalents) in comparison to Option k-1.

[7] Engineering News Record, 1997. *Construction Cost Index*. March 31.

Average cost-effectiveness values also can be derived by setting ATC_{k-1} to zero and by setting the pollutant loadings (PE_{k-1}) to the current loading. These values can be used, with caution, to compare an option to previously promulgated effluent limitations guidelines.

2.7 COMPARISONS OF COST-EFFECTIVENESS VALUES

Because the options are ranked in ascending order of pounds-equivalent of pollutants removed within each regulatory grouping, any option that has higher costs but lower removals than another option immediately can be identified (the cost-effectiveness value for the next option becomes negative). When negative values are computed for Option k, Option k-1 will be noted as "dominated" (having a higher cost and lower removals than Option k). Option k-1 is then removed from the cost-effectiveness calculations, and all cost-effectiveness values within a regulatory grouping are then recalculated without the "dominated" option. This process continues until all "dominated" options are eliminated. The remaining options can then be presented in terms of their incremental cost-effectiveness values and are considered viable options for regulatory consideration.

SECTION THREE

COST-EFFECTIVENESS RESULTS

The cost-effectiveness analysis is based on the Agency's estimates of the cost of compliance and wastewater pollution removals associated with two BAT options—one for facilities with fermentation or chemical synthesis processes (the A and C facilities) and one for facilities with biological and natural extraction processes or which formulate pharmaceuticals (the B and D facilities). For indirect dischargers the analysis calculates cost-effectiveness values for two PSES options, one for A/C facilities and one for B/D facilities.

3.1 BEST AVAILABLE TECHNOLOGY—DIRECT DISCHARGERS

3.1.1 A/C Facilities

As shown in Table 3-1, the incremental and average cost-effectiveness for this selected regulatory option is $224/PE.

3.1.2 B/D Facilities

The incremental cost effectiveness for BAT-B/D is $2,870/PE. Since the selected option is a no-additional regulation option, BAT-B/D is set equal to BPT. BPT is not evaluated in cost-effectiveness analyses, so no cost-effectiveness value is calculated.

3.2 PRETREATMENT STANDARDS FOR EXISTING SOURCES—INDIRECT DISCHARGERS

3.2.1 A/C Facilities

As shown in Table 3-1, the selected regulatory option, PSES-A/C, has an incremental and average cost-effectiveness value of $96/PE.

Table 3-1

Cost-Effectiveness Results for Pollution Control Options

Option	Total Annual		Incremental		Incremental Cost Effectiveness ($1981) ($/PE)	Average Cost Effectiveness ($1981) ($/PE)
	Pounds-Equivalent Removed (lbs.)	Cost ($1981)	Pounds-Equivalent Removed (lbs.)	Cost ($1981)		
A/C Direct Dischargers						
BAT-A/C	9,780	$2,186,106	9,780	$2,186,106	$224	$224
B/D Direct Dischargers						
BAT-B/D	87	$249,003	87	$249,003	$2,870	$2,870
A/C Indirect Dischargers						
PSES-A/C	282,614	$26,990,998	282,614	$26,990,998	$96	$96
B/D Indirect Dischargers						
PSES-B/D	80,807	$5,353,790	80,807	$5,353,790	$66	$66

Source: Data from Appendix A and B.

3.2.2 B/D Facilities

The incremental cost-effectiveness value for the selected regulatory option, PSES-B/D, has an incremental and average cost-effectiveness value of $66/PE.

SECTION FOUR

COMPARISON OF COST-EFFECTIVENESS VALUES WITH THOSE OF OTHER PROMULGATED RULES

As discussed in Section Two, incremental cost effectiveness is the appropriate measure for comparing one regulatory option to an alternative, less stringent regulatory option for the same rule. Some believe that it also may be used to compare cost effectiveness across rules when considering how the last increment of stringency in one rule compares to the last increment of stringency in another. For comparing the overall cost effectiveness of one rule to another, average cost effectiveness may be a more appropriate measure, but must be considered in context with caution. (Average cost-effectiveness can be thought of as the "increment" between no regulation and the selected option for any given rule.)

Table 4-1 presents the cost-effectiveness values for effluent limitations guidelines and standards issued for direct dischargers under BAT in other industries. For the A/C direct dischargers, the cost-effectiveness value for the selected option is $224/PE. The cost-effectiveness value for BAT-A/C is higher than those shown for most other effluent guidelines, but not all, and, for the reasons outlined below, this value is believed to understate the true cost effectiveness of the rule. For B/D direct dischargers, the selected option is set at BAT = BPT.

Table 4-2 presents the cost-effectiveness values for pretreatment standards issued for indirect dischargers under PSES in other industries. For A/C indirects, the cost-effectiveness value for the selected option is $96/PE. For B/D indirects, the value is $66/PE. The values for PSES-A/C and PSES-B/D are within the range shown for other pretreatment standards.

The cost-effectiveness values determined for this rule do not represent an estimate of the removal of the toxic pounds resulting from the removal of COD. Discharges from pharmaceutical manufacturing facilties exhibit toxicity as measured by the whole effluent toxicity test and reported as part of the routine National Pollutant Discharge Elimination System (NPDES) discharge monitoring reports. One study conducted by EPA at a pharmaceutical manufacturing facility showed a significant decrease in toxicity with a corresponding decrease in chemical oxygen demand (COD) level for the tested effluent sample from the

Table 4-1

Industry Comparison of BAT Cost-Effectiveness for Direct Dischargers (Toxic and Nonconventional Pollutants Only; Copper-Based Weights;[a] 1981 dollars)

Industry		PE Currently Discharged (thousands)	PE Remaining at Selected Option (thousands)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
Aluminum Forming		1,340	90	121
Battery Manufacturing		4,126	5	2
Canmaking		12	0.2	10
Centralized Waste Treatment[c]		3,372	1,261-1,267	5-7
Coal Mining		BAT=BPT	BAT=BPT	BAT=BPT
Coil Coating		2,289	9	49
Copper Forming		70	8	27
Electronics I		9	3	404
Electronics II		NA	NA	NA
Foundries		2,308	39	84
Inorganic Chemicals I		32,503	1,290	<1
Inorganic Chemicals II		605	27	6
Iron & Steel		40,746	1,040	2
Leather Tanning		259	112	BAT=BPT
Metal Finishing		3,305	3,268	12
Metal Products and Machinery[c]		140	70	50
Nonferrous Metals Forming		34	2	69
Nonferrous Metals Mfg I		6,653	313	4
Nonferrous Metals Mfg II		1,004	12	6
Oil and Gas: Offshore[b] Coastal—Produced Water/TWC Drilling Waste		3,809 951 BAT = Current Practice	2,328 239 BAT = Current Practice	33 35 BAT = Current Practice
Organic Chemicals		54,225	9,735	5
Pesticides		2,461	371	14
Pharmaceuticals	A/C	560	550	224
	B/D	0.1	—	BAT=BPT
Plastics Molding & Forming		44	41	BAT=BPT
Porcelain Enameling		1,086	63	6

Table 4-1 (continued)

Industry	PE Currently Discharged (thousands)	PE Remaining at Selected Option (thousands)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
Petroleum Refining	BAT=BPT	BAT=BPT	BAT=BPT
Pulp & Paper	15,524	4,069	14
Textile Mills	BAT=BPT	BAT=BPT	BAT=BPT
Transportation Equipment Cleaning[c]	15	0.8	108

[a]Although toxic weighting factors for priority pollutants varied across these rules, this table reflects the cost effectiveness at the time of regulation.

[b]Produced water only; for produced sand and drilling fluids and drill cuttings, BAT=NSPS.

[c]Proposed.

Table 4-2

Industry Comparison of PSES Cost-Effectiveness for Indirect Dischargers (Toxic and Nonconventional Pollutants Only; Copper-Based Weights[a]; 1981 dollars)

Industry		PE Currently Discharged (thousands)	PE Remaining at Selected Option (thousands)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
Aluminum Forming		1,602	18	155
Battery Manufacturing		1,152	5	15
Canmaking		252	5	38
Coal Mining[b]		NA	NA	NA
Coastal Oil and Gas[b]		NA	NA	NA
Coil Coating		2,503	10	10
Copper Forming		34	4	10
Electronics I		75	35	14
Electronics II		260	24	14
Foundries		2,136	18	116
Industrial Laundries[d]		2,002	1,594	108
Inorganic Chemicals I		3,971	3,004	9
Inorganic Chemicals II		4,760	6	<1
Iron and Steel		5,599	1,404	6
Leather Tanning		16,830	1,899	111
Metal Finishing		11,680	755	10
Nonferrous Metals Forming		189	5	90
Nonferrous Metals Manufacturing I		3,187	19	15
Nonferrous Metals Manufacturing II		38	0.41	12
Offshore Oil and Gas[b]		NA	NA	NA
OCSPSF[c]		5,210	72	34
Pharmaceuticals[c]	A/C	897	614	96
	B/D	90	9	66
Plastics Molding and Forming		NA	NA	NA

Table 4-2 (continued)

Industry	PE Currently Discharged (thousands)	PE Remaining at Selected Option (thousands)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
Porcelain Enameling	1,565	96	14
Pulp and Paper[d]	1,323	314	14

[a]Although toxic weighing factors for priority pollutants varied across these rules, this table reflects the cost effectiveness at the time of regulation.

[b]Industry has no known or expected indirect discharges.

[c]Reflects costs and removals of both air and water pollutants.

[d]Proposed.

facility and a sample effluent of a pilot-scale biological treatment plant study. Because of the limited amount of data, and the inability to identify the different mix of specific organic compounds represented by the COD measurement, the total amount of toxic pounds-equivalent represented by the nonconventional pollutant parameter of COD could not be determined.

Based on the lack of pounds-equivalent associated with COD removals, the cost-effectiveness analysis results understate the true cost effectiveness of this rule.

APPENDIX A

SUPPORTING DOCUMENTATION FOR COST-EFFECTIVENESS ANALYSIS: POLLUTANT LOADINGS ANALYSIS

Table A-1

Industry Loads and Removals by Pollutant
BAT-A/C Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	Toxic Weighting Factor	PE Removals
CN-	Cyanide	0	1.08E+00	0
CHEM3	Acetonitrile	1,146	8.50E-05	0
CHEM9	Ammonia-N	800,913	2.70E-03	2,162
CHEM10	Amyl Acetate, n-	1,616	8.60E-04	1
CHEM11	Pentanol, 1- (amyl alcohol)	52,174	1.60E-04	8
CHEM12	Aniline	0	1.50E+00	0
CHEM15	Benzene	0	4.80E-01	0
CHEM25	Methyl ethyl ketone	0	2.90E-04	0
CHEM26	Butyl acetate, n-	0	3.10E-03	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	1.70E-03	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	3.20E-05	0
CHEM35	Chlorobenzene	0	1.10E-02	0
CHEM37	Trichloromethane (chloroform)	4,080	1.00E-01	408
CHEM48	Dichlorobenzene, 1,2-	0	1.20E-02	0
CHEM51	Dichloroethane, 1,2-	147	1.50E+00	221
CHEM55	Diethylamine	0	2.80E-04	0
CHEM60	Dimethylacetamide, N,N-	0	2.09E-06	0
CHEM62	N,N-Dimethylaniline	0	8.30E-02	0
CHEM64	Dimethylformamide, N,N-	0	2.40E-06	0
CHEM66	Dimethyl sulfoxide	3,712	1.65E-06	0
CHEM67	Dioxane, 1,4-	0	1.80E-01	0
CHEM70	Ethanol	195,517	5.80E-04	113
CHEM71	Ethyl acetate	87,223	7.60E-04	66
CHEM77	Ethylene glycol	0	8.40E-05	0
CHEM79	Formaldehyde	0	2.30E-03	0
CHEM80	Formamide	0	0.00E+00	0
CHEM84	Heptane, n-	0	6.20E-02	0
CHEM87	Hexane, n-	241	3.10E-02	7
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	2.10E-03	0
CHEM94	Isopropanol (2-propanol)	165,987	5.60E-03	930
CHEM95	Isopropyl Acetate	286	6.90E-05	0
CHEM96	Isopropyl Ether	0	6.10E-04	0
CHEM97	Methanol	712,931	3.30E-04	235
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	1.60E-01	0
CHEM102	Dichloromethane (methylene chloride)	41,905	1.20E-01	5,029
CHEM103	Methyl formate (formic acid, methyl ester)	8,437	8.90E-06	0
CHEM105	Methyl isobutyl ketone	14,462	2.10E-03	30
CHEM113	Petroleum Naptha	0	6.70E-02	0
CHEM114	Phenol	8,995	2.83E-02	254
CHEM115	Polyethylene Glycol 600	0	5.60E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	2.70E-05	0
CHEM118	Acetone	17,832	1.60E-03	29
CHEM124	Pyridine	0	1.60E-01	0
CHEM129	Tetrahydrofuran	31,821	7.00E-03	223
CHEM130	Toluene	8,042	6.40E-03	51
CHEM136	Triethylamine	0	1.50E-04	0
CHEM139	Xylenes	2,581	4.30E-03	11
CHEMBOD	Biochemical Oxygen Demand 5-day	0	0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0	0.00E+00	0
CHEMTSS	Total Suspended Solids	0	0.00E+00	0
	Totals	2,160,048		9,780

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table A-2

Industry Loads and Removals by Pollutant
BAT-B/D Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	Toxic Weighting Factor	PE Removals
CN-	Cyanide	0	1.08E+00	0
CHEM3	Acetonitrile	0	8.50E-05	0
CHEM9	Ammonia-N	0	2.70E-03	0
CHEM10	Amyl Acetate, n-	0	8.60E-04	0
CHEM11	Pentanol, 1- (amyl alcohol)	0	1.60E-04	0
CHEM12	Aniline	0	1.50E+00	0
CHEM15	Benzene	0	4.80E-01	0
CHEM25	Methyl ethyl ketone	0	2.90E-04	0
CHEM26	Butyl acetate, n-	0	3.10E-03	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	1.70E-03	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	3.20E-05	0
CHEM35	Chlorobenzene	0	1.10E-02	0
CHEM37	Trichloromethane (chloroform)	0	1.00E-01	0
CHEM48	Dichlorobenzene, 1,2-	0	1.20E-02	0
CHEM51	Dichloroethane, 1,2-	0	1.50E+00	0
CHEM55	Diethylamine	0	2.80E-04	0
CHEM60	Dimethylacetamide, N,N-	0	2.09E-06	0
CHEM62	N,N-Dimethylaniline	0	8.30E-02	0
CHEM64	Dimethylformamide, N,N-	0	2.40E-06	0
CHEM66	Dimethyl sulfoxide	0	1.65E-06	0
CHEM67	Dioxane, 1,4-	0	1.80E-01	0
CHEM70	Ethanol	7,477	5.80E-04	4
CHEM71	Ethyl acetate	0	7.60E-04	0
CHEM77	Ethylene glycol	0	8.40E-05	0
CHEM79	Formaldehyde	171	2.30E-03	0
CHEM80	Formamide	0	0.00E+00	0
CHEM84	Heptane, n-	0	6.20E-02	0
CHEM87	Hexane, n-	0	3.10E-02	0
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	2.10E-03	0
CHEM94	Isopropanol (2-propanol)	14,646	5.60E-03	82
CHEM95	Isopropyl Acetate	0	6.90E-05	0
CHEM96	Isopropyl Ether	0	6.10E-04	0
CHEM97	Methanol	0	3.30E-04	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	1.60E-01	0
CHEM102	Dichloromethane (methylene chloride)	0	1.20E-01	0
CHEM103	Methyl formate (formic acid, methyl ester)	0	8.90E-06	0
CHEM105	Methyl isobutyl ketone	0	2.10E-03	0
CHEM113	Petroleum Naptha	0	6.70E-02	0
CHEM114	Phenol	0	2.83E-02	0
CHEM115	Polyethylene Glycol 600	46	5.60E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	2.70E-05	0
CHEM118	Acetone	0	1.60E-03	0
CHEM124	Pyridine	0	1.60E-01	0
CHEM129	Tetrahydrofuran	0	7.00E-03	0
CHEM130	Toluene	0	6.40E-03	0
CHEM136	Triethylamine	0	1.50E-04	0
CHEM139	Xylenes	0	4.30E-03	0
CHEMBOD	Biochemical Oxygen Demand 5-day	0	0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0	0.00E+00	0
CHEMTSS	Total Suspended Solids	0	0.00E+00	0
	Totals	22,339		87

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table A-3

Industry Loads and Removals by Pollutant
PSES-A/C Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	POTW Removal Efficiency (%)	Removals After POTW (lbs/yr)	Toxic Weighting Factor	PE Removals
CN-	Cyanide	0	50%	0	1.08E+00	0
CHEM3	Acetonitrile	0	0%	0	8.50E-05	0
CHEM9	Ammonia-N	1,425,793	82%	259,494	2.70E-03	701
CHEM10	Amyl Acetate, n-	294,153	83%	50,594	8.60E-04	44
CHEM11	Pentanol, 1- (amyl alcohol)	0	83%	0	1.60E-04	0
CHEM12	Aniline	0	80%	0	1.50E+00	0
CHEM15	Benzene	120,896	19%	98,047	4.80E-01	47,063
CHEM25	Methyl ethyl ketone	0	83%	0	2.90E-04	0
CHEM26	Butyl acetate, n-	412,547	83%	70,958	3.10E-03	220
CHEM27	Butanol, 1- (n-butyl alcohol)	0	80%	0	1.70E-03	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	81%	0	3.20E-05	0
CHEM35	Chlorobenzene	84,094	18%	69,042	1.10E-02	759
CHEM37	Trichloromethane (chloroform)	45,219	1%	44,812	1.00E-01	4,481
CHEM48	Dichlorobenzene, 1,2-	16,376	78%	3,553	1.20E-02	43
CHEM51	Dichloroethane, 1,2-	546	77%	124	1.50E+00	186
CHEM55	Diethylamine	61,644	67%	20,466	2.80E-04	6
CHEM60	Dimethylacetamide, N,N-	0	79%	0	2.09E-06	0
CHEM62	N,N-Dimethylaniline	0	83%	0	8.30E-02	0
CHEM64	Dimethylformamide, N,N-	0	79%	0	2.40E-06	0
CHEM66	Dimethyl sulfoxide	0	95%	0	1.65E-06	0
CHEM67	Dioxane, 1,4-	0	75%	0	1.80E-01	0
CHEM70	Ethanol	110	89%	12	5.80E-04	0
CHEM71	Ethyl acetate	1,693,800	83%	291,334	7.60E-04	221
CHEM77	Ethylene glycol	0	96%	0	8.40E-05	0
CHEM79	Formaldehyde	0	85%	0	2.30E-03	0
CHEM80	Formamide	0	67%	0	0.00E+00	0
CHEM84	Heptane, n-	17,502	37%	11,061	6.20E-02	686
CHEM87	Hexane, n-	1,133,860	37%	716,599	3.10E-02	22,215
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	29,737	73%	8,088	2.10E-03	17
CHEM94	Isopropanol (2-propanol)	11	81%	2	5.60E-03	0
CHEM95	Isopropyl Acetate	9,426	83%	1,621	6.90E-05	0
CHEM96	Isopropyl Ether	9,280	83%	1,596	6.10E-04	1
CHEM97	Methanol	22	80%	4	3.30E-04	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	978,930	15%	832,091	1.60E-01	133,135
CHEM102	Dichloromethane (methylene chloride)	677,934	15%	577,600	1.20E-01	69,312
CHEM103	Methyl formate (formic acid, methyl ester)	23,283	83%	4,005	8.90E-06	0
CHEM105	Methyl isobutyl ketone	254,906	81%	48,942	2.10E-03	103
CHEM113	Petroleum Naptha	0	80%	0	6.70E-02	0
CHEM114	Phenol	0	95%	0	2.83E-02	0
CHEM115	Polyethylene Glycol 600	0	96%	0	5.60E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	88%	0	2.70E-05	0
CHEM118	Acetone	2,234,971	83%	373,240	1.60E-03	597
CHEM124	Pyridine	0	0%	0	1.60E-01	0
CHEM129	Tetrahydrofuran	91,062	83%	15,663	7.00E-03	110
CHEM130	Toluene	640,348	36%	411,104	6.40E-03	2,631
CHEM136	Triethylamine	374,837	83%	64,472	1.50E-04	10
CHEM139	Xylenes	22,140	20%	17,624	4.30E-03	76
CHEMBOD	Biochemical Oxygen Demand 5-day	0			0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0			0.00E+00	0
CHEMTSS	Total Suspended Solids	0			0.00E+00	0
	Totals	10,653,427		3,992,148		282,614

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table A-4

Industry Loads and Removals by Pollutant
PSES-B/D Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	POTW Removal Efficiency (%)	Removals After POTW (lbs/yr)	Toxic Weighting Factor	PE Removals
CN-	Cyanide	0	50%	0	1.08E+00	0
CHEM3	Acetonitrile	0	0%	0	8.50E-05	0
CHEM9	Ammonia-N	0	82%	0	2.70E-03	0
CHEM10	Amyl Acetate, n-	810,977	83%	139,488	8.60E-04	120
CHEM11	Pentanol, 1- (amyl alcohol)	0	83%	0	1.60E-04	0
CHEM12	Aniline	0	80%	0	1.50E+00	0
CHEM15	Benzene	0	19%	0	4.80E-01	0
CHEM25	Methyl ethyl ketone	0	83%	0	2.90E-04	0
CHEM26	Butyl acetate, n-	0	83%	0	3.10E-03	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	80%	0	1.70E-03	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	81%	0	3.20E-05	0
CHEM35	Chlorobenzene	0	18%	0	1.10E-02	0
CHEM37	Trichloromethane (chloroform)	0	1%	0	1.00E-01	0
CHEM48	Dichlorobenzene, 1,2-	0	78%	0	1.20E-02	0
CHEM51	Dichloroethane, 1,2-	0	77%	0	1.50E+00	0
CHEM55	Diethylamine	0	67%	0	2.80E-04	0
CHEM60	Dimethylacetamide, N,N-	0	79%	0	2.09E-06	0
CHEM62	N,N-Dimethylaniline	0	83%	0	8.30E-02	0
CHEM64	Dimethylformamide, N,N-	0	79%	0	2.40E-06	0
CHEM66	Dimethyl sulfoxide	0	95%	0	1.65E-06	0
CHEM67	Dioxane, 1,4-	0	75%	0	1.80E-01	0
CHEM70	Ethanol	0	89%	0	5.80E-04	0
CHEM71	Ethyl acetate	11,639	83%	2,002	7.60E-04	2
CHEM77	Ethylene glycol	0	96%	0	8.40E-05	0
CHEM79	Formaldehyde	0	85%	0	2.30E-03	0
CHEM80	Formamide	0	67%	0	0.00E+00	0
CHEM84	Heptane, n-	0	37%	0	6.20E-02	0
CHEM87	Hexane, n-	0	37%	0	3.10E-02	0
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	73%	0	2.10E-03	0
CHEM94	Isopropanol (2-propanol)	300	81%	58	5.60E-03	0
CHEM95	Isopropyl Acetate	217,733	83%	37,450	6.90E-05	3
CHEM96	Isopropyl Ether	0	83%	0	6.10E-04	0
CHEM97	Methanol	0	80%	0	3.30E-04	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	15%	0	1.60E-01	0
CHEM102	Dichloromethane (methylene chloride)	785,175	15%	668,969	1.20E-01	80,276
CHEM103	Methyl formate (formic acid, methyl ester)	0	83%	0	8.90E-06	0
CHEM105	Methyl isobutyl ketone	0	81%	0	2.10E-03	0
CHEM113	Petroleum Naptha	0	80%	0	6.70E-02	0
CHEM114	Phenol	1	95%	0	2.83E-02	0
CHEM115	Polyethylene Glycol 600	0	96%	0	5.60E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	88%	0	2.70E-05	0
CHEM118	Acetone	1,520,984	83%	254,004	1.60E-03	406
CHEM124	Pyridine	0	0%	0	1.60E-01	0
CHEM129	Tetrahydrofuran	0	83%	0	7.00E-03	0
CHEM130	Toluene	0	36%	0	6.40E-03	0
CHEM136	Triethylamine	0	83%	0	1.50E-04	0
CHEM139	Xylenes	0	20%	0	4.30E-03	0
CHEMBOD	Biochemical Oxygen Demand 5-day	0			0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0			0.00E+00	0
CHEMTSS	Total Suspended Solids	0			0.00E+00	0
	Totals	3,346,808		1,101,971		80,807

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

APPENDIX B

SUPPORTING DOCUMENTATION FOR COST-EFFECTIVENESS ANALYSIS: COST ANALYSIS

Table B-1

Computation of Annualized Costs in 1990 and 1981 Dollars

Costs	BAT-A/C	BAT-B/D	PSES-A/C	PSES-B/D
Capital Cost ($1990)	$5,569,135	$887,021	$80,864,749	$22,067,126
O&M Cost ($1990)	$2,423,726	$248,325	$28,597,244	$5,010,342
Total Annualized Capital Cost ($1990)	$589,536	$93,898	$8,560,152	$2,335,974
Total Annual Cost ($1990)	$2,926,352	$333,318	$36,130,524	$7,166,657
Deflator	0.7470	0.7470	0.7470	0.7470
Total Cost ($1981)	$2,186,106	$249,003	$26,990,998	$5,353,790

Source: Capital and O&M Costs: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category; Deflator: Engineering News Record, 1997. Construction Cost Index. March 31.

APPENDIX C

COST-EFFECTIVENESS ANALYSIS RESULTS USING THE ALTERNATIVE PWF APPROACH

The pollutant weighting factor (PWF) method is an alternative to the TWF method for assessing water-based effects. PWFs are derived from the more protective of either the chronic aquatic life criteria (or toxic effect levels) or the human health criteria (or toxic effect levels) established for the consumption of water and fish. For carcinogenic substances, the human health risk level is 10^{-6} (i.e., protective to a level allowing 1 in 1,000,000 excess lifetime cancer cases over background). In contrast to TWFs, PWFs are not related to a benchmark pollutant. PWFs are derived by taking the reciprocal of the more stringent (smallest value) of the aquatic life or human health criterion or toxic effect level, both expressed in concentration units of micrograms per liter (µg/L):

$$PWF = \frac{1}{AQ}, \text{ if } AQ < HHWO \text{ or } PWF = \frac{1}{HHWO}, \text{ if } HHWO < AQ$$

where:

PWF	=	pollutant weighting factor
AQ	=	chronic aquatic life value (µg/L)
HHWO	=	human health (ingesting water and organisms value (µg/L)

The results of using PWFs rather than TWFs in the cost-effectiveness analysis are shown in Table C-1. As Table C-1 shows, the selected option for BAT-A/C has an average and incremental cost-effectiveness value of $205/PE, PSES-A/C has an average and incremental cost-effectiveness value of $112/PE and the selected option for PSES-B/D has an average and incremental cost-effectiveness value of $38/PE. Tables C-2 through C-5 provide the detailed supporting data.

Table C-1

Cost-Effectiveness Results for Pollution Control Options Using PWFs

Option	Total Annual		Incremental		Incremental Cost Effectiveness ($1981) ($/PE)	Average Cost Effectiveness ($1981) ($/PE)
	Pounds-Equivalent Removed (lbs.)	Cost ($1981)	Pounds-Equivalent Removed (lbs.)	Cost ($1981)		
A/C Direct Dischargers						
BAT-A/C	10,660	$2,186,106	10,660	$2,186,106	$205	$205
B/D Direct Dischargers						
BAT-B/D	15	$249,003	15	$249,003	$16,102	$16,102
A/C Indirect Dischargers						
PSES-A/C	240,339	$26,990,998	240,339	$26,990,998	$112	$112
B/D Indirect Dischargers						
PSES-B/D	140,579	$5,353,790	140,579	$5,353,790	$38	$38

Source: Data from Appendix B and C.

Table C-2

Industry Loads and Removals by Pollutant Based on PWFs
BAT-A/C Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	Pollutant Weighting Factor	PE Removals
CN-	Cyanide	0	1.90E-01	0
CHEM3	Acetonitrile	1,146	4.80E-03	6
CHEM9	Ammonia-N	800,913	4.90E-04	392
CHEM10	Amyl Acetate, n-	1,616	1.50E-04	0
CHEM11	Pentanol, 1- (amyl alcohol)	52,174	2.80E-05	1
CHEM12	Aniline	0	2.50E-01	0
CHEM15	Benzene	0	8.40E-01	0
CHEM25	Methyl ethyl ketone	0	4.80E-05	0
CHEM26	Butyl acetate, n-	0	5.60E-04	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	2.90E-04	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	5.60E-06	0
CHEM35	Chlorobenzene	0	1.50E-03	0
CHEM37	Trichloromethane (chloroform)	4,080	1.80E-01	734
CHEM48	Dichlorobenzene, 1,2-	0	1.80E-03	0
CHEM51	Dichloroethane, 1,2-	147	2.60E+00	382
CHEM55	Diethylamine	0	5.00E-05	0
CHEM60	Dimethylacetamide, N,N-	0	3.70E-07	0
CHEM62	N,N-Dimethylaniline	0	1.50E-02	0
CHEM64	Dimethylformamide, N,N-	0	2.90E-04	0
CHEM66	Dimethyl sulfoxide	3,712	2.90E-07	0
CHEM67	Dioxane, 1,4-	0	3.10E-01	0
CHEM70	Ethanol	195,517	1.00E-04	20
CHEM71	Ethyl acetate	87,223	1.00E-04	9
CHEM77	Ethylene glycol	0	1.50E-05	0
CHEM79	Formaldehyde	0	4.10E-04	0
CHEM80	Formamide	0	0.00E+00	0
CHEM84	Heptane, n-	0	1.10E-02	0
CHEM87	Hexane, n-	241	4.40E-03	1
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	3.80E-04	0
CHEM94	Isopropanol (2-propanol)	165,987	1.00E-03	166
CHEM95	Isopropyl Acetate	286	1.20E-05	0
CHEM96	Isopropyl Ether	0	1.10E-04	0
CHEM97	Methanol	712,931	5.80E-05	41
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	2.90E-02	0
CHEM102	Dichloromethane (methylene chloride)	41,905	2.10E-01	8,800
CHEM103	Methyl formate (formic acid, methyl ester)	8,437	1.60E-06	0
CHEM105	Methyl isobutyl ketone	14,462	3.60E-04	5
CHEM113	Petroleum Naptha	0	1.20E-02	0
CHEM114	Phenol	8,995	5.00E-03	45
CHEM115	Polyethylene Glycol 600	0	1.00E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	4.90E-06	0
CHEM118	Acetone	17,832	2.90E-04	5
CHEM124	Pyridine	0	2.90E-02	0
CHEM129	Tetrahydrofuran	31,821	1.30E-03	41
CHEM130	Toluene	8,042	1.00E-03	8
CHEM136	Triethylamine	0	2.60E-05	0
CHEM139	Xylenes	2,581	7.50E-04	2
CHEMBOD	Biochemical Oxygen Demand 5-day	0	0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0	0.00E+00	0
CHEMTSS	Total Suspended Solids	0	0.00E+00	0
	Totals	2,160,048		10,660

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table C-3

Industry Loads and Removals by Pollutant Based on PWFs
BAT-B/D Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	Pollutant Weighting Factor	PE Removals
CN-	Cyanide	0	1.90E-01	0
CHEM3	Acetonitrile	0	4.80E-03	0
CHEM9	Ammonia-N	0	4.90E-04	0
CHEM10	Amyl Acetate, n-	0	1.50E-04	0
CHEM11	Pentanol, 1- (amyl alcohol)	0	2.80E-05	0
CHEM12	Aniline	0	2.50E-01	0
CHEM15	Benzene	0	8.40E-01	0
CHEM25	Methyl ethyl ketone	0	4.80E-05	0
CHEM26	Butyl acetate, n-	0	5.60E-04	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	2.90E-04	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	5.60E-06	0
CHEM35	Chlorobenzene	0	1.50E-03	0
CHEM37	Trichloromethane (chloroform)	0	1.80E-01	0
CHEM48	Dichlorobenzene, 1,2-	0	1.80E-03	0
CHEM51	Dichloroethane, 1,2-	0	2.60E+00	0
CHEM55	Diethylamine	0	5.00E-05	0
CHEM60	Dimethylacetamide, N,N-	0	3.70E-07	0
CHEM62	N,N-Dimethylaniline	0	1.50E-02	0
CHEM64	Dimethylformamide, N,N-	0	2.90E-04	0
CHEM66	Dimethyl sulfoxide	0	2.90E-07	0
CHEM67	Dioxane, 1,4-	0	3.10E-01	0
CHEM70	Ethanol	7,477	1.00E-04	1
CHEM71	Ethyl acetate	0	1.00E-04	0
CHEM77	Ethylene glycol	0	1.50E-05	0
CHEM79	Formaldehyde	171	4.10E-04	0
CHEM80	Formamide	0	0.00E+00	0
CHEM84	Heptane, n-	0	1.10E-02	0
CHEM87	Hexane, n-	0	4.40E-03	0
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	3.80E-04	0
CHEM94	Isopropanol (2-propanol)	14,646	1.00E-03	15
CHEM95	Isopropyl Acetate	0	1.20E-05	0
CHEM96	Isopropyl Ether	0	1.10E-04	0
CHEM97	Methanol	0	5.80E-05	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	2.90E-02	0
CHEM102	Dichloromethane (methylene chloride)	0	2.10E-01	0
CHEM103	Methyl formate (formic acid, methyl ester)	0	1.60E-06	0
CHEM105	Methyl isobutyl ketone	0	3.60E-04	0
CHEM113	Petroleum Naptha	0	1.20E-02	0
CHEM114	Phenol	0	5.00E-03	0
CHEM115	Polyethylene Glycol 600	46	1.00E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	4.90E-06	0
CHEM118	Acetone	0	2.90E-04	0
CHEM124	Pyridine	0	2.90E-02	0
CHEM129	Tetrahydrofuran	0	1.30E-03	0
CHEM130	Toluene	0	1.00E-03	0
CHEM136	Triethylamine	0	2.60E-05	0
CHEM139	Xylenes	0	7.50E-04	0
CHEMBOD	Biochemical Oxygen Demand 5-day	0	0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0	0.00E+00	0
CHEMTSS	Total Suspended Solids	0	0.00E+00	0
	Totals	22,339		15

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table C-4

Industry Loads and Removals by Pollutant Based on PWFs
PSES-A/C Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	POTW Removal Efficiency (%)	Removals After POTW (lbs/yr)	Pollutant Weighting Factor	PE Removals
CN-	Cyanide	0	50%	0	1.90E-01	0
CHEM3	Acetonitrile	0	0%	0	4.80E-03	0
CHEM9	Ammonia-N	1,425,793	82%	259,494	4.90E-04	127
CHEM10	Amyl Acetate, n-	294,153	83%	50,594	1.50E-04	8
CHEM11	Pentanol, 1- (amyl alcohol)	0	83%	0	2.80E-05	0
CHEM12	Aniline	0	80%	0	2.50E-01	0
CHEM15	Benzene	120,896	19%	98,047	8.40E-01	82,359
CHEM25	Methyl ethyl ketone	0	83%	0	4.80E-05	0
CHEM26	Butyl acetate, n-	412,547	83%	70,958	5.60E-04	40
CHEM27	Butanol, 1- (n-butyl alcohol)	0	80%	0	2.90E-04	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	81%	0	5.60E-06	0
CHEM35	Chlorobenzene	84,094	18%	69,042	1.50E-03	104
CHEM37	Trichloromethane (chloroform)	45,219	1%	44,812	1.80E-01	8,066
CHEM48	Dichlorobenzene, 1,2-	16,376	78%	3,553	1.80E-03	6
CHEM51	Dichloroethane, 1,2-	546	77%	124	2.60E+00	322
CHEM55	Diethylamine	61,644	67%	20,466	5.00E-05	1
CHEM60	Dimethylacetamide, N,N-	0	79%	0	3.70E-07	0
CHEM62	N,N-Dimethylaniline	0	83%	0	1.50E-02	0
CHEM64	Dimethylformamide, N,N-	0	79%	0	2.90E-04	0
CHEM66	Dimethyl sulfoxide	0	95%	0	2.90E-07	0
CHEM67	Dioxane, 1,4-	0	75%	0	3.10E-01	0
CHEM70	Ethanol	110	89%	12	1.00E-04	0
CHEM71	Ethyl acetate	1,693,800	83%	291,334	1.00E-04	29
CHEM77	Ethylene glycol	0	96%	0	1.50E-05	0
CHEM79	Formaldehyde	0	85%	0	4.10E-04	0
CHEM80	Formamide	0	67%	0	0.00E+00	0
CHEM84	Heptane, n-	17,502	37%	11,061	1.10E-02	122
CHEM87	Hexane, n-	1,133,860	37%	716,599	4.40E-03	3,153
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	29,737	73%	8,088	3.80E-04	3
CHEM94	Isopropanol (2-propanol)	11	81%	2	1.00E-03	0
CHEM95	Isopropyl Acetate	9,426	83%	1,621	1.20E-05	0
CHEM96	Isopropyl Ether	9,280	83%	1,596	1.10E-04	0
CHEM97	Methanol	22	80%	4	5.80E-05	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	978,930	15%	832,091	2.90E-02	24,131
CHEM102	Dichloromethane (methylene chloride)	677,934	15%	577,600	2.10E-01	121,296
CHEM103	Methyl formate (formic acid, methyl ester)	23,283	83%	4,005	1.60E-06	0
CHEM105	Methyl isobutyl ketone	254,906	81%	48,942	3.60E-04	18
CHEM113	Petroleum Naptha	0	80%	0	1.20E-02	0
CHEM114	Phenol	0	95%	0	5.00E-03	0
CHEM115	Polyethylene Glycol 600	0	96%	0	1.00E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	88%	0	4.90E-06	0
CHEM118	Acetone	2,234,971	83%	373,240	2.90E-04	108
CHEM124	Pyridine	0	0%	0	2.90E-02	0
CHEM129	Tetrahydrofuran	91,062	83%	15,663	1.30E-03	20
CHEM130	Toluene	640,348	36%	411,104	1.00E-03	411
CHEM136	Triethylamine	374,837	83%	64,472	2.60E-05	2
CHEM139	Xylenes	22,140	20%	17,624	7.50E-04	13
CHEMBOD	Biochemical Oxygen Demand 5-day	0			0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0			0.00E+00	0
CHEMTSS	Total Suspended Solids	0			0.00E+00	0
	Totals	10,653,427		3,992,148		240,339

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.

Table C-5

Industry Loads and Removals by Pollutant Based on PWFs
PSES-B/D Facilities

Pollutant Code	Pollutant Name	Removals (lbs/yr)	POTW Removal Efficiency (%)	Removals After POTW (lbs/yr)	Pollutant Weighting Factor	PE Removals
CN-	Cyanide	0	50%	0	1.90E-01	0
CHEM3	Acetonitrile	0	0%	0	4.80E-03	0
CHEM9	Ammonia-N	0	82%	0	4.90E-04	0
CHEM10	Amyl Acetate, n-	810,977	83%	139,488	1.50E-04	21
CHEM11	Pentanol, 1- (amyl alcohol)	0	83%	0	2.80E-05	0
CHEM12	Aniline	0	80%	0	2.50E-01	0
CHEM15	Benzene	0	19%	0	8.40E-01	0
CHEM25	Methyl ethyl ketone	0	83%	0	4.80E-05	0
CHEM26	Butyl acetate, n-	0	83%	0	5.60E-04	0
CHEM27	Butanol, 1- (n-butyl alcohol)	0	80%	0	2.90E-04	0
CHEM29	Methyl-2-propanol, 2- (tert-butyl alcohol)	0	81%	0	5.60E-06	0
CHEM35	Chlorobenzene	0	18%	0	1.50E-03	0
CHEM37	Trichloromethane (chloroform)	0	1%	0	1.80E-01	0
CHEM48	Dichlorobenzene, 1,2-	0	78%	0	1.80E-03	0
CHEM51	Dichloroethane, 1,2-	0	77%	0	2.60E+00	0
CHEM55	Diethylamine	0	67%	0	5.00E-05	0
CHEM60	Dimethylacetamide, N,N-	0	79%	0	3.70E-07	0
CHEM62	N,N-Dimethylaniline	0	83%	0	1.50E-02	0
CHEM64	Dimethylformamide, N,N-	0	79%	0	2.90E-04	0
CHEM66	Dimethyl sulfoxide	0	95%	0	2.90E-07	0
CHEM67	Dioxane, 1,4-	0	75%	0	3.10E-01	0
CHEM70	Ethanol	0	89%	0	1.00E-04	0
CHEM71	Ethyl acetate	11,639	83%	2,002	1.00E-04	0
CHEM77	Ethylene glycol	0	96%	0	1.50E-05	0
CHEM79	Formaldehyde	0	85%	0	4.10E-04	0
CHEM80	Formamide	0	67%	0	0.00E+00	0
CHEM84	Heptane, n-	0	37%	0	1.10E-02	0
CHEM87	Hexane, n-	0	37%	0	4.40E-03	0
CHEM93	Methyl propanal, 2- (isobutyraldehyde)	0	73%	0	3.80E-04	0
CHEM94	Isopropanol (2-propanol)	300	81%	58	1.00E-03	0
CHEM95	Isopropyl Acetate	217,733	83%	37,450	1.20E-05	0
CHEM96	Isopropyl Ether	0	83%	0	1.10E-04	0
CHEM97	Methanol	0	80%	0	5.80E-05	0
CHEM101	Methoxyethanol, 2- (methyl cellosolve)	0	15%	0	2.90E-02	0
CHEM102	Dichloromethane (methylene chloride)	785,175	15%	668,969	2.10E-01	140,483
CHEM103	Methyl formate (formic acid, methyl ester)	0	83%	0	1.60E-06	0
CHEM105	Methyl isobutyl ketone	0	81%	0	3.60E-04	0
CHEM113	Petroleum Naptha	0	80%	0	1.20E-02	0
CHEM114	Phenol	1	95%	0	5.00E-03	0
CHEM115	Polyethylene Glycol 600	0	96%	0	1.00E-05	0
CHEM117	Propanol, 1- (n-propanol)	0	88%	0	4.90E-06	0
CHEM118	Acetone	1,520,984	83%	254,004	2.90E-04	74
CHEM124	Pyridine	0	0%	0	2.90E-02	0
CHEM129	Tetrahydrofuran	0	83%	0	1.30E-03	0
CHEM130	Toluene	0	36%	0	1.00E-03	0
CHEM136	Triethylamine	0	83%	0	2.60E-05	0
CHEM139	Xylenes	0	20%	0	7.50E-04	0
CHEMBOD	Biochemical Oxygen Demand 5-day	0			0.00E+00	0
CHEMCOD	Chemical Oxygen Demand	0			0.00E+00	0
CHEMTSS	Total Suspended Solids	0			0.00E+00	0
	Totals	3,346,808		1,101,971		140,579

Source: U.S. EPA, 1998. Technical Development Document for Effluent Limitations Guidelines and Standards for the Pharmaceutical Manufacturing Point Source Category.
U.S. EPA, 1998. Toxic and Pollutant Weighting Factors for Pharmaceutical Manufacturing Industry Final Effluent Guidelines.