# Department of Civil Engineering
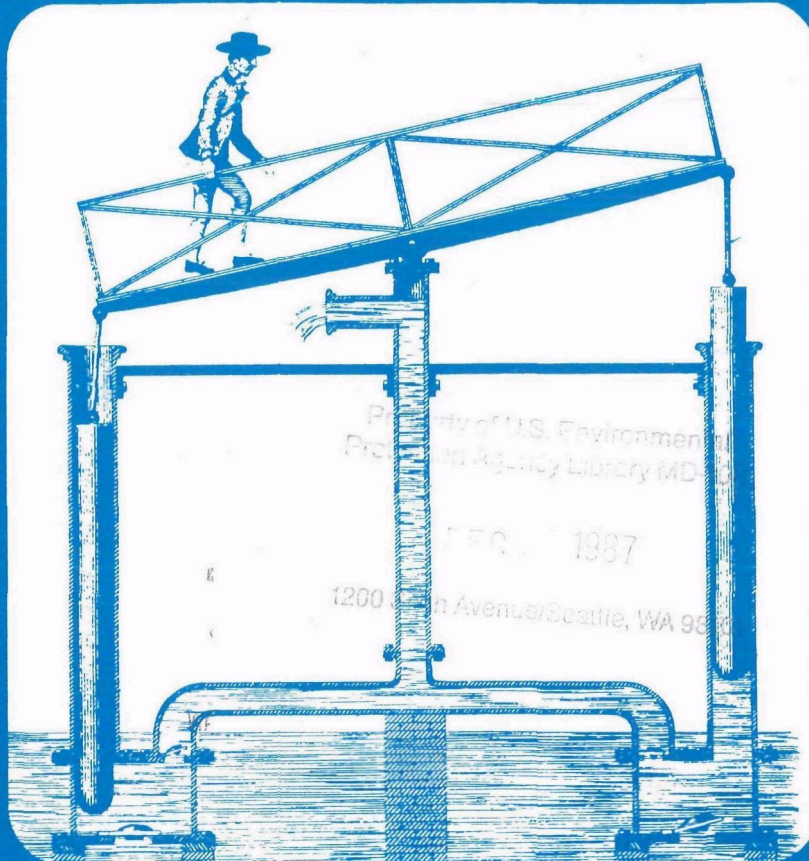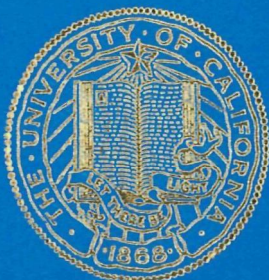
University of California, Davis

FINAL REPORT


EMISSIONS OF VOLATILE AND POTENTIALLY
TOXIC ORGANIC COMPOUNDS FROM
SEWAGE TREATMENT PLANTS AND COLLECTION
SYSTEMS


by


Daniel P.Y. Chang
Edward D. Schroeder
Richard L. Corsi

Department of Civil Engineering
University of California, Davis

# DISCLAIMER

i

"THE STATEMENTS AND CONCLUSIONS IN THIS REPORT ARE THOSE OF THE CONTRACTOR AND NOT NECESSARILY THOSE OF THE CALIFORNIA AIR RESOURCES BOARD.  THE MENTION OF COMMERICAL PRODUCTS, THEIR SOURCE OR THEIR USE IN CONNECTION WITH MATERIAL REPORTED HEREIN IS NOT TO BE CONSTRUED AS EITHER AN ACTUAL OR IMPLIED ENDORSEMENT OF SUCH PRODUCTS."

# TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## ACRONYMS

| | |
|---|---|
| AC | Adsorption Capacity (to activated carbon) |
| ADL | Above Detection Limit |
| BDL | Below Detection Limit |
| BOD | Biochemical Oxygen Demand |
| BOD5 | 5 day Biochemical Oxygen Demand |
| BODu | Ultimate Biochemical Oxygen Demand |
| CARB | California Air Resources Board |
| CFR | Code of Federal Regulations |
| CFSTR | Continuous Flow Stirred-Tank Reactor |
| COD | Chemical Oxygen Demand |
| CSDLAC | County Sanitation Districts of Los Angeles County |
| DAF | Dissolved Air Flotation |
| DSE | Domestic Sewage Exclusion |
| EPA | Environmental Protection Agency |
| FR | Federal Register |
| GAC | Granular Activated Carbon |
| HTP | Hyperion Treatment Plant |
| IU | Industrial User |
| IUPAC | International Union of Pure and Applied Chemists |
| JWPCP | Joint Water Pollution Control Plant |
| MGD | Million Gallons per Day |
| MLSS | Mixed Liqour Suspended Solids |
| MUD | Municipal Utility District |
| MWTP | Municipal Wastewater Treatment Plant |
| NEEDS | . A Report to EPA concerning the needs of MWTPs |
| NPDES | National Pollution Discharge Elimination System |

| | |
|---|---|
| NPP | National Pretreatment Program |
| OCSD | Orange County Sanitation District |
| ORT | Odor Removal Tower |
| PAC | Powdered Activated Carbon |
| PAR | Pretreatment Annual Report |
| PCE | Perchloroethylene |
| PFR | Plug-Flow Reactor |
| POTW | Publicly-Owned Treatment Work |
| PTOC | Potentially Toxic Organic Compound (assumed volatile) |
| RBC | Rotating Biological Contactor |
| RCRA | Resource Conservation and Recovery Act |
| RFP | Request For Proposals |
| RWQCB | Regional Water Quality Control Board |
| STP | Sewage Treatment Plant |
| SWRCB | State Water Resources Control Board (California) |
| TCA | 1,1,1 Trichloroethane |
| TCE | Trichloroethylene |
| TEST | Toxic Emissions during Sewage Treatment (a model) |
| THM | Trihalomethane |
| TSS | Total Suspended Solids |
| VOC | Volatile Organic Compound |
| WAS | Waste Activated Sludge |
| WEST | Worst-case Emissions during Sewage Treatment (a model) |
| WWTF | Wastewater Treatment Facility |
| WWTP | Wastewater Treatment Plant |

# ACKNOWLEDGEMENTS

ABSTRACT

Publicly-owned treatment works (POTWs) are a source of potentially toxic organic compound (PTOC) emissions for which limited data are available. This study was commissioned by the California Air Resources Board (CARB) in order to assess the potential for PTOC emissions from municipal wastewater treatment plants (MWTPs) and collection systems throughout California. The fates of 16 PTOCs were reviewed in terms of volatilization, biodegradation, and adsorption to solids and biomass as the primary removal mechanisms from wastewater. For the compounds that were studied, it was concluded that volatilization is the dominant removal mechanism in MWTPs. However, the paucity of existing data regarding the occurrence and distribution of PTOCs in collection systems made it impossible to estimate emissions from those sources. A methodology was developed to predict PTOC emissions from 589 MWTPs in California. A limited but growing data base was used along with extrapolation methods to estimate speciated PTOC emissions from MWTPs on statewide, county-by-county, and plant-by-plant bases. The results indicated that approximately 800 tons per year (tpy) of total PTOCs were emitted from MWTPs throughout California. Toluene and methylene chloride dominated the total PTOC emissions. Each was estimated to have been emitted in excess of 200 tpy. A small number of the 589 MWTPs were identified as having accounted for a large fraction of the total PTOC emissions. Furthermore, a comparison of PTOC emissions from two large MWTPs in the South Coast Air Basin (SCAB) suggested that emissions of some PTOCs from those sources were comparable to, and possibly greater than, emissions from the largest known point sources in the SCAB. Finally, specific MWTPs and treatment processes were recommended for future source sampling, and areas that will require future research in order to reduce the uncertainties in emissions estimates were identified.

# 1. INTRODUCTION

Recent concerns regarding human exposure to potentially toxic organic compounds (PTOCs) and the role that PTOCs play in the formation of photochemical air pollution have necessitated a review of PTOC emission sources. Municipal wastewater treatment plants (MWTPs) are a source of PTOC emissions for which limited data are available. This document reports the findings of a study to assess the potential for PTOC emissions from publicly-owned treatment works (POTWs) in California.

## Specific Objectives

The work objectives that were specified in the Request for Proposals (RFP), issued by the California Air Resources Board (CARB), are summarized below.

1. Conduct a literature search to obtain information regarding emissions of PTOCs from POTWs. The PTOCs to consider include acrylonitrile, benzene, bromodichloromethane, carbon tetrachloride, chlorobenzene, chloroform, dibromochloromethane, 1,1-dichloroethylene, 1,2-dichloroethane, ethylbenzene, methylene chloride, perchloroethylene, toluene, 1,1,1-trichloroethane, trichloroethylene, and vinyl chloride.

2. Develop and/or refine models for estimating emissions of the 16 PTOCs from POTWs.

3. Complete a county-by-county inventory of POTWs in California and rank them by capacity.

4. Estimate the quantity and ultimate method of disposal of sludge and solid refuse recovered by MWTPs in California.

5. Estimate the fraction of each PTOC that adsorbs to sludge.

6. Using the models and methods described above, complete county-by-county and statewide emission estimates for methane and non-methane hydrocarbons, and total and speciated PTOCs. The level of confidence associated with the estimates will also be addressed.

1

7. Include a comprehensive description of all data bases used in the compilation of the emissions inventory, and indicate explicitly which data were taken from each data base.

8. Prepare a final report which describes, in detail, the projected PTOC emissions, as well as the models and methods used to arrive at those projections. A discussion of data acquisition techniques, mathematical calculations, uncertainties in estimates, and recommendations for future sampling are to be included.


In addition to the objectives specified in the RFP, the following additional tasks were completed as it was felt that the resulting information would be useful to the staff of the CARB during future emission studies.

1. For emission inventory purposes, the location (latitude and longitude) of every MWTP in the state of California were obtained.

2. In addition to the methodology applied to estimate the total emissions from each POTW, treated as individual point sources, a model was developed to estimate emissions from specific wastewater treatment processes. With knowledge of the individual process locations, the model will allow for greater spatial resolution with respect to emissions estimates based upon entire MWTPs. The process-specific model can be used with standard Gaussian dispersion models to predict downwind concentrations. The detailed emissions model is the subject of Appendix H of this report.

3. During the course of this study, it became evident that the quantity of trihalomethanes (THMs) formed in MWTPs is often greater, as a result of chlorination practices in the MWTP, than that received in the influent to the MWTP. Thus, a review of the factors affecting THM formation, potential precursors, and evidence of THM formation in California is included.

A combination of a lack of existing sample data on total methane and non-methane hydrocarbon emissions or a suitable surrogate, prevented

us from making reliable estimates of those emissions. That objective was not accomplished.

## Scope

Many organic compounds can be found in the influent to MWTPs. However, because of the limited time and resources associated with this contract, a manageable list of 16 PTOCs was selected for review as requested in the RFP. Although many other potentially toxic organic compounds exist, throughout the remainder of this report, the term "PTOCs" will refer to the subset comprised of those 16 compounds noted previously.

The contract did not provide for actual field sampling for the PTOCs. Thus, the completion of those objectives involving quantitative estimates of PTOCs required the use of existing data bases. Unfortunately, existing data bases are incomplete with respect to PTOC mass loadings into MWTPs. In addition, those facilities that have sampled for PTOCs typically sample on a very infrequent basis (e.g., 4 days per year). The existing data base is expected to improve in the following years, as the Environmental Protection Agency's (EPA) Pretreatment Program takes full effect. Data bases that were employed in this study will be described in detail in a later section.

Information regarding the monitoring of PTOCs in sewer lines is virtually non-existent. At this time it is not possible to predict emissions from collection systems. However, the factors that affect emissions from collection systems are described in this report, and past sampling efforts are reviewed.

## Organization of the Report

It was assumed that the readers of this report may not have a complete understanding of wastewater treatment or the important characteristics of those PTOCs that are commonly discharged to wastewater collection systems. Thus, Sections 2 and 3 provide brief overviews of

3

wastewater treatment systems, common terminology associated with the field of wastewater treatment, and a description of the characteristics, sources, and occurrences of the PTOCs selected for review. A glossary (Appendix A) and a list of acronyms (page vi) used in the report are provided as well as both chemical and common names, structural formulas and important physico-chemical parameters of the PTOCs (Tables 1 and 5).

The fate of PTOCs in collection systems and MWTPs is reviewed in Section 4. The results of data analyses completed to predict the importance of removal mechanisms other than volatilization are also presented. Previous studies regarding volatile emissions from wastewater to the atmosphere are described.

A presentation of emissions estimation techniques, limitations, and assumptions is included in Section 5. A discussion of uncertainties based upon sampling procedures, analysis techniques, and estimation methods is also included.

A complete analysis of predicted PTOC emissions is provided in Section 6. Emissions estimates are provided on a county-by-county and statewide basis. Reference is made to a data base, provided to the CARB on magnetic recording media, which provides emissions estimates for every MWTP in California. Special attention is given to those counties which contribute significant emissions to the statewide total.

In Sections 7 and 8, conclusions are drawn regarding the significance of volatilization as a PTOC removal mechanism in POTWs, and recommendations are forwarded for future studies and source sampling, respectively.

A process-specific model is described in Appendix H of this report. A theoretical development is provided, along with a description of required model inputs. An interactive FORTRAN program has been written and provided to the CARB along with example applications.

## 2. PUBLICLY-OWNED TREATMENT WORKS AND WASTEWATER TREATMENT

This section provides a brief overview of POTWs and wastewater treatment facilities. The reader is referred to the glossary in Appendix A, as needed, for further descriptions and definitions associated with municipal wastewater treatment. A number of texts and public documents with detailed descriptions of wastewater treatment and associated processes are listed in the Supplemental Readings.

Wastewater systems that are referred to as publicly-owned treatment works (POTWs) are defined by section 212 of the Clean Water Act (33 U.S.C. 1292). For the purposes of this study, a POTW is defined as a system that is owned by a public entity, and which conveys wastewater to or from a municipal wastewater treatment plant (MWTP). As shown in Figure 1, this includes the wastewater collection system, wastewater and sludge treatment facilities, and effluent, sludge disposal, or outfall, systems.

The wastewater collection system is typically composed of an extensive network of sewerage piping used to convey wastewater discharged by users of the POTW. Collection systems vary in type and length. Collection systems are considered to be either combined or separate. In combined systems, storm water and wastewater are conveyed through the same system. Conversely, in separate systems wastewater is segregated from stormwater, leading to more uniform seasonal flows. Most systems in California are of the separate type. The collection system length for some large POTWs, such as the County Sanitation Districts of Los Angeles County, are on the order of thousands of miles!

Users of POTWs can be classified into many categories. Most commonly, users are classified as residential, commercial, or industrial (see Glossary for definitions). Other users may include institutions such as hospitals, prisons, and educational facilities. Potentially toxic organic compounds are most often discharged by industrial users (IUs), but the contribution from residential, commercial, and institutional users may also be significant. Specific sources of PTOCs are addressed in detail in Section 3.

INDUSTRIAL

COMMERCIAL

WASTEWATER TREATMENT PLANT

RESIDENTIAL

OTHER

COLLECTION SYSTEM

| PRIMARY TREATMENT | SECONDARY TREATMENT | ADVANCED TREATMENT |
|---|---|---|

EFFLUENT DISCHARGE

SLUDGE TREATMENT

SLUDGE DISPOSAL
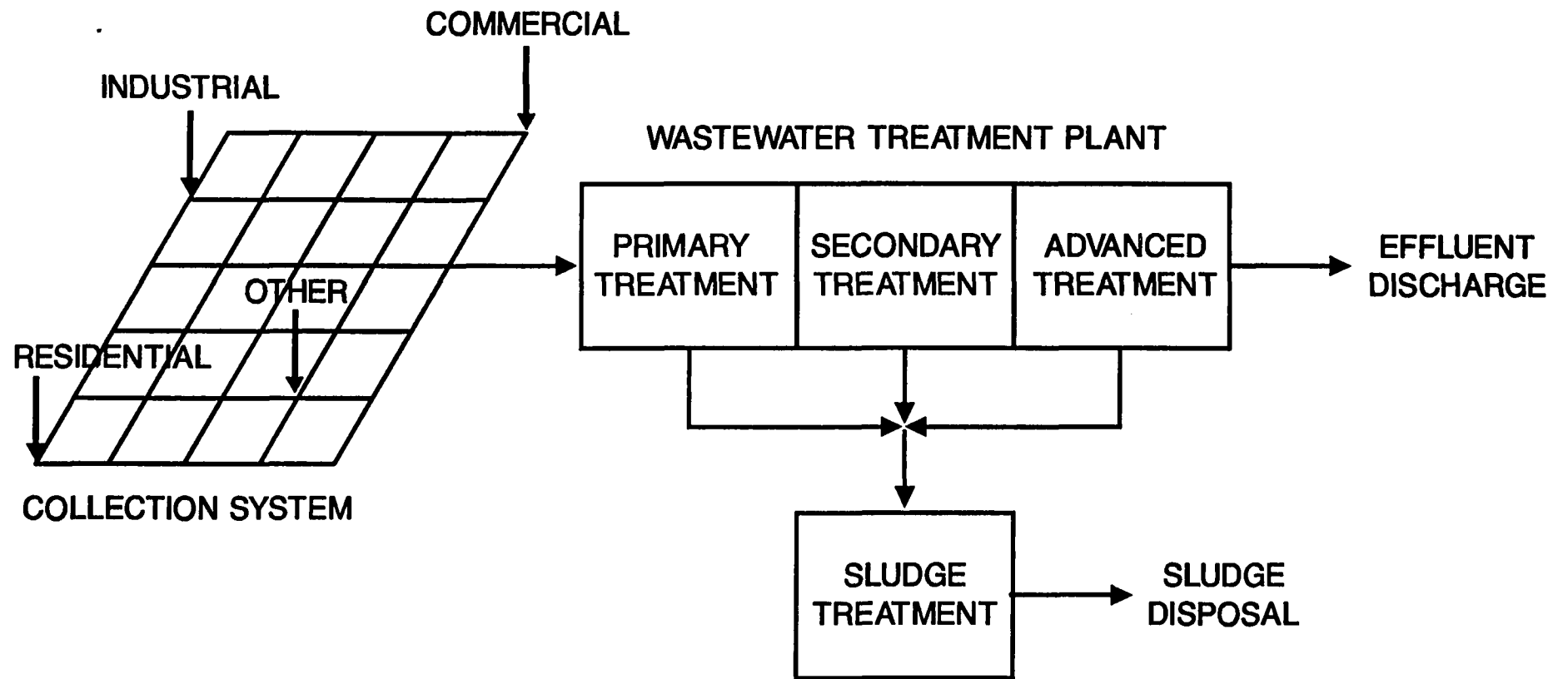
Figure 1: Simplified Representation of a POTW

Municipal wastewater treatment plants are composed of processes to treat both the incoming wastewater and solids separated from the wastewater or that are generated during biological treatment. Wastewater treatment processes are typically categorized as primary, secondary, or advanced treatment. Primary treatment may include the use of bar screens, comminuters, grit chambers, and primary clarifiers. While not all MWTPs employ secondary treatment, it is common practice in large facilities and those facilities that discharge to potentially sensitive receiving waters. Secondary treatment typically includes biological treatment such as activated sludge systems, trickling filters, oxidation ponds, rotating biological contactors, overland flow, and marsh systems. Advanced, or tertiary, treatment systems may include filtration units, biological nitrification systems, stripping towers, and the use of activated carbon adsorption systems. Chlorination is often employed as a treatment step to disinfect treated wastewater before it is dis-charged to a receiving water. Dechlorination of the effluent using sulfur dioxide commonly follows disinfection.

Receiving systems for effluent discharge vary considerably, and are highly dependent upon the geographic location of the POTW. For instance, effluent from MWTPs in the Central Valley region of California are typically discharged to surface receiving waters, usually rivers or smaller surface waters that flow into rivers. Effluent is also employed for restrictive agricultural uses, or may be disposed of to the atmosphere from evaporation ponds, or to the ground-water using percolation ponds. In Los Angeles and Orange counties, as well as all along the California coast, a large fraction of municipal effluent is discharged to the ocean. Finally, many large MWTPs in the South and East San Francisco Bay regions discharge final effluent directly to San Francisco Bay.

Sludge is collected during primary and secondary treatment, and sometimes during advanced treatment. Secondary and advanced treatment sludges are typically thickened, and combined sludges are commonly sta-bilized using anaerobic digestion. The combined, digested sludge is

dewatered by centrifuge, belt press, or drying beds, before ultimate disposal to a landfill. Incineration, composting, and discharge to the ocean are also currently employed as disposal processes.

# 3. POTENTIALLY TOXIC ORGANIC COMPOUNDS OF INTEREST

## Compounds and Characteristics

The potentially toxic organic compounds, as well as several of their important physico-chemical characteristics, are shown in Table 1. Names approved by the International Union of Pure and Applied Chemists (IUPAC) are provided under the heading of chemical name. Common synonyms are also provided. The relatively low solubility, and high vapor pressures for most of the PTOCs under consideration indicate their tendency toward volatilization.
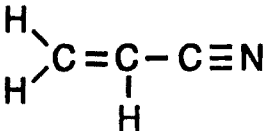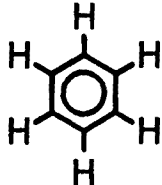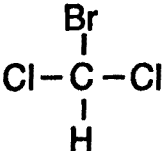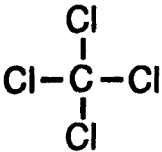
## Sources

As was indicated in Section 2, several types of users discharge to POTWs. Those classified as residential, commercial, or industrial may be broken down further according to the specific source. Tables 2 and 3 are provided to indicate typical uses of PTOCs, and to list those sources that have been known to discharge significant amounts of PTOCs to POTWs.

## Pretreatment Requirements

On June 26, 1978, the EPA issued regulations for a National Pretreatment Program (NPP). Revised regulations (Appendix B) became effective on March 30, 1981. The NPP was established to protect POTWs and their surrounding environments from the adverse effects associated with the discharge of hazardous and/or toxic wastes to the POTW's wastewater system. In particular, it was desired to protect biological treatment systems from interferences and failures, to minimize the potential for the pass-through of toxic wastes in the MWTP effluent, to prevent the contamination of municipal sludge, and to reduce the exposure of workers to chemical hazards. The NPP is the primary mechanism for achieving such objectives. It has gained increased importance in that role following the Domestic Sewage Exclusion (DSE) enacted under

9

## Table 1A : POTENTIALLY TOXIC ORGANIC COMPOUNDS
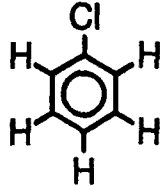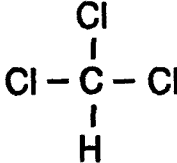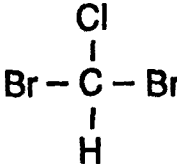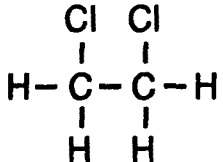
| Chemical Name | Synonyms | Chemical Structure | Molecular Weight g/g-mole | Solubility mg/l | Vapor Pressure (mmHg) | Boiling Point (°C) | Henry's Law Constant (X1000) (atm-m³/mol) |
|---|---|---|---|---|---|---|---|
| 2- Propenenitrile | Acrylonitrile Vinyl cyanide | $H \!\!\diagdown\!\! C = C - C \equiv N$, $H \diagup$ with H below | 53.06 | 73500 | 100[2] | 77.3 | 0.067[1] |
| Benzene | | benzene ring structure | 78.11 | 1800 | 76 | 80.1 | 5.55 |
| Bromodichloro-methane | | $Cl - \overset{Br}{\underset{H}{C}} - Cl$ | 163.83 | – | 50 | 90.0 | 2.12 |
| Tetrachloromethane | Carbon tetra-chloride | $Cl - \overset{Cl}{\underset{Cl}{C}} - Cl$ | 153.84 | 785 | 90 | 76.5 | 30.2 |

Solubility and vapor pressure at 20°C except (1) = 15°C, (2) = 23°C, (3) = 25°C

Henry's Law constants at 25°C except (1) = 15°C

References: Mackay et al. (1979), Nicholson et al. (1984), USEPA (1983), Verschueren (1977), CRC (1977)

## Table 1B : POTENTIALLY TOXIC ORGANIC COMPOUNDS
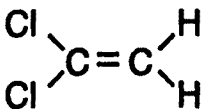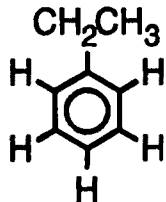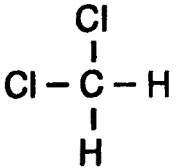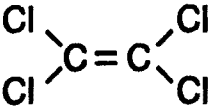
| Chemical Name | Synonyms | Chemical Structure | Molecular Weight g/g-mole | Solubility mg/l | Vapor Pressure (mmHg) | Boiling Point (°C) | Henry's Law Constant (X1000) (atm-m$^3$/mol) |
|---|---|---|---|---|---|---|---|
| Chlorobenzene | Phenyl chloride | | 112.56 | 500 | 8.8 | 132.0 | 3.93 |
| Trichloromethane | Chloroform | | 119.38 | 8000 | 160 | 61.7 | 3.39 |
| Chlorodibromo-methane | Dibromochloro-methane | | 208.29 | — | 15 | 122.0 | 0.78 |
| 1,2 Dichloroethane | Ethylene dichloride | | 98.96 | 8690 | 61 | 83.5 | 1.1 |

Solubility and vapor pressure at 20°C except (1) ▪ 15°C, (2) = 23°C, (3) ▪ 25°C
Henry's Law constants at 25°C except (1) = 15°C
References: Mackay et al. (1979), Nicholson et al. (1984), USEPA (1983), Verschueren (1977), CRC (1977)

## Table 1C : POTENTIALLY TOXIC ORGANIC COMPOUNDS
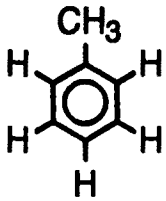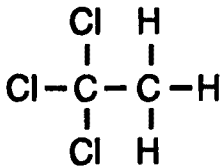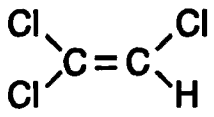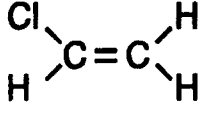
| Chemical Name | Synonyms | Chemical Structure | Molecular Weight g/g-mole | Solubility mg/l | Vapor Pressure (mmHg) | Boiling Point (°C) | Henry's Law Constant (X1000) (atm-m$^3$/mol) |
|---|---|---|---|---|---|---|---|
| 1,1 Dichloroethylene | Vinylidene chloride | | 96.94 | 400 | 500 | 37.0 | 15.0 |
| Ethylbenzene | | | 106.16 | 152 | 7 | 136.0 | 6.4 |
| Dichloromethane | Methylene chloride | | 84.94 | 20000 | 349 | 39.8 | 3.19 |
| Tetrachloroethene | Perchloro-ethylene (PCE) | | 165.83 | 150[2] | 14 | 121.0 | 28.7 |

Solubility and vapor pressure at 20°C except (1) = 15°C, (2) = 23°C, (3) = 25°C
Henry's Law constants at 25°C except (1) = 15°C
References: Mackay et al. (1979), Nicholson et al. (1984), USEPA (1983), Verschueren (1977), CRC (1977)

## Table 1D : POTENTIALLY TOXIC ORGANIC COMPOUNDS

| Chemical Name | Synonyms | Chemical Structure | Molecular Weight g/g-mole | Solubility mg/l | Vapor Pressure (mmHg) | Boiling Point (°C) | Henry's Law Constant (X1000) (atm-m³/mol) |
|---|---|---|---|---|---|---|---|
| Methyl benzene | Toluene | | 92.13 | 515 | 22 | 110.8 | 5.93 |
| 1,1,1 Trichloroethane | Methyl chloroform | | 133.41 | 4400 | 100 | 74.1 | 4.92 |
| Trichloroethene | Trichloro-ethylene (TCE) | | 131.39 | 1100[3] | 58 | 87.0 | 11.7 |
| Chloroethene | Vinyl chloride | | 62.50 | 1[3] | 2660[3] | -13.4 | 36.0 |

Solubility and vapor pressure at 20°C except (1) = 15°C, (2) = 23°C, (3) = 25°C
Henry's Law constants at 25°C except (1) = 15°C
References: Mackay et al. (1979), Nicholson et al. (1984), USEPA (1983), Verschueren (1977), CRC (1977)

13

Table 2:  Common Uses of PTOCs

| Compound | Uses |
|---|---|
| Acrylonitrile | production of resins and fibers; modifier for natural polymers; stored grain fumigant, |
| Benzene | fuel additive; solvent (waxes, resins, oils, etc.). |
| Carbon tetrachloride | solvent (oils, fats, lacquers, rubber waxes, resins); insecticide; drying agent for spark plugs. |
| Chlorobenzene | solvent in insecticide and herbicide formulation; solvent for paints; auto parts degreaser; heat transfer medium; manufacture of phenol. |
| Chloroform | solvent (oil, rubber, alkaloids, waxes, resin); cleansing agent; soil fumigant; solvent for pharmaceuticals. |
| 1,1 Dichloroethylene | intermediate in the production of vinylidene polymer plastics. |
| Ethylbenzene | resin solvent; conversion to styrene monomer. |
| 1,2 Dichloroethane | solvent (fats, oils, gums, waxes, resins, rubber); extract for tobacco; manufacture of acetyl cellulose. |
| Methylene chloride | solvent for cellulose acetate; solvent in food processing; degreasing agent; cleansing agent; paint stripping; fire extinguisher compounds; beer flavoring from hops; extraction of caffeine from coffee; metal degreaser; solvent in textile processing. |
| Perchloroethylene | solvent in dry cleaning; solvent in textile processing; metal degreaser. |
| Toluene | solvent (paints, lacquers, gums, resins); extraction of principles from plants; gasoline additive; production of benzene, dyes, and explosives. |
| 1,1,1 Trichloroethane | cold-type metal cleaning; cleaning of plastic molds; aerosol formulation. |
| Trichloroethylene | solvent (fats, waxes, resins, oils, rubber, paints, cellulose esters, ethers, varnishes); degreasing agent; dry cleaning. |
| Vinyl chloride | refrigerant; direct production of polyvinyl chloride. |

References:  Merck Index (1983), USEPA (1986).

14

Table 3: Common Sources of PTOCs

| Compounds | Sources |
|---|---|
| Acrylonitrile | production of resins and acrylic fiber. |
| Benzene | metal finishing; non-ferrous metals; organic chemicals, plastics, and synthetics industries; pharmaceuticals; manufacturing (dyes, artificial leather, linoleum, varnishes, lacquers, paints); motor vehicle services. |
| Bromodichloromethane | non-ferrous metals; organic chemicals, plastics, and synthetics industries; chlorinated drinking water. |
| Carbon tetrachloride | adhesives industry; metal finishing; organic chemicals, plastics, and synthetics industries; pharmaceuticals; food processing; fluorocarbon production. |
| Chlorobenzene | organic chemicals, plastics, and synthetics industries; pharmaceuticals; motor vehicle services. |
| Chlorodibromomethane | chlorinated drinking water. |
| Chloroform | adhesives industry; aluminum forming; leather tanning and finishing; pulp, paper, and fiberboard manufacture; organic chemicals, plastics, and synthetics industries; pharmaceuticals; rubber industry; chlorinated drinking water. |
| 1,1 Dichloroethylene | metal finishing. |
| Ethylbenzene | adhesives industry; production of electrical products; organic chemicals, plastics, and synthethics industries; leather tanning and finishing; metal finishing; motor vehicle services; pharmaceuticals. |
| Methylene chloride | adhesives industry; aluminum forming; production of electrical products; leather tanning and finishing; non-ferrous metals; organic chemicals, plastics, and synthetics industries; pharmaceuticals; wood finishing; motor vehicle services; food processing; photographic chemicals. |
| Perchloroethylene | copper forming; metal finishing; textile mills; non-ferrous metals; organic chemicals, plastics, and synthetics industries; dry cleaners; wood finishing. |

15

Table 3: Sources of PTOCs                                          Cont'd

| Compounds | Sources |
|---|---|
| Toluene | adhesives industry; organic chemicals, plastics, and synthetics industries; leather tanning and finishing; metal finishing; pharmaceuticals; motor vehicle services; laundries; wood finishing. |
| 1,1,1 Trichloroethane | production of electrical products; metal finishing; plastic forming; pharmaceuticals; motor vehicle services. |
| Trichloroethylene | adhesives industry; aluminum forming; textile mills; motor vehicle services; dry cleaners. |
| Vinyl chloride | polyvinyl chloride manufacturers. |

References: USEPA (1983), USEPA (1986).

section 1004 (27) of the Resource Conservation and Recovery Act (RCRA). The DSE provides that a hazardous waste, when mixed with domestic sewage, is no longer considered to be hazardous according to RCRA definitions. Thus, POTWs that receive such waste are not subject to RCRA treatment, storage and disposal facility requirements. A recent report describes the philosophy behind and the suspected impacts of the DSE (USEPA, 1986).

General pretreatment regulations (listed in 40 CFR 403) require that any POTW, or POTWs operated by the same authority, with a combined design flow of greater than 5 million gallons per day (MGD) must establish a pretreatment program. Furthermore, that program is to be a condition of the POTW's National Pollutant Discharge Elimination System (NPDES) permit. If a POTW has a design flow of less than 5 MGD, it may be required to establish a pretreatment program if nondomestic users discharge wastes that cause interferences or upsets, contamination of sludge, NPDES permit violations, or if the users are subject to pretreatment standards. In the State of California, over 100 MWTPs exist within POTWs that are required to establish Pretreatment programs. Those MWTPs account for approximately 90% of the total municipal wastewater that is treated in California. A summary of California POTWs that have fully-established, or that are developing, pretreatment programs is provided in Appendix C.

To implement an effective pretreatment program, a POTW must have the ability to:

1. identify and evaluate its nondomestic users,

2. operate under a legal authority that will enable it to apply and enforce the requirements of the General Pretreatment Regulations (Appendix B),

3. characterize discharges to its treatment system and establish sufficiently protective local effluent limits,

4. monitor industrial users to determine compliance and noncompliance,

5. provide funds, equipment, and personnel,

6. properly administer and manage its pretreatment program.

A comprehensive review of pretreatment program approval and implementation procedures can be found in the EPA's "Guidance Manual for POTW Pretreatment Program Development," (Hanmer et al., 1983).

Two types of standards are used to control pollutant discharges to POTWs. The first, "prohibited discharge standards", applies to all commercial and industrial establishments which discharge to POTWs. Prohibited standards restrict the discharge of pollutants that create a fire or explosion hazard in sewers or treatment works, are corrosive (pH < 5.0), obstruct flow, upset treatment processes, or increase the temperature of the wastewater entering the plant to above 40°C. "Categorical standards" apply to industrial and commercial discharges in 25 industrial categories ("categorical industries"), and are intended to restrict the discharge of 126 priority pollutants, including all of the 16 PTOCs.

As part of their pretreatment programs, POTWs in California report to the appropriate Regional Water Quality Control Board (RWQCB) and to the Region IX office of the EPA. The State Water Resources Control Board (SWRCB) also maintains copies of a large percentage of the reports. In general, quarterly reports document the monitoring of industrial and commercial users, violations, and enforcement activities. Summaries of nondomestic users, user additions, and user losses are also common. Annual reports typically document the overall treatment characteristics of MWTPs within the POTW. These include monitoring results for conventional pollutant parameters such as biochemical oxygen demand (BOD), total suspended solids (TSS), and oil and grease, as well as hydraulic loading characteristics, and the results of any sampling for priority pollutants in the influent, effluent, and sludge streams. This data source on PTOCs will become extremely valuable in future years. However, because of the recent implementation of the National Pretreatment Program, measurements for those MWTPs that have sampled for PTOCs are typically limited to the past one or two years.

# 4. THE FATE OF POTENTIALLY TOXIC ORGANIC COMPOUNDS IN PUBLICLY-OWNED TREATMENT WORKS

Within a wastewater collection and treatment system PTOCs may be removed, transformed, generated or simply transported through the system unchanged. Five primary mechanisms are involved: (1) volatile emissions, (2) degradation, (3) adsorption to sludge, (4) pass-through (i.e., passage through the entire system), and (5) generation as a result of chlorination or as byproducts of degradation of precursor compounds. Furthermore, these mechanisms are not mutually exclusive, as competition and simultaneous action can be significant.

A schematic summary of the mechanisms which affect PTOCs in POTWs is provided in Figure 2. As indicated, volatile emissions can occur throughout the collection and treatment system. Degradation, particularly through biological activity (biodegradation), can also occur throughout most of the system. Adsorption to sludge occurs during primary, secondary, and advanced treatment. Pass-through is reflected in a total system removal efficiency of less than 100%, and the subsequent discharge of PTOC residuals to the final receiving system. Finally, PTOCs may be generated via the degradation of other PTOCs, or by the formation of trihalomethanes (THMs) during and after chlorination.

The mechanisms described above are discussed in greater detail in the remainder of this section. This section has been included to summarize the extent of existing knowledge about the fate of priority pollutants during wastewater collection and treatment. The importance of adsorption to sludge, biodegradation, pass-through, and formation during chlorination are also illustrated by presenting selected results of this study. Quantitative estimates of the extent of volatile emissions are described in greater detail in Section 6.

.

19

MANHOLE
COVER
OR
STORM DRAIN

COLLECTION SYSTEM

TREATMENT PLANT

PASS-THROUGH

RECEIVING
WATER

PRIMARY
SLUDGE

SECONDARY
SLUDGE

SLUDGE TREATMENT

SLUDGE DISPOSAL

LEGEND:

$\updownarrow$ = VOLATILE EMISSIONS

$e$ = BIODEGRADATION
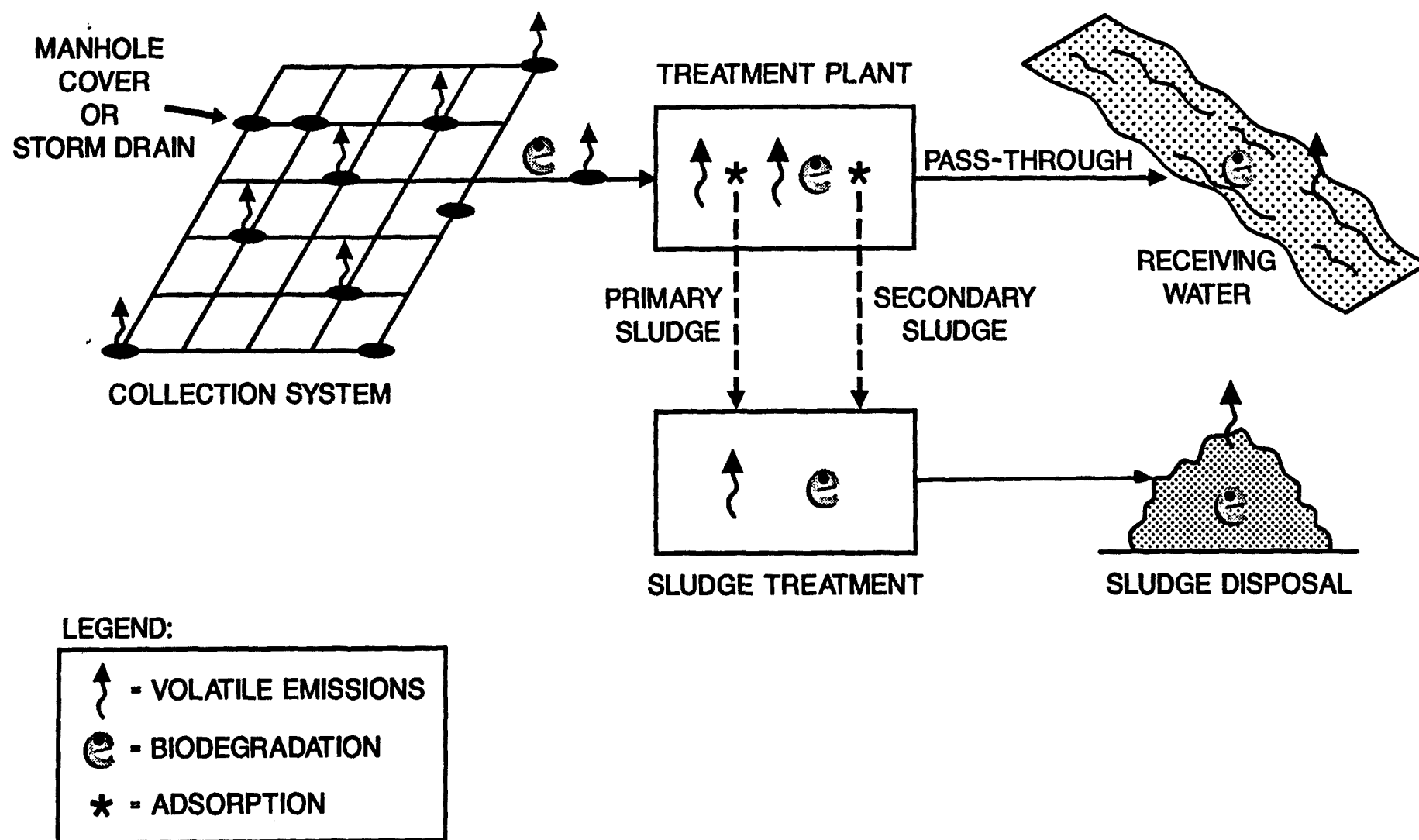
$*$ = ADSORPTION

Figure 2: The Fate of PTOCs in POTWs

## Removal From Collection Systems

Organic compounds may be removed from the aqueous phase in the collection system by adsorption to particles, biodegradation, exfiltration, pass-through to the treatment facility, or volatilization. Past studies have focused upon material balances at points of entry to the collection system and discharge to the wastewater treatment facility. Few measurements of gas phase concentrations and air exchange with the atmosphere have been made. Thus, the relative significance of the removal mechanisms in collection systems is not well understood at this time. However, based upon past studies using a shallow stream desorption model, volatile organic compounds appear to desorb rapidly to the gas phase in sewers (USEPA, 1986). These results indicate that emissions from collection systems to the ambient atmosphere are potentially significant with respect to the other removal mechanisms. Due to the paucity of experimental data on the topics of adsorption, biodegradation, and exfiltration in collection systems, those mechanisms will not be addressed here. Pass-through to the treatment system will be addressed in Section 6, and appear as MWTP influent mass loadings. Thus, this subsection will only address the existing knowledge regarding volatilization from collection systems.

In addition to the competition among removal mechanisms, several factors can affect the volatile emissions of PTOCs from collection systems. Those factors include the physico-chemical characteristics and concentrations of the PTOCs, flowrate and system geometry as they affect turbulence, effective interfacial area, headspace volume in the sewer line, and ventilation of the collection system (USEPA, 1986; Matthews, 1975). The latter is believed to be very important, as the characteristics of air exchange between the sewer line and the ambient atmosphere are significantly different depending upon the type of system. For instance, in combined storm and sanitary sewers, air exchange occurs at manhole covers and storm drains. However, storm drains are not employed for separate sanitary sewer systems. Thus, it is expected that of the two types of collection systems, combined systems are more conducive to volatile losses of PTOCs. Unlike many older

municipalities in the Eastern United States, most cities in California employ separate sanitary sewers. One exception is the city and county of San Francisco, where combined systems are still in use.

Few studies have reported the occurrence and emissions of PTOCs from wastewater collection systems. In part, this is due to the fact that collection systems can be both a physically difficult and dangerous environment in which to conduct sampling. However, recent studies of organic compound occurrences in collection system atmospheres have afforded some insight as to the potential magnitudes of PTOC emissions from those sources. Lucas (1981) observed high levels of many pollutants in the headspace above wastewater in interceptor sewers. A combined modeling/monitoring effort indicated that volatilization from sewer lines may have accounted for significant losses of PTOCs from a large POTW in Philadelphia (Frederick, 1985).

Reported results of monitoring for PTOCs in California collection systems are scarce. However, studies were recently completed that document the concentration of several PTOCs in trunk lines in Sunnyvale (Santa Clara County) and Huntington Park (Los Angeles County). Partial results of those studies are summarized in Table 4. Because of a lack of data on the ventilation flowrates, emissions from the Sunnyvale and Huntington Park systems could not be projected.

In summary, it appears that volatile emissions of PTOCs from collection systems may be significant, particularly in sewer lines serving industrial and commercial establishments which discharge large quantities of PTOCs to POTWs. Those emissions may be of greatest concern where combined sanitary/storm sewers are employed. However, high concentrations in the atmosphere of separate systems indicates that they may also be significant sources of PTOC emissions. Unfortunately, the lack of existing sample data does not allow for meaningful emission estimates. This is an area where future studies would be of great value to reduce the uncertainties associated with the relative significance of collection systems as PTOC emission sources.

Table 4: PTOC Concentrations in Collection System Atmospheres

| Compound | Gas Concentration (ppb) | |
|---|---|---|
| | Sunnyvale[1] | Huntington Park[2] |
| Benzene | 4.9 | 4600 |
| Ethylbenzene | 2.9 | NR |
| Methylene chloride | 36.4 | NR |
| Perchloroethylene | NR | 4300 |
| Toluene | 35.6 | 5800 |
| 1,1,1 Trichloroethane | NR | 60000 |

NR = Not reported.
Sunnyvale values based on the average of 5 samples.
Huntington Park values based on a single bulb sample.

(1) Dixon and Bremen (1984).
(2) Porter (1986).

## Volatilization Within Wastewater Treatment Plants

The purpose of this subsection of the report is to provide the reader with background material regarding past efforts to measure volatile PTOC emissions from wastewater treatment processes. Results from laboratory and field tests are reviewed.

Measurements completed to assess the relative importance of volatilization as a chemical removal mechanism appear to be sensitive to the experimental arrangement. For instance, analyses completed in the laboratory tend to predict that volatilization is not as important in biological reactors as would be indicated by pilot plant and field studies. Possible reasons for the discrepancies include such factors as differences in the acclimation of organisms and unmeasured losses from pilot or bench-scale equipment.

Lawson and Siegrist (1981) studied the relative importance of volatilization and biodegradation in bench-scale biological reactors. They found that biodegradation dominated volatilization for acrylonitrile, toluene, and 1,2-dichloroethane. The latter was found to have the highest percent volatilized (10%) during the experiments. Kincannon et al. (1983) observed similar results for acrylonitrile, methylene chloride, and benzene in the laboratory. However, volatilization was found to be complete (100%) for 1,1,1-trichloroethane and 1,2-dichloroethane. The fate of toxic organic compounds in activated sludge and integrated powdered activated carbon (PAC) systems were recently investigated in the laboratory (Weber et al., 1983; Weber et al., 1986). After a certain concentration of PAC addition was exceeded, the ratio of volatilization to biodegradation was observed to decrease significantly. The ratio of biodegradation to volatilization losses typically exceeded 3:1 for the PTOCs that were studied.

Field studies have been conducted in order to assess the relative significance of PTOC emissions during wastewater treatment, and to categorize treatment processes according to their relative significance with respect to emissions from other treatment processes.

The fate of toluene in an organic chemical wastewater facility was studied (Berglund et al., 1985). It was observed that 10-15% of the toluene volatilized during primary treatment, 25-35% volatilized from an equalization basin, and 10-34% was removed by volatilization in aeration basins. This exemplifies the fact that while aerated secondary treatment may be very efficient at stripping PTOCs to the atmosphere, a significant amount of the PTOCs may be removed by volatilization before ever reaching secondary treatment. A recent report to Congress (USEPA, 1986) described various processes from which volatilization can be expected to occur. In addition to aeration basins, other processes included flumes, grit chambers, sumps, equalization basins, pH adjustment stations, nutrient addition stations, clarifiers, oxidation basins, open storage tanks, wastewater transfer lines, pipes, and ditches.

The report to Congress (USEPA, 1986) also noted the importance of acclimation of the secondary treatment system with respect to volatile emissions. Volatile losses from unacclimated activated sludge systems were typically observed to be greater than 80% for VOCs. However, the degree of volatilization was significantly reduced, as low as 25% for benzene, ethylbenzene, and toluene, within acclimated systems.

While most studies have focused upon emissions from activated sludge systems, some studies have also indicated the potential for emissions from other wastewater processes. Jenkins et al. (1980) suggested that volatile losses accounted for the high removal efficiencies of chloroform (78.9-98.3%) and toluene (95.7-100%) during overland flow treatment. Biodegradation and adsorption were addressed and it was found that neither could account for the observed losses. However, overland flow systems are currently rare in the state of California.

The California Air Resources Board (1985) recently conducted source tests at two large MWTPs in California. Based upon the concentrations of specific PTOCs in or above individual treatment processes, it would appear that emissions from grit chambers, digester tanks, and aerated channels are potentially significant with respect to emissions

from other processes. Concentrations of vinyl chloride, toluene, and 1,1-dichloroethylene were much greater in digester gases than in the other processes that were sampled. However, the high concentrations do not necessarily result in high emissions, as digester gases are most often flared or combusted to generate power. The PTOCs are expected to be efficiently destroyed during those processes. Emissions can, however, occur through out-breathing pressure-relief valves or around the skirt of floating roof digesters.

In summary, there are limitations to the generalizations that can be made based upon previous monitoring studies. Laboratory studies to predict the fate of PTOCs in wastewater are usually completed under conditions that are not typical of those found in the field. While they may be valuable in assessing the relative affinities of various PTOCs for specific removal pathways, the results can not be accurately extrapolated to field conditions. Field studies are the most valuable for obtaining direct measurements of PTOC removal. However, the lack of existing data based upon similar studies makes it difficult to generalize about the fate of PTOCs in MWTPs. More complete studies of PTOC concentrations, in both the liquid and gas phases, and off-gas flowrates at individual treatment processes would be desirable.

## Removal in the Sludge Stream

Chemical contaminants can adsorb at the solution/air interfaces of non-viable suspended solids or biomass. Furthermore, sorption can occur with uptake into biomass. Because almost all of the literature regarding the removal of organic compounds in sludge streams refers to adsorptive processes, in this report, the mechanism for removal in the sludge stream will be referred to as adsorption.

Adsorption to suspended solids can occur during primary treatment, with subsequent removal in the primary sludge stream. Some fraction of the suspended solids pass through to secondary treatment, as does the remaining contaminant mass which is not adsorbed to solids. Some of the

adsorbed contaminant is removed  from the system as pass-through in the effluent stream and via sludge wastage (secondary sludge removal). However, a significant amount is typically recycled. This leads to a potential for accumulation on biomass, as noted in the literature for benzene, ethylbenzene, and chlorobenzene (USEPA, 1982). Accumulation might also be the explanation for detection of PTOCs in sludge, when they were not detected in the influent stream (Feiler, 1979; USEPA, 1982).

After a compound is adsorbed to biomass and removed in the  sludge stream, it can be biodegraded to a chemical of lesser concern. However, transformation or formation of other chemicals of concern can also occur. An example would be reductive  dechlorination during anaerobic digestion, whereby chlorine atoms  are removed from a molecule leading to a compound with fewer chlorine atoms.

An adsorbed PTOC also has the potential to be desorbed and volatilized to the atmosphere during one of several stages of sludge treatment. For instance, dissolved air flotation is used  to thicken sludge. This is an aerated process which might be  conducive to desorption and stripping. Also, drying processes and  sludge composting expose large amounts of surface area of the sludge to the atmosphere. Sludge is commonly disposed of to landfills, where desorption, degradation, leaching, and volatilization of adsorbed  contaminants can occur. Volatile emissions and groundwater contamination as a result of sludge disposal practices at landfills is a growing concern.

Several factors which affect a compound's affinity for  adsorption to sludge have been described in the literature. They include the presence of other compounds which  compete for adsorption sites, electrolytes, oils and greases, and  the presence of sorbents (USEPA, 1986). Strier and Gallup (1983)  analyzed priority pollutants grouped according to their physico-chemical properties. They concluded that the physico-chemical  parameters that favor adsorption are a low water solubility, high  partition coefficient, high molar volume, low Henry's law constant, low oxidizability, and low chemical reactivity. The contribution of the wastewater matrix has also been reviewed (Strier and Gallup,

1983). A lack of emulsifiers and a high dissolved salt content both tend to reduce solubility thereby increasing the tendency for adsorption. High total suspended solids, which serve as additional adsorption sites, also promote adsorption. The presence of a light oily phase provides a means by which contaminants may partition out of liquid water before being adsorbed to the surface of solids, leading to decreased adsorption. Finally, since adsorption is usually an exothermic process, low temperatures are expected to increase the amount of adsorption.

Two physico-chemical parameters which have been used to compare relative affinities for adsorption are the log of the octanol/water partition coefficient (log(Kow)) and the activated carbon adsorption capacity (AC) (Dixon and Bremen, 1984). Table 5 shows log(Kow) and AC values for the 16 PTOCs. It has been observed that if the log(Kow) is greater than 3.5, a compound is significantly hydrophobic and adsorptive on solid organic matter such as mixed liquor suspended solids (MLSS) and sludge. The highest log(Kow) value for the PTOCs is 3.15 for ethylbenzene. It has also been noted that the relative adsorption of organics on biomass is similar to that for activated carbon, but with the value of AC typically an order of magnitude lower (Dixon and Bremen, 1984). Thus, in terms of log(Kow) and AC, ethylbenzene, chlorobenzene, and perchloroethylene would be expected to have a greater affinity for adsorption than other PTOCs. Vinyl chloride and methylene chloride would be expected to have a relatively low affinity for adsorption.

A set of categories to estimate partition coefficients (fraction removed in sludge stream) was developed based upon a compound's octanol/water partition coefficient, Henry's law constant and analyses of sludge samples obtained from 50 POTWs (USEPA, 1986). The categories and average partition coefficients are shown in Table 6. The criteria for grouping the compounds is given in the column headings. None of the PTOCs of interest to this study fell into group A. Aromatic PTOCs (benzene, chlorobenzene, ethylbenzene, toluene) fell into group B, as did 1,1,1-trichloroethane. Other PTOCs with partition coefficients greater than 0.1 and falling into group C included bromodichloromethane,

28

## Table 5: PTOC Adsorption Parameters

| Compound | Log (Kow) | AC (mg/g) |
|---|---|---|
| Acrylonitrile | -0.14 | 1.4 |
| Benzene | 2.13 | 1.0 |
| Bromodichloromethane | 1.88 | 7.9 |
| Carbon tetrachloride | 2.64 | 11. |
| Chlorobenzene | 2.84 | 91. |
| Chloroform | 1.97 | 2.6 |
| Dibromochloromethane | 2.09 | 4.8 |
| 1,1 Dichloroethylene | 1.48 | 4.9 |
| Ethylbenzene | 3.15 | 53. |
| 1,2 Dichloroethane | 1.48 | 3.6 |
| Methylene chloride | 1.25 | 1.3 |
| Perchloroethylene | 2.88 | 51. |
| Toluene | 2.69 | 26. |
| 1,1,1 Trichloroethane | 2.17 | 2.5 |
| Trichloroethylene | 2.29 | 28. |
| Vinyl chloride | 0.60 | -- |

Log(Kow) = Logarithm (base 10) of the octanol/water partition coefficient (dimensionless).

AC = Activated carbon adsorption capacity at neutral pH and a PTOC concentration of 1 mg/L.

References: USEPA (1980), USEPA (1983).

## Table 6: Partition Coefficients for Adsorption to Sludge

| Group | Log(Kow) | $K_H$(x1000) (atm-cu.m/mole) | Partition Coefficient |
|-------|----------|------------------------------|------------------------|
| A | > 4 | < 1 | 0.366 |
| B | 2 - 4 | 1 - 10 | 0.149 |
| C | < 2 | 1 - 10 | 0.1395 |
| D | < 2 | < 1 | 0.10 |
| E | > 4 | 1 - 2 | 0.0895 |
| F | 2 - 4 | < 1 | 0.079 |
| G | 2 - 4 | > 10 | 0.035 |
| H | < 2 | > 10 | 0.0075 |

Group numbers (A-H) were adopted for this study.

Log(Kow) = Logarithm (base 10) of the octanol/water partition coefficient (dimensionless).

$K_H$ = Henry's law constant.

Partition coefficient = fraction partitioned to sludge.

Reference: USEPA ( 1986).

30

chloroform, 1,2-dichloroethane and methylene chloride. Acrylonitrile fell into group D, dibromochloromethane into group F, and carbon tetrachloride, perchloroethylene, and trichloroethylene into group G. The only PTOCs in group H were 1,1-dichloroethylene and vinyl chloride.

Several recent studies have addressed the analysis of organic contaminants in sludge (Bell and Tsezos, 1986; Lawson and Seigrist, 1981; Schröder, 1986). However, there are difficulties associated with the measurements of contaminants in sludge, particularly for volatile organic compounds. Volatilization can occur prior to or during sampling. Preservation of samples against degradation during sample transport, and analysis in a complex matrix pose additional problems. Furthermore, physical adsorption is often a reversible process, and contaminants can return to the aqueous phase (Bell and Tsezos, 1986).

Despite the difficulties noted, laboratory studies have been valuable in assessing the relative affinities of different chemicals for adsorption and have led to an improved understanding of how adsorption might be affected by changes in sludge and wastewater treatment systems. Biosorption was found to be negligible compared to volatilization and biodegradation for several PTOCs studied in the laboratory (Kincannon and Stover, 1983). Those observations were made for benzene, chlorobenzene, ethylbenzene, 1,2-dichloroethane, methylene chloride, toluene, and 1,1,1-trichloroethane. However, in pilot plant studies Schröder (1986) observed a significant quantity of chloroform, trichloroethylene, and chlorobenzene in sludge.

The removal of PTOCs by adsorption at primary clarifiers and activated sludge tanks was reviewed (Dixon and Bremen, 1984). The results observed for PTOCs are summarized in Table 7. It is obvious that adsorption during primary treatment was much more significant than adsorption to biomass during biological treatment. This is not surprising, as volatile stripping occurs during aerated secondary treatment. As indicated by the grouping shown in Table 6, partitioning to sludge was relatively high for benzene, chlorobenzene, ethylbenzene, and toluene. However, the trichloroethylene result shown in Table 7 is inconsistent with

31

Table 7: A Comparison of Adsorption to Primary and Secondary Sludge

| Compound | % Adsorption to Primary Sludge | % Adsorption to Secondary Sludge |
|---|---|---|
| Benzene | 15.6 | 0.09 |
| Carbon tetrachloride | 0.08 | 0.16 |
| Chlorobenzene | 10.6 | 0.03 |
| Chloroform | 0.52 | 0.23 |
| Ethylbenzene | 33.3 | 0.25 |
| Methylene chloride | 3.2 | 0.04 |
| Toluene | 9.4 | 0.06 |
| Trichloroethylene | 17.5 | 0.09 |

References: Dixon and Bremen (1984).

its grouping shown in Table 6. The reasons for the discrepancy between observed and predicted behavior were not given.

The most comprehensive contaminant mass flow analysis in MWTPs to date was completed as part of an EPA sponsored "50 POTW Study" (USEPA, 1982). An analysis of the raw mass flow data provided in that report was completed to study the significance of adsorption as a PTOC removal mechanism. The results are shown in Table 8. Toluene was found to be the PTOC most effectively removed in sludge streams, with an average removal of 9.7%. The values in Table 8 represent total removal from all sludge streams. With the exceptions of methylene chloride and chlorobenzene, the percent removal in sludge was less than 5% for the other PTOCs. The surprisingly high results for methylene chloride might be an artifact because of its use in laboratories as a solvent, and the subsequent possibility of contamination during analysis. The possibility for significant contamination is increased since the concentrations of PTOCs in sludge are often near the detection limits.


## Biodegradation

Of the four primary removal mechanisms (volatilization, adsorption, biodegradation, pass-through), biodegradation is the most complex and difficult to resolve in terms of its significance with respect to the other mechanisms. This subsection is provided to describe the extent of existing knowledge regarding biodegradation, especially as it relates to PTOCs in wastewater. An overview of biodegradation and where it occurs in MWTPs is included. Factors which are known to affect biodegradation are reviewed. Actual measurements of biodegradation are discussed along with the uncertainties and limitations of such techniques. The objective of the discussion is to provide the reader with background regarding the relative biodegradability of the PTOCs, a realization of the complexity of the biodegradation process, and an understanding of the important factors which can affect the extent of biodegradation.

33

## Table 8: PTOC Removal in Sludge Streams

| Compound | # of Plants | % Removed |
|---|---|---|
| Toluene | 44 | 9.7 |
| Methylene chloride | 41 | 8.0 |
| Chlorobenzene | 6 | 5.1 |
| Carbon tetrachloride | 6 | 4.3 |
| Perchloroethylene | 43 | 4.1 |
| Trichloroethylene | 44 | 4.1 |
| Ethylbenzene | 38 | 4.0 |
| Vinyl chloride | 7 | 1.3 |
| 1,2 Dichloroethane | 10 | 1.1 |
| Benzene | 26 | 1.0 |
| Chloroform | 37 | 0.7 |
| 1,1,1 Trichloroethane | 38 | 0.7 |
| Bromodichloromethane | 3 | 0. |
| 1,1 Dichloroethylene | 11 | 0. |
| Dibromochloromethane | 0 | - |

% Removed indicates total removal from all sludge streams.

Microorganisms that are responsible for the breakdown of organic contaminants are characterized by a high degree of variation in their biological nature. Although the principal microorganisms are bacteria, many diverse types exist. These have been summarized elsewhere (Tchobanoglous and Schroeder, 1985). The organisms have been classified as aerobic, anaerobic, and facultative. The former require oxygen for survival and reproduction. Anaerobic bacteria are adversely affected by the presence of oxygen, and facultative bacteria are able to grow in both aerobic and anaerobic environments. Because of the wide variety of microorganisms that occur in nature and the open characteristics of treatment processes, a continual innoculation can be expected in any biological wastewater treatment process. An important result is that the species best able to compete under a set of physical and chemical conditions will predominate.

A commonly utilized aerobic biological system is the activated sludge process (AS). The majority of AS units employ air to provide the oxygen to sustain the biomass of the system, in which case the aeration basins are typically open to the atmosphere. Less typical are covered, pure-oxygen systems. Additional aerobic systems include trickling filters, rotating biological contactors, overland flow systems, and oxidation ponds. Descriptions of such systems have been given elsewhere (Tchobanoglous and Schroeder, 1985).

A method of characterizing biological treatment process performance is degradation efficiency; defined as the ratio of contaminant concentration leaving the system to the contaminant concentration entering the system. The degradation efficiency of a biological system is affected by the degree of acclimation of the system. Acclimation is characterized by a lag period during which time little or no degradation takes place (Skow, 1982). The delay is thought to be caused by two phenomena (Skow, 1982). The first involves the selection of appropriate biological species that are capable of assimilating the contaminant, in which case the lag period is due ˎ to an initial phase of exponential population growth of that microorganism. The second phenomenon involves the adaptation of microorganisms through the induction of enzymes that

facilitate degradation. The acclimation period has been noted to vary from hours to weeks depending upon the contaminant, microbial population, and the medium (Skow, 1982). The length of the acclimation period can have a significant affect on the relative importance of biodegradation, adsorption, and volatilization. For instance, if a system is unacclimated, a highly volatile contaminant may volatilize long before biodegradation can compete as a removal mechanism. This is exemplified by results that have been compiled by the EPA, as shown in Table 9 (Frederick, 1985). The results were developed from pilot plant studies. They show that unacclimated systems were characterized by greater volatilization than were acclimated systems. Similar results were observed by Patterson and Kodukala (1981).

The ability of a system to acclimate and remain acclimated is very sensitive to deviations from steady-state conditions (Blackburn et al., 1985). However, PTOC mass loadings in influent streams are typically characterized by a high degree of variability. In addition, it has been noted that the actual magnitude of the contaminant concentration is significant (Alexander, 1973). For instance, if the concentration is too low, biodegradation will be limited because of a lack of sufficient stimulus to initiate an enzymatic response (Alexander, 1973). There is additional evidence that compounds which are usually degradable can be persistent at low concentrations (Digeronimo et al., 1979; Jannasch, 1967). This may be significant for the PTOCs, since many studies to quantify the degree of biodegradation were completed at PTOC concentrations above 10 mg/L, while typical concentrations in the influent to MWTPs are less than 10 μg/L.

A complete assimilation and examination of existing biodegradation data, across individual classes of compounds, has not been effectively completed. Thus, the variables which control rates of biodegradation are not well understood. However, several general observations have been made regarding the factors that affect the degree of biodegradation. These can be classified as substrate-related, organism-related and environment-related.

Table 9. The Effects of Acclimation on Stripping and Biodegradation

| Compound | Fraction Stripped | | Fraction Biodegraded | |
|---|---|---|---|---|
| | Acclim. | Unacclim. | Acclim. | Unacclim. |
| Benzene | 0.25 | 0.80 | 0.74 | 0.18 |
| Carbon tetrachloride | 0.80 | 0.90 | 0.07 | 0. |
| Chlorobenzene | 0.30 | 0.50 | 0.55 | 0.35 |
| Chloroform | 0.70 | 0.90 | 0.28 | 0.08 |
| 1,1 Dichloroethylene | 0.80 | 0.90 | 0.20 | 0.10 |
| Ethylbenzene | 0.25 | 0.80 | 0.69 | 0.14 |
| 1,2 Dichloroethane | 0.50 | 0.90 | 0.45 | 0.05 |
| Perchloroethylene | 0.50 | 0.80 | 0.47 | 0.17 |
| Toluene | 0.25 | 0.80 | 0.47 | 0. |
| 1,1,1 Trichloroethane | 0.80 | 0.90 | 0.19 | 0.14 |
| Trichloroethylene | 0.70 | 0.80 | 0.24 | 0.14 |
| Vinyl chloride | 0.90 | 0.95 | 0.08 | 0.03 |

Reference: USEPA (1986).

37

Much of the work that has addressed the effects of substrate characteristics has focused upon the solubility of organic compounds (Strier and Gallup, 1983). It has been observed that biodegradation is facilitated for compounds with intermediate solubilities in water, or log(Kow) values between 1.5 and 3.5 (Skow, 1982; Strier and Gallup, 1983). This range corresponds to all of the PTOCs with the exception of 1,1-dichloroethylene, 1,2-dichloroethane, methylene chloride, and vinyl chloride, all of which have log(Kow) values less than 1.5. As noted previously, the contaminant concentration is also an important factor since low concentrations may not be sufficient to initiate the biodegradation process. Also, high concentrations of toxic organic compounds may lead to deleterious "shock-loading" of the biological system (Allen et al., 1985).

Other substrate-related factors can be subclassified under chemical structure. However, the relationships among biodegradation and such factors are not universally agreed upon. It has been observed that biodegradation decreases as the degree of halogenation of a compound increases, and that more than one chloro or nitro group substituted on a benzene ring tends to reduce a compound's degradability (USEPA, 1986).

Because of the complexity of viable systems, the significance of organism-related factors are even less well understood than substrate-related factors. A review of organism-related factors is beyond the scope of this study.

Environment-related factors which have been observed to increase biodegradation include the presence of emulsifiers, low non-viable suspended solids concentrations, and pH values in the range of 6 to 9 (Strier and Gallup, 1983). Higher temperatures, a sufficient dissolved oxygen concentration, the availability of co-metabolites serving as food for biota, and sufficient reaction and solid retention times have all been observed to assist biodegradation (Allen et al., 1985; Strier and Gallup, 1983; USEPA, 1986).

Competing reaction mechanisms can also be significant with respect to the degree of biodegradation. The relationship between biodegrada-

tion and volatilization is complicated because many of the factors that affect one mechanism also affect the other.

Most of the measurements made to quantify biodegradation are completed by differencing (i.e., subtracting adsorption and volatile losses from the total removal) after the completion of laboratory or pilot scale experiments. However, difficulties often exist in measuring and/or controlling volatile losses. Thus, inflated biodegradation rates exist in the literature as volatilization losses are mistakenly taken to be degradation losses (Lawson and Siegrist, 1981; Schröder, 1986). Significant test-to-test variabilities in measured biodegradation rates have been observed, as some tests provide a better environment for degradation than others. Such difficulties should be kept in mind before attempting to extrapolate from laboratory, or pilot scale, results to actual field conditions. The factors mentioned previously are likely to be quite different in an actual wastewater treatment facility.

Using bench-scale activated sludge systems, Blackburn et al. (1985) found that biodegradation accounted for 67-70% of the removal of toluene. For acrylonitrile, methylene chloride, and benzene, Kincannon et al. (1984) observed that biodegradation accounted for 100%, 93%, and 84% of the total removal, respectively, in continuous flow biological reactors. However, 1,1,1-trichloroethane was found to completely volatilize. In similar systems, greater than 98% of the removal of acrylonitrile and toluene was attributed to biodegradation (Lawson and Siegrist, 1981). In a completely acclimated bench-scale activated sludge system, biodegradation was observed to account for between 78 and 84% of the total removal of benzene, toluene, ethylbenzene, and chlorobenzene (Weber et al., 1986). However, conditions in all of the experiments were greatly simplified with respect to typical field conditions.

The discussion to this point has dealt primarily with aerobic systems. However, based upon limited digester gas sample data (California Air Resources Board, 1985) and typical PTOC concentrations in the influent stream, it appears that vinyl chloride is produced during anaerobic digestion. The source of the vinyl chloride could be the re-

sult of simultaneous removal of a chlorine and a hydrogen atom from a precursor compound, such as 1,2-dichloroethane, with subsequent formation of vinyl chloride. Alternatively, successive substitution of chlorine by hydrogen atoms on compounds such as perchloroethylene might explain the occurrence of vinyl chloride. The sequential dehalogenation of chlorinated ethenes to form vinyl chloride in groundwater environments has been observed (Barrio-Lage et al., 1986). A recent study also indicated that chlorinated organics form as a result of the Purifax process due to the addition of chlorine gas to stabilize sludge (Pincince and Fournier, 1984).

It is safe to say that little is known regarding the biodegradability of PTOCs, or the relative importance of biodegradation with respect to the other removal mechanisms. A better understanding of PTOC biodegradation (e.g., acclimation) would improve our understanding of the extent of volatilization during wastewater treatment. Modification of wastewater treatment processes to increase biodegradation rates might be a useful control technique to reduce volatile losses of PTOCs, and is an area where further research is warranted.

## Formation

During the course of literature and data review for this study, it became apparent that halogenated organics form as a result of chlorination during wastewater treatment. It was observed that THMs formed during wastewater treatment in amounts greater than were initially present in the influent streams of MWTPs. This was particularly true for chloroform, and less significant for bromodichloromethane and dibromochloromethane. A detailed review of THM formation is provided in Appendix D. Factors which affect THM formation are described there, along with potential precursors and important reaction mechanisms. Post-chlorination emissions are also discussed. Only a cursory review is provided here.

To study the potential for the formation of chloroform, MWTPs that

post-chlorinate on a continuous basis were separated from those that do not regularly chlorinate. In the latter case, the ratio of chloroform concentration in the effluent stream to concentrations in the influent stream (Ce/Ci) was always less than 1. This reflects a net average removal of chloroform. However, for those plants that do post-chlorinate, the value of Ce/Ci was often greater than unity, and as high as 12.7. The data are clearly suggestive of chloroform formation as a result of chlorination. It would also be expected that Ce/Ci would be much greater if the influent concentration was replaced by the chloroform concentration immediately prior to chlorination, since much of the chloroform entering a MWTP in the influent stream would be removed during treatment prior to post-chlorination. This pattern of removal followed by higher Ce/Ci ratios was observed during the 50 POTW study (EPA, 1982).

## Pass-through

Up to this point, the removal of PTOCs during wastewater treatment has been described in terms of volatilization, adsorption, and biodegradation. That portion of the PTOC mass which is not removed in the MWTP is discharged in the effluent stream. The same removal mechanisms that operate in a treatment plant continue to act in a receiving water. However, conditions are typically less favorable to biodegradation than in treatment systems designed to induce biological degradation, and less solid surface area is typically available for adsorption. Therefore, it is conceivable that volatilization could account for an even larger percentage of the fate of PTOCs which are discharged than occurs within MWTPs. For the purposes of this study, calculated removal efficiencies and volatile emission estimates do not include emissions associated with pass-through.

Average total percent removals (100% - % pass-through) for 12 PTOCs are shown in Table 10. Acrylonitrile was not observed above its detection limits in either the 50 POTW study or this study. In many MWTPs, the effluent concentrations of THMs were much greater than the cor-

41

Table 10: Average Total Removal Efficiencies for PTOCs

| Compound | No. of Plants | | Average Removal Efficiency (%) | | Standard Deviation (%) | |
|---|---|---|---|---|---|---|
| | 50 POTW | Calif. | 50 POTW | Calif. | 50 POTW | Calif. |
| Benzene | 21 | 13 | 80.9 | 72.1 | 29.8 | 34.6 |
| Carbon tetrachloride | 2 | 3 | 76.5 | 94.7 | 16.3 | 8.4 |
| Chlorobenzene | 7 | 3 | 99.8 | 86.7 | 0.4 | 23.1 |
| 1,1 Dichloroethylene | 7 | 8 | 63.7 | 76.8 | 44.7 | 31.3 |
| Ethylbenzene | 38 | 20 | 87.1 | 84.0 | 29.0 | 28.9 |
| 1,2 Dichloroethane | 8 | 6 | 64.1 | 96.7 | 45.3 | 3.7 |
| Methylene chloride | 49 | 29 | 49.0 | 64.6 | 32.2 | 26.3 |
| Perchloroethylene | 45 | 35 | 79.0 | 79.0 | 25.7 | 28.9 |
| Toluene | 48 | 39 | 92.1 | 86.4 | 13.9 | 23.5 |
| 1,1,1 Trichloroethane | 42 | 27 | 86.7 | 79.5 | 22.8 | 23.8 |
| Trichloroethylene | 46 | 23 | 88.3 | 83.1 | 20.3 | 23.5 |
| Vinyl chloride | 3 | 0 | 95.7 | -- | 3.8 | -- |

42

responding influent concentrations. Thus it was not possible to compute meaningful removal efficiencies for the THMs.

It is common for influent concentrations to be above detection limits (ADL) and effluent concentrations to be below detection limits (BDL). One technique to handle such data is to assume a total percent removal of 100%. This assumption is relatively accurate for PTOCs that are found in concentrations several times greater than their detection limits (e.g., toluene). However, uncertainties associated with such an assumption increase for PTOCs that are present at concentrations that are only slightly above their detection limits (e.g., 1,2-dichloroethane). Therefore, an influent concentration to effluent detection limit ratio of three was arbitrarily chosen as the criterion for using such data in computing average removal efficiencies. The average percent removals for PTOCs other than the THMs were typically found to be in the range of 75-95%. The exception was methylene chloride which had a significantly lower percent removal based upon both the 50 POTW study and the data collected for this study.

Differences in the type and degree of treatment account for some of the variance of the data presented in Table 10. For instance, if volatilization was the most important removal mechanism, MWTPs that utilized aerated secondary treatment were likely to have high total removals. Additional removal would be expected due to biodegradation. The results shown in Table 10 reflect average removal rates without regard to the type or degree of treatment. For MWTPs which employ only primary treatment, the average percent removals are likely to be lower than those shown in Table 10.

## Summary

In this section, the fate of PTOCs in both wastewater collection and treatment systems was addressed. For collection systems it was found that the potential exists for significant emissions, but a lack of existing sample data does not allow for meaningful emissions estimates.

It is believed that this is one source which deserves further attention in order to reduce the uncertainties associated with the relative significance of emissions.

Wastewater treatment processes were reviewed in terms of volatilization, adsorption, biodegradation, and pass-through as PTOC removal mechanisms. The formation of trihalomethanes was also discussed. Mechanisms were described in terms of existing laboratory, pilot plant, and field studies. From a limited data set, some general observations were made.

Adsorption and removal in sludge streams typically accounted for less than 10% of the incoming mass of any PTOC. In addition, the total fraction removed in sludge streams is greater in primary sludge than in waste-activated sludge. Although many of the PTOCs have been observed to biodegrade during simplified laboratory analyses, little is known regarding the biodegradation of PTOCs during treatment in actual municipal wastewater treatment plants. The most important factor can be defined as the degree of acclimation of the microbial population to the PTOC of interest. Based upon current knowledge of the acclimation process, it is concluded that requirements for the acclimation to PTOCs usually remain unsatisfied in MWTPs. If that is true, studies have indicated that the percent degraded during conventional activated sludge treatment would be typically less than 20%. One possible exception would be chlorobenzene (% biodegraded = 35%).

Based upon PTOC concentrations in the influent and effluent streams of MWTPs throughout California, it was clear that chloroform formed as a result of chlorine disinfection. In addition, the degree of formation was often significant with respect to chloroform mass loadings in the influent stream.

The overall removal efficiency of PTOCs during wastewater treatment was estimated to be, on the average, between 75% and 95%. Exceptions (lower than 75%) included the trihalomethanes which can form as a result of chlorination, and methylene chloride. For most of the PTOCs,

the remaining 5% to 25% were discharged in the effluent stream. The ultimate fate following discharge was expected to be volatilization.

<sup>45</sup>

Based upon the observations discussed above, a large fraction of PTOCs that enter a MWTP are expected to be removed via volatile losses.

# 5. EMISSIONS ESTIMATION METHODS AND DATA QUALITY AND AVAILABILITY

In this section, methods used to estimate PTOC losses from wastewater due to volatilization and adsorption to sludge are described. A discussion of the corresponding assumptions and limitations, and an analysis of the data available for use in the estimation methods was also included. This was done in order to provide the reader with an understanding of typical sampling and analysis techniques that are used to measure PTOC concentrations in influent and effluent streams, as well as to indicate the extent and representativeness of the data collected for MWTPs in California.

## Emissions Estimates

The uncontrolled emission rate, "$E_m$", of a specific PTOC, "$m$", from a MWTP can be expressed as a fraction of the average total removal of "$m$" such that

$$E_m = (f_m/n) \sum_{j=1}^{n} (C_{m,i,j} - C_{m,e,j})Q_j, \tag{1}$$

where "$f_m$" is an average stripping factor for PTOC "$m$" ($0 < f_m < 1$), "$n$" is the number of sampling periods, "$Q_j$" is the average wastewater flowrate during sampling period "$j$", and "$C_{m,i,j}$" and "$C_{m,e,j}$" are the concentrations of PTOC "$m$" in the influent and effluent streams, respectively, during sampling period "$j$". Of course, all parameters should have consistent units, or should be converted to the desired units. The worst-case emission estimate is based upon a value of "$f_m$" equal to unity. <u>Because this study focussed upon the potential for PTOC emissions, worst-case, uncontrolled, emission estimates were computed.</u>

If "$C_{m,i,j}$" and "$C_{m,e,j}$" are replaced by flow-weighted, average values, "$C_{m,i}$" and "$C_{m,e}$", respectively, Equation 1 can be rewritten as

$$\cdot E_m = f_m (C_{m,i} - C_{m,e})Q, \tag{2}$$

where "$Q$" is the flowrate averaged over all sample periods.

Equation 2 can be applied if concentrations are known in both the influent and effluent streams. For MWTPs in which effluent data are not available, the worst-case emission rate can be estimated by

$$E_m = b_m \, f_m \, (C_{m,i} - C_{m,e})Q, \qquad (3)$$

where "$b_m$" is an average total removal efficiency for PTOC "$m$". Equation 3 is also useful for estimating the emissions of trihalomethanes. For THMs, Equation 2 is not suitable as formation during treatment causes an increase in "$C_{m,e}$" and a corresponding decrease in the estimated emission rate. However, Equation 3 does not account for volatile emissions which can occur following the formation of THMs. For this study, values for "$b_m$" were based upon the total removal efficiencies shown in Table 10. A value of $b_m = 0.9$ was chosen for the THMs, based upon removal efficiencies for similar compounds. While Equation 2 is preferred to Equation 3, it should be noted that only four of the fifty-one MWTPs for which data were gathered did not submit effluent data. Those four facilities accounted for only one percent of the total municipal wastewater treated in California. The most significant effect of the use of Equation 3 was on the estimate of chloroform emissions. While the worst-case assumption was conservative with respect to emissions estimates, it was partially offset by not accounting for volatile emissions of the chloroform that were generated as a result of chlorination. The formation of bromodichloromethane and dibromochloromethane was relatively insignificant with respect to chloroform and was ignored.

Twenty-three percent of the municipal wastewater in California was treated by MWTPs for which no concentration data were obtained. Several methods were examined to extrapolate emissions estimates to those MWTPs. The simplest was to assume average statewide concentrations at those MWTPs without data. However, the coefficient of variation (cv) for specific PTOCs taken over all MWTPs with available data was typically greater than a factor of three. Using such an approach would tend to overestimate emissions in less-industrialized regions, and underestimate emissions in heavily industrialized regions. A second approach was to

maintain a statewide analysis while attempting to correlate concentrations with available parameters. However, normalizing the PTOC concentrations by total suspended solids, total phenols, phenol (acids), cyanide, and fractional industrial flow all failed to significantly reduce the cvs with respect to the non-normalized cvs. A more successful approach was to partition the MWTPs with existing data into geographic regions where similar mixes of industrial users discharge to POTWs. This approach led to decreases in the cvs for most of the PTOCs in nearly every region. In addition, normalizing by the fraction of flow accounted for by industrial users further reduced the cvs. After comparing other methods of correlation with distinct geographic regions, the industrial flow approach was adopted, as it appeared to be superior to the other methods that were studied. The counties that were grouped into specific regions for analysis are indicated in Figure 3.

For MWTPs that did not treat industrial flows and for which data were missing, extrapolation was completed by analyzing corresponding facilities for which data were available, i.e., which had no industrial flow contribution. Average PTOC concentrations from those facilities were assumed to apply to all facilities without industrial flow contributions.

The significance of extrapolation, on a county-by-county basis is indicated in Table 11 which shows the percent of total wastewater that is accounted for by MWTPs with existing concentration data. The contribution of extrapolated emissions, on a percent flow basis, was much smaller in the populated, industrialized counties where PTOC mass loadings to POTWs were relatively high. A larger percentage of the extrapolated emissions estimates were needed in rural, nonindustrialized counties with relatively lower total emissions.

The approach described above was used to estimate emissions from approximately 600 MWTPs in California. Estimates for individual MWTPs were summed to predict county-by-county and statewide emissions on a speciated and total PTOC basis. This was accomplished through the use of a program, WEST (Worst-case Emissions during Sewage Treatment), which was developed for this study, and coded in FORTRAN 77. WEST (Appendix

LEGEND:

1. SOUTHERN, CENTRAL, AND NORTHERN VALLEY

2. CONTRA COSTA / SOLANO

3. ALAMEDA / SANTA CLARA

4. SAN FRANCISCO / SAN MATEO

5. VENTURA

6. LOS ANGELES / ORANGE

7. RIVERSIDE / SAN BERNARDINO / SAN DIEGO
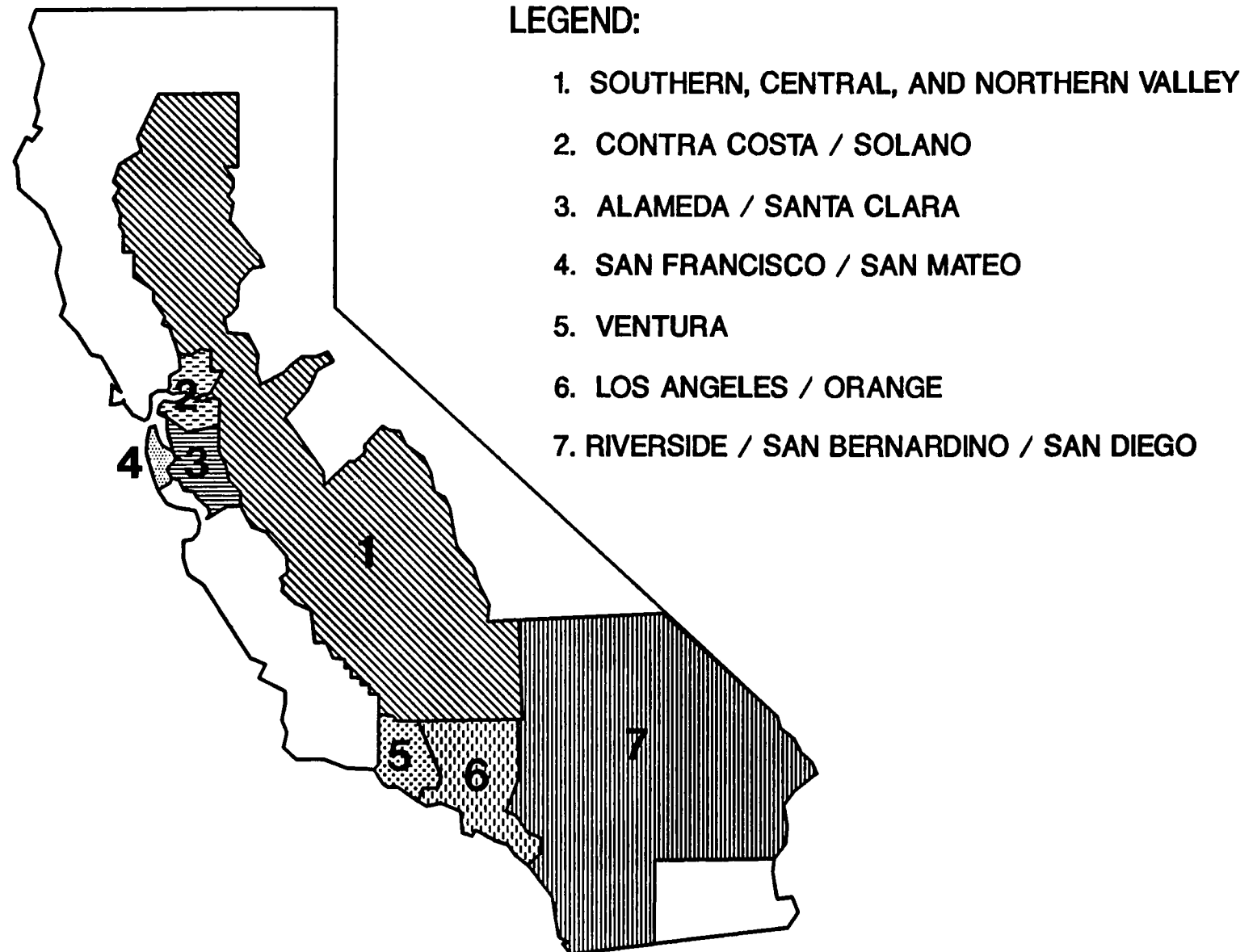
Figure 3: Data Extrapolation Regions

Table 11: Percent of Flow Accounted for by MWTPs with Data

| County | Total Flow[1] (MGD) | Percent of Flow Accounted for by MWTPs with Data |
|---|---|---|
| Alameda | 124 | 97 % |
| Contra Costa | 72 | 93 |
| Fresno | 51 | 82 |
| Kern | 36 | 51 |
| Los Angeles | 984 | 93 |
| Marin | 21 | 21 |
| Merced | 13 | 37 |
| Monterey | 24 | 62 |
| Orange | 278 | 92 |
| Riverside | 58 | 42 |
| Sacramento | 127 | 99 |
| San Diego | 184 | 86 |
| San Francisco | 115 | 99 |
| San Joaquin | 56 | 81 |
| San Luis Obispo | 11 | 36 |
| San Mateo | 60 | 59 |
| Santa Clara | 175 | 99 |
| Santa Cruz | 21 | 39 |
| Solano | 29 | 81 |
| Sonoma | 23 | 14 |
| Ventura | 49 | 56 |
| All others | 650 | 0 |
| Statewide | 2800 | 78 |

(1) Based upon annual averages from 1983 to 1986, and NEEDS data.

E) draws upon flowrate and concentration data stored in an external file (COUNTY.DAT).

## Sludge Generation Estimates

Two methods for estimating sludge generation were compared. One method of extrapolation (method 1) was to normalize the existing sludge generation data by the wastewater flowrate, and analyze those facilities without data in terms of their known flowrates. This method was crude, as it did not account for the actual solids loading into the MWTP, or the degree of treatment. Total suspended solids (TSS) information was usually available for most of the MWTPs. Therefore, a second method (method 2) to estimate sludge generation was

$$S_g = (S_i - S_e)Q, \qquad\qquad (4)$$

where "$S_g$" is the amount of sludge generated (mass/time), "$Q$" is the average wastewater flowrate, and "$S_i$" and "$S_e$" are the total suspended solids concentrations in the influent and effluent streams, respectively. If effluent TSS values were not available, an average percent reduction of 80-90% was assumed. Since effluent concentrations of less than 50 mg/l were typical, the error incurred in doing so was small. Method 2 is believed to be more appropriate than method 1, as it accounted for the actual solids loadings to individual MWTPs. However, for comparative purposes both methods were applied in this study. Influent TSS concentrations were extracted from a data base (NEEDS) maintained by the California Water Resources Control Board. In order of priority, flowrate data were obtained from direct contacts with POTWs, reviews of Pretreatment Annual Reports, and dry weather flow data available in the NEEDS survey.

## Estimating the Removal of PTOCs in Sludge

The amount of each PTOC that was removed in sludge streams was estimated on a county-by-county and statewide basis. This was completed by summing removal rates, "$S_m$", at individual treatment facilities. The

value of "$S_m$" was estimated as the product of the mass loading in the influent stream and the appropriate partition coefficient as listed in Table 8. The resulting equation was

$$S_m = K_m \, C_{m,i} Q,$$ (5)

where "$S_m$" is the amount (mass/time) of PTOC "m" removed in the sludge streams of a specific MWTP, "$K_m$" is the partition coefficient (fraction of incoming mass of PTOC "m" that is removed in sludge), and "Q" and "$C_{m,i}$" are as defined previously.


## Data Quality and Availability: PTOC Sampling Procedures

A generally approved method for PTOC sample collection has not been established. Subsequently, collection methods vary among MWTPs in California. For instance, some MWTPs use containers with a top surface open to the atmosphere to sample the influent and effluent streams. Samples are typically transferred immediately to teflon-lined capped glass vials with no observable air space in the vial. Other MWTPs proceed further to minimize exposure to air by utilizing a closed container with a tube attached for siphoning wastewater samples into the container. The tube opening is then sealed prior to removing the sample container from the wastewater stream. Sludge samples are commonly taken as a single "scoop" before being sealed in a container.

Sampling locations also vary among the MWTPs. Some treatment plants sample influent streams in the collection system before the wastewater ever reaches the headworks, while others sample at, or slightly downstream of, the headworks. Effluent streams are most often sampled after chlorination, but some are sampled prior to dechlorination. A few MWTPs report concentrations in the effluent stream at the point of ultimate discharge, which can exist miles from the actual treatment plant. In the latter case, volatile losses in the outfall line may further reduce concentrations, and the additional reaction time for those facilities that chlorinate may act to increase THM concentrations in the effluent stream.

Temporal requirements are an important part of sampling. For influent, effluent, and sludge streams, such requirements have been outlined in the Federal Register (FR) (1981). The FR states that the data collected shall be representative of seasonal and yearly conditions, as well as of similar quantity and quality as normal influent and effluent flows. In addition, twelve samples are to be taken at approximately equal intervals during the course of each annual period of plant operation. Representative samples must be taken into account for both workdays and non-workdays.

Requirements were also established for sampling procedures based upon both composite and grab samples. For composite samples, influent and effluent data must be obtained through 24-hour samples which are proportioned by flow. Either discrete or continuous sampling is allowed. However, for discrete sampling at least twelve samples are recommended for compositing. These must be flow-proportioned either by varying the volume of each aliquot, or the time interval between each aliquot. Aliquots used for the collection of volatile pollutants must be combined immediately prior to analysis.

The effects of lag time (hydraulic retention time) in an MWTP may lead to influent and effluent samples which do not correspond to the same wastewater "parcels". However, for continuous sampling over a 24-hour period, the FR states that "effluent sample collection need not be delayed to compensate for hydraulic retention unless the POTW elects to include retention time compensation or unless the Approval Authority requires retention time compensation." Furthermore, if retention time is required to be taken into account it is required "to be based on a 24-hour average daily flow value." The average daily flow corresponds to the average flow during the same month of the previous year.

When composite samples are not feasible, grab sampling may be necessary. Here, grab sample refers to an individual sample collected over a time period of less than fifteen minutes. Retention time should be taken into account whenever grab samples are used.

According to the FR (1981), composite sludge samples should be taken during the same period as the influent and effluent samples. Each

composite sample must contain a minimum of twelve discrete samples taken over a 24-hour period. If necessary, grab samples may also be taken.

In MWTPs in California, influent and effluent samples are typically drawn during the same 24-hour period, without accounting for the hydraulic retention time. In most cases, eight grab samples are taken, once every three hours, and composited immediately prior to analysis.

The frequency between 24-hour composite/grab sampling for volatile priority pollutants varies significantly from plant to plant. For instance, the Point Loma Wastewater Treatment Plant in San Diego reports average influent and effluent concentrations for all volatile priority pollutants on a once per month basis. Other facilities sample on a quarterly, or wet season/dry season basis. Due to the infancy of the EPA's National Pretreatment Program (NPP), volatile priority pollutant sampling extends back only one or two years for most POTWs, and some relatively large POTWs have yet to sample for such pollutants.

Sampling for PTOCs in sludge streams is not as common as in influent and effluent streams. Many of the MWTPs in California have not sampled sludge streams for volatile priority pollutants, and the data from those which have are not of great value to adsorption studies because of sampling location. Sludge "scoops" are usually taken from digested and partially or fully dewatered sludge. Volatilization, transformation, and degradation during digestion, and volatilization during dewatering make it impossible to predict the actual mass removal in untreated (raw) sludge.

## Sample Analysis Techniques

The EPA has specified a maximum time period, between the sampling and analysis of most volatile priority pollutants, of fourteen days. Many POTWs must contract with a private laboratory having a gas chromatograph (GC) or GC/mass spectrometer (GC/MS) capabilities to analyze the wastewater samples. However, several major POTWs (e.g., County Sanitation Districts of Los Angeles County, City of Los Angeles, East

54

Bay MUD, and the Sacramento Regional Wastewater Treatment Plant) have laboratories which carry out the analyses.

The majority of POTWs in California, and private laboratories contracted by POTWs, utilize EPA method 624 for the analysis of influent and effluent samples. Detection limits for this method are listed in Table 12. However, the method detection limit for specific wastewaters may differ from those listed in Table 12 depending upon the nature of interferences in the sample matrix. Method 624 is a purge-and-trap technique which utilizes mass spectrometry as the detection method.

A recent study of the analysis methods for volatile compounds revealed intra-laboratory and inter-laboratory differences in results for duplicate samples analyzed using method 624 (Gurka, 1984). The intra-laboratory study revealed differences generally less than 30%, with a range of 5% to 300% depending on the compound. The inter-laboratory differences were characterized by the same range, with differences typically less than 70%. The highest variabilities were reported for compounds that are common background contaminants in laboratories (i.e., methylene chloride, 1,2 dichloroethane, and chloroform). In the same study, it was observed that problems exist in retaining volatile priority pollutants on solid samples, such as POTW sludge matrices.

The preceding discussion exemplifies the fact that uncertainties in the data exist due to sampling and analysis techniques. The intra-laboratory study suggested that such inaccuracies can lead to overestimates or underestimates of concentration by as much as a factor of three.


Data Sources

Several sources of data were investigated as part of this study. It is easiest to describe those sources in terms of data categorized as concentration, flow, and other treatment characteristics (e.g., treatment train). The former two types of data were needed to complete mass flow estimates in influent, and effluent streams. The latter was re-

Table 12: Typical Detection Limits for the PTOCs

| Compound | Detection Limits ($\mu g/L$) | |
|---|---|---|
| | EPA Method 624 | Range (Data Survey) |
| Acrylonitrile | - | 1.0 - 100 |
| Benzene | 4.4 | 0.1 - 5 |
| Bromodichloromethane | 2.2 | 0.1 - 2 |
| Carbon tetrachloride | 2.8 | 0.1 - 3 |
| Chlorobenzene | 6.0 | 0.1 - 5 |
| Chloroform | 1.6 | 0.1 - 2 |
| Dibromochloromethane | 3.1 | 0.1 - 3 |
| 1,1 Dichloroethylene | 2.8 | 0.1 - 3 |
| Ethylbenzene | 7.2 | 0.1 - 6 |
| 1,2 Dichloroethane | 2.8 | 0.1 - 3 |
| Methylene chloride | 2.8 | 0.1 - 4 |
| Perchloroethylene | 4.1 | 0.1 - 4 |
| Toluene | 6.0 | 0.1 - 6 |
| 1,1,1 Trichloroethane | 3.8 | 0.1 - 4 |
| Trichloroethylene | 1.9 | 0.1 - 2 |
| Vinyl chloride | 2.0 | 0.1 - 5 |

quired to complete more refined analyses of individual treatment plants (Appendix H).


Concentration data

As a preliminary step in attempting to obtain concentration data, each of the nine Regional Water Quality Control Boards (RWQCBs) were contacted. While it was not possible for most of the RWQCBs to supply summaries of PTOC measurements at POTWs within their respective region, most of the RWQCBs were cooperative in assisting with the study. They were able to provide lists of the appropriate contacts at each of the POTWs within their region. Through such initial contacts it became apparent that many of the POTWs that sample for volatile priority pollutants summarize and submit sample results in their Pretreatment Annual Reports (PARs) and/or NPDES reports.

PAR and NPDES reports are maintained by the individual POTWs that are required to complete such reports, as well as their respective RWQCB. In addition, the Region IX Office of the EPA, and the State Water Resources Control Board (SWRCB), maintain copies of the reports for POTWs throughout California. A list of the POTWs that are required to submit PAR reports is provided in Appendix C. To obtain data from those reports, visits to the SWRCB and the EPA Regional office were made. This proved to be valuable, as some of the reports which had yet to be obtained by either the SWRCB or the EPA had been received by the other.

While most of the reports that were reviewed (> 100) contained sample information for some priority pollutants, a majority did not contain information for volatile priority pollutants. Furthermore, the degree of data that were submitted by those POTWs that did sample varied from influent/effluent/sludge streams to concentrations in only one or two of those streams. Many POTWs reported concentrations on a quarterly basis, while some reported sample measurements taken only once in a calendar year. Less sample data were available for sludge streams than for influent and effluent streams. Nearly all of the samples that

were reported corresponded to sampling completed during 1985. Some extended into the first two quarters of 1986, while a few data sets extended back to 1984. Due to the infancy of the National Pretreatment Program, and relatively recent concerns regarding the fate of VOCs during wastewater treatment, a large fraction of the POTWs have completed only one or two years of sampling for volatile priority pollutants. The existing data base will grow and will become a valuable resource in the coming years.

Several major POTWs did not include sample data for volatile priority pollutants in their PAR reports, or their PAR reports were not found at the SWRCB or the EPA. For this reason, a follow-up survey was completed by telephone, letters of request, and plant visits. The response was generally positive, with most of the POTWs promptly responding to our requests. The direct survey actually accounted for data at MWTPs that represented a higher percentage of the municipal wastewater treated in California than did the data compiled through analyses of the PAR reports. The extent of the concentration data base will be discussed in the following subsection.

Flow data

Hydraulic loading data were typically provided in the PARs. Influent flowrates were commonly provided on an average annual basis. However, some POTWs submitted average monthly or average wet season and dry season flows, and several POTWs reported flows that occurred during the period that concentration sampling was completed. Flowrate data were also obtained as a result of the survey described for concentration data. Average dry-weather flows were provided by the SWRCB via the NEEDS data base that was completed for the EPA. The NEEDS data base (hereafter referred to simply as the NEEDS) consists of information regarding the characteristics of municipal wastewater collection and treatment systems. It was completed in order to assess the future needs of POTWs in terms of federal assistance. However, the data contained in the NEEDS suffers from uncertainties due to the following reasons:

1. Many of the quantitative values are based upon engineering estimates rather than historical data.

2. Some of the information in the NEEDS is outdated (e.g., not updated since 1978-82). The SWRCB is currently in the process of completing a partial update.

3. For some of the MWTPs, no historical or estimated values are provided.

Because of these limitations, data from the NEEDS were used on a low-priority basis (i.e., only if data could not be obtained from more reliable sources).

## Other treatment characteristics

Other treatment characteristics refers primarily to MWTP treatment trains, and more detailed information regarding specific treatment processes. For the largest MWTPs in California, this information was obtained by contacting the appropriate individuals at either the MWTP or the POTW. Information was generally available concerning plant layouts and process specifications. For smaller MWTPs, treatment train data were extracted from the NEEDS and then compiled as described in the following subsection. A cross-check of treatment train information contained in the NEEDS with information provided by the MWTPs revealed that the NEEDS was fairly accurate with respect to MWTP treatment characteristics. However, because much of the information in the NEEDs has not been updated for several years, recent modifications to MWTPs are often not accounted for in the NEEDS data base.

## Data Base Compilation

Data from the sources described in the previous subsection were compiled and maintained on mini and microcomputers in the Department of Civil Engineering at the University of California at Davis. The mini-computer was used for computational analyses of the larger data sets. A commercial data base software package was used to maintain data for

reporting purposes on the microcomputer. The data base structure is described in detail in Appendix F. The remainder of this subsection describes the extent and nature of data that were obtained for each of the categories listed previously.

Concentration data

A summary of the MWTPs from which concentration data were compiled is provided in Table 13. The MWTPs listed in Table 13 represent less than 10%, by number, of the MWTPs in California. However, they account for 77% of the total municipal wastewater that is treated in California. Those with both influent and effluent data account for greater than 76%. Those with only influent data account for 1%. Table 13 also indicates that, even for the largest MWTPs in California, a very limited amount of data exists regarding mass loadings of PTOCs. As noted previously, the frequency of sampling for PTOCs is low, and for many of the MWTPs it was non-existent until the past one or two years. The data compiled for this study are representative of the extent of existing concentration data, but must be interpreted cautiously. Table 11 indicates the percent of total flow, on a county-by-county basis, that is accounted for by MWTPs with either influent data alone, or concentration data in both the influent and effluent streams.

Flow data

Flow data were obtained for every MWTP in the NEEDS data base. For the major POTWs, the NEEDS data were supplemented with more recent (e.g., 1985) flow data. Existing wastewater flowrates were maintained in a manner that allowed for NEEDS dry weather flowrates to be separated from the other flow values.

Other treatment characteristics

Treatment train information was obtained for all of the MWTPs in the NEEDS. Major MWTPs (> 25 MGD) were contacted directly to obtain plant specifications and treatment process information. The NEEDS

Table 13a:  A Summary of MWTPs with Existing Concentration Data[1]

| Facility Name | County | Number of Sample Days Influent | Number of Sample Days Effluent | Code[2] |
|---|---|---|---|---|
| Alvarado (Union City) | Alameda | 1 | 1 | A |
| East Bay MUD (Oakland) | " | 6 | 3 | D |
| Hayward | " | 1 | 3 | B |
| Livermore | " | 3 | 3 | A |
| Oro Loma (Castro Valley) | " | 1 | 2 | B |
| San Leandro | " | 1 | 4 | B |
| C. Contra Costa (Martinez) | Contra Costa | 1 | 4 | B |
| Delta Diablo (Pittsburg) | " | 2 | 5 | B |
| Richmond/San Pablo | " | 1 | 1 | A |
| Fresno | Fresno | 1 | 1 | A |
| Selma/Kingsburg/Fowler | " | 1 | 0 | — |
| Bakersfield #2 | Kern | 1 | 1 | A |
| Bakersfield #3 | " | 1 | 1 | A |
| Hyperion (El Segundo) | Los Angeles | 5 | 5[a] | D |
| JWPCP (Carson) | " | 2 | 1 | C |
| Long Beach | " | 2 | 1 | C |
| Los Coyotes (Cerritos) | " | 2 | 1 | C |
| Pomona | " | 2 | 1 | C |
| San Jose Creek (Whittier) | " | 2 | 1 | C |
| Saugus-Newhall | " | 2 | 1 | C |
| Valencia | " | 2 | 1 | C |
| Whittier Narrows (El Monte) | " | 2 | 1 | C |
| Ignacio | Marin | 1 | 2 | B |
| Novato | " | 1 | 2 | B |
| Merced | Merced | 3 | 3 | E |
| Monterey/Salinas[b] | Monterey | 1 | 1 | A |
| Irvine Ranch | Orange | 1 | 1 | A |
| OCSD #1 | " | 3 | 12[c] | B |
| OCSD #2 | " | 3 | 12[c] | B |
| Riverside | Riverside | 1 | 1 | A |
| Sacramento Regional | Sacramento | 9 | 9 | A |
| Encina Joint Powers (Carlsbad)[d] | San Diego | 1 | 0 | — |

Table 13b: A Summary of MWTPs with Existing Concentration Data[1]

| Facility Name | County | Number of Sample Days Influent | Effluent | Code[2] |
|---|---|---|---|---|
| Point Loma (San Diego) | San Diego | 18 | 18 | A |
| Richmond-Sunset | San Francisco | 2 | 2 | A |
| Southeast/Northpoint | " | 2 | 2 | A |
| Stockton Regional | San Joaquin | 2 | 2 | A |
| San Luis Obispo | San Luis Obispo | 1 | 1 | E |
| San Francisco Int'l Airport[e] | San Mateo | 1 | 1 | A |
| Burlingame | " | 1 | 4 | B |
| South Bayside (Redwood City) | " | 2 | 2 | A |
| South San Fran-San Bruno | " | 1 | 1 | A |
| Gilroy | Santa Clara | 2 | 0 | — |
| Palo Alto WWTF | " | 2 | 2 | A |
| San Jose-Santa Clara | " | 6 | 9 | B |
| Sunnyvale | " | 4 | 4 | A |
| Watsonville | Santa Cruz | 1 | 0 | — |
| Fairfield-Suison | Solano | 1 | 5 | B |
| Vallejo | " | 1 | 2 | B |
| Petaluma | Sonoma | 1 | 4 | B |
| Hill Canyon (Thousand Oaks) | Ventura | 2 | 2 | A |
| Oxnard | " | 1 | 1 | A |

(1) Based upon data that were collected from Pretreatment Annual Reports and POTW survey.

(2) A = influent and effluent data correspond to same day; B = all influent data have corresponding effluent data from the same day, but additional effluent data exists; C = all effluent data have corresponding influent data from the same day, but additional influent data exists; D = some, but not all, of the influent and effluent data correspond to the same day; E = influent and effluent data do not correspond to the same day.

(a) At 5 mile effluent outfall.
(b) Blended influent from Monterey, Salinas #1, and 4 smaller MWTPs. Monterey and Salinas #1 WWTFs made up greater than 70% of the total flow.
(c) Combined effluent from OCSD #1 and OCSD # 2.
(d) Data from sampling completed in 1978.
(e) Includes an industrial wastewater treatment plant, and a water quality control plant.

62

information, with minor adjustments for some of the larger MWTPs, was compiled as a separate data set so that those facilities with specific treatment processes or configurations could be easily identified.

## Assumptions and Limitations

This subsection is provided in order to describe the assumptions and limitations regarding the use of the compiled data. The discussion is of fundamental importance with respect to assessing the representativeness and uncertainties associated with estimated removal and emission rates. Those rates will be discussed in Section 6. Again, data is addressed in terms of concentration, flow, and other treatment characteristics.

## Concentration

In the following sections, emissions and mass removal estimates will be presented in units which suggest a long-term basis (i.e., tons/year). In making such estimates, it was assumed that the limited data which are available are representative of "typical" concentration and flow conditions. In reality, quantitative estimates based upon a small number of samples drawn during discrete sampling periods may not be representative of the long-term average.

One limitation to the existing data is that most of the MWTPs did not account for hydraulic retention time when concentrations were measured in both the influent and effluent streams. This, coupled with uncertainties in analysis techniques, may be the reason that for a few MWTPs the non-THM PTOC concentrations in the effluent stream were greater than those in the influent stream. For lack of a better approach, the effects of hydraulic retention time were neglected, and non-THM effluent concentrations were assumed to be equal to influent concentrations when they were actually reported to be greater than the influent concentrations.

Another assumption was made regarding the treatment of concentrations that were listed as below detection limit (BDL). Such concen-

trations were assumed to be zero. In terms of concentrations in the effluent stream, such an assumption is conservative with respect to emissions estimates. The opposite is true for the influent stream. However, at major MWTPs in industrialized regions such as the South Coast Air Basin (SCAB) most of the PTOC concentrations in influent streams were well above detection limits, so that the BDL=0 assumption should not lead to underestimates of emission rates. The PTOCs that were least likely to be affected by the BDL=0 assumption were those that were frequently detected, and at concentrations well above the detectable limit. Chloroform, methylene chloride, perchloroethylene, and toluene satisfied these requirements.

The BDL=0 assumption also had varying degrees of significance depending upon the specific PTOC detection limit. For instance, although acrylonitrile was not detected by any MWTP that sampled for it, its detection limit was quite high (1-100 μg/L) with respect to the other PTOCs.

Flow data

Many of the POTWs that supplied volatile priority pollutant measurements did not provide corresponding flowrates. However, the use of annual average flowrates was found to be sufficient for this study. Throughout most of the state, temporal variations in wastewater flow were much less significant than those in PTOC concentrations.

For those treatment facilities for which 1985 annual average flowrates were not readily available, the NEEDS dry weather flow data were applied.

Most of the hydraulic flow data were available only for the influent stream. For lack of a more appropriate approach, it was assumed that the average flowrate in the effluent stream was equal to the average influent flow. This neglects losses due to evaporation which may be significant during warm weather in MWTPs that employ ponds with large surface-to-volume ratios.

Although several uncertainties in the use of flow data were noted above, such uncertainties were small with respect to those for concentration data.

## Other treatment characteristics

Except for special characteristics (e.g., fractional secondary treatment) treatment trains were not considered in preliminary emissions estimates. They are important for more refined emissions modeling (Appendix H). However, for the largest MWTPs in industrialized regions, up-to-date treatment train and process specifications were obtained directly from the MWTP or corresponding POTW.

## Summary of Uncertainties

The uncertainties in emissions or total removal rates stem from a number of factors. These include losses arising from sampling techniques, variabilities in the results obtained using existing analysis techniques, lack of a sufficient data base to confidently extrapolate to typical or representative conditions in individual MWTPs, and the necessity to extrapolate to MWTPs without existing PTOC loading data. A qualitative summary can be completed based upon the concepts described above to alert the reader of uncertainties in the estimates reported in Section 6. Semi-quantitative estimates are more difficult to make. However, the concepts described above were used along with best engineering judgement (BEJ) to compile a qualitative and semi-quantitative summary of the uncertainties associated with the emissions estimates described in Section 6. That summary is provided in the remainder of this subsection.

Sampling techniques: Whenever dealing with volatile compounds, one must be aware of the potential for volatile losses during sample collection, preservation, and analysis. Unfortunately, such losses could not be quantified from the existing data as they were highly dependent upon the sampling approach and devices used, as well as the degree of care taken in handling the samples. After reviewing the procedures that were used

in order to obtain concentrations in the influent and effluent streams, it is the authors' judgement that the relative significance of losses during sampling, transport and preservation before analysis were small in comparison to uncertainties in other factors described below.

Analysis techniques: As noted previously, comparison studies of laboratories conducting VOC analyses have indicated that limitations in current analytical techniques can lead to uncertainties as high as a factor of three for PTOCs that are commonly found in laboratory environments, e.g., methylene chloride. The limited information on intralaboratory errors suggested that the majority of VOC analyses were within about 30%. Differences formed from influent and effluent concentrations would result in somewhat larger error bounds, the closer the difference between influent and effluent concentrations, the larger the relative error, but the absolute error would tend to decrease. Thus, we believe that the larger sources of emissions, which had a larger contribution and significance to the emission inventory, should have had a smaller error associated with them. Similarly, for the inter-laboratory comparisons typical errors for VOC analyses were less than about 70%, and one would anticipate smaller errors with increasing sample concentrations. Thus, based upon the PTOCs involved in the lab study and experience with other VOCs, we believe a typical range of uncertainty resulting from the chemical analyses should be less than 100% (a factor of two).

Temporal variations in data: The historical data available for individual MWTPs were limited either by the number of days, or sampling periods, during which PTOC samples were drawn. The assumption that the existing data is representative of typical flow and concentration, i.e., mass loading, conditions was an additional source of uncertainty in the emission estimates. Hourly variations in wastewater flowrates were accounted for by most POTWs, since flow-proportioned composite samples were common. Flow variations over longer time periods were not significant at most MWTPs. For the largest MWTPs in California, recent annual average flowrates were available. For others, flows corresponding to the PTOC sampling periods were available, and concentrations were

weighted accordingly in order to better represent average mass loadings. For smaller MWTPs that were not directly contacted and that did not submit PAR reports, average dry-weather flow data from the NEEDS data base were used. On the average, NEEDs flows were found to underestimate more recent annual average flowrates by approximately 20%. The differences could be caused by the out-dated nature of the NEEDS data, as well as higher flowrates due to infiltration during wet seasons which are not accounted for by the NEEDS. The overall uncertainties in wastewater flowrates are not expected to exceed approximately 20% on an MWTP-by-MWTP basis, and should be even less on a county-by-county and statewide basis.

Temporal variations in PTOC concentration were expected to be much greater than those for flowrate. Estimating the uncertainties due to such variations was difficult because of a lack of historical data. Long-term reductions in the use and discharge of priority pollutants as a result of environmental regulations and programs such as the National Pretreatment Program could result in additional systematic errors in the emission estimates beyond those of day-to-day variability of industrial and commercial discharges. Furthermore, variations and uncertainties are expected to differ according to the specific PTOC. Table 14 summarizes temporal variations in the influent concentrations of the most commonly detected PTOCs, at three large MWTPs in California. Assuming normal distribution functions for the influent concentration, a 95% confidence limit would correspond to about a factor of three. (In reality, concentrations appeared to be more closely approximated by log-normal distributions.) These tentative uncertainty estimates were based upon a limited number of sample points at a small number of MWTPs. Given the amount of data available , a more sophisticated statistical analysis was not warranted. Additional, though smaller sources of errors were associated with temporal variation of effluent concentrations and lack of account of hydraulic retention time during some sampling. Insufficient data existed for quantification.

Extrapolation to MWTPs without data:   Based upon a comparison of extrapolated results for MWTPs with existing data on total PTOC emis-

67

# Table 14: Temporal Variation of PTOC Concentrations in Influent Streams

| Facility/Compound | # of sample days | Sampling period | Concentration (µg/l) | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | | | Average[1] | Extremes min | max | Coefficient of Variation |
| **Point Loma WWTF** | | 4/85 – 8/86 | | | | |
| Chloroform | 18 | | 7.3 | <1.6 | 55.5 | 1.71 |
| Perchloroethylene | 18 | | 7.8 | <1 | 56 | 1.71 |
| Toluene | 18 | | 51.3 | <2 | 260 | 1.30 |
| **Sacramento Regional WWTF** | | 5/83 – 5/86 | | | | |
| Chloroform | 9 | | 5.9 | <1 | 12 | 0.98 |
| Perchloroethylene | 9 | | 11.8 | <2 | 31 | 1.08 |
| Toluene | 7 | | 10.1 | <2 | 45 | 1.60 |
| **East Bay MUD WWTF** | | 9/84 – 6/86 | | | | |
| Chloroform | 6 | | 20.9 | 6 | 44 | 0.62 |
| Perchloroethylene | 6 | | 122.5 | <4.1 | 610 | 1.95 |
| Toluene | 6 | | 37.6 | 18 | 52 | 0.34 |
| **Hyperion Treatment Plant** | | 2/86 – 4/86 | | | | |
| Chloroform | 5 | | 21.4 | 16.2 | 24.7 | 0.16 |
| Perchloroethylene | 5 | | 102.1 | 65.5 | 138 | 0.27 |
| Toluene | 5 | | 151.8 | 49.7 | 425 | 1.03 |

(1) Values listed as below detection limit were assumed to be equal to zero.

sions against those without, differences as high as a factor of five were observed. For individual PTOCs, the differences could have been higher. However, the MWTPs that fell into the extrapolation category accounted for only 23% of the total municipal wastewater treated throughout California. Furthermore, most of those MWTPs were located in non-industrialized areas where large discharges of PTOCs were not expected. In the extrapolation procedure, this was accounted for by normalizing by the fraction of the total flow that originated from industrial dischargers. It should be noted that a partial survey of MWTPs and POTWs indicated that the method of classification of industrial and commercial dischargers was not uniform. Significant sources of emissions projected using extrapolated concentrations are identified in Section 6 of this report.

Although, overall uncertainties in emissions due to extrapolation may be relatively high for individual MWTPs, the uncertainties should not be as large on a regional or statewide basis. A county-by-county summary of the wastewater flowrate accounted for by MWTPs with concentration data was presented in Table 11. The information included in Table 11 also serves as an indicator of the extent of extrapolation in various counties.

Assuming worst-case conditions: From an emissions standpoint, "worst-case" refers to the condition in which the total removal of PTOCs in a MWTP is attributed entirely to volatilization. The existing literature suggested that the errors associated with such an assumption are probably small for volatile organic compounds (e.g., the PTOCs). The combined removal by adsorption and unacclimated biodegradation were typically reported to be less than 30% of the total compound removal. The removal decreased as the volatility of the PTOC increased and the degradability and affinity for adsorption decreased. In addition, errors in the emissions estimate vary according to the physical processes employed by individual MWTPs. For primary treatment facilities biodegradation would be insignificant and the assumption of volatilization as the only removal mechanism would be better than for facilities which employ biological treatment.

Assuming uncontrolled emissions: Some MWTPs that utilized covered treatment processes attempted to treat off-gases, primarily to reduce emissions of odorous gases such as hydrogen sulfide. The efficiency of the off-gas control devices for removing gaseous PTOCs has not been determined. Although the number of MWTPs that treat off-gases was small, probably less that 10, the effects of efficient off-gas treatment could be significant as some of the larger MWTPs utilize off gas control devices.

Removal efficiencies: For those MWTPs with influent-only or no data, Equation 3 was used to estimate emissions. Values had to be selected for the overall removal efficiency factor "$b_m$". For this study, average values of "$b_m$" were calculated based upon the MWTPs with existing influent and effluent data. The efficiencies were typically high (> 80%), and were probably conservative for many primary treatment facilities for which extrapolation was required. On an individual MWTP basis, it is the authors' collective judgement that the removal efficiencies led to overestimates as high as a factor of two, and underestimates as great as 25%. However, only 24% of the total municipal wastewater discharged in California fell into that category.

Overall uncertainty: As was illustrated by the previous discussion, the uncertainties in emissions estimates were a function of many factors. Those factors included whether or not the uncertainties were based upon estimated emissions at individual MWTPs, or on a regional or statewide basis, the degree and quality of data available for individual MWTPs, and the method used to estimate emissions (i.e., direct estimate from existing data, or extrapolation). Because of such diverse factors, the prescription of overall uncertainties in estimated emissions must be based upon best engineering judgement which incorporates as much of the existing quantitative information as possible. As some facilities are characterized by a larger historical data base than others, ranges of the uncertainty for individual MWTPs are presented in Table 15. In addition, the degree of uncertainty associated with emissions varied from MWTP-to-MWTP and from PTOC-to-PTOC, while the data base used for extrapolation varied from county-to-county. A range of factors from two to

Table 15: Estimated Uncertainties in Emissions Estimates[1]

| Category | Within a Factor of[2] |
|---|---|
| Individual Treatment Facilities: | |
| influent and effluent data | 2 - 5 |
| influent data only | 2 - 5+ |
| extrapolation | 5 - 10 |
| County-by-County | 2 - 10 |
| Statewide | 2 - 4 |

(1) Based upon "best engineering judgement"

(2) Ranges account for differences in the extent of historical data from individual MWTPs and/or different uncertainties for different PTOCs.

ten is estimated for counties. Those counties at the lower end of the range include Alameda, Contra Costa, Los Angeles, Orange, Sacramento, San Francisco, and Santa Clara. In those counties, the degree of extra- polation was low, as MWTPs with both influent and effluent data accounted for a large fraction of the county's wastewater discharge. The statewide uncertainty factor range is based upon the fact that most of the emissions in California occurred in those counties mentioned above. A range is given, as uncertainties vary according to the speci- fic PTOC. PTOCs at the lower end of the range include perchloro- ethylene, toluene, and 1,1,1 trichloroethane. The PTOCs at the upper end of the range include bromodichloromethane, carbon tetrachloride, chlorobenzene, chloroform, dibromochloromethane, 1,1 dichloroethylene, 1,1 dichloroethane, methylene chloride, and vinyl chloride. These ob- servations were based upon the frequency and magnitude of detected con- centrations, the potential for emissions that were not accounted for from the formation of THMs during chlorination, and other sources of errors (e.g., analytical techniques) noted for individual PTOCs as pre- viously described.

The trend in uncertainty of the estimates was such that the larger the emissions, both by PTOC and by individual source, the smaller the uncertainty, i.e., closer to a factor of two. The largest contributors to the uncertainty being the temporal variation of influent loadings in those cases. With increased data availability expected as a result of recent reporting requirements, the uncertainty in future estimates should be reduced.

# 6. RESULTS and DISCUSSION

Emissions estimates are presented in this section based upon Equations 2 and 3 of Section 5. The estimates represent a "worst-case" scenario in the sense that the difference between the mass of PTOCs entering the MWTP in the influent and leaving in the effluent was assumed to completely volatilize. The estimates do not account for adsorption to sludge, biodegradation within the plant, nor the possible presence of control devices on off-gas streams. In spite of those limitations, it is felt that the estimates provide a good approximation to the potential levels of emissions from MWTPs in California given the available data, and are an improvement over estimates previously reported (Dixon and Bremen, 1984). The format of the presentation is such that a successively more detailed breakdown of the emissions is provided, first on a statewide basis, followed by county-by-county and individual MWTP analyses. Thus, the reader can easily trace statewide emissions to the most significant counties, and the county-wide emissions to the MWTPs which were the most significant sources of either speciated or total PTOC emissions. Estimates of sludge generation and the removal of PTOCs in sludge streams are also presented on a statewide and county-by-county basis. These are followed by a discussion of the results. Conclusions and recommendations are provided in Sections 7 and 8.

## Statewide Emissions

On an annual basis an estimated 803 tons of the 16 PTOCs were emitted from MWTPs throughout California during the period roughly corresponding to 1983 to 1985. If emissions of THMs, formed as a result of chlorination, as well as emissions of PTOCs that pass through the treatment system were to be taken into account, that total would have risen to approximately 1400 tons/year (tpy). For scaling purposes, those PTOCs with emissions less than 10 tpy are shown in Figure 4 while those with emissions of greater than or equal to 10 tpy are shown in Figure 5.

73

# STATEWIDE EMISSIONS

## < 10 TONS/YEAR
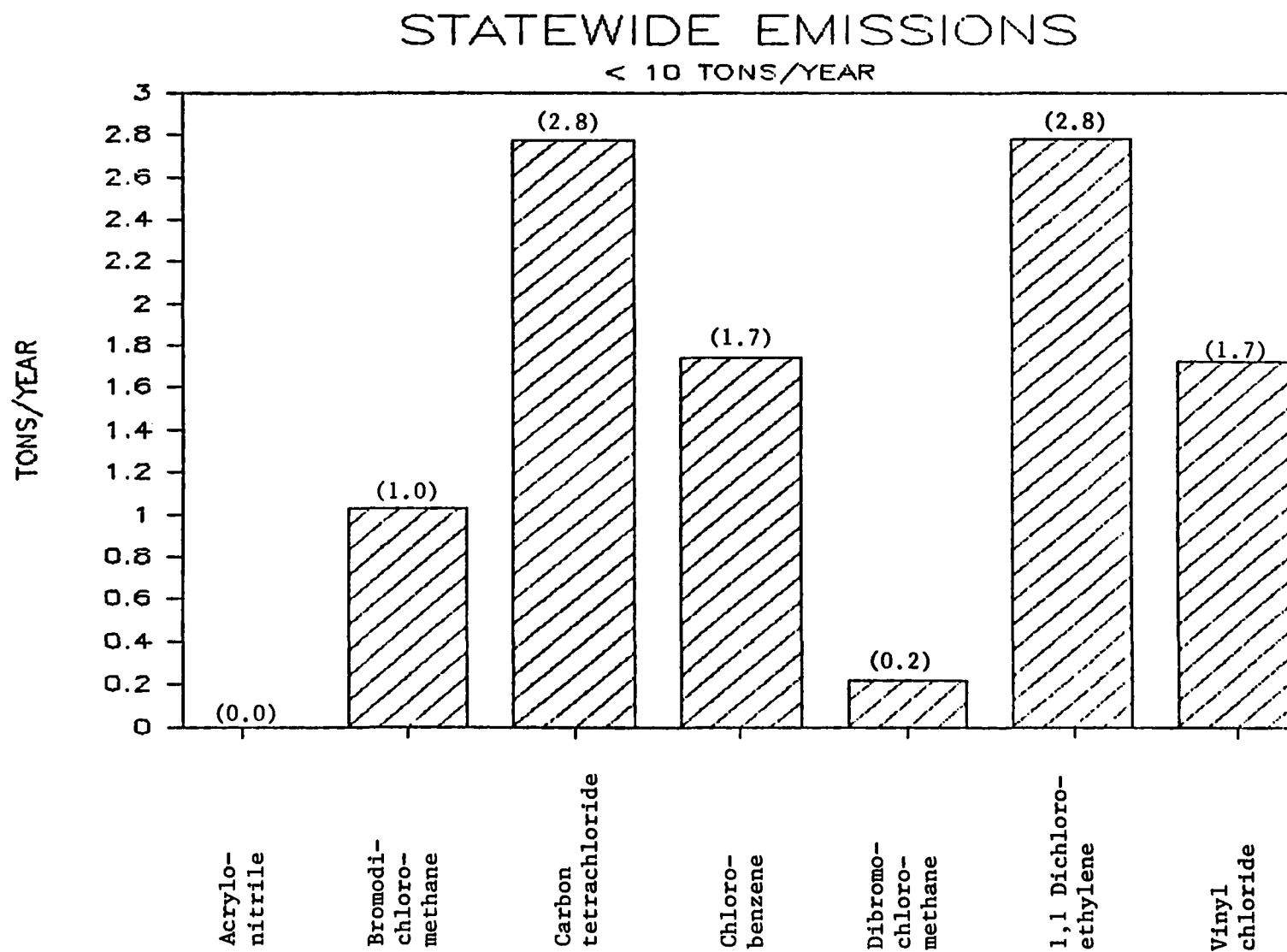


Figure 4:  Statewide Emissions of PTOCs Totalling Less Than 10 tpy.
Values in parenthesis above bars are emissions in tpy.

# STATEWIDE EMISSIONS
## > 10 TONS/YEAR
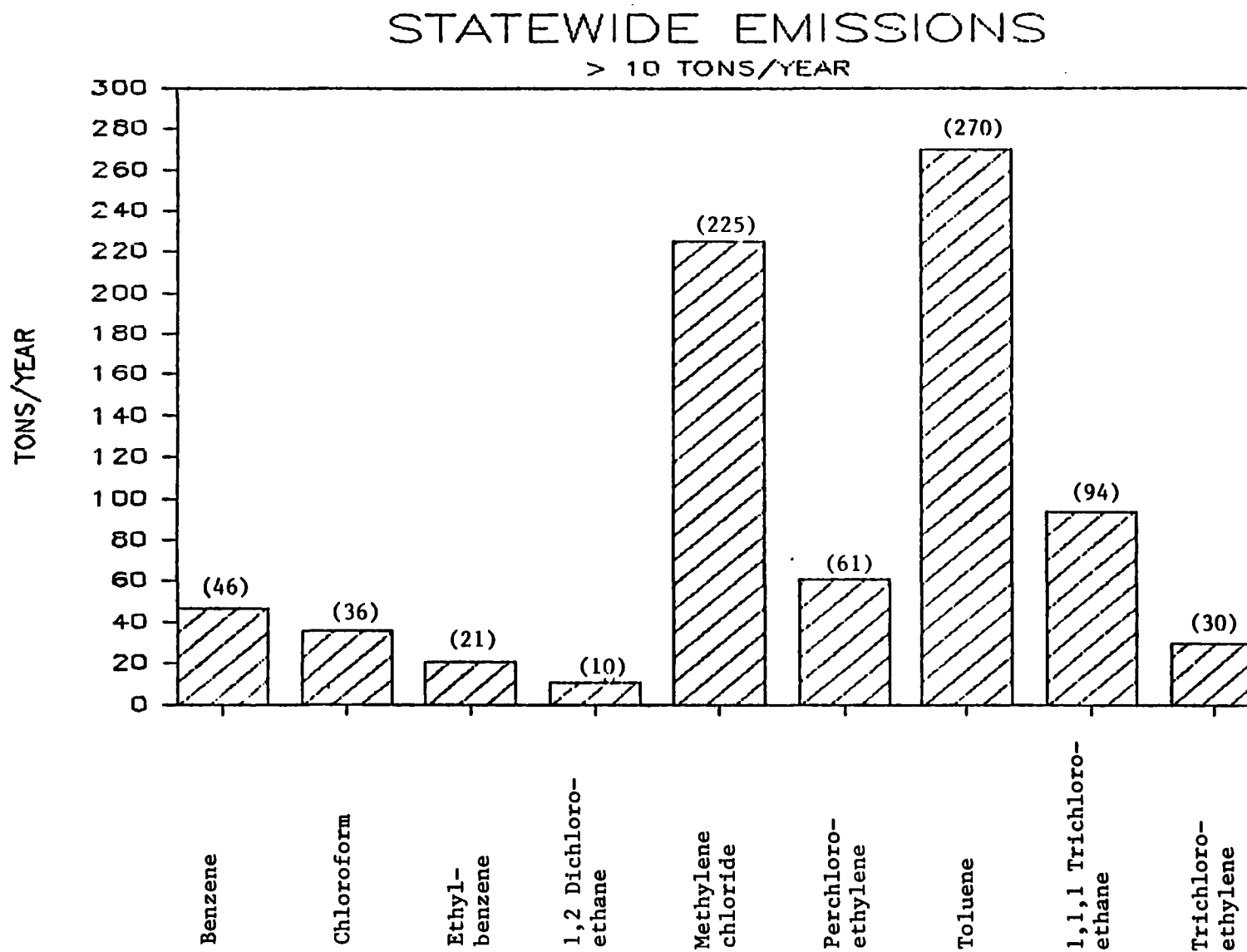
Figure 5:  Statewide Emissions of PTOCs Totalling Greater Than 10 tpy.
Values in parenthesis above bars are emissions in tpy.

The zero emissions estimate for acrylonitrile was based on the fact that acrylonitrile was never detected at any of the MWTPs for which existing concentration data were obtained. However, detection limits for acrylonitrile were typically much higher (10-100 µg/L) than those for the other PTOCs. It is possible that acrylonitrile could have been discharged and emitted without detection. Based upon a flow-weighted average detection limit of 30 µg/L, acrylonitrile emissions could have been as high as 140 tpy. However, knowledge of its limited uses and sources (Tables 2 and 3), and the fact that it went undetected consistently, suggests that there were very low emissions of acrylonitrile from MWTPs in California.

The estimated emissions for bromodichloromethane and dibromochloromethane would have been higher if THM formation had been considered. For instance, at a number of MWTPs, one or both of those PTOCs were detected in the effluent stream but not in the influent stream. While accounting for the formation resulting from chlorination would have increased the estimated emissions of both PTOCs by a factor of approximately two, the statewide emissions for each would have remained relatively low.

A review of past data at MWTPs in Los Angeles County suggested that carbon tetrachloride emissions from MWTPs have decreased significantly (greater than an order of magnitude) during the past decade, as the use of carbon tetrachloride has been severely restricted. The estimate reported here reflects the newer data.

It is possible that emissions of both 1,1 dichloroethylene and vinyl chloride have been underestimated, as the estimates did not account for their formation as a result of the degradation of more halogenated compounds, particularly during anaerobic digestion. A lack of existing data made it impossible to estimate such emissions. This is an area where future measurements could prove to be valuable.

The estimated emissions for chloroform may be low for the same reasons listed previously for bromodichloromethane and dibromochloro-

methane. If THM formation had been taken into account, the estimated statewide emissions of chloroform would have been approximately 50 tpy. The increase is lower than a factor of two, because a large percentage of the chloroform emissions were attributed to MWTPs that did not chlorinate on a regular basis. The two PTOCs with emissions estimated to be greater than 200 tpy were methylene chloride and toluene. The combined emissions for those two PTOCs accounted for greater than 62% of the total mass emissions of all PTOCs.

## County-By-County Emissions

The ten counties with the highest total PTOC emissions are shown in Figure 6. The total and speciated PTOC emissions for each of the 58 counties in California are listed in Table 16. The ten counties shown in Figure 6 accounted for 93% of the total PTOC emissions throughout the state. Los Angeles County alone accounted for 59% of those emissions. Thirty-seven counties individually contributed less than 1.0 tpy to the statewide emission total. Of the ten counties shown in Figure 6, Los Angeles, San Diego and Stanislaus counties require additional comments to clarify the nature of uncertainties in the estimates.

In San Diego County, high emissions (47 tpy) were estimated from the Encina Joint Powers WWTF in Carlsbad. However, that estimate was based upon data collected in 1978, when very high concentrations of methylene chloride and 1,1,1 trichloroethane were observed in the influent stream. Based upon reductions in influent concentrations observed in other MWTP data over the same period, emissions from the Encina Joint Powers WWTF, and San Diego County, were likely to have been over-estimated.

Emissions in Stanislaus County were based entirely upon extrapolation from other MWTPs in the Central Valley. Large "industrial flow" contributions were reported at the Modesto and Riverbank treatment facilities and resulted in most of the estimated emissions for that county. It was not known whether the "industrial flows" were represen-

# TOTAL PTOC EMISSIONS
## COUNTY-BY-COUNTY
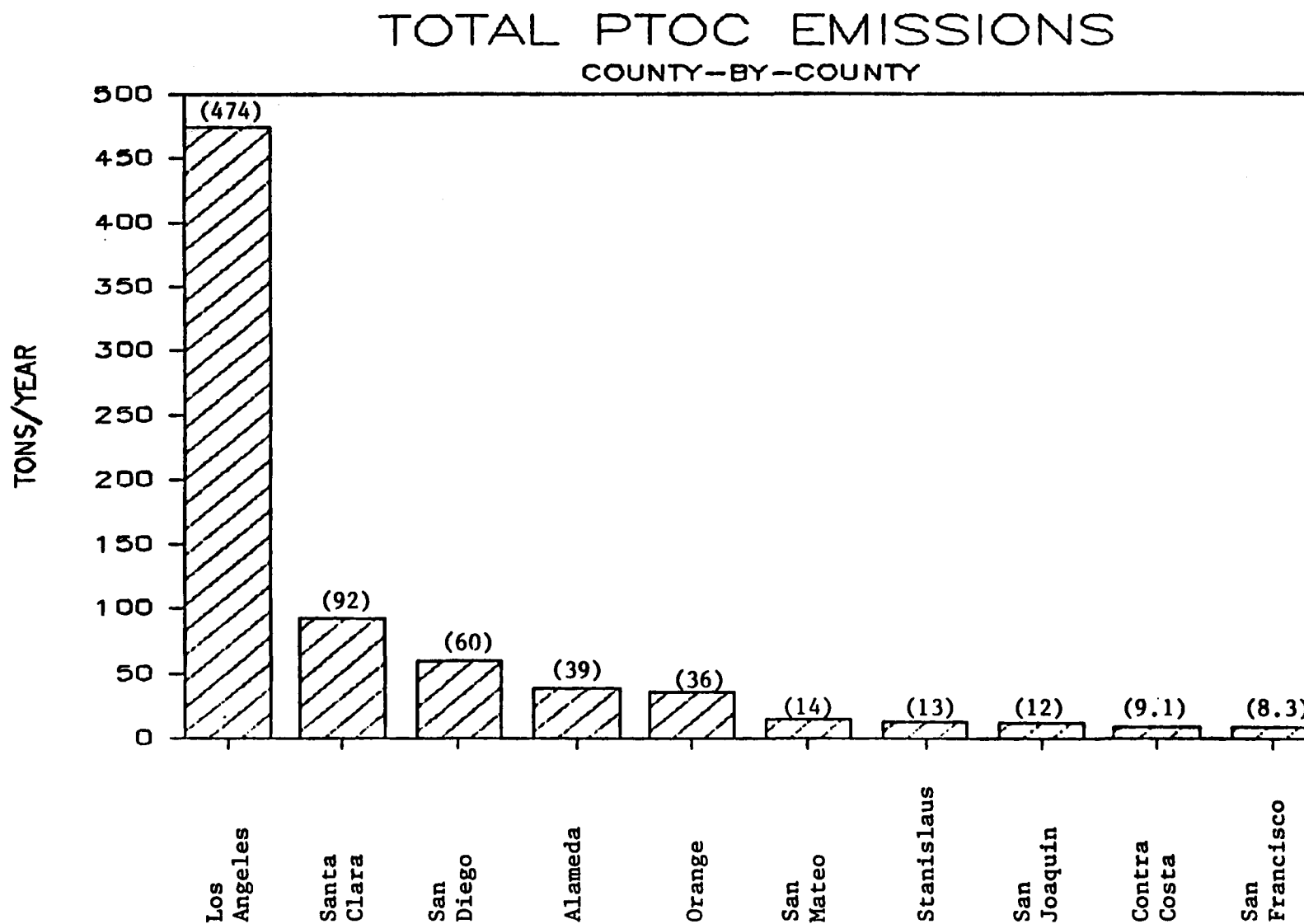


**Figure 6:** PTOC Emissions from the 10 Counties with the Highest Emissions. Values in parenthesis above bars are emissions in tpy.

## Table 16a: County-By-County Emissions

| COUNTY NAME | TOTAL EMISSIONS (TONS/YEAR) | INDIVIDUAL PTOC EMISSIONS (TONS/YEAR) | | | | |
|---|---|---|---|---|---|---|
| | | (2) | (3) | (4) | (5) | (6) |
| Los Angeles | 473.53 | 41.44 | 0.22 | 0.93 | 0.34 | 13.32 |
| Santa Clara | 92.30 | 0.00 | 0.00 | 0.00 | 0.00 | 3.13 |
| San Diego | 59.77 | 0.30 | 0.37 | 0.00 | 0.00 | 0.82 |
| Alameda | 38.86 | 1.24 | 0.18 | 1.84 | 0.00 | 0.35 |
| Orange | 35.70 | 1.24 | 0.04 | 0.00 | 0.00 | 1.36 |
| San Mateo | 14.20 | 0.04 | 0.03 | 0.00 | 1.34 | 1.85 |
| Stanislaus | 13.03 | 0.00 | 0.00 | 0.00 | 0.02 | 0.95 |
| San Joaquin | 11.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.52 |
| Contra Costa | 9.06 | 0.14 | 0.00 | 0.00 | 0.00 | 3.68 |
| San Francisco | 8.28 | 0.67 | 0.00 | 0.00 | 0.00 | 0.83 |
| Sacramento | 6.93 | 0.00 | 0.00 | 0.00 | 0.00 | 1.23 |
| San Bernardino | 5.93 | 0.26 | 0.09 | 0.00 | 0.00 | 0.64 |
| Fresno | 5.85 | 0.00 | 0.00 | 0.00 | 0.02 | 0.22 |
| Solano | 3.30 | 0.07 | 0.00 | 0.00 | 0.00 | 1.42 |
| Ventura | 2.95 | 0.84 | 0.04 | 0.00 | 0.00 | 0.78 |
| Tulare | 2.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 |
| Yolo | 2.41 | 0.01 | 0.00 | 0.00 | 0.00 | 0.28 |
| Merced | 2.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 |
| Riverside | 1.90 | 0.07 | 0.01 | 0.00 | 0.00 | 0.47 |
| Santa Barbara | 1.11 | 0.02 | 0.01 | 0.00 | 0.00 | 0.43 |
| Kern | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| Sutter | 0.89 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Monterey | 0.88 | 0.01 | 0.00 | 0.00 | 0.00 | 0.23 |
| Sonoma | 0.85 | 0.01 | 0.00 | 0.00 | 0.00 | 0.31 |
| Marin | 0.70 | 0.02 | 0.00 | 0.00 | 0.00 | 0.26 |
| Santa Cruz | 0.65 | 0.01 | 0.00 | 0.00 | 0.00 | 0.26 |
| Kings | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Humboldt | 0.39 | 0.01 | 0.00 | 0.00 | 0.00 | 0.15 |
| Imperial | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |
| San Luis Obispo | 0.38 | 0.01 | 0.00 | 0.00 | 0.00 | 0.17 |
| Shasta | 0.37 | 0.01 | 0.00 | 0.00 | 0.00 | 0.14 |
| Napa | 0.34 | 0.01 | 0.00 | 0.00 | 0.00 | 0.13 |
| Butte | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Placer | 0.31 | 0.01 | 0.00 | 0.00 | 0.00 | 0.12 |
| El Dorado | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 |
| San Benito | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |
| Nevada | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 |
| Madera | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Mendocino | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Tehama | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Lake | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| Glenn | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Siskiyou | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Tuolumne | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Yuba | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Plumas | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Inyo | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Colusa | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Mono | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| Lassen | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Del Norte | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Amador | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Calavaras | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Mariposa | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Trinity | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Modoc | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Sierra | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Alpine | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

(2) Benzene
(3) Bromodichloromethane
(4) Carbon tetrachloride
(5) Chlorobenzene
(6) Chloroform

## Table 16b: County-By-County Emissions

EMISSIONS INDIVIDUAL PTOCS
(TONS/YEAR)

| COUNTY | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|
| Los Angeles | 0.05 | 0.34 | 15.40 | 8.19 | 136.48 | 19.62 | 191.36 |
| Santa Clara | 0.00 | 0.00 | 0.04 | 0.00 | 42.75 | 8.33 | 32.65 |
| San Diego | 0.00 | 0.00 | 2.20 | 0.01 | 14.06 | 1.03 | 4.94 |
| Alameda | 0.07 | 1.24 | 0.13 | 0.00 | 4.34 | 14.19 | 7.21 |
| Orange | 0.00 | 0.00 | 0.18 | 0.14 | 14.43 | 1.69 | 8.75 |
| San Mateo | 0.00 | 0.90 | 0.55 | 1.89 | 2.64 | 1.78 | 1.40 |
| Stanislaus | 0.00 | 0.08 | 0.27 | 0.00 | 0.71 | 2.95 | 2.71 |
| San Joaquin | 0.00 | 0.01 | 0.03 | 0.00 | 0.08 | 2.40 | 7.59 |
| Contra Costa | 0.00 | 0.00 | 0.06 | 0.02 | 3.30 | 0.81 | 0.71 |
| San Francisco | 0.00 | 0.00 | 0.45 | 0.00 | 0.82 | 0.00 | 2.47 |
| Sacramento | 0.00 | 0.00 | 0.00 | 0.00 | 0.87 | 2.08 | 2.16 |
| San Bernardino | 0.00 | 0.00 | 0.63 | 0.00 | 0.95 | 0.44 | 2.56 |
| Fresno | 0.00 | 0.06 | 0.09 | 0.00 | 0.31 | 0.56 | 0.87 |
| Solano | 0.00 | 0.00 | 0.05 | 0.01 | 0.69 | 0.45 | 0.40 |
| Ventura | 0.03 | 0.07 | 0.03 | 0.00 | 0.05 | 0.48 | 0.13 |
| Tulare | 0.00 | 0.02 | 0.05 | 0.00 | 0.17 | 0.57 | 0.53 |
| Yolo | 0.00 | 0.01 | 0.05 | 0.00 | 0.17 | 0.51 | 0.48 |
| Merced | 0.00 | 0.01 | 0.08 | 0.00 | 0.13 | 0.57 | 0.43 |
| Riverside | 0.00 | 0.00 | 0.12 | 0.01 | 0.32 | 0.15 | 0.58 |
| Santa Barbara | 0.01 | 0.00 | 0.01 | 0.01 | 0.19 | 0.14 | 0.17 |
| Kern | 0.00 | 0.00 | 0.05 | 0.00 | 0.08 | 0.29 | 0.23 |
| Sutter | 0.00 | 0.01 | 0.02 | 0.00 | 0.05 | 0.20 | 0.18 |
| Monterey | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.25 | 0.10 |
| Sonoma | 0.00 | 0.00 | 0.01 | 0.01 | 0.14 | 0.14 | 0.14 |
| Marin | 0.00 | 0.00 | 0.01 | 0.01 | 0.12 | 0.08 | 0.12 |
| Santa Cruz | 0.00 | 0.00 | 0.01 | 0.01 | 0.09 | 0.11 | 0.09 |
| Kings | 0.00 | 0.00 | 0.01 | 0.00 | 0.03 | 0.10 | 0.09 |
| Humboldt | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.05 | 0.06 |
| Imperial | 0.00 | 0.00 | 0.01 | 0.00 | 0.05 | 0.06 | 0.06 |
| San Luis Obispo | 0.01 | 0.00 | 0.01 | 0.00 | 0.06 | 0.04 | 0.05 |
| Shasta | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.05 | 0.05 |
| Napa | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.04 | 0.05 |
| Butte | 0.00 | 0.00 | 0.01 | 0.00 | 0.04 | 0.06 | 0.06 |
| Placer | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.04 | 0.05 |
| El Dorado | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.04 | 0.04 |
| San Benito | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.04 | 0.04 |
| Nevada | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.03 | 0.03 |
| Madera | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.04 |
| Mendocino | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.03 |
| Tehama | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.03 |
| Lake | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.02 |
| Glenn | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.03 |
| Siskiyou | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 |
| Tuolumne | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 |
| Yuba | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 |
| Plumas | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.02 |
| Inyo | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Colusa | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 |
| Mono | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Lassen | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Del Norte | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Amador | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| Calavaras | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mariposa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Trinity | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Modoc | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sierra | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Alpine | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

(7)  Dibromochloromethane
(8)  1,1 Dichloroethylene
(9)  Ethylbenzene
(10) 1,2 Dichloroethane
(11) Methylene chloride
(12) Perchloroethylene
(13) Toluene

# Table 16c: County-By-County Emissions

| COUNTY | EMISSIONS INDIVIDUAL PTOCS (TONS/YEAR) | | |
|---|---|---|---|
| | (14) | (15) | (16) |
| Los Angeles | 35.95 | 8.18 | 1.72 |
| Santa Clara | 2.64 | 2.76 | 0.00 |
| San Diego | 36.01 | 0.03 | 0.00 |
| Alameda | 6.54 | 1.54 | 0.00 |
| Orange | 6.87 | 1.00 | 0.00 |
| San Mateo | 1.10 | 0.67 | 0.00 |
| Stanislaus | 0.64 | 4.69 | 0.00 |
| San Joaquin | 0.07 | 1.14 | 0.00 |
| Contra Costa | 0.24 | 0.10 | 0.00 |
| San Francisco | 1.02 | 2.02 | 0.00 |
| Sacramento | 0.29 | 0.30 | 0.00 |
| San Bernardino | 0.31 | 0.04 | 0.00 |
| Fresno | 0.40 | 3.30 | 0.00 |
| Solano | 0.09 | 0.13 | 0.00 |
| Ventura | 0.46 | 0.03 | 0.00 |
| Tulare | 0.13 | 0.88 | 0.00 |
| Yolo | 0.12 | 0.76 | 0.00 |
| Merced | 0.11 | 0.74 | 0.00 |
| Riverside | 0.11 | 0.06 | 0.00 |
| Santa Barbara | 0.07 | 0.05 | 0.00 |
| Kern | 0.04 | 0.18 | 0.00 |
| Sutter | 0.04 | 0.32 | 0.00 |
| Monterey | 0.11 | 0.02 | 0.00 |
| Sonoma | 0.05 | 0.04 | 0.00 |
| Marin | 0.04 | 0.03 | 0.00 |
| Santa Cruz | 0.05 | 0.02 | 0.00 |
| Kings | 0.02 | 0.16 | 0.00 |
| Humboldt | 0.03 | 0.02 | 0.00 |
| Imperial | 0.02 | 0.05 | 0.00 |
| San Luis Obispo | 0.02 | 0.01 | 0.00 |
| Shasta | 0.02 | 0.02 | 0.00 |
| Napa | 0.02 | 0.02 | 0.00 |
| Butte | 0.02 | 0.07 | 0.00 |
| Placer | 0.02 | 0.01 | 0.00 |
| El Dorado | 0.02 | 0.01 | 0.00 |
| San Benito | 0.02 | 0.01 | 0.00 |
| Nevada | 0.01 | 0.01 | 0.00 |
| Madera | 0.01 | 0.07 | 0.00 |
| Mendocino | 0.01 | 0.01 | 0.00 |
| Tehama | 0.01 | 0.04 | 0.00 |
| Lake | 0.01 | 0.01 | 0.00 |
| Glenn | 0.01 | 0.04 | 0.00 |
| Siskiyou | 0.01 | 0.01 | 0.00 |
| Tuolumne | 0.01 | 0.01 | 0.00 |
| Yuba | 0.01 | 0.01 | 0.00 |
| Plumas | 0.01 | 0.01 | 0.00 |
| Inyo | 0.01 | 0.00 | 0.00 |
| Colusa | 0.00 | 0.02 | 0.00 |
| Mono | 0.00 | 0.00 | 0.00 |
| Lassen | 0.00 | 0.00 | 0.00 |
| Del Norte | 0.00 | 0.00 | 0.00 |
| Amador | 0.00 | 0.00 | 0.00 |
| Calavaras | 0.00 | 0.00 | 0.00 |
| Mariposa | 0.00 | 0.00 | 0.00 |
| Trinity | 0.00 | 0.00 | 0.00 |
| Modoc | 0.00 | 0.00 | 0.00 |
| Sierra | 0.00 | 0.00 | 0.00 |
| Alpine | 0.00 | 0.00 | 0.00 |

(14) 1,1,1 Trichloroethane
(15) Trichloroethylene
(16) Vinyl chloride

tative of "industrial flows" at MWTPs in the Central Valley for which data were available.

Several of the PTOCs were emitted in relatively small quantities on a county-by-county basis. For instance, the maximum county-wide emissions of bromodichloromethane, chlorobenzene, dibromochloromethane, and 1,1-dichloroethylene were each less than 1.5 tpy.

Los Angeles County was responsible for large fractions of the statewide emissions of other PTOCs. In particular, Los Angeles County accounted for 100% and 89% of the vinyl chloride and benzene emissions, respectively. It also accounted for greater than 70% of the emissions of ethylbenzene, 1,2 dichloroethane, and toluene, and greater than 50% of the statewide emissions of methylene chloride. Two large plants contributed the majority of the estimated potential emissions. As will be subsequently discussed, the controlled emissions from one of those plants could be substantially lower.

With the exception of Los Angeles County, only a few other counties contributed large fractions of individual PTOCs to the statewide total. For instance, Alameda County accounted for 67% and 43% of the statewide emissions of carbon tetrachloride and 1,1 dichloroethylene, respectively. In addition, 77% of the chlorobenzene emitted by MWTPs in California was emitted in San Mateo County.

MWTP-By-MWTP Emissions

The MWTPs with total PTOC emissions of greater than 2.0 tpy were ranked according to total PTOC emissions, and are listed in Table 17. Twenty-nine MWTPs emitted greater than 2.0 tpy of total PTOCs. Of those 29 treatment facilities, 8 were located in Los Angeles County. The emissions estimates for those facilities noted with asterisks were based upon extrapolation techniques described in Section 5 and were characterized by a greater degree of uncertainty than most of the other facilities listed in Table 17.

82

Table 17a: Plant-By-Plant Emissions

| PLANT NAME | TOTAL EMISSIONS (TONS/YEAR) | INDIVIDUAL PTOC EMISSIONS (TONS/YEAR) | | |
| --- | --- | --- | --- | --- |
| | | (2) | (3) | (4) |
| Joint WPCP | 296.09 | 29.55 | 0.00 | 0.00 |
| Hyperion WWTF | 112.32 | 8.50 | 0.17 | 0.87 |
| San Jose/Santa Clara WPCP | 58.67 | 0.00 | 0.00 | 0.00 |
| Encina Joint Powers STP | 46.94 | 0.00 | 0.00 | 0.00 |
| * Terminal Island WWTF | 29.75 | 1.34 | 0.03 | 0.02 |
| Palo Alto WWTF | 29.14 | 0.00 | 0.00 | 0.00 |
| East Bay MUD WWTF | 25.07 | 1.21 | 0.18 | 0.00 |
| OCSD WWTF No. 2 | 20.42 | 1.07 | 0.00 | 0.00 |
| Los Coyotes WRP | 14.82 | 1.54 | 0.00 | 0.03 |
| OCSD WWTF No. 1 | 13.26 | 0.13 | 0.02 | 0.00 |
| Pt Loma WWTF | 11.41 | 0.25 | 0.35 | 0.00 |
| Stockton Reg. WWTF | 10.35 | 0.00 | 0.00 | 0.00 |
| Hayward WWTF | 10.10 | 0.00 | 0.00 | 1.84 |
| South Bayside WWTP | 8.66 | 0.00 | 0.03 | 0.00 |
| Southeast/North Point | 7.56 | 0.64 | 0.00 | 0.00 |
| Sacto Reg WWTF | 6.87 | 0.00 | 0.00 | 0.00 |
| * Modesto WWTF | 6.71 | 0.00 | 0.00 | 0.00 |
| * L.A. Glendale WWRP | 5.46 | 0.25 | 0.01 | 0.00 |
| Richmond/San Pablo WWTF | 5.30 | 0.05 | 0.00 | 0.00 |
| Sunnyvale WWTF | 4.37 | 0.00 | 0.00 | 0.00 |
| * Chino Basin Reg TP #1 | 3.93 | 0.18 | 0.06 | 0.00 |
| * Riverbank WWTF | 3.85 | 0.00 | 0.00 | 0.00 |
| Fresno WWTF | 3.78 | 0.00 | 0.00 | 0.00 |
| * Burbank WWRF | 3.19 | 0.14 | 0.00 | 0.00 |
| San Francisco Intnl. Airp | 3.07 | 0.03 | 0.00 | 0.00 |
| Pomona WRP | 2.50 | 0.00 | 0.00 | 0.00 |
| Whittier Narrows WRP | 2.42 | 0.03 | 0.00 | 0.00 |
| San Leandro WWTF | 2.17 | 0.00 | 0.00 | 0.00 |
| Central Contra Costa WWTF | 2.01 | 0.06 | 0.00 | 0.00 |

* = emissions based upon extrapolation

(2) Benzene
(3) Bromodichloromethane
(4) Carbon tetrachloride

Table 17b: Plant-By-Plant Emissions

| PLANT NAME | INDIVIDUAL PTOC EMISSIONS (TONS/YEAR) | | | | | |
|---|---|---|---|---|---|---|
| | (5) | (6) | (7) | (8) | (9) | (10) |
| Joint WPCP | 0.00 | 2.63 | 0.00 | 0.00 | 3.99 | 0.00 |
| Hyperion WWTF | 0.32 | 6.57 | 0.03 | 0.19 | 8.87 | 7.70 |
| San Jose/Santa Clara WPCP | 0.00 | 1.73 | 0.00 | 0.00 | 0.00 | 0.00 |
| Encina Joint Powers STP | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| * Terminal Island WWTF | 0.01 | 2.17 | 0.01 | 0.08 | 1.44 | 0.32 |
| Palo Alto WWTF | 0.00 | 0.97 | 0.00 | 0.00 | 0.00 | 0.00 |
| East Bay MUD WWTF | 0.00 | 0.04 | 0.05 | 0.00 | 0.00 | 0.00 |
| OCSD WWTF No. 2 | 0.00 | 0.48 | 0.00 | 0.00 | 0.11 | 0.03 |
| Los Coyotes WRP | 0.00 | 0.48 | 0.00 | 0.00 | 0.47 | 0.02 |
| OCSD WWTF No. 1 | 0.00 | 0.33 | 0.00 | 0.00 | 0.02 | 0.06 |
| Pt Loma WWTF | 0.00 | 0.42 | 0.00 | 0.00 | 2.09 | 0.00 |
| Stockton Reg. WWTF | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hayward WWTF | 0.00 | 0.19 | 0.00 | 1.24 | 0.06 | 0.00 |
| South Bayside WWTP | 1.33 | 1.47 | 0.00 | 0.90 | 0.47 | 1.86 |
| Southeast/North Point | 0.00 | 0.43 | 0.00 | 0.00 | 0.44 | 0.00 |
| Sacto Reg WWTF | 0.00 | 1.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| * Modesto WWTF | 0.01 | 0.48 | 0.00 | 0.04 | 0.14 | 0.00 |
| * L.A. Glendale WWRP | 0.00 | 0.40 | 0.00 | 0.02 | 0.26 | 0.06 |
| Richmond/San Pablo WWTF | 0.00 | 3.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sunnyvale WWTF | 0.00 | 0.38 | 0.00 | 0.00 | 0.04 | 0.00 |
| * Chino Basin Reg TP #1 | 0.00 | 0.34 | 0.00 | 0.00 | 0.45 | 0.00 |
| * Riverbank WWTF | 0.01 | 0.27 | 0.00 | 0.03 | 0.08 | 0.00 |
| Fresno WWTF | 0.02 | 0.03 | 0.00 | 0.05 | 0.05 | 0.00 |
| * Burbank WWRF | 0.00 | 0.23 | 0.00 | 0.01 | 0.15 | 0.03 |
| San Francisco Intnl. Airp | 0.00 | 0.05 | 0.00 | 0.00 | 0.01 | 0.02 |
| Pomona WRP | 0.00 | 0.01 | 0.00 | 0.03 | 0.00 | 0.00 |
| Whittier Narrows WRP | 0.00 | 0.01 | 0.00 | 0.01 | 0.03 | 0.02 |
| San Leandro WWTF | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 |
| Central Contra Costa WWTF | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

* = emissions based upon extrapolation

(5)  Chlorobenzene
(6)  Chloroform
(7)  Dibromochloromethane
(8)  1,1 Dichloroethylene
(9)  Ethylbenzene
(10) 1,2 Dichloroethane

Table 17c: Plant-By-Plant Emissions

| PLANT NAME | INDIVIDUAL PTOC EMISSIONS (TONS/YEAR) | | | | | |
|---|---|---|---|---|---|---|
| | (11) | (12) | (13) | (14) | (15) | (16) |
| Joint WPCP | 120.93 | 5.86 | 124.76 | 5.47 | 2.46 | 0.44 |
| Hyperion WWTF | 5.00 | 4.37 | 48.73 | 15.62 | 4.37 | 1.01 |
| San Jose/Santa Clara WPCP | 18.65 | 7.32 | 28.29 | 0.72 | 1.97 | 0.00 |
| Encina Joint Powers STP | 11.44 | 0.00 | 0.00 | 35.37 | 0.00 | 0.00 |
| * Terminal Island WWTF | 5.70 | 4.66 | 7.82 | 5.21 | 0.75 | 0.19 |
| Palo Alto WWTF | 22.18 | 0.26 | 3.69 | 1.59 | 0.45 | 0.00 |
| East Bay MUD WWTF | 3.97 | 13.13 | 4.60 | 0.68 | 1.20 | 0.00 |
| OCSD WWTF No. 2 | 7.25 | 0.96 | 5.48 | 4.30 | 0.73 | 0.00 |
| Los Coyotes WRP | 1.25 | 1.44 | 6.05 | 3.49 | 0.04 | 0.00 |
| OCSD WWTF No. 1 | 6.84 | 0.44 | 2.88 | 2.32 | 0.22 | 0.00 |
| Pt Loma WWTF | 2.38 | 0.90 | 4.45 | 0.56 | 0.00 | 0.00 |
| Stockton Reg. WWTF | 0.00 | 2.06 | 7.28 | 0.00 | 0.60 | 0.00 |
| Hayward WWTF | 0.00 | 0.72 | 0.20 | 5.59 | 0.26 | 0.00 |
| South Bayside WWTP | 0.00 | 1.08 | 0.74 | 0.39 | 0.38 | 0.00 |
| Southeast/North Point | 0.82 | 0.00 | 2.46 | 1.02 | 1.75 | 0.00 |
| Sacto Reg WWTF | 0.86 | 2.07 | 2.15 | 0.29 | 0.29 | 0.00 |
| * Modesto WWTF | 0.36 | 1.53 | 1.40 | 0.33 | 2.43 | 0.00 |
| * L.A. Glendale WWRP | 1.05 | 0.86 | 1.44 | 0.96 | 0.14 | 0.04 |
| Richmond/San Pablo WWTF | 1.64 | 0.16 | 0.30 | 0.07 | 0.03 | 0.00 |
| Sunnyvale WWTF | 1.90 | 0.73 | 0.65 | 0.33 | 0.33 | 0.00 |
| * Chino Basin Reg TP #1 | 0.62 | 0.28 | 1.78 | 0.20 | 0.01 | 0.00 |
| * Riverbank WWTF | 0.21 | 0.88 | 0.80 | 0.19 | 1.39 | 0.00 |
| Fresno WWTF | 0.20 | 0.00 | 0.48 | 0.31 | 2.65 | 0.00 |
| * Burbank WWRF | 0.61 | 0.50 | 0.84 | 0.56 | 0.08 | 0.02 |
| San Francisco Intnl. Airp | 2.37 | 0.02 | 0.12 | 0.42 | 0.03 | 0.00 |
| Pomona WRP | 0.11 | 0.03 | 0.02 | 2.30 | 0.00 | 0.00 |
| Whittier Narrows WRP | 0.57 | 0.66 | 0.56 | 0.36 | 0.17 | 0.00 |
| San Leandro WWTF | 0.09 | 0.11 | 1.93 | 0.00 | 0.00 | 0.00 |
| Central Contra Costa WWTF | 1.21 | 0.41 | 0.19 | 0.13 | 0.00 | 0.00 |

* = emissions based upon extrapolation

(11) Methylene chloride
(12) Perchloroethylene
(13) Toluene
(14) 1,1,1 Trichloroethane
(15) Trichloroethylene
(16) Vinyl chloride

While Los Angeles County was responsible for 59% of the PTOC emissions statewide, two MWTPs were responsible for 86% of the emissions in Los Angeles County and 50% of the total PTOC emissions from MWTPs throughout the entire state. The total estimated emissions from the Joint Water Pollution Control Plant (JWPCP) were 296 tpy (uncontrolled), and the total emissions from the Hyperion Treatment Plant (HTP) were 112 tpy. It should be noted that the JWPCP is not a "typical" MWTP, as it utilizes a covered conveyance and primary treatment system with control devices on off-gas vents of processes ahead of the pure-oxygen aeration units used for secondary treatment. Other large pure-oxygen treatment facilities in California include the East Bay MUD WWTF, the Orange County Sanitation District Plant #2 (OCSD #2), and the Sacramento Regional WWTP. However, these are not believed to employ as extensive a set of air pollution control devices on vented gases.

The emissions from the JWPCP reported herein were inconsistent with emissions estimated by the staff of the County Sanitation Districts of Los Angeles County (CSDLAC). The CSDLAC completed gas-phase measurements at gas scrubbers installed principally for odor control, at primary treatment off-gas vents, at aerated channels, and at vents leading from the pure-oxygen biological reactors. Preliminary results of an ongoing study by the CSDLAC indicated that total emissions of 23 VOCs, including most of the PTOCs, were 150 lb/day (27 tpy) (Caballero, 1987). Most of those emissions were attributed to PTOCs. A large fraction (80%) of the emissions were detected after passage through off-gas scrubbers. PTOC emissions resulting from gases vented from the pure-oxygen system were particularly low (< 3 lb/day), which could possibly be attributed to the fact that surface oxygenation rather than submerged diffuser oxygenation was utilized. The order of magnitude difference in total emissions as observed by the CSDLAC and estimated for this study can possibly be explained by one or more of the following reasons:

1. The time periods during which the liquid and gas-phase samples were drawn did not coincide. It is possible that unusually high PTOC loadings

in the influent stream were experienced, although for the two 24 hour periods (12-6-85 and 5-14-86) for which data were available, the influent concentrations differed by only a factor of 2.6. By the same token, the gas-phase samples could have been drawn during a period characterized by unusually low PTOC mass loadings in the influent stream.

2. Scrubbers that were designed to reduce emissions of odorous gases (e.g., hydrogen sulfide) could have also been efficient at removing PTOCs. The off-gases from most of the aerated processes were passed through caustic scrubbers, activated carbon beds, or both. The authors do not believe that removal in caustic scrubbers could have accounted for an order-of-magnitude reduction in PTOC emissions. However, the PTOCs could have adsorbed in the activated carbon beds, thereby reducing emissions. Previous testing by the CSDLAC has indicated break-through times for the beds as low as two weeks for some of the PTOCs (Caballero, 1987). The activated carbon was being replaced with rege-nerated or virgin carbon at intervals of approximately four to six months. However, even following break-through, some fraction of the stripped PTOCs could continue to be removed. The extent of this removal is not known, and further research would be valuable in order to study the treatment of off-gases as a method for reducing PTOC emissions.

3. Although many processes were analyzed as part of the gas-sampling study, additional processes which were not considered could be sources of PTOC emissions. These included emissions after adsorption to solids (e.g., stripping in, and leakage from, digesters; volatilization during composting). However, as noted in Section 4 of this report, only a small fraction of the incoming PTOC mass is typically removed in sludge streams.

4. The "worst-case" assumption (i.e., all removal of PTOCs is by volatilization) might not be valid for pure-oxygen treatment facilities which, in comparison to conventional activated sludge systems, typically contact much less gas with the liquid phase. Because pass-through was accounted for by subtracting the effluent concentrations from the in-

fluent concentrations, the removal of PTOCs, if not by volatile losses, would be expected to result from adsorption and biodegradation. As noted above, adsorption was expected to be low, leaving only biodegradation to account for PTOC removals. Such a conclusion can not be verified at the present time. However, further studies are warranted in light of the potential significance with respect to reducing PTOC emissions during wastewater treatment.

The HTP is currently a partial secondary treatment facility. On the average, 300 MGD (75%) of the incoming wastewater is treated using only primary treatment processes. The remaining 100 MGD (25%) is treated using conventional activated sludge systems. Higher in-plant PTOC emissions would be expected if a larger percentage of the wastewater was subjected to aerated secondary treatment. Emissions from the HTP could change significantly, as the facility was scheduled to be modified to a pure-oxygen activated sludge plant by 1993. At that time, four 130 MGD pure-oxygen systems will go on-line. The overall effects of the modification on emissions can not be accurately predicted at this time. The added treatment could lead to either an increase or a decrease in PTOC emissions, depending upon the importance of biodegradation or installation of off-gas control systems. In either case, a study of the PTOC emissions before and after the modifications would be valuable and would provide a better understanding of the role of such modifications on PTOC emissions.

Other Los Angeles County treatment facilities that emitted greater than 15 tpy of total PTOCs were the Terminal Island Treatment Plant (30 tpy) and the Los Coyotes Water Reclamation Plant in Cerritos (15 tpy). Estimated emissions at the Terminal Island Treatment Plant were based upon extrapolation using data from other MWTPs in Los Angeles and Orange Counties. The high emissions estimates were a result of a large industrial flow contribution to the total wastewater flow.

Throughout the rest of California, other MWTPs with total PTOC emissions greater than 10 tpy included the San Jose/ Santa Clara WPCP (59 tpy) and the Palo Alto WWTF (29 tpy) in Santa Clara County, the East Bay MUD WWTF in Oakland (25 tpy) and the Hayward WWTF (10 tpy),

88

each in Alameda County, the OCSD plants #2 (22 tpy) and #1 (13 tpy) in Huntington Beach and Fountain Valley, respectively, the Encina Joint Powers WWTF (47 tpy) and the Point Loma WWTF (11 tpy), each in San Diego County, and the Stockton Regional WWTF (10 tpy) in San Joaquin County. None of the emissions from those facilities were based upon extrapolation. The use of possibly outdated data for the Encina Joint Powers WWTF was discussed previously.

The combined benzene emissions from the JWPCP and the HTP accounted for 82% of the total benzene emissions from all MWTPs in the state (assuming no control systems). The third and fourth largest sources were also from Los Angeles County; the Los Coyotes WRP (1.5 tpy), and the Terminal Island Treatment Plant (1.3 tpy).

Ninety-eight percent of the statewide carbon tetrachloride emissions were accounted for by the Hayward WWTF (1.8 tpy) and the HTP (0.9 tpy).

Seventy-six percent of the statewide chlorobenzene emissions were emitted by the South Bayside WWTF in Redwood City.

The two largest sources of chloroform emissions were the HTP (6.6 tpy) and the Richmond/San Pablo WWTF (3.1 tpy). Recall that volatile losses after in-plant formation were not considered.

At 8.9 tpy, the HTP was the largest source of ethylbenzene emissions. The HTP also emitted 7.7 tpy of 1,2 dichloroethane.

The JWPCP was responsible for 89% (121 tpy) of the methylene chloride emissions in Los Angeles County (and 54% of the methylene chloride emissions statewide (assuming no control systems). Emissions of methylene chloride were also significant at the Palo Alto WWTF (22 tpy) and the San Jose-Santa Clara Water Pollution Control Plant (19 tpy).

Perchloroethylene emissions at the East Bay MUD WWTF (13 tpy) accounted for 52% of the total PTOC emissions from that plant. Other

sources which emitted greater than 5.0 tpy were the San Jose/Santa Clara WPCP (7.3 tpy) and the JWPCP (5.9 tpy).

An estimated 46% of the toluene (uncontrolled) emitted by MWTPs in California was emitted by the JWPCP (125 tpy). The HTP added 49 tpy. The San Jose/Santa Clara WPCP added 28 tpy, and the Terminal Island Treatment Plant and the Stockton Regional WWTF each emitted greater than 7 tpy.

The largest sources of 1,1,1 trichloroethane emissions were the Encina Joint Powers WWTF (35 tpy), the HTP (16 tpy), the Hayward WWTF (5.6 tpy), and the JWPCP (5.5 tpy).

No single MWTP dominated in terms of trichloroethylene emissions. The largest sources were the HTP (4.4 tpy), the Fresno Regional WWTF #1 (2.7 tpy), the JWPCP (2.5 tpy), the Modesto WWTF (2.4 tpy), and the San Jose/Santa Clara WPCP (2.0 tpy).

Finally, emissions of vinyl chloride occurred only at MWTPs in Los Angeles County. The MWTPs included the HTP (1.0 tpy), the JWPCP (0.4 typ), and the Terminal Island Treatment Plant (0.2 tpy).

A data base which included speciated PTOC emissions from all of the MWTPs in California was provided to the CARB on floppy-disk in partial fulfillment of the contract which sponsored this report. It also included information regarding the locations and treatment characteristics of individual MWTPs throughout California. The data base is described in detail in Appendix F.

The Significance of MWTPs in the South Coast Air Basin

In the previous subsections, quantitative estimates of worst-case, uncontrolled, emissions of PTOCs were presented on a statewide, county-by-county, and MWTP-by-MWTP bases. For completeness, the significance of such emissions will be addressed. While a discussion of the signifi-

90

cance of those emissions with respect to public health and/or photochemical oxidant formation was beyond the scope of this study, it was possible to compare the predicted emissions with known or predicted emissions from other sources. A well documented summary of the emissions of potentially toxic air contaminants exists for the South Coast Air Basin (SCAB) (Zwiacher et al., 1985). The report contains estimates of emissions from point sources (> 20 tpy) and combined area sources (< 20 tpy) throughout Los Angeles, Orange, Riverside, and San Bernardino Counties (the SCAB). Because such a summary exists, and because most of the predicted emissions from MWTPs in California occurred in the SCAB, that region was chosen for further analysis. It is important to note that the emissions report for the SCAB was updated as of 1984, and that MWTPs were not incorporated as emissions sources. Therefore, the emissions estimates completed for this study could be added to the existing emissions base.

In Table 18, emissions from all of the MWTPs in the South Coast Air Basin are compared with total emissions from other sources. From a basin-wide perspective, emissions of benzene, methylene chloride, perchloroethylene, 1,1,1 trichloroethane, and trichloroethylene from MWTPs were much less than emissions from other sources. However, emissions of toluene, chloroform, carbon tetrachloride, 1,2 dichloroethane, and vinyl chloride from MWTPs were comparable to other sources.

Predicted emissions from individual MWTPs, particularly the JWPCP, HTP, and the Terminal Island Treatment Plant, indicated that each facility could be a major source of some PTOCs with respect to other known point sources. As an example, in Table 19, emissions from the HTP are compared with emissions from the largest known sources of each PTOC in the SCAB.

The Significance of Emissions Following Wastewater Treatment

The emissions estimates presented in this section were based upon in-plant volatilization. However, at several major MWTPs, a significant quantity of PTOCs passed through the entire treatment train or were gen-

91

Table 18:  A Comparison of Emissions from MWTPs and Other Sources in the South Coast Air Basin

|  | Emissions (tons/year) | |
| --- | --- | --- |
| Compounds | MWTPs | Other Sources[1] |
| Benzene | 43. | 7983. |
| Carbon tetrachloride | 0.9 | 3. |
| Chloroform | 16. | negligible |
| 1,2 Dichloroethane | 8.3 | 12.5 |
| Methylene chloride | 152. | 14304. |
| Perchloroethylene | 22. | 12756. |
| Toluene | 203. | 1010. |
| 1,1,1 Trichloroethane | 43. | 16495. |
| Trichloroethylene | 9.3 | 546. |
| Vinyl chloride | 1.7 | 1.3 |

(1)  From Zwiacher et al. (1985).

**Table 19:** A Comparison of Emissions from the Hyperion Treatment Plant and Large Point Sources in the South Coast Air Basin

Emissions (tons/year)

| Compound | Hyperion | Largest Point Source[1] |
|---|---|---|
| Benzene | 8.5 | 34. |
| Carbon tetrachloride | 0.9 | 3. |
| Chloroform | 6.6 | <0.025 |
| 1,2 Dichloroethane | 7.7 | 1.8 |
| Methylene chloride | 5.0 | 529. |
| Perchloroethylene | 4.4 | 214. |
| Toluene | 49. | 103. |
| 1,1,1 Trichloroethane | 15.6 | 588. |
| Trichloroethylene | 4.4 | 5.0 |
| Vinyl chloride | 1.0 | 1.3[2] |

(1) From Zwiacher et al (1985).

(2) Combined emissions from three PVC producing facilities.

93

erated during the chlorination process. Those PTOCs were not accounted for in the emissions estimates. Ultimately, those PTOCs could have volatilized from either the effluent conveyance system or the receiving water to which they were discharged. In many cases it would have been inappropriate to add such emissions to the total emissions from a MWTP, as the point of discharge was often located several miles from the treatment facility. On a statewide basis, greater than 50% of the total wastewater treated by MWTPs is discharged directly to the Pacific Ocean. Furthermore, such MWTPs in the South Coast Air Basin and San Diego account for a large percentage of the total statewide loading of PTOCs in effluent streams. It should also be noted that the ultimate fate of PTOCs that are discharged to receiving waters, particularly to the ocean, is not well understood.

The quantity of PTOCs that annually pass-through a MWTP can be estimated. An analysis was completed using PTOC concentration data for the effluent streams of MWTPs in the largest, most industrialized counties. These included the five counties with the highest total PTOC emissions from MWTPs. The results are shown in Table 20. If one further assumes that volatilization was the ultimate fate of the PTOCs, "worst-case" emissions following treatment were nearly equal to those that occurred during treatment in Los Angeles County. In Orange County, the 94 tpy emitted from effluent streams would be a factor of 2.6 greater than emissions during treatment. In both San Diego County and Alameda County emissions from effluent streams were approximately 35% of the total in-plant emissions, and emissions from MWTPs in Santa Clara County were relatively small compared to emissions during treatment. The latter was due to strict discharge requirements for those facilities which discharged into the southern end of San Francisco Bay. Bearing in mind the above caveats, the statewide PTOC emissions would have risen from 803 tpy to approximately 1400 tpy.

## Sludge Generation and PTOC Removal in Sludge Streams

Table 21 provides a list of counties ranked according to the total removal of all PTOCs by adsorption, sludge treatment, and sludge dispo-

Table 20: Worst-Case Emissions from Effluent Conveyance Systems and
Receiving Waters

| County | Total PTOC Emissions (tons/year) |
|---|---|
| Los Angeles | 446 |
| Orange | 94 |
| San Diego | 20 |
| Alameda | 14 |
| Santa Clara | 7 |
| Statewide | 600 |

## Table 21: PTOC Mass Removals in Sludge Streams

Estimated Mass Removals in Sludge Streams (tons/year)

| County | Estimated Sludge Generation (1000 tons/yr) | Total PTOCs | BENZ | CTET | CBENZ | CFORM | EBENZ | DCA | METH | PERC | TOL | TCA | TCE | VIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Los Angeles | 243 | 58.60 | 0.85 | 0.05 | 0.05 | 0.18 | 1.70 | 0.10 | 18.50 | 4.00 | 32.20 | 0.50 | 0.49 | 0.02 |
| Santa Clara | 43 | 7.20 | 0.00 | 0.00 | 0.01 | 0.02 | 0.01 | 0.00 | 3.50 | 0.35 | 3.20 | 0.02 | 0.12 | 0.00 |
| Orange | 122 | 4.30 | 0.06 | 0.01 | 0.01 | 0.02 | 0.13 | 0.00 | 2.20 | 0.41 | 1.30 | 0.11 | 0.10 | 0.00 |
| San Diego | 54 | 2.80 | 0.01 | 0.00 | 0.00 | 0.01 | 0.12 | 0.00 | 1.30 | 0.08 | 1.00 | 0.25 | 0.00 | 0.00 |
| Alameda | 40 | 2.40 | 0.03 | 0.08 | 0.00 | 0.02 | 0.02 | 0.00 | 0.62 | 0.70 | 0.74 | 0.05 | 0.09 | 0.00 |
| San Joaquin | 17 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.10 | 0.74 | 0.00 | 0.05 | 0.00 |
| Stanislaus | 16 | 0.80 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.09 | 0.15 | 0.30 | 0.01 | 0.23 | 0.00 |
| San Francicso | 17 | 0.79 | 0.01 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | 0.24 | 0.12 | 0.27 | 0.01 | 0.09 | 0.00 |
| San Mateo | 17 | 0.62 | 0.00 | 0.00 | 0.07 | 0.02 | 0.02 | 0.02 | 0.23 | 0.08 | 0.14 | 0.01 | 0.03 | 0.00 |
| Contra Costa | 21 | 0.50 | 0.00 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.34 | 0.04 | 0.07 | 0.00 | 0.01 | 0.00 |
| Sacramento | 24 | 0.47 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.12 | 0.11 | 0.21 | 0.00 | 0.01 | 0.00 |
| San Bernardino | 20 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.12 | 0.02 | 0.28 | 0.00 | 0.00 | 0.00 |
| Fresno | 13 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.07 | 0.09 | 0.00 | 0.19 | 0.00 |
| Solano | 9 | 0.21 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.10 | 0.03 | 0.05 | 0.00 | 0.01 | 0.00 |
| Tulare | 6 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.06 | 0.00 | 0.04 | 0.00 |
| Merced | 6 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.05 | 0.00 | 0.04 | 0.00 |
| Yolo | 6 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.05 | 0.00 | 0.04 | 0.00 |
| Riverside | 18 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.04 | 0.01 | 0.06 | 0.00 | 0.00 | 0.00 |
| Monterey | 8 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 |
| Ventura | 22 | 0.07 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 |
| Kern | 7 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.00 | 0.01 | 0.00 |
| Santa Barbara | 9 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 |
| Sonoma | 8 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 |
| Sutter | 2 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.00 | 0.02 | 0.00 |
| All Others | 47 | 0.29 | 0.01 | 0.01 | 0.01 | 0.05 | 0.02 | 0.01 | 0.08 | 0.02 | 0.06 | 0.02 | 0.04 | 0.01 |
| Statewide | 795 | 81.7 | 0.98 | 0.15 | 0.15 | 0.40 | 2.10 | 0.13 | 27.7 | 6.45 | 41.0 | 0.98 | 1.61 | 0.03 |

0.00 = <0.01

Where BENZ = benzene; CTET = carbon tetrachloride; CBENZ = chlorobenzene;
CFORM = chloroform; EBENZ = ethylbenzene; DCA = 1,2 dichloroethane;
METH = methylene chloride; PERC = perchloroethylene; TOL = toluene;
TCA = 1,1,1 trichloroethane; TCE = trichloroethylene; and VIN = vinyl chloride.

sal. The estimated amount of sludge generated is shown, as are speciated PTOC removals. Negligible removals were assumed for acrylonitrile, bromodichloromethane, dibromochloromethane, and 1,1 dichloroethylene.

The estimated amount of sludge generated was based on the average of amounts obtained by using both the flow-correlation and total suspended solids approaches that were described in Section 5. The estimates were corrected for known values. The resultant estimate was 0.8 million dry tpy were generated. Los Angeles and Orange Counties accounted for 46% of that total.

The sum of PTOCs removed in sludge streams statewide was 81.7 tpy, with Los Angeles County accounting for 72% of the total.

Only four individual PTOCs were removed in quantities of more than 1.0 tpy for any given county. An estimated 1.7 tpy of ethylbenzene were removed in the sludges generated in Los Angeles County. Methylene chloride and toluene removals were both greater than 1.0 tpy in Los Angeles, Santa Clara, Orange, and San Diego Counties. Perchloroethylene removals in Los Angeles County were estimated to be 4.0 tpy. On a statewide basis, only toluene (41 tpy), methylene chloride (28 tpy), perchloroethylene (6.5 tpy), ethylbenzene (2.1 tpy), and trichloroethylene (1.6 tpy) were removed in sludge at quantities exceeding 1.0 tpy.

A large fraction of the sludge that was generated in California was placed in landfills. The Hyperion Treatment Plant has practiced sludge disposal to the ocean, but will soon convert to sludge incineration and removal to landfills. A small fraction of the total sludge generated in California was composted and utilized commercially as a soil amendment.

Finally, the PTOC removals in sludge could be subtracted from statewide and county emissions to arrive at new, less than worst-case, estimates for PTOC emissions. In most counties this would have led to less than a 10% reduction in the emissions estimates.

# 7. CONCLUSIONS

Potentially toxic organic compounds (PTOCs) have been observed in the influent of MWTPs in California. With the exception of trihalomethanes, concentrations of PTOCs have been generally observed to decrease in passing from the influent to the effluent of the plant. A review of the literature has shown that the following processes are significant in removing volatile PTOCs from wastewater: volatilization, adsorption to solid particles and biomass, and biodegradation. For volatile PTOCs the literature, expert opinion, and limited data favor removal from wastewater primarily by volatilization with a lesser amount being degraded or removed with sludge. This conclusion was largely based on the following observations:

1) Biodegradation of PTOCs is known to be slow for unacclimated systems. Based upon the data collected for this study, acclimation of organisms was unlikely at the levels of PTOC concentrations typically observed in influents to MWTPs in California.

2) Volatile PTOCS have a low affinity for adsorption. The two PTOCs with the highest Henry's law constants, carbon tetrachloride and vinyl chloride, were observed to be the PTOCs that were the most efficiently removed in MWTPs.

3) An analysis of raw data obtained from previous studies indicated that adsorption to sludge accounts for only a small fraction (<10%) of the total removal of PTOCs during wastewater treatment. Furthermore, sludge treatment processes such as dissolved air flotation and sludge drying are conducive to volatile emissions of PTOCs. It was estimated that 0.8 million tons/year (tpy) of sludge were produced in California, and that 82 tpy of PTOCs were removed in sludge streams. The most common sludge disposal practice was landfilling, from which volatile emissions of PTOCs was also possible.

For those reasons, a conservative estimate of PTOC loss by volatilization was carried out by assuming that all removal of PTOCs in a MWTP would occur by volatilization.

98

Little is known regarding the fate of PTOCs in collection systems or after discharge to a receiving water. However, the limited data available suggests that volatile emissions from collection systems could be significant with respect to emissions during wastewater treatment, depending upon the type of collection system, degree of "breathing" losses from the collection system and possible degradation in the collection system. Further conclusions regarding the magnitude of these losses could not be made. The fate of PTOCS in receiving waters was also uncertain, though for most surface receiving waters one would expect a high degree of volatilization. However, a large portion of treated effluent in California was being discharged to the ocean by sub-merged outfalls.

This study has focussed upon the fate of PTOCs during wastewater treatment, with a particular emphasis on assessing the potential for in-plant volatile emissions and losses to sludge streams. The following points can be made on the basis of the literature reviewed and the data gathered:

1) PTOCs are potentially emitted from large MWTPS in industrialized areas in significant quantities in comparison with other known point sources on a statewide, county-by-county, or individual basis.

2) Counties in which MWTPs were predicted to be major sources of total and speciated PTOC emissions have now been identified.

3) MWTPs which were potentially significant individual sources of PTOC emissions have also been identified.

4) Sources of data that can be used to predict volatile PTOC emissions have been identified. The data base is expected to increase in future years leading to improved estimates of PTOC emissions.

5) Individual treatment processes that are most conducive to emissions have been identified. As a result, recommendations regarding areas

where further field sampling and research would be valuable, in order to reduce the uncertainties associated with PTOC emissions and to develop control techniques if they are deemed to be necessary, can be given.

Item 5 is discussed in detail in Section 8 and in Appendix G. Specific conclusions relating to items 1 through 4 are discussed in the remainder of this section.

A total volatilization assumption was necessary, as emissions estimates based upon sophisticated models could not be made because of limited, and sometimes non-existent, PTOC data. As federally mandated industrial pretreatment programs mature, more influent and effluent data will become available. The additional data should reduce uncertainties associated with the temporal representativeness of PTOC mass loading data at individual treatment plants (a major source of uncertainty in the values reported). However, substantial uncertainties in emissions estimates will probably continue to exist as a result of a lack of understanding regarding the roles of different removal mechanisms, sample and analysis techniques, and the necessity to extrapolate emissions to MWTPs that do not sample for PTOCs.

For this study, Pretreatment Annual Reports and surveys of regional water quality control boards, POTWs, and MWTPs allowed for PTOC data to be collected at MWTPs that treated 77% of the municipal wastewater that was discharged to POTWs in California. Extrapolation techniques were studied and applied to account for the remaining 23%. The uncertainties associated with emissions estimates were reviewed and estimated to be within a factor of two to four, depending on the PTOC, on a statewide basis. A summary of those findings is given below:

1) In recent years (1983-1986), an estimated 803 tons/year (tpy) of PTOCs were emitted during wastewater treatment throughout California. A review of past data suggested that emissions of PTOCs from MWTPs have been reduced significantly during the past decade.

2) An additional 600 tpy of total PTOCs were discharged in the effluent

streams of MWTPs throughout California. Such discharges may have led to significant additional emissions of PTOCs.

3) On a statewide basis, emissions were low (<3.0 tpy) for acrylo-nitrile, bromodichloromethane, carbon tetrachloride, chlorobenzene, dibromochloromethane, 1,1 dichloroethylene, and vinyl chloride. Emissions were relatively high (> 200 tpy) for methylene chloride and toluene. Emissions of benzene, chloroform, ethylbenzene, 1,2 dich-loroethane, perchloroethylene, 1,1,1 trichloroethane, and trich-loroethylene were in the range of 10 tpy to 100 tpy.

4) Total PTOC emissions from MWTPs were relatively low in most coun-ties and from all but a few individual MWTPs. The regions of most sig-nificant emissions were the South Coast Air Basin, particularly Los Angeles County, and the region consisting of Alameda and Santa Clara Counties.

5) The Joint Water Pollution Control Plant (JWPCP) and the Hyperion Treatment Plant (HTP), both in Los Angeles County, appeared to be po-tentially significant sources of total and speciated PTOC emissions in comparison to existing point sources in the SCAQMD. However, the JWPCP utilized pure-oxygen activated sludge treatment with off-gas controls on many aerated processes. These control devices could have led to actual controlled emissions which that were significantly lower than the uncon-trolled emissions estimated for this study. The HTP was scheduled to be modified to a pure-oxygen treatment facility by 1993, leading to future changes in the emissions from that source. A few other MWTPs could be significant point sources of PTOCs in comparison to other sources in their respective air basins.

6) Chlorination of wastewater led to significant increases in the concentration of chloroform in the effluent streams of those MWTPs that post-chlorinate. On a statewide basis, chlorination may have led to an increase in chloroform emissions from 36 tpy to approximately 50 tpy. Chlorination did not lead to significant production or emissions of bromodichloromethane or dibromochloromethane.

101

The study of MWTPs as sources of potentially toxic organic compound emissions to the atmosphere is a recent topic of concern. Large uncertainties continue to exist regarding several key elements associated with emissions from POTWs. Hopefully, this study will provide an improved understanding of the potential of MWTPs as PTOC emissions sources in California. However, in order to reduce uncertainties, to improve emissions estimates and gain a better understanding of the factors that affect the fate of PTOCs in POTWs, additional sampling and research is needed. The completion of this study has allowed for the identification of specific research needs and sampling efforts that would be valuable in the future. These will be discussed in the following section.

## 8. RECOMMENDATIONS

Precise estimates of emissions of volatile PTOCs from POTWs were not possible given the data base and level of understanding of the fate of PTOCs. Future sampling efforts would lead to a better understanding of the extent of PTOC emissions from POTWs, particularly from those which have the potential for large emissions. Additional research could build upon existing knowledge of the factors that affect the fate of PTOCs in POTWs, and investigate methods of controlling PTOC emissions. General recommendations in those areas are discussed in this section. More detailed recommendations for sampling at specific treatment facilities are provided at the end of Appendix G.

Collection Systems: Although we suspect that emissions from collection systems are relatively small, possibly the greatest uncertainty in total emission estimates stems from potential emissions from that source. To reduce the uncertainty, sampling should be undertaken in collection systems which serve industrial users known to discharge PTOCs. Collection system air exchange ("breathing") rates need to be measured to determine whether significant air exchange with the atmosphere occurs. Concurrent measurements of wastewater flowrates, surface levels and temperature gradients would be valuable for future modeling of air displacement. Concentrations in both the collection system atmosphere and the wastewater should be monitored as well in order to determine whether acclimation and significant biodegradation can occur before the wastewater reaches the treatment facility. In light of the size of the collection system and the characteristics of industrial users, collection systems in Los Angeles County may be the most appropriate for future sampling.

Emissions at MWTPs with Significant PTOC Loadings: The most appropriate method to study PTOC emissions that occur during wastewater treatment would be to complete an extensive gas and liquid-phase sampling effort at one or more MWTPs that were identified as having potentially high uncontrolled emissions. The results of this study indicated that the

103

Joint Water Pollution Control Plant, the Hyperion Treatment Plant, and the San Jose-Santa Clara Water Pollution Control Plant would be suitable candidates in that respect. Specific treatment processes which should be investigated through field sampling include bar screens, aerated grit chambers, aerated conveyance channels, primary clarifiers and clarifier weirs, conventional and pure-oxygen activated sludge systems, trickling filters, anaerobic digesters, chlorine contact chambers, and effluent outfall systems. The identification of treatment facilities with specific processes that should be considered for future sampling are listed at the end of Appendix G.

Pure-Oxygen Activated Sludge Treatment: Several of the MWTPs that were ranked highly as individual sources of PTOC emissions utilized pure-oxygen activated sludge treatment. Because those systems were covered and employed lower gas-to-liquid volume ratios than conventional activated sludge treatment processes, reduced PTOC emissions would be expected from such systems. The Hyperion Treatment Plant (HTP) was scheduled to be converted from a primary/conventional activated sludge system to a pure-oxygen activated sludge plant by 1993. To study the stripping efficiencies of conventional and pure-oxygen systems it would be valuable to complete gas and liquid-phase sampling at the HTP's aeration basins before and after the process modifications. Concurrent laboratory and pilot-scale studies of the effects of different oxygenation systems (i.e., surface oxygenators, and coarse and fine bubble diffusers) on volatilization might also suggest the most appropriate design considerations for simultaneously satisfying the requirements of efficient biological treatment and reduced PTOC emissions.

Biodegradation as an Emissions Control Technique: Biodegradation could be a feasible method for reducing PTOC emissions during secondary wastewater treatment. However, it is believed that conditions necessary to maintain a microbial population fully acclimated to PTOCs are rarely, if ever, met at municipal wastewater treatment plants. Research to study the factors that affect acclimation could lead to physical, chemical, or biological treatment modifications, e.g., sequenced batch reactor operation, which would increase the relative fraction of PTOCs degraded while reducing the fraction volatilized.

Production of PTOCs by Degradation: Biodegradation, particularly during anaerobic digestion, can lead to the production of PTOCs through sequential dehalogenation of other halogenated compounds. For instance, the more volatile vinyl chloride can be formed as a result of the degradation of perchloroethylene or trichloroethylene. Great uncertainties exist regarding losses of digester gases and the subsequent emissions of PTOCs such as vinyl chloride and 1,1 dichloroethylene. Knowledge of the degradation/formation process could be improved through laboratory or pilot-scale studies. Emissions of PTOCs from anaerobic digesters should be investigated through field sampling. Pressure-relief valves are a potential source of PTOC releases from digesters, as are openings on the roofs of floating roof digesters.

Off-Gas Control Devices: Spray scrubbers and activated carbon filters are control devices sometimes used to treat off-gases from those MWTPs characterized by covered treatment processes. The Joint Water Pollution Control Plant utilized both caustic scrubbers and activated carbon filters to treat off-gases. However, the efficiencies of those devices at removing PTOCs from off-gases were not known. Field studies to investigate the efficiencies of those devices are warranted, particularly at the JWPCP, where high uncontrolled emissions of PTOCs were estimated.

Formation of Trihalomethanes: The formation of chloroform during and after chlorination can occur at MWTPs. The results of this study indicated that chloroform formation could be significant, not only with respect to emissions of chloroform prior to chlorination, but also to other known sources of chloroform. Field studies of liquid-phase chloroform concentrations immediately before, during, and after chlorine injection, and gas-phase sampling for chloroform above and downwind of chlorine contact chambers would be valuable to further assess the magnitude of the chloroform formation problem. Treatment facilities that appeared to form chloroform in significant amounts relative to detectable influent mass loadings included the San Jose-Santa Clara WPCP, Sunnyvale WWTF, Sacramento Regional WWTF, East Bay MUD WWTF, and Fairfield-Suisun WWTF.

Research regarding the formation of chloroform could be valuable in order to identify important precursor compounds. In addition, methods to remove precursors prior to chlorination, or to modify disinfection processes in order to operate with less chlorine available for reaction to form THMs, could lead to reductions in chloroform formation and emissions.

Volatilization from Effluent Outfall and Receiving Waters:  The results of this study indicated that approximately 600 tons/year of PTOCs were discharged in the effluent streams of MWTPs.  The potential emissions of those PTOCs from effluent conveyance channels and from receiving waters was not well understood.  A large fraction of the PTOCs were discharged to the ocean where they could have subsequently risen, volatilized, and been carried onshore.  However, great uncertainty exists regarding the roles of chemical and biological reactions in the degradation of PTOCs in an ocean environment.  Similarly, large quantities of sludge have been placed in the ocean.  If sludge deposits have built up, it is con- ceivable that anaerobic decomposition will occur (perhaps at greatly reduced rates in comparison to sludge digesters) and produce bulk gas releases which will transport volatile PTOCs to the surface where they can subsequently be advected on shore.  Additional research in these areas should be undertaken.

# REFERENCES

Alexander, M., (1973), "Biodegradation: Problems of Molecular Recalcitrance and Microbial Fallibility," Adv. Appl. Microbiol., 7, 35.

Allen, C.C.; Green, D.A.; White, J.B.; and J.B. Coburn, (1986), Preliminary Assessment of Air Emissions from Aerated Waste Treatment Systems at Hazardous Waste Treatment Storage and Disposal Facilities, U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Office of Research and Development, Cincinnati, Ohio.

Amy, G.L.; Chadik, P.A.; King, P.H.; and W.J. Cooper, (1984), "Chlorine Utilization During Trihalomethane Formation in the Presence of Ammonia and Bromide," Environmental Science Technology, 18(10), 781-786.

Barrio-Lage, G.; Parsons, F.Z.; Nassar, R.S.; and P.A. Lorenzo, (1986), "Sequential Dehalogenation of Chlorinated Ethenes," Environmental Science Technology, 20(1), 96-99.

Bell, J.P.; and M. Tsezos, (1987), "Removal of Hazardous Organic Pollutants by Adsorption on Microbial Biomass," Water Sci. Tech., 19, 409-416.

Berglund, R.L.; Whipple, G.M.; Hansen, J.L.; Alsop, G.M.; Siegrist, T.W.; Wilker, B.E.; and C.R. Dempsey, (1985), "Fate of Low Solubility Chemicals in a Petroleum Chemical Wastewater Treatment Facility," Presented at the National Meeting of AICHE.

Blackburn, J.W.; Troxler, W.L.; Truong, K.N.; Zink, R.P.; Meckstroth, S.C.; Florance, J.R.; Groen, A.; Sayler, G.S.; Beck, R.W.; Minear, R.A.; Breen, A.; and O. Yagi, (1985), Organic Chemical Fate Prediction in Activated Sludge Treatment Processes, EPA/600/S2-85/102, U.S. Environmental Protection Agency, Water Engineering Research Laboratory, Cincinnati, OH.

Caballero, R., (1987), County Sanitation Districts of Los Angeles County, personal communication.

California Air Resources Board, (1985), "Source Tests for Vinyl Chloride and Other VOCs at Sewage Treatment Plants," a CARB memorandum.

Chemical Rubber Company (CRC), (1977), CRC Handbook of Chemistry and Physics, ed. R. C. Weast, CRC Press, Inc., Cleveland.

Chow, B.M.; and P.V. Roberts, (1981), "Halogenated Byproduct Formation by ClO2 and CL2," Proceedings of the ASCE, 107, (EE4), 609-618.

Cooper, W.J.; Villate, J.T.; Ott, E.M.; Slifker, R.A.; Parsons, F.Z.; and G.A. Graves, (1985), "Formation of Organohalogen Compounds in Chlorinated Secondary Wastewater Effluent," Chapter 34 in Water Chlorination: Environmental Impact and Health Effect, ed. by R.L. Jolley et al, Lewis Publishers, Inc., Chelsea, Michigan, 483-497.

Digeronimo, M.J.; Boethling, R.S.; and M. Alexander, (1979), "Effects of Chemical Structure and Concentration on Microbial Degradation in Model Ecosystems," in Proceedings of the Workshop: Microbial Degradation of Pollutants in Marine Environments, ed. by A.W. Bourquin and P.H. Pritchard, EPA-600/9-79-012.

Dixon, G.; and B. Bremen, (1984), "Technical Background and Estimation Methods for Assessing Air Releases from Sewage Treatment Plants," Versar, Inc., Memorandum.

Dore, M.; Merlet, N.; De Laat, J.; and J. Goichon, (1982), "Reactivity of Halogens with Aqueous Micropollutants: A Mechanism for the Formation of Trihalomethanes," Journal of the American Water Works Assoc., 74(2), 103-107.

Federal Register, (1981), "Part II. Environmental Protection Agency. General Pretreatment Regulations for Existing and New Sources," 46(18), 9439-9460.

Feiler, H., (1979), Fate of Priority Pollutants in Publicly Owned Treatment Works (Pilot Study), EPA-440/1-79-300, U.S. Environmental Protection Agency, Office of Water and Waste Management, Washington, DC.

Frederick, R., (1985), "Removal of Pollutants by POTW's - Best Available Information," EPA Memorandum, U.S. Environmental Protection Agency, Washington, D.C.

Gurka, D.F., (1984), Interlaboratory Comparison Study: Methods for Volatile and Semivolatile Compounds, EPA-600/S4-84-027, U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Hanmer, R.; Barrett, B.R.; Prothro, M.G.; and J.D. Gallup, (1983), Guidance Manual for Pretreatment Program Development, U.S. Environmental Protection Agency, Office of Water Enforcement and Permits.

Helz, G.R.; Uhler, A.D.; and R. Sugam, (1985), "Dechlorination and Trihalomethane Yields," Bull. Environ. Contam. Toxicol., 34(4), 497-503.

Itoh, S.I.; Naito, S.; and T. Unemoto, (1985), "Acetoacetic Acid as a Potential Trihalomethane Precursor in the Biodegradation Intermediates Produced By Sewage Bacteria," Water Research, 19(10), 1305-1309.

Jannasch, H.W., (1967), "Growth of Marine Bacteria at Limiting Concentrations of Organic Carbon in Seawater," Limnol. Oceanogr., 12, 264.

Jenkins, T.F.; Leggett, D.C.; and C.J. Martel, (1980), "Removal of Volatile Trace Organics from Wastewater by Overland Flow Land Treatment," J. Environ. Sci. Health, A15(3), 211-224.

Kavanaugh, M.C.; Trussell, A.R.; Kromer, J.; and R.R. Trussell, (1980), "An Empirical Kinetic Model of Trihalomethane Formation: Applications to Meet the Proposed THM Standard," Journal of the American Water Works Assoc., October, 578-582.

Kincannon, D.F.; Stover, E.L.; Nichols, V.; and D. Medley, (1983), "Removal Mechanisms for Toxic Priority Pollutants," Journal of the Water Pollution Control Federation, 55(2), 157-183.

Kincannon, D.F.; and E.L. Stover, (1983), Determination of Activated Sludge Biokinetic Constants for Chemical and Plastic Industrial Waste-water, EPA-600/2-83-073A, U.S. Environmental Protection Agency.

Lawson, C.T.; and S.A. Siegrist, (1981), "Removal Mechanism for Selected Priority Pollutants in Activated Sludge Systems," 1981 Natl. Conference on Environmental Engineering, Proceedings of the ASCE Environmental Engineering Division Specialty Conference, F.M. Saunders, ed., 356-363.

Lucas, A.D., (1981), Health Hazard Evaluation Report No. HETA 81-207-945, Metropolitan Sewer District, Cincinnati, Ohio. Cincinnati, Ohio: National Institute for Occupational Safety and Health.

Mackay, D.; Shiu, W.Y.; and R.P. Sutherland, (1979), "Determination of Air-Water Henry's Law Constants for Hydrophobic Pollutants," Environmental Science Technology, 13(3), 333-337.

Matthews, P.J., (1975), "Limits for Volatile Organic Liquids in Sewers. Part 1," Journal of Effluent Water Treat., 15(11), 565-567.

Merck Index, (1983), The Merck Index, eds. M. Windholz, S. Budavari, R. Blumetti, E. Otterbein, Merck and Co,., Inc., New Jersey.

Nicholson, B.C.; Maguire, B.P.; and D.B. Bursill, (1984), "Henry's Law Constants for the Trihalomethanes: Effects of Water Composition and Temperature," Environmental Science Technology, 18(7), 518-521.

Patterson, J.W.; and P.S. Kodukala, (1981), "Biodegradation of Hazardous Organic Pollutants," Chemical Engineering Progress, 77(4), 48-55.

Pincince, A.B.; and C.J. Fournier, (1984), Chlorinated Organic Compounds in Digested, Heat-Conditioned, and Purifax-Treated Sludges, EPA-600/S2-84-117, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH.

Porter, M., (1986), South Coast Air Quality Management District, personal communication. .

Riznychok, W.M.; Mueller, J.A.; and J.J. Giunta, (1983), "Air Stripping of Volatile Organic Compounds from Sanitary and Industrial Effluents," Toxic Hazard. Waste, Proceedings of the Mid-Atlantic Ind. Waste Conference, 15th, M.D. LaGrega, et al., eds., 390-401.

Sax, N.I., (1975), Dangerous Properties of Industrial Materials, Van Nostrand Reinhold Co., Litton Educational Publishing, Inc., New York.

Schröder, H. Fr., (1987), "Chlorinated Hydrocarbons in Biological Sewage Purification - Fate and Difficulties in Balancing," Water Sci. Tech., 19, 429-438.

Skow, K.M., (1982), "Rate of Biodegradation," Chapter 9 in Handbook of Chemical Property Estimation Methods, ed. by W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt, McGraw-Hill Book Company, New York.

Strier, M.P.; and J.D. Gallup, (1983), "Removal Pathways and Fate of Organic Priority Pollutants in Treatment Systems: Chemical Considerations." Proc. Ind. Waste Conf., 37, 813-824.

Takehisa, M.; Arai, H.; Arai, M.; Miyata, T.; Sakumoto, A.; Hashimoto, S.; Nishimura, K.; Watanabe, H.; Kawakami, W.; and I. Kuriyama, (1985), "Inhibition of Trihalomethane Formation in City Water By Radiation-Ozone Treatment and Rapid Composting of Radiation Disinfected Sewage Sludge," Radiat. Phys. Chem., 25,, 1-3, 63-71.

Tchobanoglous, G; and E.D. Schroeder, (1985), Water Quality, Addison-Wesley Publishing Company, Menlo Park, 123-150 and 616-617.

Thomas, R.G., (1982), "Volatilization from Water," Chap. 15 in Handbook of Chemical Property Estimation Methods, Ed. by W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt. McGraw-Hill Book Co., New York.

Verschueren, K., (1977), Handbook of Environmental Data of Organic Chemicals, Van Nostrand Reinhold Company, New York.

U.S. Environmental Protection Agency, (1980), Carbon Adsorption Isotherms for Toxic Organics, EPA-600/8-80-023, Municipal Environmental Research Laboratory, Cincinnati, Ohio.

U.S. Environmental Protection Agency, (1982), Fate of Priority Pollutants in Publicly Owned Treatment Works, vol. 1, EPA 440/1-82/303, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C.

U.S. Environmental Protection Agency, (1983), Treatability Manual, EPA-600/2-82-001a, Office of Research and Development, Washington, D.C.

U.S. Environmental Protection Agency, (1986), Report to Congress on the Discharge of Hazardous Wastes to Publicly Owned Treatment Works, EPA/530-SW-86-004, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C.

Weber, W.J.; Corfis, N.H.; and B.E. Jones, (1983), "Removal of Priority Pollutants in Integrated Activated Sludge-Activated Carbon Treatment Systems," Journal WPCF, 55(4), 369-376.

Weber, W.J.; Jones, B.E.; and L.E. Katz, (1987), "Fate of Toxic Organic Compounds in Activated Sludge and Integrated PAC Systems," Water Sci. Tech., 19, 471-482.

Zwiacher, W.E.; L.D. Yuhas; J. Whittaker; J. Fakhoury; B. Rogers; R. Olivares; E. Sunico; and S. Weiss, (1985), South Coast Air Quality Management District Engineering Division Report on Emissions of Potentially Toxic/Hazardous Air Contaminants in the South Coast Air Basin. 1984 Update.

SUPPLEMENTAL READING

Clark, C.S.; Bjornson, H.S.; Linnemann, Jr., C.C.; and P.S. Gartside, (1984), Evaluation of Health Risks Associated with Wastewater Treatment and Sludge Composting, EPA-600/S1-84-014, U.S. Environmental Protection Agency, Health Effects Research Lboratory, Research Triangle Park, NC.

Eckenfelder, W.W.; and A. Wadkins, (1983), "The Removal of Priority Pollutants in the Acativated Sludge Process," Australian Water and Wastewater Association Technical Papers, Tenth Federal Convention, Sydney, Australia.

Edzwald, J.K., (1984), Removal of Trihalomethane Precursors by Direct Filtration and Conventional Treatment, EPA-600/2-84-068, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, OH.

Glaze, W.H.; Burieson, J.L.; Henderson, J.E.; Jones, P.C.; and W. Kinstley, (1982), Analysis of Chlorinated Organic Compounds Formed During Chlorination of Wastewater Products, EPA-600/4-82-072, U.S. Environmental Protection Agency.

Jekel, M.R.; and P.V. Roberts, (1980), "Total Organic Halogen as a Parameter for the Characterization of Reclaimed Waters: Measurement, Occurance, Formation, and Removal," Environmental Science Technology, 14(8), 970-975.

Jordan, E.C., (1982), Fate of Priority Pollutants in Publicly-Owned Treatment Works, EPA-440/1-82/302, U.S. Environmental Protection Agency, Effluent Guidelines Division, Washington, D.C.

Levins, P.; Adams, J.; Brenner, P.; Coons, S.; Thrun, K.; and A. Wechsler, (1979), Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants 2. Muddy Creek Drainage Basin, Cincinnati, Ohio, EPA/440/4-81/004, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C.

Levins, P.; Adams, J.; Brenner, P.; Coons, S.; Thrun, K.; and J. Varone, (1979), Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants 3. Coldwater Creek Drainage Basin, St. Louis, Missouri, EPA/440/4-81-005, U.S. Environmental Protection Agency, DOffice of Water Planning and Standards, Washington, D.C.

Levins, P.; Adams, J.; Brenner, P.; Coons, S.; Thrun, K.; and J. Varone, (1979), Sources of Toxic Pollutants Found in Influent to Sewage Treatment Plants 4. R.M. Clayton Drainage Basin, Atlanta, Georgia, EPA/440/4-81-006, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C.

Levins, P.; Adams, J.; Brenner, P.; Coons, S.; Freitas, C.; Thrun, K.; and J. Varone, (1979), Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants 5. Hartford Water Pollution Control Plant, Hartford, Connecticut, EPA/440/4-81/007, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C.

Levins, P.; Adams, J.; Brenner, P.; Coons, S.; Harris, G.; Jones, C.; Thrun, K.; and A. Wachsler, (1979), Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants 6. Integrated Interpretation, EPA/440/4-81/007, U.S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C.

Lewis, J., (9/1985) "Pretreatment of Industrial Waste," EPA Journal, 5-7.

Lurker, P.A.; Clark, C.S.; and V.J. Elia, (1982), "Atmosphere Release of Chlorinated Organic Compounds from the Activated Sludge Process," Journal WPCF, 54(12), 1566-1573.

Lurker, P.A.; Clark, C.S.; Elia, V.J.; Gartside, P.S.; and Kinman, R.N., (1984), "Aerial Organic Chemical Release from Activated Sludge," Water Res., 18(4), 489-494.

Meuser, J.W.; and W.M. Cooke, (1981), Fate of Semivolatile Priority Pollutants in a Wastewater Treatment Plant, EPA-600/2-81-056, U.S. Environmental Protection Agency, Cincinnati, OH.

Overcash, M.R.; Weber, J.B.; and W. Tucker, (1986), Toxic and Priority Organics in Municipal Sludge Land Treatment Systems, EPA/600/S2-86/010, U.S. Environmental Protection Agency, Water Engineering Research Laboratory, Cincinnati, OH.

Sievers, R.E.; Barkley, R.M.; Eiceman, G.A.; Haack, L.P.; Shapiro, R.H.; and H.F. Walton, (1978), "Generation of Volatile Organic Compounds from Nonvolatile Precursors in Water by Treatment With Chlorine or Ozone," Water Chlorination: Proceedings of the Conference on Environ. Impact Health Eff., 2, R.L. Jolley, et al., eds., 615-624.

Singh, H.B.; Jaber, H.M.; and J.E. Davenport, (1984), Reactivity/Volatility Classification of Selected Organic Chemicals: Existing Data, EPA-600/S3-84-082, U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, NC.

Wilson, J.L., (1981), Determination of Volatile Organics in Industrial and Municipal Wastewaters, EPA-600/4-81-071, U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

APPENDIX A:  Glossary

The following definitions are intended to serve those readers with a limited knowledge of wastewater treatment. To avoid confusion, many of the definitions are not general, and refer only to descriptions appropriate to wastewater treatment.

Absorption: Dissolution of a substance into the body of another.

Acclimation: The process by which biomass adjusts to the utilization of an organic contaminant.

Activated carbon (AC): Porous wood or coal char particles used to collect soluble substances through the process of adsorption. AC is typically categorized as granular (GAC) or powdered (PAC).

Activated sludge system (AS): A commonly used biological process in which a suspended, aerobic, microbial culture is used to treat primary effluent.

Adsorption: The physical and/or chemical process in which a substance is accumulated at an interface between distinct phases.

Advanced treatment: Tertiary treatment. Treatment used to accomplish further removal of suspended and dissolved materials remaining after secondary treatment.

Aeration: The addition of oxygen to a wastewater in order to meet the biological requirements of aerobic biomass, or to meet effluent dissolved oxygen requirements. Diffused bubble and surface agitation by mechanical means are two common aeration methods. Both air and pure oxygen have been utilized for aeration purposes. The former is also employed for particle suspension.

Aerobic processes: Biological treatment processes that occur in the presence of oxygen. Certain bacteria (obligate aerobes) can survive only in the presence of dissolved oxygen.

Anaerobic processes: Biological treatment processes that occur in the absence of oxygen. Certain bacteria (obligate anaerobes) can survive only in the absence of dissolved oxygen.

Anaerobic digestion: The stabilization of organic matter in sludge, carried out under anaerobic conditions. Methane and carbon dioxide are the principal conversion products.

Bar screen: A screen used to catch and remove large solids (e.g., rags) from wastewater. Bar screens are an initial treatment process employed in order to reduce the possibility of pump or other equipment damage.

Batch reactor: A reactor characterized by no inflow or outflow, and completely mixed conditions.

Biochemical oxygen demand (BOD): The amount of oxygen used in the metabolism of biodegradable organic compounds.

Biodegradation: A biologically induced change in the chemical structure of a specific compound.

Biological treatment: The use of microbial cultures to remove organic material from wastewater.

Biomass: Living organisms, usually microbial, that play an active role in treating wastewater through the biodegradation of organic matter.

Biomass yield: The mass of biomass cells produced per unit mass of organic matter removed (utilized) by the biomass.

Building sewers: Building connections. Building sewers connect to the building plumbing and are used to convey wastewater from the buildings to lateral sewers.

Chemical oxygen demand (COD): The oxygen equivalent of the organic matter that can be oxidized by a certain test procedure.

Chlorination: The addition of chlorine to wastewater to achieve disinfection, odor control, corrosion control, bacterial reduction, and several other objectives. The most common use of chlorine addition is for the disinfection (destruction) of disease-causing organisms prior to discharge from the treatment plant to a receiving water.

Clarifier: A sedimentation basin. Clarifiers are used to separate suspended particles from wastewater by gravitational settling.

Collection system: The network of sewerage piping used to convey wastewater from discharging sources to a treatment facility.

Combined sewers: Sewers used for the collection of both wastewater and storm water.

Combined sludge: A mixture of both primary and secondary sludge.

Commercial user: A privately-owned commercial establishment that discharges to a POTW collection system. Commercial users include such dischargers as restaurants, dry cleaners, gasoline and motor vehicle services, supermarkets, and office buildings.

Comminuter: A device used to reduce the size of solids in wastewater.

Desorption: The process of detachment from a solid surface.

Digested sludge: Sludge which has been stabilized as a result of anaerobic digestion.

Digester gas: Gas formed as a result of the degradation of organic matter during anaerobic digestion. The principal components of digestor gas are methane and carbon dioxide.

Effluent: The wastewater stream which flows out of the treatment plant, or from a specific treatment stage (e.g., primary effluent).

Equalization basin: A wastewater holding basin used to dampen flowrate variations.

Exfiltration: The process in which wastewater is lost from the collection system to the ground as a result of defective pipes, pipe joints, connections, or other means.

Facultative process: Biological-treatment processes in which the organisms are indifferent to the presence of dissolved oxygen.

Grit: Solids with relatively large specific gravities (e.g., sand, gravel, cinders, seeds, eggshells, bone chips, coffee grounds, food wastes, etc.).

Grit chamber: A device used to remove grit from the wastewater stream. Grit chambers are typically aerated in order to provide a mixing pattern in which grit particles are removed by centrifugal action and friction against the chamber wall.

Industrial user: An industrial establishment, usually involved with product manufacture, that discharges to a POTW collection system. Examples of industrial users are electroplaters, oil refineries, textile mills, power plants, and pulp mills.

Infiltration: The process in which water enters a collection system from the ground due to defective pipes, pipe joints, connections, or other means.

Influent: The raw wastewater entering a treatment plant, or the treated wastewater entering a specific treatment stage (e.g., secondary influent).

Institutional user: A private or public institution which is not classified as commercial, industrial, or residential, that discharges to a POTW collection system. Examples of institutional users are hospitals, educational institutions, prisons, and military bases.

Interceptor sewer: Large sewers that are used to intercept a number of main or trunk sewers and convey the wastewater to treatment or other disposal facilities.

Lateral sewers: Branch sewers. The first element of a wastewater collection system. Lateral sewers collect wastewater from one or more building sewers and convey it to a main sewer.

Main sewers: Sewers used to convey wastewater from one or more lateral sewers to trunk or interceptor sewers.

NEEDS: An EPA data base which consists of information regarding the treatment characteristics of municipal wastewater treatment and collection systems.

Nitrification: The conversion of nitrogen in the form of ammonia to nitrate.

Outfall: The effluent wastewater stream that is conveyed from a treatment plant to an ultimate receiving system.

Overland flow: The treatment of wastewater by application to sloped terraces. The wastewater flows across the vegetated surfaces where physical, chemical, and biological processes improve the quality of the wastewater.

Pass-through: The process in which a compound is not removed during treatment (i.e., it passes through the entire treatment plant from the influent to the effluent stream).

Percolation pond: A holding basin designed to remove wastewater by percolation to the underlying soil column.

Pretreatment: The treatment of industrial-wastewater streams prior to discharge to a municipal sewerage system.

Pretreatment annual report (PAR): A report submitted by POTWs, with design flows greater than 5 MGD, to the EPA, California Water Resources Control Board, and the RWQCB. PARs typically consist of information regarding the enforcement of industrial pretreatment programs, and the monitoring of pollutants in influent and effluent wastewater streams.

Primary sludge: Solid material removed as a result of sedimentation (gravitational settling) prior to secondary treatment.

Primary treatment: The removal of a portion of the suspended solids and organic matter in wastewater as it enters a treatment plant. Primary treatment is usually accomplished through physical processes (e.g., bar screens and primary clarifiers).

Priority pollutant: One of approximately 126 pollutants identified to be regulated by categorical discharge standards established by the EPA. Priority pollutants were selected on the basis of their known or suspected carcinogenicity, mutagenicity, or teratogenicity.

Publicly-Owned Treatment Works (POTW): A system which is owned by a public entity, and which involves wastewater collection systems, treatment systems, or both.

Pure-oxygen activated sludge system: An activated sludge system which utilizes nearly pure oxygen, rather than air, to sustain aerobic microbial processes.

Purifax process: A patented commercial process in which chlorine gas is added to wastewater sludge, septage, or digester supernatant to stabilize and condition the material before dewatering and disposal.

Recycle: The return of effluent to the influent or some intermediate point.

Residential user: A POTW user that discharges household wastewaters from toilets, drains, etc..

Retention time (hydraulic): The average time that a "parcel" of wastewater exists in a treatment process or group of processes. The hydraulic residence time is taken to be the process volume divided by the wastewater flowrate into the process.

Rotating biological contactor (RBC): A series of closely spaced circular disks which are partially submerged in wastewater and slowly rotated to promote contact with the air. Biological growths become attached to the surfaces of the disks, and act to degrade organic matter present in the wastewater.

Secondary sludge: Solid material removed as a result of sedimentation (gravitational settling) or other secondary clarification process. Secondary sludge typically contains a large amount of biomass, in addition to non-viable solids.

Secondary treatment: Further treatment, of the effluent from primary treatment, to remove the residual organic matter and suspended material. Secondary treatment typically consists of the use of biological processes.

Separated sewers: Sewers intended solely for the collection of wastewater.

Shock loading: The upset of a biological treatment process due to a high dose of a contaminant which is detrimental to biomass in the system.

Sludge: The solid material removed, collected, and disposed of during wastewater treatment.

Stabilization: The biological process by which the organic matter in sludges is stabilized, usually by conversion to gases and cell tissue.

Tertiary treatment: See advanced treatment.

Total suspended solids: The concentration sum of all solid materials that are suspended, as opposed to dissolved, in a wastewater.

Trickling filter: An aerobic, attached-growth, biological-treatment process used to remove organic matter or to achieve nitrification. The trickling filter consists of a bed of highly permeable media in which microorganisms are attached and through which wastewater is percolated.

Trihalomethane: A compound with the chemical structure of methane with three of the hydrogen atoms replaced by halogens.

Trunkline: Trunk sewer. A Large sewer that is used to convey wastewater from main sewers to treatment or disposal facilities, or to larger intercepting sewers.

User: A source of wastewater that is discharged to a municipal sewerage system.

Volatilization: The process whereby liquids and solids vaporize and escape to the atmosphere.

Wastewater: Used, unwanted water discharged to municipal sewerage systems by residential, commercial, industrial and institutional users.

Wastewater treatment: An improvement in the quality of wastewater due to a combination of physical, chemical, and biological processes.

APPENDIX B: Regulations for the National Pretreatment Program

Part II

# Environmental
# Protection Agency

General Pretreatment Regulations for
Existing and New Sources

the date of issuance of the June 26, 1978 regulations.

Douglas M. Costle.

*Administrator.*

January 13, 1981.

40 CFR Part 403 is revised to read as follows:

## PART 403—GENERAL PRETREATMENT REGULATIONS FOR EXISTING AND NEW SOURCES OF POLLUTION

Sec.
403.1    Purpose and applicability.
403.2    Objective of general pretreatment regulation.
403.3    Definitions.
403.4    State or local law.
403.5    National pretreatment standards: prohibited discharges.
403.6    National pretreatment standards: categorical standards.
403.7    Revision of categorical pretreatment
-    standards to reflect POTW removal of pollutants.
403.8    POTW pretreatment programs: development by POTW.
403.9    POTW pretreatment programs and/or authorization to revise pretreatment standards: submission for approval.
403.10    Development and submission of NPDES State pretreatment programs.
403.11    Approval procedures for POTW
-  -  - programs and revisions of categorical pretreatment standards.
403.12    Reporting requirements for POTW's and industrial users.
403.13    Variances from categorical pretreatment standards for fundamentally different factors.
403.14    Confidentiality.
403.15    Net/Gross calculation.
403.16    Upset provision.
Appendix A—PRM 75-34.
Appendix B—65 Toxic pollutants.
Appendix C—34 Industrial categories.
Appendix D—Selected industrial subcategories exempted from regulated pursuant to paragraph 8 of the *NRDC v. Costle* consent decree.

Authority: Section 54(c)(2) of the Clean Water Act of 1977 (Pub. L. 95-217), §§ 204(b)(1)(C), 208(b)(2)(C)(iii), 301(b)(1)(A)(ii), 301(b)(2)(A)(ii), 301(b)(2)(C), 301(h)(5), 301(i)(2), 304(e), 304(g), 307, 308, 309, 402(b), 405, and 501(a) of the Federal Water Pollution Control Act (Pub. L. 92-500), as amended by the Clean Water Act of 1977.

### § 403.1  Purpose and applicability.

(a) This part implements sections 204(b)(1)(C), 208(b)(2)(C)(iii), 301(b)(1)(A)(ii), 301(b)(2)(A)(ii), 301(h)(5) and 301(i)(2), 304 (e) and (g), 307, 308, 309, 402(b), 405, and 501(a) of the Federal Water Pollution Control Act as amended by the Clean Water Act of 1977 (Pub. L. 95-217) or "The Act." It establishes responsibilities of Federal, State, and local government, industry and the public to implement National Pretreatment Standards to control

pollutants which pass through or interfere with treatment processes in Publicly Owned Treatment Works (POTWs) or which may contaminate sewage sludge.

(b) This regulation applies: (1) to pollutants from non-domestic sources covered by Pretreatment Standards which are indirectly discharged into or transported by truck or rail or otherwise introduced into POTWs as defined below in § 403.3; (2) to POTWs which receive wastewater from sources subject to National Pretreatment Standards; (3) to States which have or are applying for National Pollutant Discharge Elimination System (NPDES) programs approved in accordance with section 402 of the Act; and (4) to any new or existing source subject to Pretreatment Standards. National Pretreatment Standards do not apply to sources which Discharge to a sewer which is not connected to a POTW Treatment Plant.

### § 403.2  Objectives of general pretreatment regulations.

By establishing the responsibilities of government and industry to implement National Pretreatment Standards this regulation fulfills three objectives: (a) to prevent the introduction of pollutants into POTWs which will interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge; (b) to prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and (c) to improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

### § 403.3  Definitions.

For the purpose of this regulation:
(a) Except as discussed below, the general definitions, abbreviations, and methods of analysis set forth in 40 CFR Part 401 shall apply to this regulation.
(b) The term "Act" means Federal Water Pollution Control Act, also known as the Clean Water Act, as amended. 33 U.S.C. 1251. et seq.
(c) The term "Approval Authority" means the Director in an NPDES State with an approved State pretreatment program and the appropriate Regional Administrator in a non-NPDES State or NPDES State without an approved State pretreatment program.
(d) The term "Approved POTW Pretreatment Program" or "Program" or "POTW Pretreatment Program" means a program administered by a POTW that meets the criteria established in this regulation (§§ 403.3 and 403.9) and which has been approved by a Regional Administrator or State Director in

accordance with § 403.11 of this regulation.
(e) The term "Director" means the chief administrative officer of a State or Interstate water pollution control agency with an NPDES permit program approved pursuant to section 402(b) of the Act and an approved State pretreatment program.
(f) The term "Enforcement Division Director" means one of the Directors of the Enforcement Divisions within the Regional offices of the Environmental Protection Agency or this person's delegated representative.
(g) The term "Indirect Discharge" or "Discharge" means the introduction of pollutants into a POTW from any non-domestic source regulated under section 307(b), (c) or (d) of the Act.
(h) The term "Industrial User" or "User" means a source of Indirect Discharge.
(i) The term "Interference" means an inhibition or disruption of the POTW, its treatment processes or operations, or its sludge processes, use or disposal which is a cause of or significantly contributes to either a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation) or to the prevention of sewage sludge use or disposal by the POTW in accordance with the following statutory provisions and regulations or permits issued thereunder (or more stringent State or local regulations): Section 405 of the Clean Water Act. the Solid Waste Disposal Act (SWDA) (including title II more commonly referred to as the Resource Conservation and Recovery Act (RCRA) and including State regulations contained in any State sludge management plan prepared pursuant to Subtitle D of the SWDA), the Clean Air Act, and the Toxic Substances Control Act. An Industrial User significantly contributes to such a permit violation or prevention of sludge use or disposal in accordance with above-cited authorities whenever such User:
(1) Discharges a daily pollutant loading in excess of that allowed by contract with the POTW or by Federal. State or local law;
(2) Discharges wastewater which substantially differs in nature or constituents from the User's average Discharge: or
(3) Knows or has reason to know that its Discharge. alone or in conjunction with Discharges from other sources. would result in a POTW permit violation or prevent sewage sludge use or disposal in accordance with the above-cited authorities as they apply to the POTW's selected method of sludge management.

(j) The term "National Pretreatment Standard." "Pretreatment Standard." or "Standard" means any regulation containing pollutant discharge limits promulgated by the EPA in accordance with section 307 (b) and (c) of the Act. which applies to Industrial Users. This term includes prohibitive discharge limits established pursuant to § 403.5.

(k) The term "New Source" means any building. structure. facility. or installation from which there is or may be a Discharge. the construction of which commenced:

(1) After promulgation of Pretreatment Standards under section 307(c) of the Act which are applicable to such source: or

(2) After proposal of Pretreatment Standards in accordance with section 307(c) of the Act which are applicable to such source. but only if the Standards are promulgated in accordance with section 307(c) within 120 days of their proposal.

(l) The terms "NPDES Permit" or "Permit" means a permit issued to a POTW pursuant to section 402 of the Act.

(m) The term "NPDES State" means a State (as defined in 40 CFR § 122.3) or Interstate water pollution control agency with an NPDES permit program approved pursuant to section 402(b) of the Act.

(n) The term "Pass Through" means the Discharge of pollutants through the POTW into navigable waters in quantities or concentrations which are a cause of or significantly contribute to a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation). An Industrial User significantly contributes to such permit violation where it:

(1) Discharges a daily pollutant loading in excess of that allowed by contract with the POTW or by Federal. State. or local law;

(2) Discharges wastewater which substantially differs in nature and constituents from the User's average Discharge:

(3) Knows or has reason to know that its Discharge. alone or in conjunction with Discharges from other sources. would result in a permit violation: or

(4) Knows or has reason to know that the POTW is. for any reason. violating its final effluent limitations in its permit and that such Industrial User s Discharge either alone or in conjunction with Discharges from other sources. increases the magnitude or duration of the POTW's violations.

(o) The term "Publicly Owned Treatment Works" or "POTW" means treatment works as defined by section

212 of the Act. which is owned by a State or municipality (as defined by section 502(4) of the Act). This definition includes any devices and systems used in the storage. treatment. recycling and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers. pipes and other conveyances only if they convey wastewater to a POTW Treatment Plant. The term also means the municipality as defined in section 502(4) of the Act. which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works.

(p) The term "POTW Treatment Plant" means that portion of the POTW which is designed to provide treatment (including recycling and reclamation) of municipal sewage and industrial waste.

(q) The term "Pretreatment" means the reduction of the amount of pollutants. the elimination of pollutants. or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing such pollutants into a POTW. The reduction or alteration may be obtained by physical. chemical or biological processes. process changes or by other means. except as prohibited by § 403.8(d). Appropriate pretreatment technology includes control equipment. such as equalization tanks or facilities. for protection against surges or slug loadings that might interfere with or otherwise be incompatible with the POTW. However. where wastewater from a regulated process is mixed in an equalization facility with unregulated wastewater or with wastewater from another regulated process. the effluent from the equalization facility must meet an adjusted pretreatment limit calculated in accordance with § 403.6(e).

(r) The term "Pretreatment Requirements" means any substantive or procedural requirement related to Pretreatment. other than a National Pretreatment Standard. imposed on an Industrial User.

(s) The term "Regional Administrator" means the appropriate EPA Regional Administrator.

(t) The term "Submission" means: (1) a request by a POTW for approval of a Pretreatment Program to the EPA or a Director: (2) a request by a POTW to the EPA or a Director for authority to revise the discharge limits in categorical Pretreatment Standards to reflect POTW pollutant removals: or (3) a request to the EPA by an NPDES State for approval of its State pretreatment program.

§ 403.4 State or local law.

Nothing in this regulation is intended to affect any Pretreatment Requirements. including any standards

or prohibitions. established by State or local law as long as the State or local requirements are not less stringent: than any set forth in National Pretreatment Standards. or any other requirements or prohibitions established under the Act or this regulation. States with an NPDES permit program approved in accordance with section 402 (b) and (c) of the Act or States requesting NPDES programs. are responsible for developing a State pretreatment program in accordance with § 403.10 of this regulation.

§ 403.5 National pretreatment standards: prohibited discharges.

(a) General prohibitions. Pollutants introduced into POTW's by an non-domestic source shall not Pass Through the POTW or Interfere with the operation or performance of the works. These general prohibitions and the specific prohibitions in paragraph (b) of this section apply to all non-domestic sources introducing pollutants into a POTW whether or not the source is subject to other National Pretreatment Standards or any national. State. or local Pretreatment Requirements.

(b) Specific prohibitions. In addition. the following pollutants shall not be introduced into a POTW:

(1) Pollutants which create a fire or explosion hazard in the POTW:

(2) Pollutants which will cause corrosive structural damage to the POTW. but in no case Discharges with pH lower than 5.0. unless the works is specifically designed to accommodate such Discharges:

(3) Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in Interference:

(4) Any pollutant. including oxygen demanding pollutants (BOD. etc.) released in a Discharge at a flow rate and/or pollutant concentration which will cause Interference with the POTW.

(5) Heat in amounts which will inhibit biological activity in the POTW resulting in Interference. but in no case heat in such quantities that the temperature at the POTW Treatment Plant exceeds 40°C (104°F) unless the Approval Authority. upon request of the POTW. approves alternate temperature limits.

(c) When Specific Limits Must be Developed by POTW. (1) POTW's developing POTW Pretreatment Programs pursuant to § 403.8 shall develop and enforce specific limits to implement the prohibitions listed in § 403.5 (a) and b .

(2) All other POTW's shall. in cases where pollutants contributed by Users result in Interference or Pass Through. and such violation [...] to recur.

develop and enforce specific effluent limits for Industrial User(s), and all other users, as appropriate, which, together with appropriate changes in the POTW Treatment Plant's Facilities or operation, are necessary to ensure renewed and continued compliance with the POTW's NPDES permit or sludge use or disposal practices.

(3) Specific effluent limits shall not be developed and enforced without individual notice to persons or groups who have requested such notice and an opportunity to respond.

(d) *Local Limits.* Where specific prohibitions or limits on pollutants or pollutant parameters are developed by a POTW in accordance with paragraph (c) above, such limits shall be deemed Pretreatment Standards for the purposes of section 307(d) of the Act.

(e) *EPA and State Enforcement Actions.* If, within 30 days after notice of an Interference or Pass Through violation has been sent by EPA or the NPDES State to the POTW, and to persons or groups who have requested such notice, the POTW fails to commence appropriate enforcement action to correct the violation, EPA or the NPDES State may take appropriate enforcement action.

(f) *Compliance Deadlines.* Compliance with the provisions of this section is required beginning on [44 days after ——— publication in the Federal Register], except for paragraph (b)(5) of this section which must be complied with by August 25, 1981.

### § 403.6  National Pretreatment Standards: Categorical Standards.

National Pretreatment Standards specifying quantities or concentrations of pollutants or pollutant properties which may be Discharged to a POTW by existing or new Industrial Users in specific industrial subcategories will be established as separate regulations under the appropriate subpart of 40 CFR Chapter I, Subchapter N. These Standards, unless specifically noted otherwise, shall be in addition to the general prohibitions established in § 403.5 of this regulation.

(a) *Category Determination Request.* (1) *Application Deadline.* Within 60 days after the effective date of a Pretreatment Standard for a subcategory under which an Industrial User may be included, or within 60 days after the Federal Register notice announcing the availability of the technical development document for that subcategory, whichever is later, the existing Industrial User or POTW may request that the Enforcement Division Director or Director, as appropriate, provide written certification on whether ·

the Industrial User falls within that particular subcategory. A new source must request this certification prior to commencing discharge. Where a request for certification is submitted by a POTW, the POTW shall notify any affected Industrial User of such submission. The Industrial User may provide written comments on the POTW submission to the Enforcement Division Director or Director, as appropriate, within 30 days of notification.

(2) *Contents of application.* Each request shall contain a statement:

(i) Describing which subcategories might be applicable; and

(ii) Citing evidence and reasons why a particular subcategory is applicable and why others are not applicable. Each such statement shall contain an oath stating that the facts contained therein are true on the basis of the applicant's personal knowledge or to the best of his information and belief. The oath shall be that set forth in § 403.7(b)(2)(ii), except that the phrase "§ 403.7(d)" shall be replaced with "§ 403.6(a)."

(3) *Deficient Requests.* The Enforcement Division Director or Director will only act on written requests for determinations that contain all of the information required. Persons who have made incomplete submissions will be notified by the Enforcement Division Director or Director that their requests are deficient and, unless the time period is extended, will be given 30 days to correct the deficiency. If the deficiency is not corrected within 30 days or within an extended period allowed by the Enforcement Division Director or the Director, the request for a determination shall be denied.

(4) *Final Decision.* ·

(i) When the Enforcement Division Director or Director receives a submittal he or she will, after determining that it contains all of the information required by paragraph (2) of this section, consider the submission, any additional evidence that may have been requested, and any other available information relevant to the request. The Enforcement Division Director or Director will then make a written determination of the applicable subcategory and state the reasons for the determination.

(ii) Where the request is submitted to the Director, the Director shall forward the determination described in this paragraph to the Enforcement Division Director who may make a final determination. The Enforcement Division Director may waive receipt of these determinations. If the Enforcement Division Director does not modify the Director's decision within 60 days after receipt thereof, or if the Enforcement Division Director waives receipt of the

determination, the Director's decision is final.

(iii) Where the request is submitted by the Industrial User or POTW to the Enforcement Division Director or where the Enforcement Division Director elects to modify the Director's decision, the Enforcement Division Director's decision will be final.

(iv) The Enforcement Division Director or Director, as appropriate, shall send a copy of the determination to the affected Industrial User and the POTW. Where the final determination is made by the Enforcement Division Director, he or she shall send a copy of the determination to the Director.

(5) *Requests for Hearing and/or Legal Decision.* Within 30 days following the date of receipt of notice of the final determination as provided for by paragraph (a)(4)(iv) of this section, the Requester may submit a petition to reconsider or contest the decision to the Regional Administrator who shall act on such petition expeditiously and state the reasons for his or her determination in writing.

(b) *Deadline for Compliance With Categorical Standards.* Compliance by existing sources with categorical Pretreatment Standards shall be within 3 years of the date the Standard is effective unless a shorter compliance time is specified in the appropriate subpart of 40 CFR Chapter I, Subchapter N but in any case no later than July 1, 1984. Direct Discharges with NPDES permits modified or reissued to provide a variance pursuant to section 301(i)(2) of the Act shall be required to meet compliance dates set forth in any applicable categorical Pretreatment Standard. Existing sources which become Industrial Users subsequent to promulgation of an applicable categorical Pretreatment Standard shall be considered existing Industrial Users except where such sources meet the definition of a New Source as defined in § 403.3(k). Compliance with categorical Pretreatment Standards for New Sources will be required upon promulgation.

(c) *Concentration and Mass Limits.* Pollutant discharge limits in categorical Pretreatment Standards will be expressed either as concentration or mass limits. Wherever possible, where concentration limits are specified in standards, equivalent mass limits will be provided so that local State or Federal authorities responsible for enforcement may use either concentration or mass limits. Limits in categorical Pretreatment Standards shall apply to the effluent of the process regulated by the Standard, or as otherwise specified by the Standard.

(d) *Dilution Prohibited as Substitute for Treatment.* Except where expressly authorized to do so by an applicable categorical Pretreatment Standard. no Industrial User shall ever increase the use of process water or, in any other way, attempt to dilute a Discharge as a partial or complete substitute for adequate treatment to achieve compliance with a categorical Pretreatment Standard. The Control Authority (as defined in § 403.12(a)) may impose mass limitations on Industrial Users which are using dilution to meet applicable Pretreatment Standards or in other cases where the imposition of mass limitations is appropriate.

(e) *Combined Wastestream Formula.* Where process effluent is mixed prior to treatment with wastewaters other than those generated by the regulated process. fixed alternative discharge limits may be derived by the Control Authority. as defined in § 403.12(a). or by the Industrial User with the written concurrence of the Control Authority. These alternative limits shall be applied to the mixed effluent. When deriving alternative categorical limits. the Control Authority or Industrial User shall calculate both an alternative daily maximum value using the daily maximum value(s) specified in the appropriate categorical Pretreatment Standard(s) and an alternative consecutive sampling day average value using the long-term average value(s) specified in the appropriate categorical Pretreatment Standard(s). The Industrial User shall comply with the alternative daily maximum and long-term average limits fixed by the Control Authority until the Control Authority modifies the limits or approves an Industrial User modification request. Modification is authorized whenever there is a material or significant change in the values used in the calculation to fix alternative limits for the regulated pollutant. An Industrial User must immediately report any such material or significant change to the Control Authority. Where appropriate new alternative categorical limits shall be calculated within 30 days.

(1) *Alternative limit calculation.* For purposes of these formulas. the "average daily flow" means a reasonable measure of the average daily flow for a 30-day period. For new sources. flows shall be estimated using projected values. The alternative limit for a specified pollutant will be derived by the use of either of the following formulas:

(i) *Alternative Concentration Limit:*

$$C_T = \left( \dfrac{\sum\limits_{i=1}^{N} C_i P_i}{\sum\limits_{i=1}^{N} P_i} \right) \left( \dfrac{P_T - F_D}{P_T} \right)$$

where

$C_T$ = the alternative concentration limit for the combined wastestream.

$C_i$ = the categorical Pretreatment Standard concentration limit for a pollutant in the regulated stream L

$P_i$ = the average daily flow (at least a 30-day average) of stream i to the extent that it is regulated for such pollutant.

$F_D$ = the average daily flow (at least a 30-day average) from boiler blowdown streams. non-contact cooling streams. sanitary wastestreams (where such streams are not regulated by a categorical Pretreatment Standard) and from any process wastestreams which were or could have been entirely exempted from categorical Pretreatment Standards pursuant to paragraph 8 of the *NRDC v. Costle* Consent Decree (12 ERC 1833) for one or more of the following reasons (see Appendix D):

(1) the pollutants of concern are not detectable in the effluent from the Industrial User (paragraph (8)(a)(iii));

(2) the pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));

(3) the pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or

(4) the wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(i)).

$P_T$ = the average daily flow (at least a 30-day average) through the combined treatment facility (includes $F$, $F_D$ and unregulated streams).

N = the total number of regulated streams.

(ii) *Alternative Mass Limit:*

$$M_T = \left( \sum\limits_{i=1}^{N} M_i \right) \left( \dfrac{P_T - F_D}{\sum\limits_{i=1}^{N} P_i} \right)$$

where

$M_T$ = the alternative mass limit for a pollutant in the combined wastestream.

$M_i$ = the categorical Pretreatment Standard mass limit for a pollutant in the regulated

stream i (the categorical pretreatment mass limit multiplied by the appropriate measure of production).

$F_i$ = the average flow (at least a 30-day average) of stream i to the extent that it is regulated for such pollutant.

$F_D$ = the average flow (at least a 30-day average) from boiler blowdown streams. non-contact cooling streams. sanitary wastestreams (where such streams are not regulated by a categorical Pretreatment Standard) and from any process wastestreams which were or could have been entirely exempted from categorical Pretreatment Standards pursuant to paragraph 8 of the *NRDC v. Costle* Consent Decree (12 ERC 1833) for one or more of the following reasons (see Appendix D):

(1) the pollutants of concern are not detectable in the effluent from the Industrial User (paragraph (8)(a)(iii));

(2) the pollutants of concern are present only in trace amounts and are neither causing nor likely to cause toxic effects (paragraph (8)(a)(iii));

(3) the pollutants of concern are present in amounts too small to be effectively reduced by technologies known to the Administrator (paragraph (8)(a)(iii)); or

(4) the wastestream contains only pollutants which are compatible with the POTW (paragraph (8)(b)(i)).

$F_T$ = the average flow (at least a 30-day average) through the combined treatment facility (includes $F$, $F_D$ and unregulated streams).

N = the total number of regulated streams.

(2) *Alternate Limits Below Detection Limit.* An alternative pretreatment limit may not be used if the alternative limit is below the analytical detection limit for any of the regulated pollutants.

(3) *Self-monitoring.* Self-monitoring required to insure compliance with the alternative categorical limit shall be as follows:

(i) The type and frequency of sampling. analysis and flow measurement shall be determined by reference to the self-monitoring requirements of the appropriate categorical Pretreatment Standard(s);

(ii) Where the self-monitoring schedules for the appropriate Standards differ. monitoring shall be done according to the most frequent schedule;

(iii) Where flow determines the frequency of self-monitoring in a categorical Pretreatment Standard. the sum of all regulated flows (F) is the flow which shall be used to determine self-monitoring frequency.

## § 403.7 Revision of categorical pretreatment standards to reflect POTW removal of pollutants.

This section provides the criteria and procedures to be used by a POTW in revising the pollutant discharge limits specified in categorical Pretreatment Standards to reflect Removal of pollutants by the POTW.

(a) *Definitions.* For the purpose of this section: (1) "Removal" shall mean a reduction in the amount of a pollutant in the POTW's effluent or alteration of the nature of a pollutant during treatment at the POTW. The reduction or alteration can be obtained by physical, chemical or biological means and may be the result of specifically designed POTW capabilities or it may be incidental to the operation of the treatment system. Removal as used in this subpart shall not mean dilution of a pollutant in the POTW. The demonstration of Removal shall consist of data which reflect the Removal achieved by the POTW for those specific pollutants of concern included on the list developed pursuant to section 307(a) of the Act. Each categorical Pretreatment Standard will specify whether or not a Removal Allowance may be granted for indicator or surrogate pollutants regulated in that Standard.

(2) "Consistent Removal" shall mean the average of the lowest 50 percent of the removals measured according to paragraph (d)(2) of this section. All sample data obtained for the measured pollutant during the time period prescribed in paragraph (d)(2) of this section must be reported and used in computing Consistent Removal. If a substance is measurable in the influent but not in the effluent, the effluent level may be assumed to be the limit of measurement, and those data may be used by the POTW at its discretion and subject to approval by the Approval Authority. If the substance is not measurable in the influent the data may not be used. Where the number of samples with concentrations equal to or above the limit of measurement is between 8 and 12, the average of the lowest 6 removals shall be used. If there are less than 8 samples with concentrations equal to or above the limit of measurement, the Approval Authority may approve alternate means for demonstrating Consistent Removal. The term "measurement" refers to the ability of the analytical method or protocol to quantify as well as identify the presence of the substance in question.

(3) "Overflow" means the intentional or unintentional diversion of flow from the POTW before the POTW Treatment Plant.

(b) *Revision of Categorical Pretreatment Standards to Reflect POTW Pollutant Removal.* Any POTW receiving wastes from an Industrial User to which a categorical Pretreatment Standard applies may, subject to the conditions of this section, revise the discharge limits for a specific pollutant(s) covered in the categorical Pretreatment Standard applicable to that User. Revisions will only be made where the POTW demonstrates Consistent Removal of each pollutant for which the discharge limit in a categorical Pretreatment Standard is to be revised at a level which justifies the amount of revision to the discharge limit. In addition, revision of pollutant discharge limits in categorical Pretreatment Standards by a POTW may only be made provided that:

(1) *Application.* The POTW applies for, and receives, authorization from the Regional Administrator and/or Director to revise the discharge limits in Pretreatment Standards, for specific pollutants, in accordance with the requirements and procedures set out in this section and §§ 403.9 and 403.11; and

(2) *POTW Pretreatment Programs.* The POTW has a Pretreatment Program approved in accordance with §§ 403.8, 403.9, and 403.11; provided, however, a POTW may conditionally revise the discharge limits for specific pollutants, even though a Pretreatment Program has not been approved, in accordance with the following terms and conditions. These provision also govern the issuance of provisional authorizations under § 403.7(d)(2)(vii):

(i) All Industrial Users who wish to receive a conditional or provisional revision of categorical Pretreatment Standards must submit to the POTW the information required in § 403.12(b)(1)–(7) pertaining to the categorical Pretreatment Standard as modified by the conditional or provisional removal allowance, except that the compliance schedule required by § 403.12(b)(7) is not required where a provisional allowance is requested. The submission shall indicate what additional technology, if any, will be needed to comply with the categorical Pretreatment Standards as revised by the POTW;

(ii) The POTW must compile and submit data demonstrating removal in accordance with the requirements of paragraphs (d)(1)–(7) of this section. The POTW shall submit to the Approval Authority a removal report which comports with the signatory and certification requirements of § 403.12 (l) and (m). This report shall contain a certification by any of the persons specified in § 403.12(1) or by an

independent engineer containing the following statement: "I have personally examined and am familiar with the information submitted in the attached document, and I hereby certify under penalty of law that this information was obtained in accordance with the requirements of § 403.7(d). Moreover, based upon my inquiry of those individuals immediately responsible for obtaining the information reported herein, I believe that the submitted information is true. accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.";

(iii) The POTW must submit to the Approval Authority an application for pretreatment program approval meeting the requirements of §§ 403.8 and 403.9(a or (b) in a timely manner, not to exceed the time limitation set forth in a compliance schedule for development o a pretreatment program included in the POTW's NPDES permit;

(iv) If a POTW grants conditional or provisional revision(s) and the Approve Authority subsequently makes a final determination, after notice and an opportunity for a hearing, that the POTW failed to comply with the conditions in paragraphs (b)(2)(ii) or (iii of this section, or that its sludge use or disposal practices are not in compliance with the provisions of paragraph (b)(4) of this section, the revision shall be terminated by the Approval Authority and all Industrial Users to whom the revised discharge limits had been applied shall achieve compliance with the applicable categorical Pretreatment Standard(s) within a reasonable time (not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s)) as specified by the Approval Authority. However, the revision(s) shall not be terminated where the POTW has not made a timel: application for program approval if the POTW has made demonstrable progres towards and has demonstrated and continues to demonstrate an intention t submit an approvable pretreatment program as expeditiously as possible within an additional period of time, not to exceed one year. established by the Approval Authority;

(v) If a POTW grants conditional or provisional revision(s) and the POTW of Approval Authority subsequently make a final determination, after notice and an opportunity for a hearing, that the Industrial User(s) failed to comply with conditions in paragraph (b)(2)(i) of this section, including in the case of a conditional revision, the dates specifie in the compliance schedule required by

127

§ 403.12(b)(7), the revision shall be terminated by the POTW or the Approval Authority for the non-complying Industrial Users and all non-complying Industrial Users to whom the revised discharge limits had been applied shall achieve compliance with the applicable categorical Pretreatment standard(s) within the time period specified in such Standard(s). The revision(s) shall not be terminated where a violation of the provisions of this subparagraph results from causes entirely outside of the control of the Industrial User or the Industrial User has demonstrated substantial compliance; and

(vi) The POTW shall submit to the Approval Authority by December 31 of each year the name and address of each Industrial User that has received a conditionally or provisionally revised discharge limit. If the revised discharge limit is revoked, the POTW must submit the information in paragraph (b)'2)(i) above to the Approval Authority.

(3) *Compensation for overflow.* POTW's which at least once annually Overflow untreated wastewater to receiving waters may claim Consistent Removal of a pollutant only by complying with either paragraphs (b)(3)(i) or (ii) below. However, this subsection shall not apply where Industrial User(s) can demonstrate that Overflow does not occur between the Industrial User(s) and the POTW Treatment Plant:

(i) The Industrial User provides containment or otherwise ceases or reduces Discharges from the regulated processes which contain the pollutant for which an allowance is requested during all circumstances in which an Overflow event can reasonably be expected to occur at the POTW or at a sewer to which the Industrial User is connected. Discharges must cease or be reduced. or pretreatment must be increased. to the extent necessary to compensate for the removal not being provided by the POTW. Allowances under this provision will only be granted where the POTW submits to the Approval Authority evidence that:

(A) All Industrial Users to which the POTW proposes to apply this provision have demonstrated the ability to contain or otherwise cease or reduce. during circumstances in which an Overflow event can reasonably be expected to occur. Discharges from the regulated processes which contain pollutants for which an allowance is requested:

(B) The POTW has identified circumstances in which an Overflow event can reasonably be expected to occur. and has a notification or other

viable plan to insure that Industrial Users will learn of an impending Overflow in sufficient time to contain. cease or reduce Discharging to prevent untreated Overflows from occurring. The POTW must also demonstrate that it will monitor and verify the data required in paragraph (b)(3)(i)(C) herein to insure that Industrial Users are containing, ceasing or reducing operations during POTW System Overflow: and

(C) All Industrial Users to which the POTW proposes to apply this provision have demonstrated the ability and commitment to collect and make available upon request by the POTW. State Director or EPA Regional Administrator daily flow reports or other data sufficient to demonstrate that all Discharges from regulated processes containing the pollutant for which the allowance is requested were contained. reduced or otherwise ceased, as appropriate. during all circumstances in which an Overflow event was reasonably expected to occur; or

(ii)(A) The Consistent Removal claimed is reduced pursuant to the following equation:

$$r_c = r_m \frac{8760 - Z}{8760}$$

Where:

$r_c$ = POTW's Consistent Removal rate for that pollutant as established under paragraphs (a)(1) and (d)(2) of this section

$r_m$ = removal corrected by the Overflow factor

$Z$ = hours per year that Overflow occurred between the Industrial User(s) and the POTW Treatment Plant the hours either to be shown in the POTW's current NPDES permit application or the hours, as demonstrated by verifiable techniques. that a particular Industrial User's Discharge Overflows between the Industrial User and the POTW Treatment Plant and

(B)(1) After July 1, 1983. Consistent Removal may be claimed only where efforts to correct the conditions resulting in untreated Discharges by the POTW are underway in accordance with the policy and procedures set forth in "PRM 75–34" or "Program Guidance Memorandum–61" (same document) published on December 18, 1975 by EPA Office of Water Program Operations (WH–546). (See Appendix A.) Revisions to discharge limits in categorical Pretreatment Standards may not be made where efforts have not been committed to by the POTW to minimize pollution from Overflows. At minimum.

by July 1, 1983. the POTW must have completed the analysis required by PRM 75–34 and be making an effort to implement the plan.

(2) If. by July 1, 1983. a POTW has begun the PRM 75–34 analysis but due to circumstances beyond its control has not completed it. Consistent Removal subject to the approval of the Approval Authority. may continue to be claimed according to the formula in paragraph (b)(3)(ii)(A) above so long as the POTW acts in a timely fashion to complete the analysis and makes an effort to implement the non-structural cost-effective measures identified by the analysis: and so long as the POTW has expressed its willingness to apply. after completing the analysis. for a construction grant necessary to implement any other cost-effective Overflow controls identified in the analysis should federal funds become available. so applies for such funds. and proceeds with the required construction in an expeditious manner. In addition. Consistent Removal may. subject to the approval of the Approval Authority. continue to be claimed according to the formula in paragraph (b)(3)(ii)(A) above where the POTW has completed and the Approval Authority has accepted the analysis required by PRM 75–34 and the POTW has requested inclusion in its NPDES permit of an acceptable compliance schedule providing for timely implementation of cost-effective measures identified in the analysis. (In considering what is timely implementation. the Approval Authority shall consider the availability of funds. cost of control measures. and seriousness of the water quality problem.): and

(4) *Compliance with applicable sludge requirements.* Such revision will not contribute to the POTW's inability to comply with its NPDES permit or with the following statutory provisions and regulations or permits issued thereunder (or more stringent State or local regulations) as they apply to the sludge management methods being used: section 405 of the Clean Water Act; the Solid Waste Disposal Act (SWDA) (including Title II. more commonly referred to as the Resource Conservation Recovery Act (RCRA) and including State regulations contained in any State sludge management plan prepared pursuant to Subtitle D of SWDA)). the Clean Air Act and the Toxic Substances Control Act. The POTW will be authorized to revise discharge limits only for those pollutants that do not contribute to the violation of

its NPDES permit or any of the above statutes.

(c) *POTW application for authorization to revise discharge limits.* (1) Application for authorization to revise discharge limits for Industrial Users who are or in the future may be subject to categorical Pretreatment Standards, or approval of discharge limits conditionally or provisionally revised for Industrial Users by the POTW pursuant to paragraphs (b)(2) and (d)(2)(vii) shall be submitted by the POTW to the Approval Authority.

(2) Each POTW may submit such an application no more than once per year with respect to either:

- (i) any categorical Pretreatment Standard promulgated in the prior 18 months;

(ii) any new or modified facilities or production changes resulting in the Discharge of pollutants which were not previously discharged and which are subject to promulgated categorical Standards; or

- (iii) any significant increase in Removal efficiency attributable to specific identifiable circumstances or corrective measures (such as improvements in operation and maintenance practices, new treatment or treatment capacity, or a significant change in the influent to the POTW Treatment Plant).

- (3) The Approval Authority may, however, elect not to review such application(s) upon receipt, in which case the POTW's conditionally or provisionally revised discharge limits will remain in effect until reviewed by the Approval Authority. This review may occur at any time in accordance with the procedures of § 403.11, but in no event later than the time of any pretreatment program approval or any NPDES permit reissuance thereafter.

(4) If the Consistent Removal claimed is based on an analytical technique other than the technique specified for the applicable categorical Pretreatment Standard, the Approval Authority may require the POTW perform additional analyses.

(d) *Contents of application to revise discharge limits.* Requests for authorization to revise discharge limits in categorical Pretreatment Standards must be supported by the following information:

(1) *List of Pollutants.* A list of pollutants for which discharge limit revisions are proposed.

(2) *Consistent Removal Data.* Influent and effluent operational data demonstrating Consistent Removal or other information, as provided for in paragraph (a)(2) of this section, which demonstrates Consistent Removal of the

pollutants for which discharge limit revisions are proposed. This data shall meet the following requirements:

(i) *Representative Data: Seasonal.* The data shall be representative of yearly and seasonal conditions to which the POTW is subjected for each pollutant for which a discharge limit revision is proposed.

(ii) *Representative Data: Quality and Quantity.* The data shall be representative of the quality and quantity of normal effluent and influent flow if such data can be obtained. If such data are unobtainable, alternate data or information may be presented for approval to demonstrate Consistent Removal as provided for in paragraph (a)(2) of this section.

(iii) *Sampling Procedures: Composite.* (A) The influent and effluent operational data shall be obtained through 24-hour flow-proportional composite samples. Sampling may be done manually or automatically, and discretely or continuously. For discrete sampling, at least 12 aliquots shall be composited. Discrete sampling may be flow-proportioned either by varying the time interval between each aliquot or the volume of each aliquot. All composites must be flow-proportional to either stream flow at time of collection of influent aliquot or to the total influent flow since the previous influent aliquot. Volatile pollutant aliquots must be combined in the laboratory immediately before analysis.

(B)(1) Twelve samples shall be taken at approximately equal intervals throughout one full year. Sampling must be evenly distributed over the days of the week so as to include non-workdays as well as workdays. If the Approval Authority determines that this schedule will not be most representative of the actual operation of the POTW Treatment Plant, an alternative sampling schedule will be approved.

(2) In addition, upon the Approval Authority's concurrence, a POTW may utilize an historical data base amassed prior to the effective date of this section provided that such data otherwise meet the requirements of this paragraph. In order for the historical data base to be approved it must present a statistically valid description of daily, weekly and seasonal sewage treatment plant loadings and performance for at least one year.

(C) Effluent sample collection need not be delayed to compensate for hydraulic detention unless the POTW elects to include detention time compensation or unless the Approval Authority requires detention time compensation. The Approval Authority may require that each effluent sample

be taken approximately one detention time later than the corresponding influent sample when failure to do so would result in an unrepresentative portrayal of actual POTW operation. The detention period is to be based on a 24-hour average daily flow value. The average daily flow used will be based upon the average of the daily flows during the same month of the previous year.

(iv) *Sampling Procedures: Grab.* Where composite sampling is not an appropriate sampling technique, a grab sample(s) shall be taken to obtain influent and effluent operational data. Collection of influent grab samples should preceed collection of effluent samples by approximately one detention period. The detention period is to be based on a 24-hour average daily flow value. The average daily flow used will be based upon the average of the daily flows during the same month of the previous year. Grab samples will be required, for example, where the parameters being evaluated are those, such as cyanide and phenol, which may not be held for any extended period because of biological, chemical or physical interactions which take place after sample collection and affect the results. A grab sample is an individual sample collected over a period of time not exceeding 15 minutes.

(v) *Analytical methods.* The sampling referred to in paragraphs (d)(2)(i)–(iv) and (d)(5) of this section and an analysis of these samples shall be performed in accordance with the techniques prescribed in 40 CFR Part 136 and amendments thereto. Where 40 CFR Part 136 does not contain sampling or analytical techniques for the pollutant in question, or where the Administrator determines that the Part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analysis shall be performed using validated analytical methods or any other applicable sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator.

(vi) *Calculation of removal.* All data acquired under the provisions of this section must be submitted to the Approval Authority. Removal for a specific pollutant shall be determined either, for each sample, by measuring the difference between the concentrations of the pollutant in the influent and effluent of the POTW and expressing the difference as a percent of the influent concentration, or, where such data cannot be obtained. Removal may be demonstrated using other data

or procedures subject to concurrence by the Approval Authority as provided for in paragraph (a)(2) of this section.

(vii) *Exception to sampling data requirement: provisional removal demonstration.* For pollutants which are not currently being discharged (new or modified facilities, or production changes) application may be made by the POTW for provisional authorization to revise the applicable categorical Pretreatment Standard prior to initial discharge of the pollutant. Consistent Removal may be based provisionally on data from treatability studies or demonstrated removal at other treatment facilities where the quality and quantity of influent are similar. In calculating and applying for provisional removal allowances, the POTW must comply with the provisions of paragraphs (b)(1)–(4) of this section. Within 18 months after the commencement of Discharge of the pollutants in question. Consistent Removal must be demonstrated pursuant to the requirements of paragraphs (a)(2) and (d)(2)(i)–(vi) of this section.

(3) *List of industrial subcategories.* A list of the industrial subcategories for which discharge limits in categorical Pretreatment Standards will be revised. including the number of Industrial Users in each such subcategory and an identification of which of the pollutants on the list prepared under paragraph (d)(1) of this section are Discharged by each subcategory.

(4) *Calculation of revised discharge limits.* Proposed revised discharge limits for each of the subcategories of Industrial Users identified in paragraph (d)(3) of this section calculated in the following manner:

(i) The proposed revised discharge limit for a specified pollutant shall be derived by use of the following formula:

$$Y = \frac{x}{1-r}$$

where:

x = pollutant discharge limit specified in the applicable categorical Pretreatment Standard
r = POTW's Consistent Removal rate for that pollutant as established under paragraphs (a)(2), (d)(2) and. if appropriate. (b)(3)(ii)(A) of this section. (percentage expressed as a decimal)
Y = revised discharged limit for the

specified pollutant (expressed in same units as x)

(ii) In calculating revised discharge limits. such revision for POTW Removal of a specified pollutant shall be applied equally to all existing and new Industrial Users in an industrial subcategory subject to categorical Pretreatment Standards which Discharge that pollutant to the POTW.

(5) *Data on sludge characteristics.* Data showing the concentrations and amounts in the POTW's sludge of the pollutants for which discharge limit revisions are proposed and for which EPA. the State or locality have published sludge disposal or use criteria applicable to the POTW's current method of sludge use or disposal. These data shall meet the following requirements.

(i) The data shall be obtained through a composite sample taken during the same sampling periods selected to measure Consistent POTW Removals in accordance with the requirements of paragraph (d)(2) of this section. Each composite sample will contain a minimum of 12 discrete samples taken at equal time intervals over a 24 hour period. Where a composite sample is not an appropriate sampling technique, grab samples shall be taken.

(ii) Sampling and analysis of the samples referred to in paragraph (d)(5)(i) of this section shall be performed in accordance with the sampling and analytical techniques described previously in paragraph (d)(2)(v) of this section.

(6) *Description of sludge management.* A specific description of the POTW's current methods of use or disposal of its sludge and data demonstrating that the current sludge use or disposal methods comply and will continue to comply with the requirements of paragraph (b)(4) of this section.

(7) *Certification statement.* The certification statement required by paragraph (b)(2)(ii) of this section stating that the pollutant Removals and associated revised discharged limits have been or will be calculated in accordance with this regulation and any guidelines issued by EPA under Section 304(g) of the Act.

(e) *Procedure for authorizing modification of standards.* (1) Application for authorization to revise National Pretreatment Standards shall comply with § 403.9(d) and paragraphs (c) and (d) of this section. Notice. public comment. and review by the Approval

Authority shall comply with § 403.11.

(2) POTW's which have received a construction grant from funds authorized for any fiscal year beginning after September 30, 1978. will only be considered for authorization to modify National Standards after they have completed the analysis required by section 201(g)(5) of the Act and demonstrated that modification of the discharge limits in National Standards will not preclude the use of innovative or alternative technology. In addition. where sludge disposal or treatment technology is or will be acquired or constructed with construction grant funds. POTWs should refer to § 35.917(d)(6) and Appendix A of Part 35 of Title 40 of the Code of Federal Regulations to determine the funding eligibility of sludge disposal or treatment facilities.

(3) The Approval Authority shall. at such time as it elects to review the Submission under paragraph (c) of this section. or at the time of POTW pretreatment program approval or NPDES permit reissuance thereafter. authorize the POTW to revise Industrial User discharge limits. as submitted pursuant to paragraph (d)(4) of this section. which comply with the provisions of this section.

(4) Nothing in these regulations precludes an Industrial User or other interested party from assisting the POTW in preparing and presenting the information necessary to apply for authorization to revise categorical Pretreatment Standards.

(f) *Continuation and withdrawal of authorization.* (1) *Monitoring and reporting of consistent removal.* Following authorization to revise the discharge limits in Pretreatment Standards. the POTW shall continue to monitor and report on (at such frequencies and over such intervals as may be specified by the Regional Administrator. but in no case less than two times per year) the POTW's Removal capabilities for all pollutants for which authority to revise the Standards was granted. Such monitoring and reporting shall be in accordance with § 403.12 (i) and (j) pertaining to pollutant removal capability reports.

(2) *Re-evaluation of revisions.* Approval of authority to revise Pretreatment Standards will be re-examined whenever the POTW's NPDES Permit is reissued. unless the Regional Administrator determines the need to re-evaluate the authority pursuant to paragraph (f)(5) of this section. In order

to maintain a removal allowance, the POTW must comply with all federal, State and local Statutes, regulations and permits applicable to the POTWs selected method of sludge use or disposal. In addition, where Overflows of untreated waste by the POTW continue to occur the Regional Administrator may condition continued authorization to revise discharge limits upon the POTW performing additional analysis and/or implementing additional control measures as is consistent with EPA policy on POTW Overflows.

(3) *Inclusion in POTW permit.* Once authority to revise discharge limits for a specified pollutant is granted, the revised discharge limits for Industrial Users of the system as well as the Consistent Removal documented by the POTW for that pollutant and the other requirements of paragraph (b) of this section, shall be included in the POTW's NPDES Permit upon the earliest reissuance or modification (at or following Program approval) and shall become enforceable requirements of the POTW's NPDES Permit.

(4) *EPA review of state removal allowance approvals.* Where the NPDES State has an approved pretreatment program, the Regional Administrator may agree, in the Memorandum of Agreement under 40 CFR 123.7, to waive the right to review and object to Submissions for authority to revise discharge limits under this section. Such an agreement shall not restrict the Regional Administrator's right to comment upon or object to permits issued to POTW's except to the extent permitted under 40 CFR 123.7(b)(3)(i)(D).

(5) *Modification or withdrawal of revised limits.*—(i) *Notice to POTW.* The Approval Authority shall notify the POTW if, on the basis of pollutant removal capability reports received pursuant to paragraph (f)(1) of this section or other information available to it, the Approval Authority determines:

(A) that one or more of the discharge limit revisions made by the POTW, or the POTW itself, no longer meets the requirements of this section, or

(B) that such discharge limit revisions are causing or significantly contributing to a violation of any conditions or limits contained in the POTW's NPDES Permit. A revised discharge limit is significantly contributing to a violation of the POTW's permit if it satisfies the definition set forth in § 40.33 (i) or (n).

(ii) *Corrective action.* If appropriate corrective action is not taken within a reasonable time, not to exceed 60 days unless the POTW or the affected Industrial Users demonstrate that a longer time period is reasonably

necessary to undertake the appropriate corrective action, the Approval Authority shall either withdraw such discharge limits or require modifications in the revised discharge limits.

(iii) *Public notice of withdrawal or modification.* The Approval Authority shall not withdraw or modify revised discharge limits unless it shall first have notified the POTW and all Industrial Users to whom revised discharge limits have been applied, and made public, in writing, the reasons for such withdrawal or modification, and an opportunity is provided for a hearing. Following such notice and withdrawal or modification, all Industrial Users to whom revised discharge limits had been applied, shall be subject to the modified discharge limits or the discharge limits prescribed in the applicable categorical Pretreatment Standards, as appropriate, and shall achieve compliance with such limits within a reasonable time (not to exceed the period of time prescribed in the applicable categorical Pretreatment Standard(s) as may be specified by the Approval Authority.

(g) *Removal allowances in State-run pretreatment programs under § 403.10(e).* Where an NPDES State with an approved pretreatment program elects to implement a local pretreatment program in lieu of requiring the POTW to develop such a program (see § 403.10(e)) the POTW shall nevertheless be responsible for demonstrating Consistent Removal as provided for in this section. The POTW will not, however, be required to develop a pretreatment program as a precondition to obtaining approval of the allowance as required by paragraph (b)(2) of this section. Instead, before a removal allowance is approved, the State will be required to demonstrate that sufficient technical personnel and resources are available to ensure that modified discharge limits are correctly applied to affected Users and that Consistent Removal is maintained.

**§ 403.8 POTW pretreatment programs: development by POTW.**

(a) *POTW's required to develop a pretreatment program.* Any POTW (of combination of POTW's operated by the same authority) with a total design flow greater than 5 million gallons per day (mgd) and receiving from Industrial Users pollutants which Pass Through or Interfere with the operation of the POTW or are otherwise subject to Pretreatment Standards will be required to establish a POTW Pretreatment Program unless the NPDES State exercises its option to assume local responsibilities as provided for in § 403.10(e). The Regional Administrator

or Director may require that a POTW with a design flow of 5 mgd or less develop a POTW Pretreatment Program if he or she finds that the nature or volume of the industrial influent, treatment process upsets, violations of POTW effluent limitations, contamination of municipal sludge, or other circumstances warrant in order to prevent Interference with the POTW or Pass Through. In addition, any POTW desiring to modify categorical Pretreatment Standards for pollutants Removed by the POTW (as provided for by § 403.7) must have an approved POTW Pretreatment Program prior to obtaining final approval of a removal allowance. POTW's may receive conditional approval of a removal allowance, as provided for by § 403.7(b)(2), prior to obtaining POTW Pretreatment Program Approval. A POTW may receive § 403.7(g) authority to revise Pretreatment Standards without being required to develop a POTW Pretreatment Program where the NPDES State has assumed responsibility for running a local program in lieu of the POTW in accordance with § 403.10(e).

(b) *Deadline for Program Approval.* A POTW which meets the criteria of paragraph (a) of this section must receive approval of a POTW Pretreatment Program no later than 3 years after the reissuance or modification of its existing NPDES-permit but in no case later than July 1, 1983. POTW's whose NPDES permits are modified under section 301(h) of the Act, shall have a Pretreatment Program within less than 3 years as provided for in 40 CFR Part 125. Subpart G (44 FR 34783 (1979). The POTW Pretreatment Program shall meet the criteria set forth in paragraph (f) of this section and will be administered by the POTW to ensure compliance by Industrial Users with applicable Pretreatment Standards and Requirements.

(c) *Incorporation of approved programs in permits.* A POTW may develop an approvable POTW Pretreatment Program any time before the time limit set forth in paragraph (b) of this section. If (1) the POTW is located in a State which has an approved State permit program under section 402 of the Act and an approved State pretreatment program in accordance with § 403.10; or (2) the POTW is located in a State which does not have an approved permit program under section 402 of the Act: the POTW's NPDES Permit will be reissued or modified by the NPDEs State or EPA. respectively, to incorporate the approved Program conditions as enforceable conditions of the Permit. If

the POTW is located in an NPDES State which does not have an approved State pretreatment program. the approved POTW Pretreatment Program shall be incorporated into the POTW's NPDES Permit as provided for in § 403.10(d).

(d) *Incorporation of compliance schedules in permits.* If the POTW does not have an approved Pretreatment Program at the time the POTW's existing Permit is reissued or modified, the reissued or modified Permit will contain the shortest reasonable compliance schedule. not to exceed three years or July 1. 1983. whichever is sooner. for the approval of the legal authority, procedures and funding required by paragraph (f) of this section. Where the POTW is located in an NPDES State currently without authority to require a POTW Pretreatment Program. the Permit shall incorporate a modification or termination clause as provided for in § 403.10(d) and the compliance schedule shall be incorporated when the Permit is modified or reissued pursuant to such clause.

(e) *Cause for Reissuance or Modification of Permits.* Under the authority of section 402(b)(1)(C) of the Act. the Approval Authority may modify, or alternatively, revoke and reissue a POTW's Permit in order to:

(1) put the POTW on a compliance schedule for the development of a POTW Pretreatment Program where the addition of pollutants into a POTW by an Industrial User or combination of Industrial Users presents a substantial hazard to the functioning of the treatment works. quality of the receiving waters, human health. or the environment;

(2) coordinate the issuance of a section 201 construction grant with the incorporation into a permit of a compliance schedule for POTW Pretreatment Program:

(3) incorporate a modification of the permit approved under sections 301(h) or 301(i) of the Act;

(4) incorporate an approved POTW Pretreatment Program in the POTW permit; or

(5) incorporate a compliance schedule for the development of a POTW pretreatment program in the POTW permit.

(f) *POTW pretreatment program requirements.* A POTW Pretreatment Program shall meet the following requirements:

(1) *Legal Authority.* The POTW shall operate pursuant to legal authority enforceable in Federal. State or local courts. which authorizes or enables the POTW to apply and to enforce the requirements of sections 307 (b) and (c),

and 402(b)(8) of the Act and any regulations implementing those sections. Such authority may be contained in a statute. ordinance. or series of contracts or joint powers agreements which the POTW is authorized to enact. enter into or implement. and which are authorized by State law. At a minimum. this legal authority shall enable the POTW to:

(i) Deny or condition new or increased contributions of pollutants, or changes in the nature of pollutants. to the POTW by Industrial Users where such contributions do not meet applicable Pretreatment Standards and Requirements or where such contributions would cause the POTW to violate its NPDES permit;

(ii) Require compliance with applicable Pretreatment Standards and Requirements by Industrial Users;

(iii) Control. through permit. contract. order. or similar means. the contribution to the POTW by each Industrial User to ensure compliance with applicable Pretreatment Standards and Requirements;

(iv) Require (A) the development of a compliance schedule by each Industrial User for the installation of technology required to meet applicable Pretreatment Standards and Requirements and (B) the submission of all notices and self-monitoring reports from Industrial Users as are necessary to assess and assure compliance by Industrial Users with Pretreatment Standards and Requirements. including but not limited to the reports required in § 403.12;

(v) Carry out all inspection. surveillance and monitoring procedures necessary to determine. independent of information supplied by Industrial Users. compliance or noncompliance with applicable Pretreatment Standards and Requirements by Industrial Users. Representatives of the POTW shall be authorized to enter any premises of any Industrial User in which a Discharge source or treatment system is located or in which records are required to be kept under § 403.12(m) to assure compliance with Pretreatment Standards. Such authority shall be at least as extensive as the authority provided under section 308 of the Act;

(vi) (A) Obtain remedies for noncompliance by any Industrial User with any Pretreatment Standard and Requirement. All POTW's shall be able to seek injuctive relief for noncompliance by Industrial Users with Pretreatment Standards and Requirements. In cases where State law has authorized the municipality or POTW to pass ordinances or other local legislation. the POTW shall exercise such authorities in passing legislation to

seek and assess civil or criminal penalties for noncompliance by Industrial Users with Pretreatment Standards and Requirements. POTW's without such authorities shall enter into contracts with Industrial Users to assure compliance by Industrial Users with Pretreatment Standards and Requirements. An adequate contract will provide for liquidated damages for violation of Pretreatment Standards and Requirements and will include an agreement by the Industrial User to submit to the remedy of specific performance for breach of contract.

(B) Pretreatment Requirements which will be enforced through the remedies set forth in paragraph (f)(1)(vi)(A) will include but not be limited to. the duty to allow or carry out inspections. entry. or monitoring activities: any rules. regulations. or orders issued by the POTW; or any reporting requirements imposed by the POTW or these regulations. The POTW shall have authority and procedures (after informal notice to the discharger) immediately and effectively to halt or prevent any Discharge of pollutants to the POTW which reasonably appears to present an imminent endangerment to the health or welfare of persons. The POTW shall also have authority and procedures (which shall include notice to the affected Industrial Users and an opportunity to respond) to halt or prevent any Discharge to the POTW which presents or may present an endangerment to the environment or which threatens to interfere with the operation of the POTW. The Approval Authority shall have authority to seek judicial relief for noncompliance by Industrial Users when the POTW has acted to seek such relief but has sought a penalty which the Approval Authority finds to be insufficient. The procedures for notice to dischargers where the POTW is seeking *ex parte* temporary judicial injunctive relief will be governed by applicable state or federal law and not by this provision: and

(vii) Comply with the confidentiality requirements set forth in § 403.14.

(2) *Procedures.* The POTW shall develop and implement procedures to ensure compliance with the requirements of a Pretreatment Program. At a minimum. these procedures shall enable the POTW to:

(i) Identify and locate all possible Industrial Users which might be subject to the POTW Pretreatment Program. Any compilation. index or inventory of Industrial Users made under this paragraph shall be made available to the Regional Administrator or Director upon request;

(ii) Identify the character and volume of pollutants contributed to the POTW by the Industrial Users identified under § 403.8(f)(2)(i). This information shall be made available to the Regional Administrator or Director upon request;

(iii) Notify Industrial Users identified under § 403.8(f)(2)(i) of applicable Pretreatment Standards and any applicable requirements under section 204(b) and 405 of the Act and Subtitles C and D of the Resource Conservation and Recovery Act.

(iv) Receive and analyze self-monitoring reports and other notices submitted by Industrial Users in accordance with the self-monitoring requirements in § 403.12;

(v) Randomly sample and analyze the effluent from Industrial Users and conduct surveillance and inspection activities in order to identify, independent of information supplied by Industrial Users, occasional and continuing noncompliance with Pretreatment Standards. The results of these activities shall be made available to the Regional Administrator or Director upon request;

(vi) Investigate instances of noncompliance with Pretreatment Standards and Requirements, as indicated in the reports and notices required under § 403.12, or indicated by analysis, inspection, and surveillance activities described in paragraph (f)(2)(v) of this section. Sample taking and analysis and the collection of other information shall be performed with sufficient care to produce evidence admissible in enforcement proceedings or in judicial actions; and

(vii) Comply with the public participation requirements of 40 CFR Part 25 in the enforcement of National Pretreatment Standards. These procedures shall include provision for at least annually providing public notification, in the largest daily newspaper published in the municipality in which the POTW is located, of Industrial Users which, during the previous 12 months. were significantly violating applicable Pretreatment Standards or other Pretreatment Requirements. For the purposes of this provision, a significant violation is a violation which remains uncorrected 45 days after notification of noncompliance: which is part of a pattern of noncompliance over a twelve month period: which involves a failure to accurately report noncompliance: or which resulted in the POTW exercising its emergency authority under § 403.8(f)(1)(iv)(B).

(3) *Funding.* The POTW shall have sufficient resources and qualified personnel to carry out the authorities

and procedures described in paragraphs (f) (1) and (2) of this section. In some limited circumstances. funding and personnel may be delayed where (i) the POTW has adequate legal authority and procedures to carry out the Pretreatment Program requirements described in this section. and (ii) a limited aspect of the Program does not need to be implemented immediately (see § 403.9(b)).

**§ 403.9 POTW pretreatment programs and/or authorization to revise pretreatment standards: submission for approval.**

(a) *Who Approves Program.* A POTW requesting approval of a POTW Pretreatment Program shall develop a program description which includes the information set forth in paragraphs (b)(1)-(4) of this section. This description shall be submitted to the Approval Authority which will make a determination on the request for program approval in accordance with the procedures described in § 403.11.

(b) *Contents of POTW program submission.* The program description must contain the following information:

(1) A statement from the City Solicitor or a city official acting in a comparable capacity (or the attorney for those POTWs which have independent legal counsel) that the POTW has authority adequate to carry out the programs described in § 403.8. This statement shall:

(i) Identify the provision of the legal authority under § 403.8(f)(1) which provides the basis for each procedure under § 403.8(f)(2);

(ii) Identify the manner in which the POTW will implement the program requirements set forth in § 403.8, including the means by which Pretreatment Standards will be applied to individual Industrial Users (e.g., by order. permit. ordinance, contract, etc.); and.

(iii) Identify how the POTW intends to ensure compliance with Pretreatment Standards and Requirements, and to enforce them in the event of noncompliance by Industrial Users;

(2) A copy of any statutes, ordinances, regulations. contracts. agreements, or other authorities relied upon by the POTW for its administration of the Program. This Submission shall include a statement reflecting the endorsement or approval of the local boards or bodies responsible for supervising and/or funding the POTW Pretreatment Program if approved;

(3) A brief description (including organization charts) of the POTW organization which will administer the Pretreatment Program. If more than one agency is responsible for administration

of the Program the responsible agencies should be identified. their respective responsibilities delineated, and their procedures for coordination set forth: and

(4) A description of the funding levels and full- and part-time manpower available to implement the Program;

(c) *Conditional POTW program approval.* The POTW may request conditional approval of the Pretreatment Program pending the acquisition of funding and personnel for certain elements of the Program. The request for conditional approval must meet the requirements set forth in paragraph (b) of this section except that the requirements of paragraph (b) may be relaxed if the Submission demonstrate that:

(1) A limited aspect of the Program does not need to be implemented immediately;

(2) The POTW had adequate legal authority and procedures to carry out those aspects of the Program which wi not be implemented immediately; and

(3) Funding and personnel for the Program aspects to be implemented at later date will be available when needed. The POTW will describe in th Submission the mechanism by which this funding will be acquired. Upon receipt of a request for conditional approval, the Approval Authority will establish a fixed date for the acquisiti of the needed funding and personnel. funding is not acquired by this date, th conditional approval of the POTW Pretreatment Program and any remov allowances granted to the POTW, ma be modified or withdrawn.

(d) *Content of removal allowance submission.* The request for authority revise categorical Pretreatment Standards must contain the informati required in § 403.7(d).

(e) *Approval authority action.* Any POTW requesting POTW Pretreatmer Program approval shall submit to the Approval Authority three copies of th Submission described in paragraph (b and. if appropriate. (d) of this section Upon a preliminary determination tha the Submission meets the requiremen of paragraph (b) and. if appropriate. ( of this section. the Approval Authori shall:

(1) Notify the POTW that the Submission has been received and is under review; and

(2) Commence the public notice an evaluation activities set forth in § 40;

(f) *Notification where submission* defective. If. after review of the Submission as provided for in paragr (e) of this section. the Approval Authority determines that the Submission does not comply with th

requirements of paragraph (b) or (c), and, if appropriate. (d). of this section. the Approval Authority shall provide notice in writing to the applying POTW and each person who has requested individual notice. This notification shall identify any defects in the Submission and advise the POTW and each person who has requested individual notice of the means by which the POTW can comply with the applicable requirements of paragraphs (b), (c), and, if appropriate. (d) of this section.

(g) *Consistency with water quality management plans.* (1) In order to be approved the POTW Pretreatment program shall be consistent with any approved water quality management plan developed in accordance with 40 CFR Parts 130, 131, as revised, where such 208 plan includes Management Agency designations and addresses pretreatment in a manner consistent with 40 CFR Part 403. In order to assure such consistency the Approval Authority shall solicit the review and comment of the appropriate 208 planning Agency during the public comment period provided for in 403.11(b)(1)(ii) prior to approval or disapproval of the Program.

(2) Where no 208 plan has been approved or where a plan has been approved but lacks Management Agency designations and/or does not address pretreatment in a manner consistent with this regulation, the Approval Authority shall nevertheless solicit the review and comment of the appropriate 208 planning agency.

**§ 403.10 Development and submission of NPDES State pretreatment programs.**

(a) *Approval of State Programs.* No State NPDES program shall be approved under section 402 of the Act after the effective date of these regulations unless it is determined to meet the requirements of paragraph (f) of this section. Notwithstanding any other provision of this regulation, a State will be required to act upon those authorities which it currently possesses before the approval of a State Pretreatment Program.

(b) *Deadline for requesting approval.* Any NPDES State with a permit program approved under section 402 of the Act prior to December 27, 1977, which requires modification to conform to the requirements set forth in paragraph (f) of this section will be required to submit a request for approval of a modified program (hereafter State Pretreatment Program approval) by March 27, 1979 unless an NPDES State must amend or enact a law to make required modifications, in which case the NPDES

State shall request State Pretreatment Program approval by March 27, 1980.

(c) *Failure to request approval.* The EPA shall exercise the authorities available to it to apply and enforce Pretreatment Standards and Requirements until the necessary implementing action is taken by the State. Failure of a State to seek approval of a State Pretreatment Program as provided for in paragraph (b) and failure of an approved State to administer its State Pretreatment Program in accordance with the requirements of this section constitutes grounds for withdrawal of NPDES program approval under section 402(c)(3) of the Act.

(d) *Modification clause in POTW permits prior to submission deadline.* (1) Before the submission deadline for State Pretreatment Program approval set forth in paragraph (b) of this section, any Permit issued to a POTW which meets the requirements of § 403.8(a) by an NPDES State without an approved State pretreatment program shall include a modification clause. This clause will require that such Permits be promptly modified or, alternatively, revoked and reissued after the submission deadline for State Pretreatment Program approval set forth in (b) of this section to incorporate into the POTW's Permit an approved POTW Pretreatment Program or a compliance schedule for the development of a POTW Pretreatment Program according to the requirements of § 403.8 (b) and (d) and § 403.12(b). The following language is an acceptable clause for the purposes of this subparagraph:

This permit shall be modified, or alternatively, revoked and reissued by September 27, 1979 (or September 27, 1980, as appropriate) to incorporate an approved POTW Pretreatment Program or a compliance schedule for the development of a POTW Pretreatment Program as required under section 402(b)(8) of the Clean Water Act and implementing regulations or by the requirements of the approved State Pretreatment Program, as appropriate.

(2) All Permits subject to the requirements of paragraph (d)(1) of this section which do not contain the modification clause referred to in that paragraph will be subject to objection by EPA under section 402(d) of the Act as being outside the guidelines and requirements of the Act.

(3) Permits issued by an NPDES State after the Submission deadline for State Pretreatment Program approval (set forth in paragraph (b) of this section) shall contain conditions of an approved Pretreatment Program or a compliance schedule for developing such a program in accordance with § 403.8 (b) and (d) and § 403.12(b).

(e) *State Program in Lieu of POTW Program.* Notwithstanding the provision of § 403.8(a), a State with an approved Pretreatment Program may assume responsibility for implementing the POTW Pretreatment Program requirements set forth in § 403.8(f) in lieu of requiring the POTW to develop a Pretreatment Program. However, this does not preclude POTW's from independently developing Pretreatment Programs.

(f) *State Pretreatment Program requirements.* In order to be approved a request for State Pretreatment Program Approval must demonstrate that the State Pretreatment Program has the following elements:

(1) *Legal authority.* The Attorney General's Statement submitted in accordance with subparagraph (g)(1)(i) shall certify that the Director has authority under State law to operate and enforce the State Pretreatment Program to the extent required by this Part and by 40 CFR § 123.9. At a minimum, the Director shall have the authority to:

(i) Incorporate POTW Pretreatment Program conditions into permits issued to POTW's; require compliance by POTW's with these incorporated permit conditions; and require compliance by Industrial Users with Pretreatment Standards;

(ii) Ensure continuing compliance by POTW's with pretreatment conditions incorporated into the POTW Permit through review of monitoring reports submitted to the Director by the POTW in accordance with § 403.12 and ensure continuing compliance by Industrial Users with Pretreatment Standards through the review of self-monitoring reports submitted to the POTW or to the Director by the Industrial Users in accordance with § 403.12;

(iii) Carry out inspection, surveillance and monitoring procedures which will determine, independent of information supplied by the POTW, compliance or noncompliance by the POTW with pretreatment conditions incorporated into the POTW Permit and carry out inspection, surveillance and monitoring procedures which will determine, independent of information supplied by the Industrial User, whether the Industrial User is in compliance with Pretreatment Standards;

(iv) Seek civil and criminal penalties, and injunctive relief, for noncompliance by the POTW with pretreatment conditions incorporated into the POTW Permit and for noncompliance with Pretreatment Standards by Industrial Users as set forth in § 403.8(f)(1)(vi). The Director shall have authority to seek judicial relief for noncompliance by Industrial Users even when the POTW

has acted to seek such relief (e.g., if the POTW has sought a penalty which the Director finds to be insufficient);

(v) Approve and deny requests for approval of POTW Pretreatment Programs submitted by a POTW to the Director;

(vi) Deny and recommend approval of (but not approve) requests for Fundamentally Different Factors variances submitted by Industrial Users in accordance with the criteria and procedures set forth in § 403.13; and

(vii) Approve and deny requests for authority to modify categorical Pretreatment Standards to reflect removals achieved by the POTW in accordance with the criteria and procedures set forth in §§ 403.7, 403.9 and 403.11.

(2) *Procedures.* The Director shall have developed procedures to carry out the requirements of sections 307 (b) and (c); and 402(b)(1), 402(b)(2), 402(b)(8), and 402(b)(9) of the Act. At a minimum, these procedures shall enable the Director to:

(i) Identify POTW's required to develop Pretreatment Programs in accordance with § 403.8(a) and notify these POTW's of the need to develop a POTW Pretreatment Program. In the absence of a POTW Pretreatment Program. the State shall have procedures to carry out the activities set forth in § 403.8(f)(2);

(ii) Provide technical and legal assistance to POTW's in developing Pretreatment Programs;

(iii) Develop compliance schedules for inclusion in POTW Permits which set forth the shortest reasonable time schedule for the completion of tasks needed to implement a POTW Pretreatment Program. The final compliance date in these schedules shall be no later than July 1, 1983;

(iv) Sample and analyze:

(A) Influent and effluent of the POTW to identify, independent of information supplied by the POTW, compliance or noncompliance with pollutant removal levels set forth in the POTW permit (see § 403.7); and

(B) The contents of sludge from the POTW and methods of sludge disposal and use to identify, independent of information supplied by the POTW, compliance or noncompliance with requirements applicable to the selected method of sludge management;

(v) Investigate evidence of violations of pretreatment conditions set forth in the POTW Permit by taking samples and acquiring other information as needed. This data acquisition shall be performed with sufficient care as to produce evidence admissible in an enforcement proceeding or in court;

(vi) Review and approve requests for approval of POTW Pretreatment Programs and authority to modify categorical Pretreatment Standards submitted by a POTW to the Director; and

(vii) Consider requests for Fundamentally Different Factors variances submitted by Industrial Users in accordance with the criteria and procedures set forth in § 403.13.

(3) *Funding.* The Director shall assure that funding and qualified personnel are available to carry out the authorities and procedures described in paragraphs (f)(1) and (2) of this section.

(g) *Content of State Pretreatment Program Submission.* The request for State Pretreatment Program approval will consist of:

(1) (i) A statement from the State Attorney General (or the Attorney for those State agencies which have independent legal counsel) that the laws of the State provide adequate authority to implement the requirements of this Part. The authorities cited by the Attorney General in this statement shall be in the form of lawfully adopted State statutes or regulations which shall be effective by the time of approval of the State Pretreatment Program; and

(ii) Copies of all State statutes and regulations cited in the above statement;

(iii) Notwithstanding paragraphs (g)(1)(i) and (ii) of this section; if the State has the statutory authority to implement the requirements of this Part, and if the State at the time of submission of this request has an approved NPDES Program, then regulations setting forth the requirements of this section need not be promulgated by the State if the Administrator finds that the State has submitted a complete description of procedures to administer its program in conformance with the requirements of this section. States without an approved NPDES program will be required to comply with the requirements of paragraphs (g)(1)(i) and (ii) of this section.

(2) A description of the funding levels and full- and part-time personnel available to implement the program; and

(3) Any modifications or additions to the Momorandum of Agreement (required by 40 CFR 123.6) which may be necessary for EPA and the State to implement the requirements of this Part.

(h) *EPA Action.* Any approved NPDES State requesting State Pretreatment Program approval shall submit to the Regional Administrator three copies of the Submission described in paragraph (g) of this section. Upon a preliminary determination that the Submission

meets the requirements of paragraph (g) the Regional Administrator shall:

(1) Notify the Director that the Submission has been received and is under review; and

(2) Commence the program revision process set out in 40 CFR § 123.13. For purposes of that section all requests for approval of State Pretreatment Programs shall be deemed substantial program modifications. A comment period of at least 30 days and the opportunity for a hearing shall be afforded the public on all such proposed program revisions.

(i) *Notification where submission is defective.* If, after review of the Submission as provided for in paragraph (h) of this section. EPA determines that the Submission does not comply with the requirements of paragraphs (f) or (g) of this section EPA shall so notify the applying NPDES State in writing. This notification shall identify any defects in the Submission and advise the NPDES State of the means by which it can comply with the requirements of this Part.

**§ 403.11 Approval Procedures for POTW Pretreatment Programs and POTW Revision of Categorical Pretreatment Standards.**

The following procedures shall be adopted in approving or denying requests for approval of POTW Pretreatment Programs and revising Categorical Pretreatment Standards, including requests for authorization to grant conditional revised discharge limitations and provisional limitations:

(a) *Deadline for review of submission.* The Approval Authority shall have 90 days from the date of public notice of any Submission complying with the requirements of § 403.9(b) and, where removal allowance approval is sought, with §§ 403.7(d) and 403.9(d), to review the Submission. The Approval Authority shall review the Submission to determine compliance with the requirements of § 403.8(b) and (f), and, where removal allowance approval is sought, with § 403.7(a)–(e) and (g). The Approval Authority may have up to an additional 90 days to complete the evaluation of the Submission if the public comment period provided for in paragraph (b)(1)(ii) of this section is extended beyond 30 days or if a public hearing is held as provided for in paragraph (b)(2) of this section. In no event, however, shall the time for evaluation of the Submission exceed a total of 180 days from the date of public notice of a Submission meeting the requirements of § 403.9(b) and, in the case of removal allowance application, §§ 403.7(d) and 403.9(d).

(b) *Public notice and opportunity for hearing.* Upon receipt of a Submission

he Approval Authority shall commence
is review. Within 5 days after making a
determination that a Submission meets
he requirements of § 403.9(b), and
where removal allowance approval is
sought, §§ 403.7(d) and 403.9(d), or at
uch later time under § 403.7(c) that the
Approval Authority elects to review the
removal allowance Submission, the
Approval Authority shall:

(1) Issue a public notice of request for
pproval of the Submission:

(i) This public notice shall be
circulated in a manner designed to
nform interested and potentially
nterested persons of the Submission.
Procedures for the circulation of public
notice shall include:

(A) Mailing notices of the request for
pproval of the Submission to
esignated 208 planning agencies,
ederal and State fish. shellfish. and
wildlife resource agencies: and to any
ther person or group who has
equested individual notice, including
hose on appropriate mailing lists; and

(B) Publication of a notice of request
or approval of the Submission in the
argest daily newspaper within the
urisdiction(s) served by the POTW.

(ii) The public notice shall provide a
eriod of not less than 30 days following
he date of the public notice during
which time interested persons may
ubmit their written views on the
ubmission.

(iii) All written comments submitted
uring the 30 day comment period shall
e retained by the Approval Authority
nd considered in the decision on
whether or not to approve the
ubmission. The period for comment
may be extended at the discretion of the
Approval Authority; and

(2) Provide an opportunity for the
pplicant, any affected State, any
nterested State or Federal agency,
erson or group of persons to request a
ublic hearing with respect to the
Submission.

(i) This request for public hearing
shall be filed within the 30 day (or
extended) comment period described in
paragraph (b)(1)(ii) of this section and
shall indicate the interest of the person
filing such request and the reasons why
a hearing is warranted.

(ii) The Approval Authority shall hold
a hearing if the POTW so requests. In
addition. a hearing will be held if there
is a significant public interest in issues
relating to whether or not the
Submission should be approved.
Instances of doubt should be resolved in
favor of holding the hearing.

(iii) Public notice of a hearing to
consider a Submission and sufficient to
inform interested parties of the nature of
the hearing and the right to participate

shall be published in the same
newspaper as the notice of the original
request for approval of the Submission
under paragraph (b)(1)(i)(B) of this
section. In addition. notice of the
hearing shall be sent to those persons
requesting individual notice.

(3) Whenever the approval authority
elects to defer review of a submission
which authorizes the POTW to grant
conditional revised discharge limits
under § 403.7(b)(2) and 403.7(c), the
Approval Authority shall publish public
notice of its election in accordance with
paragraph (b)(1) of this section.

(c) *Approval authority decision.* At
the end of the 30 day (or extended)
comment period and within the 90 day
(or extended) period provided for in
paragraph (a) of this section. the
Approval Authority shall approve or
deny the Submission based upon the
evaluation in paragraph (a) of this
section and taking into consideration
comments submitted during the
comment period and the record of the
public hearing. if held. Where the
Approval Authority makes a
determination to deny the request, the
Approval Authority shall so notify the
POTW and each person who has
requested individual notice. This
notification shall include suggested
modifications and the Approval
Authority may allow the requestor
additional time to bring the Submission
into compliance with applicable
requirements.

(d) *EPA objection to Director's
decision.* No POTW pretreatment
program or authorization to grant
removal allowances shall be approved
by the Director if following the 30 day
(or extended) evaluation period
provided for in paragraph (b)(1)(ii) of
this section and any hearing held
pursuant to paragraph (b)(2) of this
section the Regional Administrator sets
forth in writing objections to the
approval of such Submission and the
reasons for such objections. A copy of
the Regional Administrator's objections
shall be provided to the applicant. and
each person who has requested
individual notice. The Regional
Administrator shall provide an
opportunity for written comments and
may convene a public hearing on his or
her objections. Unless retracted. the
Regional Administrator's objections
shall constitute a final ruling to deny
approval of a POTW pretreatment
program or authorization to grant
removal allowances 90 days after the
date the objections are issued.

(e) *Notice of decision.* The Approval
Authority shall notify those persons who
submitted comments and participated in
the public hearing. if held. of the

approval or disapproval of the
Submission. In addition. the Approval
Authority shall cause to be published a
notice of approval or disapproval in the
same newspapers as the original notice
of request for approval of the
Submission was published. The
Approval Authority shall identify in any
notice of POTW Pretreatment Program
approval any authorization to modify
categorical Pretreatment Standards
which the POTW may make. in
accordance with § 403.7. for removal of
pollutants subject to Pretreatment
Standards.

(f) *Public access to submission.* The
Approval Authority shall ensure that the
Submission and any comments upon
such Submission are available to the
public for inspection and copying.

**§ 403.12 Reporting requirements for
POTW's and industrial users.**

(a) *Definition.* The term "Control
Authority" as it is used in this section
refers to: (1) The POTW if the POTW's
Submission for its pretreatment program
(§ 403.3(t)(1)) has been approved in
accordance with the requirements of
§ 403.11: or (2) the Approval Authority if
the Submission has not been approved.

(b) *Reporting requirement for
industrial users upon effective date of
categorical pretreatment standard—
baseline report.* Within 180 days after
the effective date of a categorical
Pretreatment Standard. or 180 days after
the final administrative decision made
upon a category determination
submission under § 403.6(a)(4).
whichever is later. existing Industrial
Users subject to such categorical
Pretreatment Standards and currently
discharging to or scheduled to discharge
to a POTW shall be required to submit
to the Control Authority a report which
contains the information listed in
paragraph (b)(1)–(7) of this section.
Where reports containing this
information already have been
submitted to the Director or Regional
Administrator in compliance with the
requirements of 40 CFR 128.140(b). the
Industrial user will not be required to
submit this information again. New
sources shall be required to submit to
the Control Authority a report which
contains the information listed in
paragraphs (b)(1)–(5) of this section:

(1) *Identifying information.* The User
shall submit the name and address of
the facility including the name of the
operator and owner:

(2) *Permits.* The User shall submit a
list of any environmental control permits
held by or for the facility:

(3) *Description of operations.* The
User shall submit a brief description of
the nature, average rate of production,

and Standard Industrial Classification of the operation(s) carried out by such Industrial User. This description should include a schematic process diagram which indicates points of Discharge to the POTW from the regulated processes.

(4) *Flow measurement.* The User shall submit information showing the measured average daily and maximum daily flow, in gallons per day, to the POTW from each of the following:

(i) regulated process streams; and

(ii) other streams as necessary to allow use of the combined wastestream formula of § 403.6(e). (See paragraph (b)(5)(v) of this section.) The Control Authority may allow for verifiable estimates of these flows where justified by cost or feasibility considerations.

(5) *Measurement of Pollutants.* (i) The user shall identify the Pretreatment Standards applicable to each regulated process;

(ii) In addition, the User shall submit the results of sampling and analysis identifying the nature and concentration (or mass, where required by the Standard or Control Authority) of regulated pollutants in the Discharge from each regulated process. Both daily maximum and average concentration (or mass, where required) shall be reported. The sample shall be representative of daily operations;

(iii) Where feasible, samples must be obtained through the flow-proportional composite sampling techniques specified in the applicable categorical Pretreatment Standard. Where composite sampling is not feasible, a grab sample is acceptable;

(iv) Where the flow of the stream being sampled is less than or equal to 950,000 liters/day (approximately 250,000 gpd), the User must take three samples within a two-week period. Where the flow of the stream being sampled is greater than 950,000 liters/day (approximately 250,000 gpd), the User must take six samples within a two-week period;

(v) Samples should be taken immediately downstream from pretreatment facilities if such exist or immediately downstream from the regulated process if no pretreatment exists. If other wastewaters are mixed with the regulated wastewater prior to pretreatment the User should measure the flows and concentrations necessary to allow use of the combined wastestream formula of § 403.6(e) in order to evaluate compliance with the Pretreatment Standards. Where an alternate concentration or mass limit has been calculated in accordance with § 403.6(e) this adjusted limit along with

supporting data shall be submitted to the Control Authority;

(vi) Sampling and analysis shall be performed in accordance with the techniques prescribed in 40 CFR Part 136 and amendments thereto. Where 40 CFR Part 136 does not contain sampling or analytical techniques for the pollutant in question, or where the Administrator determines that the Part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analysis shall be performed by using validated analytical methods or any other applicable sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator;

(vii) The Control Authority may allow the submission of a baseline report which utilizes only historical data so long as the data provides information sufficient to determine the need for industrial pretreatment measures;

(viii) The baseline report shall indicate the time, date and place, of sampling, and methods of analysis, and shall certify that such sampling and analysis is representative of normal work cycles and expected pollutant Discharges to the POTW;

(6) *Certification.* A statement, reviewed by an authorized representative of the Industrial User (as defined in subparagraph (k) of this section) and certified to by a qualified professional, indicating whether Pretreatment Standards are being met on a consistent basis, and, if not, whether additional operation and maintenance (O and M) and/or additional pretreatment is required for the Industrial User to meet the Pretreatment Standards and Requirements; and

(7) *Compliance Schedule.* If additional pretreatment and/or O and M will be required to meet the Pretreatment Standards; the shortest schedule by which the Industrial User will provide such additional pretreatment and/or O and M. The completion date in this schedule shall not be later than the compliance date established for the applicable Pretreatment Standard.

(i) Where the Industrial User's categorical Pretreatment Standard has been modified by a removal allowance (§ 403.7), the combined wastestream formula (§ 403.6(e)), and/or a Fundamentally Different Factors variance (§ 403.13) at the time the User submits the report required by paragraph (b) of this section, the information required by paragraphs (b)(6) and (7) of this section shall pertain to the modified limits.

(ii) If the categorical Pretreatment Standard is modified by a removal allowance (§ 403.7), the combined wastestream formula (§ 403.6(e)), and/or a Fundamentally Different Factors variance (§ 403.13) after the User submits the report required by paragraph (b) of this section, any necessary amendments to the information requested by paragraphs (b)(6) and (7) of this section shall be submitted by the User to the Control Authority within 60 days after the modified limit is approved.

(c) *Compliance Schedule for Meeting Categorical Pretreatment Standards.* The following conditions shall apply to the schedule required by paragraph (b)(7) of this section:

(1) The schedule shall contain increments of progress in the form of dates for the commencement and completion of major events leading to the construction and operation of additional pretreatment required for the Industrial User to meet the applicable categorical Pretreatment Standards (e.g. hiring an engineer, completing preliminary plans, completing final plans, executing contract for major components, commencing construction, completing construction, etc.).

(2) No increment referred to in paragraph (c)(1) of this section shall exceed 9 months.

(3) Not later than 14 days following each date in the schedule and the final date for compliance, the Industrial User shall submit a progress report to the Control Authority including, at a minimum, whether or not it complied with the increment of progress to be met on such date and, if not, the date on which it expects to comply with this increment of progress, the reason for delay, and the steps being taken by the Industrial User to return the construction to the schedule established. In no event shall more than 9 months elapse between such progress reports to the Control Authority.

(d) *Report on compliance with categorical pretreatment standard deadline.* Within 90 days following the date for final compliance with applicable categorical Pretreatment Standards or in the case of a New Source following commencement of the introduction of wastewater into the POTW, any Industrial User subject to Pretreatment Standards and Requirements shall submit to the Control Authority a report indicating the nature and concentration of all pollutants in the Discharge from the regulated process which are limited by Pretreatment Standards and Requirements and the average and maximum daily flow for these process

units in the Industrial User which are limited by such Pretreatment Standards and Requirements. The report shall state whether the applicable Pretreatment Standards or Requirements are being met on a consistent basis and, if not, what additional O and M and/or pretreatment is necessary to bring the Industrial User into compliance with the applicable Pretreatment Standards or Requirements. This statement shall be signed by an authorized representative of the Industrial User, as defined in paragraph (k) of this section, and certified to by a qualified professional.

(e) *Periodic reports on continued compliance*. (1) Any Industrial User subject to a categorical Pretreatment Standard, after the compliance date of such Pretreatment Standard, or, in the case of a New Source, after commencement of the discharge into the POTW, shall submit to the Control Authority during the months of June and December, unless required more frequently in the Pretreatment Standard or by the Control Authority or the Approval Authority, a report indicating the nature and concentration of pollutants in the effluent which are limited by such categorical Pretreatment Standards. In addition, this report shall include a record of measured or estimated average and maximum daily flows for the reporting period for the Discharge reported in paragraph (b)(4) of this section except that the Control Authority may require more detailed reporting of flows. At the discretion of the Control Authority and in consideration of such factors as local high or low flow rates, holidays, budget cycles, etc., the Control Authority may agree to alter the months during which the above reports are to be submitted.

(2) Where the Control Authority has imposed mass limitations on Industrial Users as provided for by § 403.6(d), the report required by paragraph (e)(1) of this section shall indicate the mass of pollutants regulated by Pretreatment Standards in the Discharge from the Industrial User.

(f) *Notice of slug loading*. The Industrial User shall notify the POTW immediately of any slug loading, as defined by § 403.5(b)(4), by the Industrial User.

(g) *Monitoring and analysis to demonstrate continued compliance*. The reports required in paragraphs (b)(5), (d), and (e) of this section shall contain the results of sampling and analysis of the Discharge, including the flow and the nature and concentration, or production and mass where requested by the Control Authority, of pollutants contained therein which are limited by the applicable Pretreatment Standards.

The frequency of monitoring shall be prescribed in the applicable Pretreatment Standard. All analyses shall be performed in accordance with procedures established by the Administrator pursuant to section 304(g) of the Act and contained in 40 CFR Part 136 and amendments thereto or with any other test procedures approved by the Administrator. Sampling shall be performed in accordance with the techniques approved by the Administrator. Where 40 CFR Part 136 does not include sampling or analytical techniques for the pollutants in question, or where the Administrator determines that the Part 136 sampling and analytical techniques are inappropriate for the pollutant in question, sampling and analyses shall be performed using validated analytical methods or any other sampling and analytical procedures, including procedures suggested by the POTW or other parties, approved by the Administrator.

(h) *Compliance schedule for POTW's*. The following conditions and reporting requirements shall apply to the compliance schedule for development of an approvable POTW Pretreatment Program required by § 403.8.

(1) The schedule shall contain increments of progress in the form of dates for the commencement and completion of major events leading to the development and implementation of a POTW Pretreatment Program (e.g., acquiring required authorities, developing funding mechanisms, acquiring equipment);

(2) No increment referred to in paragraph (h)(1) of this section shall exceed nine months;

(3) Not later than 14 days following each date in the schedule and the final date for compliance, the POTW shall submit a progress report to the Approval Authority including, as a minimum, whether or not it complied with the increment of progress to be met on such date and, if not, the date on which it expects to comply with this increment of progress, the reason for delay, and the steps taken by the POTW to return to the schedule established. In no event shall more than nine months elapse between such progress reports to the Approval Authority.

(i) *Initial POTW report on compliance with approved removal allowance*. A POTW which has received authorization to modify categorical Pretreatment Standards for pollutants removed by the POTW in accordance with the requirements of § 403.7 must submit to the Approval Authority within 60 days after the effective date of a Pretreatment Standard for which authorization to modify has been approved. a report

which contains the information required by §§ 403.7(d)(2), 403.7(d)(5) and 403.7(d)(6). A minimum of one sample per month during the reporting period is required.

(j) *Periodic reports by POTW to demonstrate continued compliance with removal allowance*. The reports referred to in paragraph (i) of this section will be submitted to the Approval Authority at 6-month intervals beginning with the submission of the initial report referred to in paragraph (i) of this section unless required more frequently by the Approval Authority.

(k) *Signatory requirements for industrial user reports*. The reports required by paragraphs (b), (d), and (e), of this section must be signed by an authorized representative of the Industrial User. An authorized representative may be:

(1) A principal executive officer of at least the level of vice president, if the Industrial User submitting the reports required by paragraphs (b), (d) and (e) of this section is a corporation;

(2) A general partner or proprietor if the Industrial User submitting the report required by paragraphs (b), (d) and (e) of this section is a partnership or sole proprietorship respectively.

(3) A duly authorized representative of the individual designated in subparagraph (1) or (2) of this paragraph if such representative is responsible for the overall operation of the facility from which the Indirect Discharge originates.

(l) *Signatory requirements for POTW reports*. Reports submitted to the Approval Authority by the POTW in accordance with paragraphs (b), (i) and (j) of this section must be signed by a principal executive officer, ranking elected official or other duly authorized employee if such employee is responsible for overall operation of the POTW.

(m) *Provisions governing fraud and false statements*. The reports required by paragraphs (b), (d), (e), (h), (i) and (j) of this section shall be subject to the provisions of 18 U.S.C. section 1001 relating to fraud and false statements and the provisions of section 309(c)(2) of the Act governing false statements, representations or certifications in reports required under the Act.

(n) *Record-keeping requirements*. (1) Any Industrial User and POTW subject to the reporting requirements established in this section shall maintain records of all information resulting from any monitoring activities required by this section. Such records shall include for all samples:

(i) The date, exact place, method and time of sampling and the names of the person or persons taking the samples:

(ii) The dates analyses were performed;

(iii) Who performed the analyses;

(iv) The analytical techniques/methods use; and

(v) The results of such analyses.

(2) Any Industrial User or POTW subject to the reporting requirements established in this section shall be required to retain for a minimum of 3 years any records of monitoring activities and results (whether or not such monitoring activities are required by this section) and shall make such records available for inspection and copying by the Director and the Regional Administrator (and POTW in the case of an Industrial User). This period of retention shall be extended during the course of any unresolved litigation regarding the Industrial User or POTW or when requested by the Director or the Regional Administrator.

(3) Any POTW to which reports are submitted by an Industrial User pursuant to paragraphs (b), (d), and (e) of this section shall retain such reports for a minimum of 3 years and shall make such reports available for inspection and copying by the Director and the Regional Administrator. This period of retention shall be extended during the course of any unresolved litigation regarding the discharge of pollutants by the Industrial User or the operation of the POTW Pretreatment Program or when requested by the Director or the Regional Administrator.

§ 403.13 Variances from categorical pretreatment standards for fundamentally different factors.

(a) *Definition.* The term "Requester" means an Industrial User or a POTW or other interested person seeking a variance from the limits specified in a categorical Pretreatment Standard.

(b) *Purpose and scope.* In establishing categorical Pretreatment Standards for existing sources, the EPA will take into account all the information it can collect, develop and solicit regarding the factors relevant to pretreatment standards under section 307(b). In some cases, information which may affect these Pretreatment Standards will not be available or, for other reasons, will not be considered during their development. As a result, it may be necessary on a case-by-case basis to adjust the limits in categorical Pretreatment Standards, making them either more or less stringent, as they apply to a certain Industrial User within an industrial category or subcategory. This will only be done if data specific to that Industrial User indicates it presents factors fundamentally different from those considered by EPA in developing

the limit at issue. Any interested person believing that factors relating to an Industrial User are fundamentally different from the factors considered during development of a categorical Pretreatment Standard applicable to that User and further, that the existence of those factors justifies a different discharge limit from that specified in the applicable categorical Pretreatment Standard, may request a fundamentally different factors variance under this section or such a variance request may be initiated by the EPA.

(c) *Criteria.*—(1) *General criteria.* A request for a variance based upon fundamentally different factors shall be approved only if:

(i) There is an applicable categorical Pretreatment Standard which specifically controls the pollutant for which alternative limits have been requested; and

(ii) Factors relating to the discharge controlled by the categorical Pretreatment Standard are fundamentally different from the factors considered by EPA in establishing the Standards; and

(iii) The request for a variance is made in accordance with the procedural requirements in paragraphs (g) and (h) of this section.

(2) *Criteria applicable to less stringent limits.* A variance request for the establishment of limits less stringent than required by the Standard shall be approved only if:

(i) The alternative limit requested is no less stringent than justified by the fundamental difference;

(ii) The alternative limit will not result in a violation of prohibitive discharge standards prescribed by or established under § 403.5;

(iii) The alternative limit will not result in a non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Pretreatment Standards; and

(iv) Compliance with the Standards (either by using the technologies upon which the Standards are based or by using other control alternatives) would result in either:

(A) A removal cost (adjusted for inflation) wholly out of proportion to the removal cost considered during development of the Standards; or

(B) A non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Standards.

(3) *Criteria applicable to more stringent limits.* A variance request for the establishment of limits more

stringent than required by the Standards shall be approved only if:

(i) The alternative limit request is no more stringent than justified by the fundamental difference; and

(ii) Compliance with the alternative limit would not result in either:

(A) A removal cost (adjusted for inflation) wholly out of proportion to the removal cost considered during development of the Standards; or

(B) A non-water quality environmental impact (including energy requirements) fundamentally more adverse than the impact considered during development of the Standards.

(d) *Factors considered fundamentally different.* Factors which may be considered fundamentally different are:

(1) The nature or quality of pollutants contained in the raw waste load of the User's process wastewater;

(2) The volume of the User's process wastewater and effluent discharged;

(3) Non-water quality environmental impact of control and treatment of the User's raw waste load;

(4) Energy requirements of the application of control and treatment technology;

(5) Age, size, land availability, and configuration as they relate to the User's equipment or facilities; processes employed; process changes; and engineering aspects of the application of control technology;

(6) Cost of compliance with required control technology.

(e) *Factors which will not be considered fundamentally different.* A variance request or portion of such a request under this section may not be granted on any of the following grounds:

(1) The feasibility of installing the required waste treatment equipment within the time the Act allows;

(2) The assertion that the Standards cannot be achieved with the appropriate waste treatment facilities installed, if such assertion is not based on factors listed in paragraph (d) of this section;

(3) The User's ability to pay for the required waste treatment; or

(4) The impact of a Discharge on the quality of the POTW's receiving waters.

(f) *State or local law.* Nothing in this section shall be construed to impair the right of any state or locality under section 510 of the Act to impose more stringent limitations than required by Federal law.

(g) *Application deadline.*

(1) Requests for a variance and supporting information must be submitted in writing to the Director or to the Enforcement Division Director, as appropriate.

(2) In order to be considered, request for variances must be submitted within

180 days after the effective date of the categorical Pretreatment Standard unless the User has requested a categorical determination pursuant to § 403.6(a).

(3) Where the User has requested a catergorical determination pursuant to § 403.6(a), the User may elect to await the results of the category determination before submitting a variance request under this section. Where the User so elects, he or she must submit the variance request within 30 days after a final decision has been made on the categorical determination pursuant to § 403.6(a)(4).

(h) *Contents of submission.* Written Submissions for variance request, whether made to the Enforcement Division Director or to the Director must include:

(1) The name and address of the person making the request:

(2) Identification of the interest of the Requester which is affected by the categorical Pretreatment Standard for which the variance is requested:

(3) Identification of the POTW currently receiving the waste from the Industrial User for which alternative discharge limits are requested:

(4) Identification of the categorical Pretreatment Standards which are applicable to the Industrial User:

(5) A list of each pollutant or pollutant parameter for which an alternative discharge limit is sought:

(6) The alternative discharge limits proposed by the Requester for each pollutant or pollutant parameter identified in item (5) of this paragraph:

(7) A description of the Industrial User's existing water pollution control facilities:

(8) A schematic flow representation of the Industrial User's water system including water supply, process wastewater systems, and points of Discharge: and

(9) A Statement of facts clearly establishing why the variance request should be approved, including detailed support data, documentation, and evidence necessary to fully evaluate the merits of the request, e.g., technical and economic data collected by the EPA and used in developing each pollutant discharge limit in the Pretreatment Standard.

(i) *Deficient requests.* The Enforcement Division Director or Director will only act on written requests for variances that contain all of the information required. Persons who have made incomplete Submissions will be notified by the Enforcement Division Director or Director that their requests are deficient and unless the time period is extended, will be given up to 30 days

to correct the deficiency. If the deficiency is not corrected within the time period allowed by the Enforcement Division Director or the Director, the request for a variance shall be denied.

(j) *Public notice.* Upon receipt of a complete request, the Director or Enforcement Division Director will provide notice of receipt, opportunity to review the submission, and opportunity to comment.

(1) The public notice shall be circulated in a manner designed to inform interested and potentially interested persons of the request. Procedures for the circulation of public notice shall include mailing notices to:

(i) The POTW into which the Industrial User requesting the variance discharges:

(ii) Adjoining States whose waters may be affected: and

(iii) Designated 208 planning agencies, Federal and State fish, shellfish and wildlife resource agencies; and to any other person or group who has requested individual notice, including those on appropriate mailing lists.

(2) The public notice shall provide for a period not less than 30 days following the date of the public notice during which time interested persons may review the request and submit their written views on the request.

(3) Following the comment period, the Director or Enforcement Division Director will make a determination on the request taking into consideration any comments received. Notice of this final decision shall be provided to the requestor (and the Industrial User for which the variance is requested if different), the POTW into which the Industrial User discharges and all persons who submitted comments on the request.

(k) *Review of requests by state.* (1) Where the Director finds that fundamentally different factors do not exist, he may deny the request and notify the requester (and Industrial User where they are not the same) and the POTW of the denial.

(2) Where the director finds that fundamentally different factors do exist, he shall forward the request, and a recommendation that the request be approved, to the Enforcement Division Director.

(1) *Review of requests by EPA.* (1) Where the Enforcement Division Director finds that fundamentally different factors do not exist, he shall deny the request for a variance and send a copy of his determination to the Director, to the POTW, and to the Requester (and to the Industrial User, where they are not the same).

(2) Where the Enforcement Division Director finds that fundamentally different factors do exist, and that a partial or full variance is justified, he will approve the variance. In approving the variance, the Enforcement Division Director will: •

(i) Prepare recommended alternative discharge limits for the Industrial User either more or less stringent than those prescribed by the applicable categorical Pretreatment Standard to the extent warranted by the demonstrated fundamentally different factors:

(ii) Provide the following information in his written determination:

(A) the recommended alternative discharge limits for the Industrial User concerned:

(B) the rationale for the adjustment of the Pretreatment Standard (including the Enforcement Division Director's reasons for recommending that a fundamentally different factor variance be granted) and an explanation, of how the Enforcement Division Director's recommended alternative discharge limits were derived:

(C) the supporting evidence submitted to the Enforcement Division Director; and

(D) other information considered by the Enforcement Division Director in developing the recommended alternative discharge limits;

(iii) Notify the Director and the POTW of his or her determination: and

(iv) Send the information described in paragraphs (1)(2) (i) and (ii) above to the Requestor (and to the Industrial User where they are not the same).

(m) *Request for hearing.* (1) Within 30 days following the date of receipt of notice of the Enforcement Division Director's decision on a variance request, the Requester or any other interested person may submit a petition to the Regional Administrator for a hearing to reconsider or contest the decision. If such a request is submitted by a person other than the Industrial User the person shall simultaneously serve a copy of the request on the Industrial User.

(2) If the Regional Administrator declines to hold a hearing and the Regional Administrator affirms the Enforcement Division Director's findings, the Requester may submit a petition for a hearing to the Administrator within 30 days of the Regional Administrator's decision.

**§ 403.14 Confidentiality.**

(a) *EPA authorities.* In accordance with 40 CFR Part 2, any information submitted to EPA pursuant to these regulations may be claimed as confidential by the submitter. Any such

claim must be asserted at the time of submission in the manner prescribed on the application form or instructions, or, in the case of other submissions, by stamping the words "confidential business information" on each page containing such information. If no claim is made at the time of submission, EPA may make the information available to the public without further notice. If a claim is asserted, the information will be treated in accordance with the procedures in 40 CFR Part 2 (Public Information).

(b) *Effluent data.* Information and data provided to the Control Authority pursuant to this part which is effluent data shall be available to the public without restriction.

(c) *State or POTW.* All other information which is submitted to the State or POTW shall be available to the public at least to the extent provided by 40 CFR § 2.302.

**§ 403.15  Net/Gross calculation.**

Categorical Pretreatment Standards may be adjusted to reflect the presence of pollutants in the Industrial Users' intake water in accordance with the provisions of paragraph (a)–(d) below:

(a) *Application deadline and contents.* Any Industrial User wishing to obtain a credit for intake pollutants must make application therefore within 60 days after the effective date of the applicable categorical Pretreatment Standard. Application shall be made to the appropriate Enforcement Division Director. Upon request of the Industrial User, the applicable Standard will be calculated on a "net" basis, i.e., adjusted to reflect credit for pollutants in the intake water, if the User demonstrates that:

(1) Its intake water is drawn from the same body of water into which the discharge from its publicly owned treatment works is made;

(2) The pollutants present in the intake water will not be entirely removed by the treatment system operated by the User;

(3) The pollutants in the intake water do not vary chemically or biologically from the pollutants limited by the applicable Standards; and

(4) The User does not significantly increase concentrations of pollutants in the intake water, even if the total amount of pollutants remains the same.

(b) *Criteria.* Standards adjusted under this paragraph shall be calculated on the basis of the amount of pollutants present after any treatment steps have been performed on the intake water by or for the Industrial User. Adjustments under this section shall be given only to the extent that pollutants in the intake

water which are limited by the Standard are not removed by the treatment technology employed by the User.

(c) *Notice.* The User shall notify the Regional Enforcement Officer if there are any significant changes in the quantity of the pollutants in the intake water or in the level of treatment provided.

(d) *EPA decision.* The Enforcement Division Director shall require the User to conduct additional monitoring (i.e., for flow and concentration of pollutants) as necessary to determine continued eligibility for and compliance with any adjustments. The Enforcement Division Director shall consider all timely applications for credits for intake pollutants plus any additional evidence that may have been submitted in response to the EPA's request. The Enforcement Division Director shall then make a written determination of the applicable credit(s), if any, state the reasons for its determination, state what additional monitoring is necessary, and send a copy of said determination to the applicant and the applicant's POTW. The decision of the Enforcement Division Director shall be final.

**§ 403.16  Upset provision.**

(a) *Definition.* For the purposes of this section, "Upset" means an exceptional incident in which there is unintentional and temporary noncompliance with categorical Pretreatment Standards because of factors beyond the reasonable control of the Industrial User. An Upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(b) *Effect of an upset.* An Upset shall constitute an affirmative defense to an action brought for noncompliance with categorical Pretreatment Standards if the requirements of paragraph (c) are met.

(c) *Conditions necessary for a demonstration of upset.* An Industrial User who wishes to establish the affirmative defense of Upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

(1) An Upset occurred and the Industrial User can identify the specific cause(s) of the Upset;

(2) The facility was at the time being operated in a prudent and workman-like manner and in compliance with applicable operation and maintenance procedures;

(3) The Industrial User has submitted the following information to the POTW

and Control Authority within 24 hours of becoming aware of the Upset (if this information is provided orally, a written submission must be provided within five days):

(i) A description of the Indirect Discharge and cause of noncompliance;

(ii) The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue;

(iii) Steps being taken and/or planned to reduce, eliminate and prevent recurrence of the noncompliance.

(d) *Burden of proof.* In any enforcement proceeding the Industrial User seeking to establish the occurrence of an Upset shall have the burden of proof.

(e) *Reviewability of agency consideration of claims of upset.* In the usual exercise of prosecutorial discretion, Agency enforcement personnel should review any claims that non-compliance was caused by an Upset. No determinations made in the course of the review constitute final Agency action subject to judicial review. Industrial Users will have the opportunity for a judicial determination on any claim of Upset only in an enforcement action brought for noncompliance with categorical Pretreatment Standards.

(f) *User responsibility in case of upset.* The Industrial User shall control production or all Discharges to the extent necessary to maintain compliance with categorical Pretreatment Standards upon reduction, loss, or failure of its treatment facility until the facility is restored or an alternative method of treatment is provided. This requirement applies in the situation where, among other things, the primary source of power of the treatment facility is reduced, lost or fails.

Appendix A—United States Environmental Protection Agency

December 16, 1975.

*Program Guidance Memorandum—61*

Subject: Grants for Treatment and Control of Combined Sewer Overflows and Stormwater Discharges.

From: John T. Rhett, Deputy Assistant Administrator for Water Program Operations (WH-546).

To: Regional Administrators, Regions I–X.

This memorandum summarizes the Agency's policy on the use of construction grants for treatment and control of combined sewer overflows and stormwater discharges during wet-weather conditions. The purpose is to assure that projects are funded only when careful planning has demonstrated they are cost-effective.

## I. Combined Sewer Overflows

### A. Background

The costs and benefits of control of various portions of pollution due to combined sewer overflows and by-passes vary greatly with the characteristics of the sewer and treatment system, the duration, intensity, frequency and areal extent of precipitation, the type and extent of development in the service area, and the characteristics, uses and water quality standards of the receiving waters. Decisions on grants for control of combined sewer overflows, therefore, must be made on a case-by-case basis after detailed planning at the local level.

Where detailed planning has been completed, treatment or control of pollution from wet-weather overflows and bypasses may be given priority for construction grant funds only after provision has been made for secondary treatment of dry-weather flows in the area. The detailed planning requirements and criteria for project approval follow.

### B. Planning Requirements

Construction grants may be approved for control of pollution from combined sewer overflows only if planning for the project was thoroughly analyzed for the 20 year planning period:

1. Alternative control techniques which might be utilized to attain various levels of pollution control (related to alternative beneficial uses, if appropriate), including at least initial consideration of all the alternatives described in the section on combined sewer and stormwater control in "Alternative Waste Management Techniques and Best Practicable Waste Treatment" (Section C of Chapter III of the information proposed for comment in March 1974).

2. The costs of achieving the various levels of pollution control by each of the techniques appearing to be the most feasible and cost-effective after the preliminary analysis.

3. The benefits to the receiving waters of a range of levels of pollution control during wet-weather conditions. This analysis will normally be conducted as part of State water quality management planning, 208 areawide management planning, or other State, regional or local planning effort.

4. The costs and benefits of addition of advanced waste treatment processes to dry-weather flows in the area.

### C. Criteria for Project Approval

The final alternative selected shall meet the following criteria:

1. The analysis required above has demonstrated that the level of pollution control provided will be necessary to protect a beneficial use of the receiving water even after technology based standards required by Section 301 of P.L. 92-500 are achieved by industrial point sources and at least secondary treatment is achieved for dry-weather municipal flows in the area.

2. Provision has already been made for funding of secondary treatment of dry-weather flows in the area.

3. The pollution control technique proposed for combined sewer overflow is a more cost-effective means of protecting the beneficial use of the receiving waters than other combined sewer pollution control techniques

and the addition of treatment higher than secondary treatment for dry-weather municipal flows in the area.

4. The marginal costs are not substantial compared to marginal benefits.

Marginal costs and benefits for each alternative may be displayed graphically to assist with determining a project's acceptability under this criteria. Dollar costs should be compared with quantified pollution reduction and water quality improvements. A descriptive narrative should also be included analyzing monetary, social and environmental costs compared to benefits, particularly the significance of the beneficial uses to be protected by the project.

## II. Stormwater Discharges

Approaches for reducing pollution from separate stormwater discharges are now in the early stages of development and evaluation. We anticipate, however, that in many cases the benefits obtained by construction of treatment works for this purpose will be small compared with the costs, and other techniques of control and prevention will be more cost-effective. The policy of the Agency is, therefore, that construction grants shall not be used for construction of treatment works to control pollution from separate discharges of stormwater except under unusual conditions where the project clearly has been demonstrated to meet the planning requirements and criteria described above for combined sewer overflows.

## III. Multi-purpose Projects

Projects with multiple purposes, such as flood control and recreation in addition to pollution control, may be eligible for an amount not to exceed the cost of the most cost-effective single purpose pollution abatement system. Normally the Separable Costs-Remaining Benefits (SCRB) method should be used to allocate costs between pollution control and other purposes, although in unusual cases another method may be appropriate. For such cost allocation, the cost of the least cost pollution abatement alternative may be used as a substitute measure of the benefits for that purpose. The method is described in "Proposed Practices for Economic Analysis of River Basin Projects," GPO, Washington, D.C., 1958, and "Efficiency in Government through Systems Analysis," by Roland N. McKean, John Wiley & Sons, Inc., 1958.

Enlargement of or otherwise adding to combined sewer conveyance systems is one means of reducing or eliminating flooding caused by wet-weather conditions. These additions may be designed so as to produce some benefits in terms of reduced discharge of pollutants to surrounding waterways. The pollution control benefits of such flood control measures, however, are likely to be small compared with the costs, and the measures therefore would normally be ineligible for funding under the construction grants program.

All multi-purpose projects where less than 100% of the costs are eligible for construction grants under this policy shall contain a special grant condition precluding EPA funding of non-pollution control elements.

This condition should, as a minimum, contain a provision similar to the following:

"The grantee explicitly acknowledges and agrees that costs are allowable only to the extent they are incurred for the water pollution control elements of this project."

Additional special conditions should be included as appropriate to assure that the grantee clearly understands which elements of the project are eligible for construction grants under Public Law 92-500.

## Appendix B—65 Toxic Pollutants

Acenaphthene
Acrolein
Acrylonitrile
Aldrin/Dieldrin
Antimony and compounds[1]
Arsenic and compounds
Asbestos
Benzene
Benzidine
Beryllium and compounds
Cadmium and compounds
Carbon tetrachloride
Chlordane (technical mixture and metabolites)
Chlorinated benzenes (other than dichlorobenzenes)
Chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane, and hexachloroethane)
Chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)
Chlorinated naphthalene
Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
Chloroform
2-chlorophenol
Chromium and compounds
Copper and compounds
Cyanides
DDT and metabolites
Dichlorobenzenes (1,2-, 1,3-, and 1,4-dichlorobenzenes)
Dichlorobenzidine
Dichloroethylenes (1,1- and 1,2-dichloroethylene)
2,4-dichlorophenol
Dichloropropane and dichloropropene
2,4-dimethylphenol
Dinitrotoluene
Diphenylhydrazine
Endosulfan and metabolites
Endrin and metabolites
Ethylbenzene
Fluoranthene
Haloethers (other than those listed elsewhere; includes chlorophenylphenyl ethers, bromophenylphenyl ether, bis(dichloroisopropyl) ether, bis-(chloroethoxy) methane and polychlorinated diphenyl ethers)
Halomethanes (other than those listed elsewhere; includes methylene chloromethyl-chloride, methylbromide, bromoform, dichlorobromomethane, trichlorofluoromethane, dichlorodifluoromethane)
Heptachlor and metabolites
Hexachlorobutadiene

---

[1] As used throughout this Appendix B the term "compounds" shall include organic and inorganic compounds.

Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Isophorone
Lead and compounds
Mercury and compounds
Naphthalene
Nickel and compounds
Nitrobenzene
Nitrophenols (Including 2,4-dinitrophenol,
  dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate esters
Polychlorinated biphenyls (PCBs)
Polynuclear aromatic hydrocarbons
  (including benzanthracenes.
  benzopyrenes.benzofluroranthene.
  chrysenes. dibenzanthracenes. and
  indenopyrenes)
Selenium and compounds
Silver and compounds
2.3.7.8-Tetrachlorodibenzo-p-dioxin (TCDD)
Tetrachloroethylene
Thallium and compounds
Toluene
Toxaphene
Trichloroethylene
Vinyl chloride
Zinc and compounds

**Appendix C—34 Industrial Categories**

Adhesives and Sealants
Aluminum Forming
Auto and Other Laundries
Battery Manufacturing
Coal Mining
Coil Coating
Copper Forming
Electrical and Electronic Components
Electroplating
Explosives Manufacturing
Foundries
Gum and Wood Chemicals
Inorganic Chemicals Manufacturing
Iron and Steel Manufacturing
Leather Tanning and Finishing
Mechanical Products Manufacturing
Nonferrous Metals Manufacturing
Ore Mining
Organic Chemicals Manufacturing
Paint and Ink Formulation
Pesticides
Petroleum Refining
Pharmaceutical Preparations
Photographic Equipment and Supplies
Plastics Processing
Plastic and Synthetic Materials
  Manufacturing
Porcelain Enameling
Printing and Publishing
Pulp and Paper Mills
Rubber Processing
Soap and Detergent Manufacturing
Steam Electric Power Plants
Textile Mills
Timber Products Processing

**Appendix D—Selected Industrial
Subcategories Exempted From Regulation
Pursuant of Paragraph 8 of the NRDC v.
Costle Consent Decree**

The following industrial subcategories
have been excluded from further rulemaking
pursuant to paragraph 8 of the *Natural
Resources Defense Council v. Costle* Consent

Decree for one or more of the following
reasons: (1) the pollutants of concern are not
detectable in the effluent from the industrial
User (paragraph 8(a)(iii)); (2) the pollutants of
concern are present only in trace amounts
and are neither causing nor likely to cause
toxic effects (paragraph 8(a)(iii)); (3) the
pollutants of concern are present in amounts
too small to be effectively reduced by
technologies known to the Administrator
(paragraph 8(a)(iii)); or (4) the wastestream
contains only pollutants which are
compatible with the POTW (paragraph
8(b)(i)). In some instances. different rationale
were given for exclusion under paragraph 8.
However. EPA has reviewed these
subcategories and has determined that
exclusion could have occurred due to one of
the four reasons listed above.

This list includes all subcategories that
have been excluded for the above-listed
reasons as of [date of publication in the
Federal Register]. This list will be updated
periodically for the convenience of the
reader.

### Auto and Other Laundries Industry

* Carpet Cleaners
* Coin Operated Laundries
* Diaper Services
* Dry Cleaners
* Power Laundries

### Battery Manufacturing Industry

* Carbon Zinc Air Cell Batteries
* Lithium Batteries
* Magnesium Carbon Batteries
* Magnesium Cell Batteries
* Miniature Alkaline Batteries
* Nickel Zinc Batteries

### Electrical and Electronic Components

* Carbon and Graphite Products
* Fixed Capacitors
* Fluorescent Lamps
* Incandescent Lamps
* Magnetic Coatings
* Mica Paper

### Electroplating

* Alkaline Cleaning
* Bright Dipping
* Chemical Machining
* Galvanizing
* Immersion Plating
* Iridite Dipping
* Pickling

### Explosives Industry

* Military Explosive Manufacturing

### Foundries Industry

* Nickel Casting
* Tin Casting
* Titanium Casting

### Gum and Wood Chemicals

* Char and Charcoal Briquets
* Gum Resin. Turpentine and Essential Oils

### Iron and Steel Industry

* Basic Oxygen Furnace (Semiwet)
* Beehive Coke Process
* Electric Arc Furnace (Semiwet)

### Inorganic Chemicals Manufacturing Industry

* Aluminum Sulfate

* Ammonium Chloride
* Ammonium Hydroxide
* Barium Carbonate
* Borax
* Boric Acid
* Bromine
* Calcium Carbide
* Calcium Carbonate
* Calcium Chloride
* Calcium Hydroxide
* Calcium Oxide
* Carbon Dioxide
* Carbon Monoxide
* Chromic Acid
* Cuprous Oxide
* Ferric Chloride
* Ferrous Sulfate
* Fluorine
* Hydrogen
* Hydrochloric Acid
* Hydrogen Peroxide
* Iodine
* Lead Monoxide
* Lithium Carbonate
* Manganese Sulfate
* Nitric Acid
* Oxygen and Nitrogen
* Potassium Chloride
* Potassium Dichromate
* Potassium Iodide
* Potassium Metal
* Potassium Permanganate
* Potassium Sulfate
* Sodium Bicarbonate
* Sodium Carbonate
* Sodium Chloride
* Sodium Fluoride
* Sodium Hydrosulfide
* Sodium Metal
* Sodium Silicate
* Sodium Sulfite
* Sodium Thiosulfate
* Stannic Oxide
* Sulfur Dioxide
* Sulfuric Acid
* Zinc Oxide
* Zinc Sulfate

### Leather Industries

* Gloves
* Luggage
* Shoes and Related Footwear
* Personal Goods

### Non Ferrous Metals Industry

* Primary Arsenic
* Primary Antimony
* Secondary Babbitt
* Primary Barium
* Secondary Beryllium
* Primary Bismuth
* Primary Boron
* Secondary Boron
* Bauxite
* Secondary Cadmium
* Primary Calcium
* Primary Cesium
* Primary Chromium
* Primary Cobalt
* Secondary Cobalt
* Secondary Columbium
* Primary Gallium
* Primary Germanium
* Primary Gold
* Secondary Precious Metals
* Primary Hafnium

- Primary and Secondary Indium
- Primary Lithium
- Primary Manganese
- Primary Magnesium
- Secondary Magnesium
- Primary Mercury
- Secondary Mercury
- Primary Molybdenum
- Secondary Molybdenum
- Primary Nickel
- Secondary Nickel
- Secondary Plutonium
- Primary Potassium
- Primary Rare Earths
- Primary Rhenium
- Secondary Rhenium
- Primary Rubidium
- Primary Platinum Group
- Primary Silicon
- Primary Sodium
- Secondary Tantalum
- Primary Tin
- Secondary Tin
- Primary Titanium
- Secondary Titanium
- Secondary Tungsten
- Primary Uranium
- Secondary Uranium
- Secondary Zinc
- Primary Zirconium

*Paint and Ink Industry*

- Solvent Base Process
- Solvent Wash Process

*Paving and Roofing Industry*

- Asphalt Concrete
- Asphalt Emulsion
- Linoleum
- Printed Asphalt Felt
- Roofing

*Pulp, Paper, Paperboard, and Converted Paper Industry*

- Converted Paper Industry

*Rubber Processing Industry*

- Latex-Dipped, Latex-Extruded, and Latex Molded Goods
- Latex Foam
- Small-sized General Molded, Extruded and Fabricated Rubber Plants
- Medium-sized General Molded, Extruded and Fabricated Rubber Plants
- Large-sized General Molded, Extruded and Fabricated Rubber Plants
- Synthetic Crumb Rubber Production— Emulsion Polymerization
- Synthetic Crumb Rubber Production— Solution Polymerization
- Synthetic Latex Rubber Production
- Tire & Inner Tube Production

*Textile Industry*

- Apparel Manufacturing
- Cordage and Twine
- Low Water Use Processing (Greige Mills)
- Padding and Upholstery Filling

*Timber Products Processing*

- Barking Process
- Finishing Processes
- Hardboard—Dry Process
- Log Washing
- Particleboard
- Planing Mills
- Sawmills

- Veneer
- Wet Storage
- Wood Preserving (Inorganics) Process

## PART 125—CRITERIA AND STANDARDS FOR THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

**Subpart D—Criteria and Standards for Determining Fundamentally Different Factors Under Sections 301(b)(1)(A), 301(b)(2) (A) and (E)(AND 307(s)] OF THE ACT**

2. 40 CFR Part 125 subpart D is amended by deleting "and 307(b)" from the title of the subpart.

3. 40 CFR § 125.30 is amended to read as follows:

**§ 125.30  Purpose and scope.**

(a) This subpart establishes the criteria and standards to be used in determining whether effluent limitations alternative to those required by promulgated EPA effluent limitations guidelines under sections 301 and 304 of the Act (hereinafter referred to as "national limits") should be imposed on a discharger because factors relating to the discharger's facilities, equipment, processes or other factors related to the discharger are fundamentally different from the factors considered by EPA in development of the national limits. This subpart applies to all national limits promulgated under sections 301 and 304 of the Act, except for those contained in 40 CFR Part 423 (steam electric generating point source category).

(b) In establishing national limits, EPA takes into account all the information it can collect, develop and solicit regarding the factors listed in sections 304(b) and 304(g) of the Act.

* * * * *

APPENDIX C:  POTWs With Pretreatment Programs

CALIFORNIA   69 Programs > 5 MGD

100 PROGRAMS REQUIRED
100 @ PROGRAMS

| NPDES NO. | AUTHORITY NAME | FACILITY NAME | CITY NAME | DISCHARGE FLOW (MGD) | INDUSTRIAL FLOW (MGD) | PROGRAM STATUS APP | MO/YR |
|---|---|---|---|---|---|---|---|
| *CA0038091 | BENICIA, CITY OF | BENICIA WWTF | BENICIA | 3.00 | neg. | @ | 8/81 |
| *CA0055531 | BURBANK, CITY OF | BURBANK WWTF | BURBANK | 9.00+ | 1.05 | @ | 7/82 |
| *CA0053597 | CAMARILLO S.D. | CAMARILLO WWTF | CAMARILLO | 6.75+ | 0.15 | @ | 3/83 |
| *CA0038628 | CENTRAL MARIN S.A. | CENTRAL MARIN | SAN RAFAEL | 10.00+ | neg. | @ | 6/83 |
| *CA0037648 | CENTRAL CONTRA COSTA | CENTRAL CONTRA COSTA | MARTINEZ | 35.00+ | 0.79 | @ | 9/82 |
| *CA0105279 | CHINO BASIN MMN WD | CHINO BASIN REG TP#1 | ONTARIO | 24.50+ | 3.58 | @ | 5/83 |
| *CA | CHINO CITY | | CHINO | | | @ | 5/83 |
| *CA0037940 | CONTRA COSTA COUNTY | 7-A | W. PITTSBURG | 9.50+ | 0.41 | @ | 7/82 |
| *CA0110604 | CO SAN DIST OF ORAN | OCSD STP NO 2 | FOUNTAIN VAL. | 227.00+ | 31.80 | @ | 1/84 |
| *CA | CUCAMONGA WT. DIST. | | CUCAMONGA | | | @ | 5/83 |
| *CA0022756 | CRESCENT CITY | CRESCENT CITY WWTF | CRESCENT CITY | 1.96 | 0.04 | @ | 7/82 |
| | | | | | | | |
| *CA0079049 | DAVIS, CITY OF | DAVIS WWTF | DAVIS | 5.00 | 0.00 | @ | 3/83 |
| *CA0037613 | DUBLIN-SAN RAMON SD | DUBLIN-SAN RAMON WWT | PLEASANTON | 9.00+ | 0.02 | @ | 6/83 |
| *CA | EASTERN MUNICIPAL W | HEMET-SAN JACINTO WW | SAN JACINTO | 3.50 | | @ | 8/83 |
| *CA0037702 | EAST BAY MUD | EAST BAY MUD WWTF | OAKLAND | 128.00+ | 10.00 | @ | 6/83 |
| *CA0079171 | EAST YOLO COMM SERV | WEST SACRAMENTO WWTF | W. SACRAMENTO | 8.00+ | 0.65 | @ | 5/83 |
| *CA0107981 | ESCONDIDO, CITY OF | HALE AVENUE WWTF | ESCONDIDO | 16.50+ | 0.81 | @ | 3/83 |
| *CA0107395 | ENCINA JT SEWERAGE | ENCINA JOINT POWERS | CARLSBAD | 13.75+ | 0.83 | @ | 7/83 |
| *CA0023418 | EUREKA | HILL STREET WWTF | EUREKA | 1.09 | 0.00 | @ | 1/83 |
| *CA0038377 | FAIRFIELD-SUISUN SD | FAIRFIELD SUISUN WWT | FAIRFIELD | 15.58+ | 2.08 | @ | 8/82 |
| *CA | FONTANA, CITY OF | | FONTANA | | | @ | 5/83 |
| | | | | | | | |
| *CA | FRESNO, CITY OF | FRESNO WWTF | FRESNO | 37.90+ | 2.30 | @ | 6/83 |
| *CA | GILROY, CITY OF | GILROY WWTF | GILROY | 0.09 | | @ | 9/83 |
| *CA0048160 | GOLETA SANITARY DIS | GOLETA WWTF | GOLETA | 10.50+ | 0.04 | @ | 7/83 |
| *CA0037656 | HAYWARD, CITY OF | HAYWARD WWTF | HAYWARD | 21.50+ | 8.00 | @ | 8/81 |
| *CA0105970 | IRVINE RANCH WATER | MICHAELSON WWTF | IRVINE | 4.00 | 0.00 | @ | 3/83 |
| *CA | JURUPA CO. SAN. | | RIVERSIDE | | | @ | 5/83 |
| *CA0109991 | LA CITY PUB WRKS | HYPERION WWTF | LOS ANGELES | 352.30+ | 32.00 | @ | 6/83 |
| CA0053953 | LA CITY PUB WRKS | L.A. GLENDALE WWJP | LOS ANGELES | 20.00 | 2.00 | | |
| CA0053856 | LA CITY PUB WRKS | TERMINAL ISLAND WWTF | SAN PEDRO | 30.00 | 8.00 | | |
| *CA0053813 | LA COUNTY S.D. | JWPCP | CARSON | 385.00+ | 96.25 | @ | 3/85 |
| *CA0056014 | LAS VIRGENES MUNWD | TAPIA WWTF | CALABASAS | 8.00+ | 0.30 | @ | 6/82 |

| NPDES NO. | AUTHORITY NAME | FACILITY NAME | CITY NAME | DISCHARGE FLOW (MGD) | INDUSTRIAL FLOW (MGD) | PROGRAM STATUS APP | MO/YR |
|---|---|---|---|---|---|---|---|
| *CA0038008 | LIVERMORE, CITY OF | LIVERMORE WWTF | LIVERMORE | 6.25+ | 0.55 | @ | 8/83 |
| *CA0079243 | LODI CITY OF | WHITE SLOUGH WWTF | LODI | 5.80+ | 0.86 | @ | 3/83 |
| *CA0048127 | LOMPOC, CITY OF | LOMPOC WWTF | LOMPOC | 5.00 | 0.08 | @ | 7/83 |
| *CA | MADERA, CITY OF | MADERA STP | MADERA | | 0.03 | @ | 9/83 |
| *CA0079219 | MERCED, CITY OF | MERCED STP | MERCED | 9.20+ | 0.43 | @ | 3/83 |
| *CA0079103 | MODESTO, CITY OF | MODESTO WWTF | MODESTO | 45.00+ | 10.00 | @ | 3/83 |
| *CA0048551 | MONTEREY REGIONAL | MONTEREY REG. WWTF | PACIFIC GROVE | 16.30+ | 2.80 | @ | 5/83 |
| CA | MONTCLAIR | | MONTCLAIR | | | @ | 5/83 |
| *CA0037575 | NAPA S.D. | NAPA SANIT. DIST WWT | NAPA | 15.40+ | 0.30 | @ | 5/83 |
| *CA0079472 | NEWMAN, CITY OF | NEWMAN WWTF | NEWMAN | 0.85 | 0.00 | @ | 4/83 |
| *CA0037737 | N. SAN MATEO CO SAN | DALY CITY WWTF | DALY CITY | 5.40+ | 0.05 | @ | 6/83 |
| | | | | | | | |
| *CA0037958 | NOVATO S.D. | NOVATO WWTF (MAIN) | NOVATO | 4.53 | neg. | @ | 9/82 |
| *CA0053961 | OAK VIEW | OAK VIEW WWTF | VENTURA | 3.00 | 0.20 | @ | 5/83 |
| *CA0107433 | OCEANSIDE, CITY OF | LA SALINA WWTF | OCEANSIDE | 15.10+ | 0.32 | @ | 12/82 |
| *CA0039591 | ORO-LOMA SAN DIST | ORO LOMA WWTF | SAN LORENZO | 20.00+ | 0.80 | @ | 8/82 |
| *CA0037834 | PALO ALTO, CITY OF | PALO ALTO WWTF | PALO ALTO | 35.00+ | 6.00 | @ | 7/82 |
| *CA0037810 | PETALUMA, CITY OF | PETALUMA WWTF | PETALUMA | 2.64 | 0.60 | @ | 6/83 |
| *CA0079731 | REDDING, CITY OF | REDDING REG WWTF | REDDING | 8.80+ | 0.00 | @ | 2/83 |
| *CA0105759 | REDLANDS, CITY OF | REDLANDS WWTF | REDLANDS | 6.00+ | 0.00 | @ | 5/83 |
| *CA0105295 | RIALTO, CITY OF | RIALTO WWTF | RIALTO | 6.00+ | 0.20 | @ | 1/83 |
| *CA0037729 | RICHMOND MUNICIPAL | RICHMOND WWTF | RICHMOND | 16.00+ | 1.00 | @ | 4/82 |
| | | | | | | | |
| 'CA0105350 | RIVERSIDE, CITY OF | RIVERSIDE CITY WWTF | RIVERSIDE | 21.75+ | 3.00 | @ | 5/83 |
| CA | RIVERBANK, CITY OF | RIVERBANK WWTF | RIVERBANK | 7.60 | 7.00 | | |
| *CA0079502 | ROSEVILLE, CITY OF | ROSEVILLE WWTF | ROSEVILLE | 11.50+ | 0.25 | @ | 1/84 |
| *CA | RUBIDUX COMM. SD | | RUBIDUX | | | @ | 5/83 |
| *CA0079111 | SACRAMENTO REG CSD | SACTO REG WWTF | SACRAMENTO | 150.00+ | 11.50 | @ | 1/83 |
| *CA0048101 | SALINAS, CITY OF | SALINAS IND WWTF | SALINAS | 6.00+ | 2.71 | @ | 5/83 |
| *CA0105392 | SAN BERNARDINO,CITY | SAN BERNARDINO WWTF | SAN BERNARDINO | 28.00+ | 1.50 | @ | 8/83 |
| *CA0053651 | SAN BUENA VENTURA | VENTURA WWTF | VENTURA | 14.00+ | 0.25 | @ | 6/82 |
| *CA0107409 | SAN DIEGO, CITY OF | PT LOMA WWTF | SAN DIEGO | 116.89+ | 8.40 | @ | 6/82 |
| *CA0107999 | SAN DIEGO, COUNTY | SAN ELIJO JP REG SEW | SAN DIEGO | 3.70 | 0.00 | @ | 6/82 |
| *CA0038610 | SAN FRANCISCO,CITY | N.POINT & SOUTHEAST | SAN FRANCISCO | 85.00+ | neg. | @ | 1/83 |

| NPDES NO. | AUTHORITY NAME | FACILITY NAME | CITY NAME | DISCHARGE FLOW (MGD) | INDUSTRIAL FLOW (MGD) | PROGRAM STATUS APP | MO/YR |
|---|---|---|---|---|---|---|---|
| *CA0037842 | SAN JOSE, CITY OF | SAN JOSE/SANTA CLARA | SAN JOSE | 160.00+ | 40.00 | @ | 1/83 |
| *CA0037745 | SAN LEANDRO, CITY | SAN LEANDRO WWTF | SAN LEANDRO | 11.00+ | 3.10 | @ | 4/82 |
| *CA0049224 | SAN LUIS OBISPO | SAN LUIS OBISPO WWTF | SAN LUIS OBISPO | 5.10+ | 0.50 | @ | 5/83 |
| *CA0037541 | SAN MATEO, CITY OF | SAN MATEO WWTF | SAN MATEO | 13.60+ | 0.00 | @ | 9/83 |
| *CA0048143 | SANTA BARBARA, CITY | SANTA BARBARA WWTF | SANTA BARBARA | 11.00+ | 0.19 | @ | 3/83 |
| *CA0048194 | SANTA CRUZ, CITY OF | SANTA CRUZ WWTF | SANTA CRUZ | 21.00+ | 1.20 | @ | 10/83 |
| *CA0048275 | SANTA MARIA, CITY | PUBLIC AIRPORT WWTF | SANTA MARIA | 2.90 | 1.50 | @ | 7/83 |
| *CA0022764 | SANTA ROSA | LAGUNA WWTF | SANTA ROSA | 15.00+ | 0.75 | @ | 6/83 |
| A | SELMA-KINGS.-FLOWER | | KINGSBURG | | | @ | 6/83 |
| *CA0037711 | SO. MARIN SA | SO.MARIN WWTF | MILL VALLEY | 2.90 | 0.00 | @ | 6/83 |
| *CA0055221 | SIMI VALLEY COUNTY | SIMI VALLEY WWTF | SIMI VALLEY | 9.10+ | 0.38 | @ | 6/82 |
| | | | | | | | |
| *CA0107417 | SO EAST REG REC AUT | SERRA REG WWTF | DANA POINT | 17.80+ | 0.03 | @ | 2/83 |
| *CA0038130 | SO SAN FRAN DPT PUB | SO SF-SAN BRUNO WWTF | SO.SAN FRAN. | 13.00+ | 1.70 | @ | 2/83 |
| *CA0102709 | SOUTH TAHOE PUD | SOUTH TAHOE WWTF | SO.LAKE TAHOE | 7.00+ | 0.00 | @ | 6/82 |
| *CA0079138 | STOCKTON DEPT OF PU | STOCKTON REG. WWTF | STOCKTON | 67.00+ | 8.00 | @ | 6/82 |
| *CA0037621 | SUNNYVALE, CITY OF | SUNNYVALE WWTF | SUNNYVALE | 21.38+ | 10.30 | @ | 6/82 |
| *CA0078948 | TURLOCK, CITY OF | TURLOCK WWTF | TURLOCK | 12.75+ | 8.10 | @ | 9/82 |
| *CA0079154 | TRACY, CITY OF | TRACY WWTF | TRACY | 5.50+ | 1.60 | @ | 3/83 |
| *CA0056294 | THOUSAND OAKS DPT | HILL CANYON WWTF | CAMARILLO | 10.00+ | 0.20 | @ | 6/82 |
| *CA0037591 | UNION SANITARY DIST | ALVARADO #3 WWTF | UNION CITY | 4.50 | 0.61 | @ | 9/81 |
| *CA | UPLAND, CITY OF | | UPLAND | | | @ | 5/83 |
| *CA0077691 | VACAVILLE DEPT OF P | EASTERLY WWTF | ELMIRA | 10.00+ | 0.33 | @ | 3/83 |
| | | | | | | | |
| A0037699 | VALLEJO SAN & FC DI | VSTED WWTF & RECL | VALLEJO | 12.50+ | 0.20 | @ | 7/82 |
| *CA | VENTURA RCSD | | FILLMORE | + | | @ | 6/82 |
| CA0054097 | OXNARD, CITY OF | OXNARD WWTF | OXNARD | 22.50 | 2.55 | | |
| *CA0079189 | VISALIA, CITY OF | VISALIA WWTF | VISALIA | 7.70+ | 1.57 | @ | 5/83 |
| *CA0048216 | WATSONVILLE, CITY | WATSONVILLE WWTF | WATSONVILLE | 13.40+ | 3.00 | @ | 5/83 |
| *CA0037974 | WEST CONTRA COSTA | WCCSD WWTF | SAN PABLO | 12.50+ | 0.65 | @ | 4/82 |
| *CA0077950 | WOODLAND, CITY OF | WOODLAND WWTF | WOODLAND | 4.00 | | @ | 8/83 |
| *CA0079260 | YUBA CITY, CITY OF | YUBA CITY WWTF . | YUBA CITY | 7.00+ | 1.60 | @ | 7/82 |
| *CA0107611 | ALISO WAT MANAGEMNT | AWMA COASTAL WWTF | SOUTH LAGUNA | 2.50 | 0.00 | @ | 2/83 |
| *CA | BAKERSFIELD, CITY | BAKERSFIELD WWTF #2 | BAKERSFIELD | 15.00+ | 0.77 | @ | 9/85 |
| *CA0037788 | BURLINGAME, CITY OF | BURLINGAME WWTF | BURLINGAME | 5.50+ | 0.50 | @ | 1/84 |

CALIFORNIA  (Continued)

| NPDES NO. | AUTHORITY NAME | FACILITY NAME | CITY NAME | DISCHARGE FLOW (MGD) | INDUSTRIAL FLOW (MGD) | PROGRAM APP | STATUS MO/YR |
|---|---|---|---|---|---|---|---|
| *CA0105236 | COLTON, CITY OF | COLTON WWTF | COLTON | 5.40+ | 0.70 | @ | 6/85 |
| *CA0105848 | CORONA, CITY OF | CORONA WWTF | CORONA | 5.50+ | 0.43 | @ | 3/85 |
| *CA0037532 | MILLBRAE, CITY OF | MILLBRAE WWTF | MILLBRAE | 3.00 | 0.05 | @ | 1/84 |
| *CA | SAN BERNARDINO CO. | | | | | @ | 9/85 |
| *CA0038369 | SOUTH BAYSIDE SYS A | S BAYSIDE WWTF | REDWOOD CITY | 26.00+ | 2.70 | @ | 6/85 |
| *CA | ONTARIO, CITY OF | | ONTARIO | | | @ | 7/83 |
| *CA0059021 | VENTURA R.C.S.D. | FILLMORE WWTF | FILLMORE | 1.33 | 0.00 | @ | 9/83 |

DELETIONS:

| NPDES NO. | AUTHORITY NAME | FACILITY NAME | CITY NAME | DISCHARGE FLOW (MGD) |
|---|---|---|---|---|
| *CA | BACKSVILLE | | | |
| *CA0104426 | EL CENTRO, CITY OF | EL CENTRO WWTF | EL CENTRO | 5.00 |
| *CA0078905 | REDDING, CITY OF | ENTERPRISES WWTF | REDDING | 1.00 |
| *CA | MOUNT VERNON CO. SA | MOUNT VERNON WWTF | | |
| *CA | VENECIA | | | |
| *CA | CLARK CO. | | | |
| *CA | SAN FRAN AIRPORT | | | |
| *CA | PORTERVILLE, CITY OF | | PORTERVILLE | |

APPENDIX D: Trihalomethane Formation

# APPENDIX D.   TRIHALOMETHANE FORMATION


## General


Trihalomethanes (THMs) are compounds characterized by a methane structure with three hydrogen atoms replaced by halogen atoms.   For instance, chloroform (trichloromethane) has the structural formula $CHCl_3$.   Of the 16 PTOCs of interest, three are classified as THMs; chloroform, bromodichloromethane, and chlorodibromomethane.

Under the appropriate conditions, the chlorination of wastewater can lead to the formation of THMs.   In this section, the important factors which affect the formation of THMs are described, along with possible precursors, and formation and reaction mechanisms.   Although a comprehensive review of THM formation is beyond the scope of this study, references are noted so that the reader may pursue additional information on the subject.


## Factors Affecting THM Formation

Several factors can influence the relative magnitude of THM formation.   These can be classified into three groups; (1) general wastewater characteristics, (2) specific biological and chemical characteristics of the wastewater, and (3) characteristics of the chlorination system.   A brief review of the factors associated with each group is presented in the following subsections.


## General wastewater characteristics

The two general wastewater conditions which can influence THM formation are pH and temperature.   From a practical standpoint, the wastewater pH should have a very small impact on haloform reactions. This is due to the typically narrow pH range of most wastewaters.   Dore et. al. (1982) found that the THM yield peaked at much higher pH values than are usually observed in municipal wastewater.   However, the peak

was found to be a function of the halogen compound used and the precursors present.

Changes in the temperature of the wastewater affect the reaction rate of THM formation and competing reactions. As with pH, a typically narrow wastewater temperature range leads to the conclusion that temperature does not significantly influence THM formation.

Specific biological and chemical characteristics of the wastewater

Competing halogens, ammonia, precursor compounds, and chemical and biological agents which lead to the formation of precursors, can all affect the quantity of individual THMs which are formed as a result of the chlorination of wastewater. The effects of competing halogens and ammonia will be discussed here. Precursors and precursor formation are addressed later.

Three halogens which may be present in wastewater are chlorine, bromine, and iodine, with iodine considered to be present in insignificant amounts relative to chlorine and bromine. Chlorine and bromine can react to form hypochlorous and hypobromous acid, respectively, which when exposed to the appropriate precursors lead to the formation of chlorinated and brominated THMs (Dore et al., 1982). In general, hypochlorous acid is considered to be more reactive with THM precursors than is hypobromous acid (Dore et al., 1982). However, brominated species have been found to be significant, even at high chlorine doses (Amy et al., 1984).

The presence of ammonia in wastewater plays an important role in the formation of trihalomethanes. Naturally occurring or added ammonia reacts with available chlorine to form chloramines, thus exerting a free chlorine demand and reducing the ultimate trihalomethane levels. It is generally believed that chloramines do not react to form THMs (Amy et al., 1984). However, Riznychok et. al. (1983) has suggested that chloramines are part of the total combined available chlorine which can react to form THMs. In either case, the presence of ammonia appears to reduce, but not totally eliminate THM production. The lack of complete

152

inhibition suggests that the reactivity of some precursors may be very high (Dore et al., 1982). It has been observed that complete elimination of THMs in chlorinated water containing humic substances is rare (Amy et al., 1984). Furthermore, greater quantities of THMS were formed during the chlorination of nitrified (ammonia reduced) effluent than during the chlorination in non-nitrified wastewater effluent (Chow and Roberts, 1981).

The significant effect of ammonia on THM formation suggests the importance of the degree of nitrification and the point of chlorine application. For instance, a sewage treatment plant that discharges to a sensitive receiving water may be required to meet stringent ammonia discharge standards. A high degree of nitrification before chlorination favors the formation of THMs. The opposite would be true for wastewaters with high ammonia concentrations and sewage treatment plants not designed for ammonia removal.

Characteristics of the chlorination system

Three important characteristics of the chlorination system are the chlorine dose, reaction time, and the location of chlorine addition.

The formation of trihalomethanes has been shown to be proportional to the chlorine dose, or amount of chlorine added to the wastewater per unit time (Dore et al., 1982; Amy et al., 1984). For a better understanding of the effect that the chlorine dose has on the THM yield, breakpoint chlorination and chlorine breakpoint curves should be considered. A thorough review of breakpoint chlorination is beyond the scope of this work.

The reaction time during which trihalomethanes can form after chlorine addition is important, but not well understood for wastewater streams. The reaction time is dependent upon the wastewater flowrate and the residence time in the chlorine contact and effluent outfall systems. The use and location of dechlorination systems are also important factors. Chloroform, bromodichloromethane, and chlorodibromomethane have all been shown to increase with increases in the reaction

153

time (Cooper et. al., 1983). Dechlorination tends to reduce, but not completely eliminate THM yields, even after a very short reaction time of 2 minutes (Helz et al., 1985). This suggests that the chemical processes involved in the production of THMs occur rapidly after chlorine addition.

The location of chlorine addition can seriously impact the relative significance of THM formation. Where disinfection is necessary, final effluent is typically chlorinated. However, some facilities require chlorination of the influent to control odors, and some require chlorinated odor control on the influent, as well as disinfection by chlorination of the effluent, stream. If the influent stream is chlorinated, several mechanisms can affect the THM yield. For instance, without influent dechlorination the increased reaction time and precursor concentration tend to favor an increase in the THM yield, while a higher ammonia concentration in the influent stream favors a reduction in the yield. In addition, the precursor concentration may actually be lower in the influent stream as precursors may form during biological treatment later in the treatment process.

## Precursors

Although it would be desirable to be able to correlate the formation of trihalomethanes with a common organic parameter such as BOD or COD, such correlations are not possible, as the formation of THMs is closely related to the chemical structure of the precursor compounds (Dore et al., 1982; Takehisa et al., 1985). The most commonly noted THM percursors are humic substances (Amy et al., 1984). Takehisa et al. (1985) observed that both humic acid and fulvic acid in natural water were precursors leading to the formation of THMs in drinking water.

Aquatic algae and their metabolic products can produce precursors of THMs, but the precursor molecules have not been identified conclusively (Itoh et al., 1985). Acetoacetic acid, known to be an intermediate of fatty acid catabolism, is typically produced by sewage bacteria during the biodegradation of organic materials (Itoh et al., 1985). In

154

addition, the chlorination of a solution containing acetoacetic acid led to a chloroform yield of 55.5% on a molar basis, and it was suggested that between 51 - 87% of the total chloroform yield of a wastewater was explained by reactions involving acetoacetic acid (Itoh et al., 1985).

Dore et. al. (1982) studied a number of potential precursors and the chloroform yield when waters containing those precursors were spiked with a known amount of chlorine. Potentially significant precursors were noted to be those compounds bearing acetyl groups, and those compounds susceptible to forming acetyl groups by oxidation. The precursors that were studied had a wide range of molar percent yields of chloroform, ranging from 0.15% for acetone, to 91.5% for resorcinol. Additional precursors and their molar percent yields included phenol (0.4%), pyruvic acid (1%), acetophenone (1.2%), phloroglucinol (55%), and acetyl acetone (91%).

## Reaction Mechanisms

The reactions of greatest concern are the THM formation reaction and the chloramine formation reaction. The reaction between hypochlorous acid and ammonia to form chloramines has a reaction rate on the order of $1.0 \times 10^6$ L/mol-s. Such a high rate would tend to indicate a low amount of THM formation when ammonia is present during chlorination. However, THMs have been observed to form even under such conditions. Cooper et al. (1983) suggested that such results can be explained by a multi-step process for THM formation. The first step is believed to be relatively fast with respect to the hypochlorous acid / ammonia reaction. Slower formation reactions follow for a period of 24 hours or more after chlorination. Amy et al. (1984) also observed an initial THM formation rate that is competitive with the formation of chloramines. It was suggested that following the initial step the THM formation mechanism is slow, but it acts in parallel with the chloramine formation mechanism. The THM formation peak has been noted to occur approximately 15 minutes after the initial chlorine contact (Riznychok et al., 1983). The overall time frame for formation has been observed to be on the order of days (Kavanaugh et al., 1980).

155

## Emissions of Trihalomethanes Following Chlorination

Volatile emissions of THMs following chlorination can be significantly affected by the location of chlorination, as well as effluent outfall characteristics. For instance, if the wastewater is chlorinated as influent, THMs have ample opportunity to volatilize throughout the entire treatment process. If the effluent is chlorinated at the sewage treatment plant and then conveyed to an ultimate receiving water, the characteristics of the effluent outfall line (e.g., open, enclosed, vented, length, etc.) can affect emissions during outfall. The nature of the receiving system is also very important. While volatilization may not occur at the sewage treatment plant or in the outfall line, if the effluent is discharged to a surface receiving water the THMs are likely to volatilize downstream.

## Summary

Trihalomethanes form during the chlorination of municipal wastewater. However, studies to date have focussed upon drinking water chlorination, and an understanding of THM formation during wastewater treatment is incomplete. The most important factors that affect THM formation are the presence of competing halogens, ammonia that competes for available chlorine, and organic precursors. The chlorine dose, reaction time, and the location of chlorine addition are also factors that affect THM formation. The most important precursors appear to be humic substances that bear acetyl groups. The reaction between such precursors and hypochlorous acid is able to compete with the formation of chloramines for a short period of time following the initial chlorine contact. Thus, even in the presence of ammonia, some degree of THM formation is expected to occur. Finally, the importance of the generated chloroform with respect to airborne emissions is believed to be dependent upon the location of chlorine addition and the effluent outfall characteristics.

APPENDIX E:  WEST Code

```
C      PROGRAM WEST (WORST-CASE EMISSIONS DURING SEWAGE TREATMENT)
C
C      DEVELOPED BY:  RICHARD L. CORSI
C                     UNIVERSITY OF CALIFORNIA AT DAVIS
C                     DECEMBER 1986
C
C      PROGRAM WEST UTILIZES AVERAGE FLOW AND CONCENTRATION DATA THAT
C      ARE STORED IN EXTERNAL FILE COUNTY.DAT. THESE DATA ARE THEN USED
C      TO COMPUTE AVERAGE EMISSION RATES FROM INDIVIDUAL WASTEWATER
C      TREATMENT PLANTS. EMISSIONS FROM INDIVIDUAL PLANTS ARE OUTPUT TO
C      EXTERNAL FILE EMSTP.PRT. COUNTY-BY-COUNTY EMISSIONS ARE OUTPUT
C      TO EXTERNAL FILE CSUM.PRT.
C
C
       REAL PR(16),SUMS(16),SUMC(16),C(16),CFLO(58),TOTF(58),PFLOW(58)
      1,EOUT(16),SR(16),SLUMC(16),SLUMS(16)
C
       OPEN(UNIT=3,FILE='CSUM.PRT',STATUS='NEW')
       OPEN(UNIT=5,FILE='COUNTY.DAT',STATUS='OLD')
       OPEN(UNIT=6,FILE='EMSTP.PRT',STATUS='NEW')
C
C      THROUGHOUT ANALYSIS, THE FOLLOWING SUBSCRIPTS ARE USED:
C
C          1    ACRYLONITRILE
C          2    BENZENE
C          3    BROMODICHLOROMETHANE
C          4    CARBON TETRACHLORIDE
C          5    CHLOROBENZENE
C          6    CHLOROFORM
C          7    DIBROMOOCHLOROBENZENE
C          8    1,1 DICHLOROETHYLENE
C          9    ETHYLBENZENE
C         10    1,2 DICHLOROETHANE
C         11    METHYLENE CHLORIDE
C         12    PERCHLOROETHYLENE
C         13    TOLUENE
C         14    1,1,1 TRICHLOROETHANE
C         15    TRICHLOROETHYLENE
C         16    VINYL CHLORIDE
C
C      ASSIGN THE FRACTIONAL REMOVAL EFFICIENCIES
C
       PR(1)=0.90
       PR(2)=0.72
       PR(3)=0.90
       PR(4)=0.95
       PR(5)=0.87
       PR(6)=0.90
       PR(7)=0.90
       PR(8)=0.77
       PR(9)=0.84
       PR(10)=0.97
       PR(11)=0.65
       PR(12)=0.79
       PR(13)=0.89
       PR(14)=0.79
       PR(15)=0.83
       PR(16)=1.0
C
C      ASSIGN THE SLUDGE ADSORPTION FACTORS
C
       SR(1)=0.0
       SR(2)=0.01
       SR(3)=0.0
       SR(4)=0.043
       SR(5)=0.051
       SR(6)=0.0067
       SR(7)=0.0
       SR(8)=0.0
       SR(9)=0.043
       SR(10)=0.011
```

```fortran
      SR(11)=0.0799
      SR(12)=0.0414
      SR(13)=0.0974
      SR(14)=0.0067
      SR(15)=0.0408
      SR(16)=0.0126
C
C     READ NUMBER OF COUNTIES IN DATABASE COUNTY.DAT (NC)
C
      READ(5,*)NC
C
C     INITIALIZE THE STATEWIDE EMISSIONS AND SLUDGE TOTALS
C
      DO 9 MM=1,16,1
        SUMS(MM)=0.0
        SLUMS(MM)=0.0
9     CONTINUE
      SUMD=0.0
      SUMF=0.0
C
C     LOOP THROUGH THE COUNTIES
C     I=COUNTY NUMBER (1=ALAMEDA ...... 58=YUBA)
C
      DO 10 I=1,NC,1
C
C     ICTY = COUNTY NUMBER; NP = NUMBER OF PLANTS IN COUNTY ICTY
C
        READ(5,*)ICTY,NP
C
C     INITIALIZE THE EMISSIONS AND SLUDGE TOTALS FOR COUNTY I
C
        DO 11 MM=1,16,1
          SUMC(MM)=0.0
          SLUMC(MM)=0.0
11      CONTINUE
C
C       INITIALIZE THE TOTAL FLOW (TOTF) FOR COUNTY I, AND FLOW
C       (CFLO) ACCOUNTED FOR BY MWTPS WITH CONCENTRATION DATA
C
        TOTF(I)=0.0
        CFLO(I)=0.0
C
C       LOOP THROUGH ALL NP PLANTS IN COUNTY I
C
        DO 20 J=1,NP,1
          SPLANT=0.0
          READ(5,1000)
C
C       IFLAG INDICATES THE DEGREE OF AVAILABLE DATA
C
          READ(5,1050)IFLAG
C
C       READ FLOW DATA AND ASSIGN THE MOST APPROPRIATE FLOWRATE
C
C       AF IS THE TOTAL FLOW LISTED IN THE NEEDS DATA BASE;
C       AIND IS THE INDUSTRIAL FLOW; ACT IS AN UPDATED FLOWRATE IF SUCH
C       A VALUE IS AVAILABLE. ALL FLOWS ARE READ AS MGD.
C
          READ(5,1100)AF,AIND,ACT
C
C       SELECT APPROPRIATE FLOWRATE
C
          IF(ACT .EQ. 0.0)THEN
            FLOW=AF
          ELSE
            FLOW=ACT
          END IF
C
C       COMPLETE SUMMATION OF FLOWS IN COUNTY I
C
          TOTF(I)=TOTF(I)+FLOW
          SUMF=SUMF+FLOW
```

159

```fortran
C       CODE (IUP) TO INDICATE IF THE DATA IN COUNTY.DAT IS UPDATED
C
        IF(ACT .GT. 0.0)THEN
          IUP=1
        ELSE
          IUP=0
        END IF
C
C       DEFINE THE FRACTION INDUSTRIAL FLOW (R)
C
        R=AIND/FLOW
C
C       ANALYSIS FOR STPS WITH KNOWN INFLUENT AND EFFLUENT DATA
C
        IF(IFLAG .EQ. 1 .OR. IFLAG .EQ. 3)THEN
          CFLO(I)=CFLO(I)+FLOW
          SUMD=SUMD+FLOW
C
C       LOOP THROUGH EACH OF THE 16 PTOCS
C
          DO 30 M=1,16,1
            READ(5,1200)CI,CE,ICODE
            SLOUT=SR(M)*FLOW*CI*1.52E-3
            IF(ICODE .EQ. 5)THEN
              IF(CE .GT. CI)THEN
                IF(M .EQ. 3 .OR. M .EQ. 6 .OR. M .EQ. 7)THEN
                  D=CI*PR(M)
                ELSE
                  D=0.0
                END IF
              ELSE
                D=CI-CE
              END IF
            ELSE IF(ICODE .EQ. 2)THEN
              D=CI
            ELSE
              D=0.0
            END IF
C
C       CALCULATE THE EMISSION RATE (EOUT) IN TONS/YEAR
C
            EOUT(M)=D*FLOW*1.52E-3
            SPLANT=SPLANT+EOUT(M)
            SUMC(M)=SUMC(M)+EOUT(M)
            SUMS(M)=SUMS(M)+EOUT(M)
            SLUMC(M)=SLUMC(M)+SLOUT
            SLUMS(M)=SLUMS(M)+SLOUT
30        CONTINUE
          WRITE(6,1300)ICTY,J,SPLANT,(EOUT(LM),LM=2,16,1)
C
C       ANALYSIS FOR STPS WITH KNOWN INFLUENT DATA
C
        ELSE IF(IFLAG .EQ. 2)THEN
          CFLO(I)=CFLO(I)+FLOW
          SUMD=SUMD+FLOW
          DO 40 M=1,16,1
            READ(5,1400)CI,ICODE
            SLOUT=SR(M)*FLOW*CI*1.52E-3
            IF(ICODE .EQ. 5)THEN
              D=PR(M)*CI
            ELSE
              D=0.0
            END IF
            EOUT(M)=D*FLOW*1.52E-3
            SPLANT=SPLANT+EOUT(M)
            SUMC(M)=SUMC(M)+EOUT(M)
            SUMS(M)=SUMS(M)+EOUT(M)
            SLUMC(M)=SLUMC(M)+SLOUT
            SLUMS(M)=SLUMS(M)+SLOUT
40        CONTINUE
          WRITE(6,1300)ICTY,J,SPLANT,(EOUT(LM),LM=2,16,1)
```

```
C          ANALYSIS FOR STPS WITH KNOWN INFLUENT DATA
C
              ELSE IF(IFLAG .EQ. 2)THEN
                 CFLO(I)=CFLO(I)+FLOW
                 SUMD=SUMD+FLOW
                 DO 40 M=1,16,1
                    READ(5,1400)CI,ICODE
                    SLOUT=SR(M)*FLOW*CI*1.52E-3
                    IF(ICODE .EQ. 5)THEN
                      D=PR(M)*CI
                    ELSE
                      D=0.0
                    END IF
                    EOUT(M)=D*FLOW*1.52E-3
                    SPLANT=SPLANT+EOUT(M)
                    SUMC(M)=SUMC(M)+EOUT(M)
                    SUMS(M)=SUMS(M)+EOUT(M)
                    SLUMC(M)=SLUMC(M)+SLOUT
                    SLUMS(M)=SLUMS(M)+SLOUT
40               CONTINUE
                 WRITE(6,1300)ICTY,J,SPLANT,(EOUT(LM),LM=2,16,1)
C
C       ENTER THE EXTRAPOLATION SEGMENT
C
              ELSE
C
C       EXTRAPOLATE CONCENTRATIONS TO THOSE STPS WITH NO INDUSTRIAL FLOW
C
                 IF(R .EQ. 0.0)THEN
                    C(1)=0.0
                    C(2)=0.60
                    C(3)=0.13
                    C(4)=0.0
                    C(5)=0.0
                    C(6)=11.2
                    C(7)=0.17
                    C(8)=0.0
                    C(9)=0.32
                    C(10)=0.30
                    C(11)=6.93
                    C(12)=4.25
                    C(13)=4.35
                    C(14)=2.13
                    C(15)=1.42
                    C(16)=0.0
                 ELSE
C
C       EXTRAPOLATE CONCENTRATIONS TO STPS IN THE INLAND VALLEY
C
                    IF(ICTY .EQ. 4 .OR. ICTY .EQ. 6 .OR. ICTY .EQ. 10 .OR.
     1                 ICTY .EQ. 11 .OR. ICTY .EQ. 13 .OR. ICTY .EQ. 15 .OR.
     1                 ICTY .EQ. 16 .OR. ICTY .EQ. 20 .OR. ICTY .EQ. 24 .OR.
     1                 ICTY .EQ. 34 .OR. ICTY .EQ. 39 .OR. ICTY .EQ. 45 .OR.
     1                 ICTY .EQ. 45 .OR. ICTY .EQ. 50 .OR. ICTY .EQ. 51 .OR.
     1                 ICTY .EQ. 52 .OR. ICTY .EQ. 54 .OR. ICTY .EQ. 57 .OR.
     1                 ICTY .EQ. 58)THEN
                       C(1)=0.0
                       C(2)=0.08*R
                       C(3)=0.0
                       C(4)=0.0
                       C(5)=0.71*R
                       C(6)=28.47*R
                       C(7)=0.0
                       C(8)=3.06*R
                       C(9)=8.91*R
                       C(10)=0.0
                       C(11)=30.06*R
                       C(12)=104.18*R
                       C(13)=84.61*R
                       C(14)=22.38*R
                       C(15)=157.7*R
                       C(16)=0.0
```

```
C       EXTRAPOLATE CONCENTRATIONS TO STPS IN CONTRA COSTA AND SOLANO
C       COUNTIES
C
                ELSE IF(ICTY .EQ. 7 .OR. ICTY .EQ. 48)THEN
                   C(1)=0.0
                   C(2)=23.3*R
                   C(3)=0.0
                   C(4)=0.0
                   C(5)=0.0
                   C(6)=548.6*R
                   C(7)=0.0
                   C(8)=0.0
                   C(9)=30.74*R
                   C(10)=7.69*R
                   C(11)=555.3*R
                   C(12)=254.2*R
                   C(13)=161.7*R
                   C(14)=34.97*R
                   C(15)=64.65*R
                   C(16)=0.0
C
C       EXTRAPOLATE CONCENTRATIONS TO STPS IN ALAMEDA AND SANTA CLARA
C       COUNTIES
C
                ELSE IF(ICTY .EQ. 1 .OR. ICTY .EQ. 43)THEN
                   C(1)=0.0
                   C(2)=21.2*R
                   C(3)=1.6*R
                   C(4)=16.82*R
                   C(5)=0.0
                   C(6)=65.03*R
                   C(7)=0.93*R
                   C(8)=11.71*R
                   C(9)=9.55*R
                   C(10)=0.0
                   C(11)=174.45*R
                   C(12)=168.89*R
                   C(13)=182.59*R
                   C(14)=88.71*R
                   C(15)=27.68*R
                   C(16)=0.0
C
C       EXTRAPOLATE CONCENTRATIONS TO STPS IN SAN MATEO AND SF COUNTIES
C
                ELSE IF(ICTY .EQ. 38 .OR. ICTY .EQ. 41)THEN
                   C(1)=0.0
                   C(2)=9.9*R
                   C(3)=1.94*R
                   C(4)=0.0
                   C(5)=81.18*R
                   C(6)=178.8*R
                   C(7)=0.0
                   C(8)=54.93*R
                   C(9)=51.78*R
                   C(10)=120.94*R
                   C(11)=102.88*R
                   C(12)=273.27*R
                   C(13)=200.31*R
                   C(14)=116.49*R
                   C(15)=111.29*R
                   C(16)=0.0
C
C       EXTRAPOLATE CONCENTRATIONS TO STPS IN LA AND ORANGE COUNTIES
C
                ELSE IF(ICTY .EQ. 19 .OR. ICTY .EQ. 30)THEN
                   C(1)=0.0
                   C(2)=124.57*R
                   C(3)=2.43*R
                   C(4)=1.52*R
                   C(5)=0.66*R
                   C(6)=161.63*R
                   C(7)=0.62*R
```

```
              C(8)=7.38*R
              C(9)=115.2*R
              C(10)=22.29*R
              C(11)=589.1*R
              C(12)=395.89*R
              C(13)=589.6*R
              C(14)=442.4*R
              C(15)=60.86*R
              C(16)=12.87*R
C
C     EXTRAPOLATE CONCENTRATIONS TO STPS IN VENTURA COUNTY
C
              ELSE IF(ICTY .EQ. 56)THEN
              C(1)=0.0
              C(2)=73.2*R
              C(3)=33.6*R
              C(4)=0.0
              C(5)=0.0
              C(6)=113.19*R
              C(7)=15.4*R
              C(8)=38.5*R
              C(9)=14.0*R
              C(10)=0.0
              C(11)=0.0
              C(12)=230.3*R
              C(13)=51.8*R
              C(14)=228.2*R
              C(15)=10.5*R
              C(16)=0.0
C
C     EXTRAPOLATE CONCENTRATIONS TO STPS IN RIVERSIDE, SAN BERNARDINO,
C     AND SAN DIEGO COUNTIES
C
              ELSE IF(ICTY .EQ. 33 .OR. ICTY .EQ. 36 .OR. ICTY
     1              .EQ. 37)THEN
              C(1)=0.0
              C(2)=45.61*R
              C(3)=12.47*R
              C(4)=0.0
              C(5)=0.0
              C(6)=69.71*R
              C(7)=0.0
              C(8)=0.36*R
              C(9)=97.98*R
              C(10)=0.0
              C(11)=176.35*R
              C(12)=64.67*R
              C(13)=367.10*R
              C(14)=47.09*R
              C(15)=2.93*R
              C(16)=0.0
C
C     EXTRAPOLATE CONCENTRATIONS TO THOSE COUNTIES NOT LISTED ABOVE
C
              ELSE
              C(1)=0.0
              C(2)=0.60
              C(3)=0.13
              C(4)=0.0
              C(5)=0.0
              C(6)=11.2
              C(7)=0.17
              C(8)=0.0
              C(9)=0.32
              C(10)=0.3
              C(11)=6.93
              C(12)=4.25
              C(13)=4.35
              C(14)=2.13
              C(15)=1.42
              C(16)=0.00
              END IF
```

```fortran
C
C      ESTIMATE THE EMISSION RATE (EOUT).. (TONS/YEAR) FOR THE STPS
C      WITHOUT KNOWN INFLUENT OR INFLUENT/EFFLUENT DATA
C
                 END IF
                 DO 50 M=1,16,1
                    SLOUT=C(M)*FLOW*SR(M)*1.52E-3
                    D=C(M)*PR(M)
                    EOUT(M)=D*FLOW*1.52E-3
                    SPLANT=SPLANT+EOUT(M)
                    SUMC(M)=SUMC(M)+EOUT(M)
                    SUMS(M)=SUMS(M)+EOUT(M)
                    SLUMC(M)=SLUMC(M)+SLOUT
                    SLUMS(M)=SLUMS(M)+SLOUT
50               CONTINUE
                 WRITE(6,1300)ICTY,J,SPLANT,(EOUT(LM),LM=2,16,1)
              END IF
20         CONTINUE
C
C      COMPUTE THE TOTAL EMISSIONS FOR EACH PTOC IN COUNTY I
C
           SUM=0.0
           SLUD=0.0
           DO 60 L=1,16,1
              SUM=SUM+SUMC(L)
              SLUD=SLUD+SLUMC(L)
60         CONTINUE
C
C      COUNTY OUTPUT: TOTAL EMISSIONS (SUM), SPECIATED EMISSIONS (SUMC),
C      TOTAL REMOVAL IN SLUDGE (SLUD), SPECIATED REMOVAL IN SLUDGE,
C      SLUMC
C
           WRITE(3,1500)I,SUM,(SUMC(LM),LM=2,16,1),
      1                  SLUD,(SLUMC(LM),LM=2,16,1)
10      CONTINUE
C
C      OUTPUT STATEWIDE LOSSES IN SLUDGE STREAMS (SPECIATED = SLUMS;
C      TOTAL = SSLUG), AND EMISSIONS (SUMS).
C
        SSLUG=0.0
        DO 70 M=1,16,1
           SSLUG=SSLUG+SLUMS(M)
70      CONTINUE
        WRITE(3,1600)SSLUG,(SLUMS(LM),LM=2,16,1)
        WRITE(3,1700)(SUMS(M),M=1,16,1)
C
C      FORMAT  GROUPING
C
1000    FORMAT(1X)
1050    FORMAT(I2)
1100    FORMAT(1X,F9.2,11X,F9.2,21X,F9.2,/)
1200    FORMAT(11X,F9.2,21X,F9.2,11X,I10)
1300    FORMAT(2(1X,I2),16(1X,F6.2))
1400    FORMAT(11X,F9.2,41X,I10)
1500    FORMAT(1X,I2,16(1X,F6.2),/,3X,16(1X,F6.2))
1600    FORMAT(//,3X,16(1X,F6.2))
1700    FORMAT(5(/),16(1X,F6.2))
        END
```

APPENDIX F:  Data Base Structure

APPENDIX F: DATA BASE STRUCTURE

In this appendix, descriptions of four data files, submitted to the staff of the CARB for future analyses relative to MWTPs, are provided. Three of the four files (TTRAIN, POTW, and SLUDGE) are related by MWTP facility numbers to establish a "linked" data base structure. Those three files contain records associated with individual MWTPs in California. File COUNTY contains information regarding emissions of PTOCs and PTOC removals in sludge streams throughout individual counties. Descriptions of the data records and data fields are provided below for each file. Equivalent FORTRAN field formats are listed for each data field.

## POTW

File POTW contains information related to the location, flow characteristics, and estimated emissions from every MWTP identified in this study. All emissions estimates are reported in tons/year to two decimal places. Those listed as 0.00 should be assumed to be less than 10 lb/year. The most recent annual average flowrates were used whenever possible (i.e., for most of the MWTPs identified in Table 13 of this report). Otherwise, average dry weather flowrates from the NEEDS data base were used. Latitude and longitude coordinates were also extracted from the NEEDS data base, although coordinates for a small number of the facilities were not available. Most of the location coordinates correspond to the site of effluent discharge, which in some cases may be several miles from the actual treatment facility. The record for each MWTP has the following two-line structure.

```
SNME  CNUM  SNUM  FNUM  LA  LO  TF  IF  TEM  P2  P3  ........  P6
P7  P8  P9  ...................  P16
```

| | | columns | | |
|---|---|---|---|---|
| SNME | Name of facility | columns | 1-25 | A25 |
| CNUM | County number | | 28-29 | I2 |
| SNUM | Plant number in county CNUM | | 32-33 | I2 |
| FNUM | Facility ID number | | 36-43 | I8 |
| LA | Latitude (degrees.minutes,seconds) | | 46-52 | F7.4 |

166

| LO   | Longitude("           ") | 55-62   | F8.4 |
|------|--------------------------|---------|------|
| TF   | Total flow (MGD)         | 65-70   | F6.2 |
| IF   | Industrial flow (MGD)    | 73-77   | F5.2 |
| TEM  | Total PTOC emissions     | 80-85   | F6.2 |
| P2   | Benzene emissions        | 88-93   | F6.2 |
| P3   | Bromodichloromethane emissions | 96-101 | |
| P4   | Carbon tetrachloride emissions | 104-109 | |
| P5   | Chlorobenzene emissions  | 112-117 | |
| P6   | Chloroform emissions     | 120-125 | |
| P7   | Dibromochloromethane emissions | 1-6 | |
| P8   | 1,1 Dichloroethylene emissions | 9-14 | |
| P9   | Ethylbenzene emissions   | 17-22   | |
| P10  | 1,2 Dichloroethane emissions | 25-30 | |
| P11  | Methylene chloride emissions | 33-38 | |
| P12  | Perchloroethylene emissions | 41-46 | F6.2 |
| P13  | Toluene emissions        | 49-54   | |
| P14  | 1,1,1 Trichloroethane emissions | 57-62 | |
| P15  | Trichloroethylene emissions | 65-70 | |
| P16  | Vinyl chloride emissions | 73-78   | |

## TTRAIN

File TTRAIN contains information regarding specific treatment processes at individual MWTPs. Twenty-eight treatment processes were chosen for entry into the data base. A 1 was entered in the record field if the MWTP utilizes the indicated process. Otherwise, a 0 was entered in the process data field. It should be noted that the treatment train data was extracted from the NEEDS data base which was observed to be outdated for some of the MWTPs. For major MWTPs, such as the eight that were visited for this study (Appendix G), revisions were made to the data base using more recent data. In addition, TTRAIN only indicates whether or not a process exists at a specific MWTP, and not where that process is located with respect to other processes in the treatment train. We have found that the use of TTRAIN with commercially available data base software can be valuable for readily identifying MWTPs in

California that utilize specific treatment processes (e.g., pure-oxygen activated sludge, multi-media filtration, etc.). The record for each MWTP consists of one row of data as indicated below.

```
FNUM  PR1  PR2  PR3 ............................... PR27  PR28
```

| | | | |
|---|---|---|---|
| FNUM | Facility ID number | Columns 1-8 | I8 |
| PR1 | Bar screening | 11 | I1 |
| PR2 | Grit or scum removal | 14 | I1 |
| PR3 | Comminution | 17 | I1 |
| PR4 | Flow equalization | 20 | I1 |
| PR5 | Pre-aeration | 23 | I1 |
| PR6 | Primary clarification | 26 | I1 |
| PR7 | Non-aerated ponds | 29 | I1 |
| PR8 | Aerated lagoons | 32 | I1 |
| PR9 | Trickling filters | 35 | I1 |
| PR10 | Attached growth processes | 38 | I1 |
| PR11 | Conventional activated sludge | 41 | I1 |
| PR12 | Pure-oxygen activated sludge | 44 | I1 |
| PR13 | Oxidation ditch | 47 | I1 |
| PR14 | Other suspended growth processes | 50 | I1 |
| PR15 | Land treatment | 53 | I1 |
| PR16 | Secondary clarification | 56 | I1 |
| PR17 | Sand filtration | 59 | I1 |
| PR18 | Mixed media filtration | 62 | I1 |
| PR19 | Pressure filtration | 65 | I1 |
| PR20 | Rock filtration | 68 | I1 |
| PR21 | Other filtration | 71 | I1 |
| PR22 | Activated carbon treatment | 74 | I1 |
| PR23 | Neutralization | 77 | I1 |
| PR24 | Breakpoint chlorination | 80 | I1 |
| PR25 | Ammonia stripping | 83 | I1 |
| PR26 | Dechlorination | 86 | I1 |
| PR27 | Post-aeration | 89 | I1 |
| PR28 | Chlorination | 92 | I1 |

## SLUDGE

File SLUDGE contains information associated with sludge treatment and disposal operations at individual MWTPs. Identification of an existing process is completed by the code described in TTRAIN (0 = does not utilize; 1 = does utilize). The sludge treatment and disposal characteristics were extracted from the NEEDS data base and are subject to the uncertainties noted previously for POTW and TTRAIN. The record for each MWTP consists of one row as indicated below.

FNUM  ST1  ST2 ....... ST9  SD1  SD2  SD3  SD4  SD5

| FNUM | Facility ID number | Columns 1-8 | I8 |
|------|--------------------|-------------|-----|
| ST1 | Aerobic digestion | 11 | I1 |
| ST2 | Anaerobic digestion | 14 | I1 |
| ST3 | Composting | 17 | I1 |
| ST4 | Purifax treatment | 20 | I1 |
| ST5 | Air drying | 23 | I1 |
| ST6 | Sludge lagoons | 26 | I1 |
| ST7 | Mechanical dewatering | 29 | I1 |
| ST8 | Air flotation thickening | 32 | I1 |
| ST9 | Incineration | 35 | I1 |
| SD1 | Landfill/trenching | 38 | I1 |
| SD2 | Land spreading | 41 | I1 |
| SD3 | Ocean disposal | 44 | I1 |
| SD4 | Sludge distribution or marketing | 47 | I1 |
| SD5 | Other sludge disposal mechanisms | 50 | I1 |

## COUNTY

File COUNTY contains information regarding estimates of total and speciated PTOC emissions for each county in California. Estimated PTOC removals in sludge streams are also provided for each county. Emissions and quantities removed in sludge are recorded in tons/year to two decimal places. Values listed as 0.00 should be taken to be less than 10 lb/year. The record for each county has the following two-line structure.

```
CNUM  CNME   TEC   E2  E3  ............................... E14  E15
E16  TS  S2  S3  ............................... S15  S16
```

| | | | | |
|---|---|---|---|---|
| CNUM | County number | Columns | 1-2 | I2 |
| CNME | County name | | 5-19 | A15 |
| TEC | Total PTOC emissions | | 22-27 | F6.2 |
| E2 | Benzene emissions | | 30-35 | " |
| E3 | Bromodichloromethane emissions | | 38-43 | " |
| E4 | Carbon tetrachloride emissions | | 46-51 | F6.2 |
| E5 | Chlorobenzene emissions | | 54-59 | " |
| E6 | Chloroform emissions | | 62-67 | " |
| E7 | Dibromochloromethane emissions | | 70-75 | " |
| E8 | 1,1 Dichloroethylene emissions | | 78-83 | " |
| E9 | Ethylbenzene emissions | | 86-91 | " |
| E10 | 1,2 Dichloroethane emissions | | 94-99 | " |
| E11 | Methylene chloride emissions | | 102-107 | " |
| E12 | Perchloroethylene emissions | | 110-115 | " |
| E13 | Toluene emissions | | 118-123 | " |
| E14 | 1,1,1 Trichloroethane emissions | | 126-131 | " |
| E15 | Trichloroethylene emissions | | 1-6 | " |
| E16 | Vinyl chloride emissions | | 9-14 | " |
| TS | Total PTOC removal in sludge | | 17-21 | F5.2 |
| S2 | Benzene removal | | 24-28 | " |
| S3 | Bromodichloromethane removal | | 31-35 | " |
| S4 | Carbon tetrachloride removal | | 38-42 | " |
| S5 | Chlorobenzene removal | | 45-49 | " |
| S6 | Chloroform removal | | 52-56 | " |
| S7 | Dibromochloromethane removal | | 59-63 | " |
| S8 | 1,1 Dichloroethylene | | 66-70 | " |
| S9 | Ethylbenzene removal | | 73-77 | " |
| S10 | 1,2 Dichloroethane removal | | 80-84 | " |
| S11 | Methylene chloride removal | | 87-91 | " |
| S12 | Perchloroethylene removal | | 94-98 | " |
| S13 | Toluene removal | | 101-105 | " |
| S14 | 1,1,1 Trichloroethane removal | | 108-112 | " |
| S15 | Trichloroethylene removal | | -115-119 | " |
| S16 | Vinyl chloride removal | | 122-126 | " |

170

APPENDIX G:  Wastewater Treatment Plant Visits

Eight municipal wastewater treatment plants (MWTPs) were visited. The MWTPs were selected on the basis of a number of factors: representative of a wide geographic cross-section of California, location in an air basin where photochemical air pollution was of concern, proximity to population centers, MWTP size, the amount of industrial flow, and characteristics of industries that discharged to the MWTP. The eight plants accounted for greater than 42% of the total dry-weather wastewater treated in California. A review of the visit to each MWTP and the general characteristics of each MWTP are provided in this section. Where available, past liquid and gas-phase sampling efforts are summarized. Finally, recommendations are made regarding future sampling efforts.

## Sacramento Regional Wastewater Treatment Plant (July 16, 1986)

The Sacramento Regional Wastewater Treatment Plant (SRWTP) was the largest sewage treatment plant (STP) in the Central Valley and the fifth largest STP, with respect to influent flow, in the state of California. The SRWTP was subjected to an average seasonal dry weather flow of 136 MGD, and an average wet weather flow of 142 MGD. The plant served an estimated 750,000 residents, as well as various commercial and industrial users. The principal industrial users were two canneries which discharged as much as 10 MGD during canning season.

Major treatment processes at the SRWTP included primary treatment, followed by pure-oxygen activated sludge treatment, chlorination, outfall, dechlorination, and discharge to the Sacramento River. Primary treatment involved influent screening, aerated grit removal, and primary sedimentation using 12 sedimentation tanks. All of the primary treatment processes were fully enclosed. Secondary treatment included eight pure-oxygen activated sludge aeration basins, followed by 16 secondary sedimentation tanks. The latter were not enclosed. Sixty to seventy

tons of sludge were generated each day. Secondary sludge was thickened by flotation before being mixed with primary sludge. The mixture was treated for approximately three weeks in anaerobic digesters. The sludge was then stored in solids storage basin ponds before being disposed of on-site by subsurface injection.

Liquid-phase samples were drawn from the influent and the effluent streams on a quarterly basis. Pre-chlorination and post-chlorination samples were completed on a less frequent basis. Influent and effluent samples were drawn by using a single "grab" sample, with the effluent sample time lagged by the estimated amount of time it would take a "plug" of water to pass through the entire treatment process. Past sampling indicated consistently higher chloroform concentrations in the effluent as compared to the influent. The formation of brominated THMs appeared to be insignificant. Sludge was not analyzed for the presence of PTOCs.

The efforts to reduce odors by enclosing most of the treatment processes, treatment of process off-gases, and the nature of industrial users, are believed to have led to lower PTOC emissions from the SRWTP relative to conventional treatment plants of comparable size.

Very few processes were noted as potential sources of PTOC emissions. Minor emissions might have occurred from the soil at the sludge disposal site. However, subsurface injection as well as a (retainer) wall, which acted to reduce air flow over the soil surface, should have reduced those emissions. In addition, the fraction of PTOCs partitioned to sludge was expected to be low, and those PTOCs in the sludge were likely to volatilize and be flared or degraded during anaerobic digestion. Another source of emissions might have been hot sludge foam which escaped from the floating roof digesters and became exposed to the atmosphere. However, this accounted for only a small fraction of the sludge, and the total exposed surface area was small. Some emissions may have occurred from uncovered secondary clarifiers, but the PTOC concentrations at that stage of the treatment process were probably very low. Emissions of trihalomethanes from the Sacramento River could have occurred following effluent chlorination and discharge.

A major source of PTOC emissions at the SRWTP was expected to be an odor removal tower (ORT) through which off-gases from primary and secondary treatment were vented to the atmosphere through an induced draft fan. The ventilation system would be suitable for sampling. Other sources of PTOC emissions could have been pressure-relief valves on each of the nine digester tanks. Each tank was equipped with up to four valves. Digester gases can contain significant concentrations of vinyl chloride. Past gas-phase sampling tests of digester gases have indicated significant concentrations of toluene, dichloroethylene, trichloroethylene, and perchloroethylene, in digester gases (California Air Resources Board, 1985). Both the ORT and out-gassing pressure-relief valves would be conducive to emissions sampling. In addition, large vacant fields surrounding the treatment plant would allow for upwind and downwind sampling if necessary.

Bakersfield Wastewater Treatment Plant #2 (August 4, 1986)

The Bakersfield WWTP #2 (BWTP2) was managed by the city of Bakersfield. It treated an annual average wastewater flow of 14.3 MGD. The BWTP2 served a population of approximately 130,000 residents, as well as 350 commercial and industrial users that accounted for 5% of the wastewater that was treated. The plant had not treated petroleum refinery wastewater.

The treatment train for the BWTP2 was relatively simple. Influent passed through bar screens and a comminutor, followed by an aerated grit chamber, and two 110 ft. diameter primary clarifiers in parallel. Secondary treatment included two aerated waste lagoon systems in parallel. Each lagoon system was composed of two lagoons. Secondary effluent was pumped to storage reservoirs. Stored effluent was ultimately used for restricted agricultural purposes. The effluent was not chlorinated. Primary and secondary sludge both underwent anaerobic digestion before being spread upon 150,000 sq. ft. of sludge drying beds located on-site. Between one· and two equivalent dry tons of sludge were treated each day.

The most significant sources of PTOC emissions at the BWTF2 were expected to be the two aerated processes, grit removal and waste lagoons. Primary clarification, digester gas relief, and stripping from sludge drying beds could have also been emissions sources. Previous sampling for priority pollutants at the BWTP2 indicated that ethylbenzene accumulated to significant concentrations in sludge. None of the other 16 PTOCs were detected in sludge samples. The last sample analysis for volatile priority pollutants was completed in 1983. At that time chloroform, ethylbenzene, methylene chloride, perchloroethylene, and toluene were all detected. However, all of those compounds occurred at relatively low concentrations (<7 $\mu g/l$). Because PTOC emissions were expected to be very low from the BWTP2, ambient or process sampling there would probably not be of great practical benefit.

## Joint Water Pollution Control Plant (August 6, 1986)

The Joint Water Pollution Control Plant (JWPCP) was managed by the County Sanitation District of Los Angeles County (CSDLAC). With an annual average flow of 365 MGD, it treated the second largest flow of wastewater in the state of California. Approximately 15% of the total flow was discharged by industrial users, which included several oil refineries and metal finishing plants. The area that it served was densely populated, with greater than 3,000,000 domestic users. In addition to the sludge generated at the plant, the JWPCP treated sludge from several other CSDLAC MWTPs. The amount of sludge treated and disposed of averaged approximately 380 tons/day.

Approximately 33% of the incoming wastewater was subjected only to primary treatment. Primary treatment at the JWPCP consisted of eight bar screens, six covered grit chambers in parallel, and fifty-two covered primary clarifiers. The grit chambers were aerated. The wastewater that underwent only primary treatment was also subjected to aeration using three traveling water screens before being discharged to the Pacific Ocean. Off-gases generated during primary treatment were vented through caustic scrubbers, activated carbon filters, or both.

The remainder (67%) of the incoming wastewater was subjected to both primary and secondary treatment. The primary effluent was treated using a pure-oxygen activated sludge system. Secondary sludge was removed using up to fifty-two secondary clarifiers in parallel. The secondary wastewater transport channel was aerated for particle suspension. Off-gases from the channel were treated by wet scrubbing. Final effluent was chlorinated only when disinfection was found to be necessary. The final effluent was discharged to the Pacific Ocean.

Secondary sludge was thickened by using up to four dissolved air flotation (DAF) tanks. Off-gases were treated using a two-stage blower with an activated carbon filter. Primary sludge and thickened secondary sludge were treated using anaerobic digestion. Approximately 7,000,000 SCF/day of digester was burned in engines for power generation, with a portion having been intermittently flared. Following digestion, the sludge was dewatered using low speed scroll or basket centrifuges. Dewatered sludge cake was transported by conveyor belts to twelve 550 ton capacity storage silos. Air in the enclosure above the silos was scrubbed using activated carbon before being vented to the atmosphere. Approximately 67% of the sludge was trucked to landfills for ultimate disposal. The remainder was composted on-site for commercial use as a soil amendment. The composting area consisted of approximately 540 windrows which covered twenty-five acres. Each windrow averaged 825 feet in length, and had a capacity of 525 wet tons of sludge. For the purpose of mixing and aeration, windrows were turned daily using a mobile composter. By 1988, a large fraction of the dewatered sludge was scheduled to be used for combustion to produce additional electricity for the plant.

Although many of the processes at the JWPCP were covered, and off-gases were typically scrubbed for odor control, many potential emission sources existed. Sources of emissions could have included aerated wastewater transport channels, fugitive emissions from the activated sludge system, leaking digesters, out-gassing pressure-relief valves on digesters, off-gases vented from scrubbers, and emissions from sludge composting operations.

Previous gas-phase sampling for some PTOCs was completed by the staff of the CSDLAC, and indicated that, compared to other processes that were analyzed, the aerated primary effluent channel was a significant source of PTOC emissions. The sum total of emissions for 23 VOCs, including twelve PTOCs, was estimated to be approximately 150 lb/day from all of the processes analyzed. Those processes included several off-gas scrubbers, the aerated primary effluent channel, and the activated sludge aeration basins.

Past analyses of digester gases indicated high concentrations of VOCs. However, no emissions estimates were made for PTOCs escaping from the digesters. Because of the large amount of digester gas that was produced at the JWPCP, it may be beneficial to complete an analysis of digester gas components. A study of the amount of digester gas lost by leakage and out-gassing pressure-relief valves would also be valuable.

Estimates of emissions from sludge compost piles had not been completed. The process of sludge aeration by turning might have been a source of volatile emissions. However, the amount of PTOCs partitioned to sludge and remaining at that stage of treatment was not expected to be significant. Future sampling efforts during sludge aeration would lead to a better understanding of the significance of sludge composting as a PTOC emission source.

Liquid-phase sampling of the JWPCP influent has indicated high concentrations (> 100 µg/l) of benzene, methylene chloride, and toluene. Chloroform, 1,1 dichloroethylene, ethylbenzene, perchloroethylene, 1,1,1 trichloroethane, trichloroethylene, and vinyl chloride have also been detected.

Because of its size, location, and readily measurable concentrations of PTOCs, the JWPCP should be considered for future sampling. Unfortunately, ambient sampling will be complicated by background sources which are common in the industrialized region surrounding the JWPCP. Grit chambers, digesters, aerated conveyance channels, and aeration basins are sources that should be considered for

future emissions sampling. An opportunity also exists for determining the efficiency of odor scrubbers and activated carbon filters.

## Hyperion Treatment Plant  (August 7, 1986)

The Hyperion Treatment Plant (HTP) was managed by the Department of Public Works of the City of Los Angeles, treated more municipal wastewater (> 400 MGD) than any MWTP in California. The population served exceeded three million people, and included a large number of industrial users. Approximately twelve percent of the incoming wastewater was attributed to industrial users. Those users were varied in nature. However, they included several large industries (e.g., metal finishers, electroplaters, and oil refineries) which possibly discharged significant amounts of PTOCs to the HTP.

Two sets of headworks were used to treat the influent streams conveyed by four main sewers. Only two of the five grit chambers that followed the headworks were aerated. Following grit removal, wastewater was passed through twelve clarifiers in parallel. Of the 400 MGD of wastewater received by the HTP, seventy-five percent was discharged to the Pacific Ocean after undergoing only primary treatment. The primary effluent which underwent secondary treatment was passed through sixteen rectangular, uncovered, biological reactors in parallel. Tapered coarse bubble aeration was employed. The secondary effluent was passed through 20 uncovered sedimentation tanks in parallel. The final effluent, primary and secondary, was discharged five miles offshore into the Pacific Ocean. Final effluent was chlorinated only in the event that a the effluent was discharged through a one mile outfall.

Secondary sludge was thickened prior to anaerobic digestion. A total of eighteen floating roof digesters were used. Digester gas was stored in tanks, flared, and intermittently vented for pressure-relief. Ultimately, approximately 250 tons/day of dry sludge was being discharged, primarily through a seven mile offshore outfall. The remainder was trucked to landfills.

178

In comparison to other MWTPs in California, emissions from the HTP were expected to be significant because of relatively high PTOC concentrations in the influent stream, and the application of uncovered, aerated processes. For instance, during six sampling periods during the first quarter of 1986, the average toluene concentration in the influent stream was 152 µg/l. The most significant source of emissions was expected to be from the aerated biological reactors in the activated sludge system. Other potentially significant emissions sources included the main sewer vents, aerated grit chambers, an aerated channel used to convey primary effluent to biological reactors, and the venting of digester gas.

Liquid-phase sampling of primary clarifier influent and effluent had been completed by the staff of the HTP. However, interferences caused a general increase in PTOC concentrations across the clarifier. Thus, emissions from primary clarifiers could not be estimated. Additional sampling of clarifiers would be appropriate. Sampling at the aerated grit chambers and transport channels would be valuable in order to assess the significance of those processes as PTOC emission sources. The floating roof digesters should be investigated as a source of emissions. An analysis of digester gas and gas-phase sampling at digester tank roof edges would be desirable to complete such an analysis. Finally, ambient sampling at the HTP would be appropriate, particularly at the eastern border of the plant. Onshore airflow could cause residents to the east of the HTP to be exposed to PTOCs emitted from the HTP.

The HTP was scheduled for modification to a pure-oxygen treatment plant by 1993. Four 130 MGD pure-oxygen systems were to be implemented by that time. The additional aeration could lead to increased PTOC emissions. However, covered pure-oxygen treatment systems are believed to be less conducive to volatile emissions than are conventional activated sludge systems which utilize higher gas-to-liquid volume ratios for aeration. The modification affords the opportunity to complete gas and liquid-phase sampling of aeration basins before and after the conversion to a pure-oxygen plant. This could lead to a better under-

standing of the relative efficiencies of pure-oxygen and conventional activated sludge systems at stripping PTOCs to the atmosphere.

A system to dehydrate and incinerate the sludge was to be employed by 1987. This would completely eliminate the need for offshore discharge of the sludge. The effects of such a modification on PTOC emissions is not well understood.

## Fresno Regional Wastewater Treatment Plant No. 1 (August 8, 1986)

The Fresno Regional Wastewater Treatment Plant No. 1 (FRWTP1) was managed by the Department of Public Works of the city of Fresno. It was the second largest MWTP, with respect to influent flowrate, in the interior valley region of California. The plant was located approximately six miles west of Fresno. The FRWTP1 treated an annual average flow of 42 MGD, and up to 8 MGD of effluent from the Fresno Regional Wastewater Treatment Plant No. 2 which was located approximately one mile south of the FRWTP1. In addition to having served a residential population of greater than 300,000, approximately six percent of the wastewater treated by the FRWTP1 was attributed to commercial and industrial users. Those users included electroplaters, industrial cleaners, hospitals, and independent and educational laboratories.

The FRWTP1 employed treatment up to the secondary level. Prechlorination was practiced at the headworks to control odors. After passing through bar screens, the wastewater was treated using up to four primary clarifiers in parallel. Primary effluent was conveyed via non-aerated channels to four activated sludge aeration basins. The basins were aerated using four coarse bubble donut diffusers per basin. Secondary effluent flowed to four final clarifiers before being pumped to a series of percolation ponds.

Primary sludge was thickened by utilizing two uncovered primary thickeners which were operated in either gravity or air flotation mode. Secondary sludge was simply being returned to the plant's headworks.

The blended sludge was stabilized using four anaerobic digesters, two of which were of the floating roof type. The staff of the FRWTP1 noted that sludge foam appeared infrequently on digester roofs. Sludge resided in the digesters for 25 to 30 days, before being placed in on-site drying beds. Digester gas was used to fire burners which produced heat necessary for the anaerobic digestion process. The gas was also compressed and used for mixing the sludge in the digesters. Some gas was flared in waste-gas burners, and the remainder was used for power generation. Approximately 250,000 cubic feet of digester gas was being produced each day.

No gas-phase sampling had been completed at the FRWTP1. However, based upon liquid-phase PTOC concentrations in the plant influent, PTOC emissions were expected to be low. The major sources of emissions were expected to be the four activated sludge aeration basins, as well as the headworks, where odors were the most pronounced. Other PTOC emission sources included the primary sludge thickeners in flotation mode, floating roof digesters, percolation ponds, and sludge drying beds.

Because of the relatively low expected PTOC emissions, gas-phase sampling at the FRWTP1 is not recommended. However, the chlorination of influent wastewater does afford the opportunity to study the formation of trihalomethanes as a result of pre-chlorination. Such THMs have ample time to volatilize as they travel through the treatment system. The aeration basins were scheduled to be modified to fine bubble systems by 1987, and secondary sludge thickeners similar to the primary sludge thickeners were to be employed. Both of the modifications would tend to increase volatilization. However, even with the expected increase in emissions, the overall PTOC emissions would probably remain low with respect to treatment plants of comparable size.

Sunnyvale Water Pollution Control Plant (August 13, 1986)

The Sunnyvale Water Pollution Control Plant (SWPCP) was managed by the City of Sunnyvale's Department of Public Works. The SWPCP employed

specific secondary and advanced treatment processes which the other seven MWTPs that were chosen for review did not employ. Furthermore, the SWPCP was characterized by an active sampling, analysis, and enforcement program, which stemmed from strict restrictions regarding the discharge of wastewater effluent into the southern end of San Francisco Bay. The SWPCP was located at the southern shore of the San Francisco Bay. It served the city of Sunnyvale, a small residential area in Cupertino, and a portion of the Moffett field naval air base. These areas accounted for a service population of greater than 100,000, and an average annual flow of approximately 20 MGD. In 1985, 69 industrial users discharged to the plant. These included several electroplaters and metal finishers, in addition to 28 electrical and electronic manufacturers. Commercial and industrial users contributed approximately 50% of the wastewater treated by the SWPCP.

The treatment train at the SWPCP included primary, secondary, and advanced treatment. Influent passed through bar screens located within an enclosed structure which was vented in order to reduce worker exposure to airborne emissions. The wastewater was then pumped to ten aerated, uncovered grit chambers, up to 10 in parallel. Primary clarification followed grit removal. Primary effluent then flowed to two oxidation ponds in parallel. All transport channels were covered and non-aerated. The two oxidation ponds covered 540 acres. They were no longer being aerated on a regular basis. However, surface aeration could be employed whenever necessary to raise dissolved oxygen levels in the ponds. Plans existed to convert the ponds to shallower, high-rate, channel ponds. Wastewater residence time in the ponds averaged 35 to 40 days before being pumped to trickling filters, one to three operated in parallel. The trickling filters were used to reduce ammonia concentrations in order to meet discharge requirements. The trickling filters were 35 feet deep, 92 feet in diameter, and they employed a corrugated aluminum packing material which presented a large surface area for biological growth. Trickling filter effluent, which included algae from the oxidation ponds, was then treated to remove the algae by employing a maximum of four air flotation tanks (AFTs). One to three AFTs were operated in parallel. Effluent from the AFTs flowed through

eight dual-media filters in parallel before being chlorinated in contact chambers with a chlorine dose rate of 2000-6000 lb/day. The chlorine contact time, before dechlorination using sulfur dioxide, ranged from 30 to 60 minutes. Final effluent was discharged to a slough where it flowed into the San Francisco Bay.

All primary sludge and 15% of the thickened algae removed in the AFTs was treated using four floating roof digesters. The remainder of the thickened algae was returned to the oxidation ponds. Digested sludge was placed in two drying beds which covered approximately 2.5 acres.

Liquid-phase sampling in 1985 indicated periods of relatively high concentrations (> 20 μg/l) of chloroform, methylene chloride, perchloroethylene, and toluene in the plant's influent stream. Composite influent and effluent samples also suggested that a significant amount of chloroform was being produced as a result of chlorination. This could be significant for the SWPCP, since final effluent was discharged to an uncovered slough which provided an opportunity for THM volatilization. In addition, a significant reduction in ammonia concentration by advanced treatment prior to chlorination reduced the competition among halogens and ammonia for available chlorine, which probably favored increased halogenation of organics.

Additional PTOC emissions could have occurred from the venting of the bar screen room, grit chambers, oxidation ponds, digester gas releases, trickling filters, and air flotation tanks. The latter two were expected to be insignificant, as PTOC concentrations were probably low at the advanced stage of treatment. The aeration of grit chambers could have lead to significant emissions of PTOCs. The termination of oxidation pond aeration should have reduced PTOC emissions during secondary treatment. However, the large surface area of the ponds is conducive to volatilization. Finally, as noted for the other plants that were visited, emissions from floating roof digesters were possible.

Because of the size of the SWPCP, extensive ambient sampling within

the plant's boundaries is not recommended. In addition, other nearby sources, including a landfill which bordered the SWPCP, would make it difficult to separate background concentrations from those attributed to the SWPCP. The most valuable future studies at the SWPCP would be upwind/downwind measurements of the chlorine contact chambers, and the slough which conveys effluent to the San Francisco Bay. Particular attention should be paid to concentrations of chloroform.

## San Jose - Santa Clara Water Pollution Control Plant (8-13-1986)

The San Jose-Santa Clara Water Pollution Control Plant (SJSCWP) was managed by the City of San Jose Department of Water Pollution Control. At an average annual flowrate of approximately 110 MGD, the SJSCWP was the sixth largest MWTP, with respect to flow, in California. It was the largest in the San Francisco Bay region. In addition to serving a residential population of 1.1 million, the SJSCWP treated wastewater from a diverse cross-section of commercial and industrial users that accounted for greater than 30% (based upon the NEEDS data base) of the total wastewater discharged to the plant. Industrial users included electroplaters, metal finishers, and several circuit board manufacturers.

The SJSCWP employed a relatively high degree of treatment. Influent screening was composed of above-ground bar screens followed by finer screens. Wastewater was then passed through two non-aerated grit chambers in parallel, before passing through a maximum of 24 rectangular, primary clarifiers in parallel. Primary effluent was conveyed in an aerated open channel to an average of eight four-stage, coarse bubble, activated sludge treatment units operated in parallel. A maximum of sixteen aeration basins were available for biological treatment. Secondary effluent was clarified before being conveyed to an average of 12 on-line, aerated (coarse bubble) nitrification basins. The average aeration rates in the secondary and advanced aeration basins were 160,000 SCF per minute and 120,000 SCF per minute, respectively. Following nitrification, the wastewater was filtered using a multi-media

filtration system before being chlorinated, dechlorinated using sulfur dioxide, and discharged to the San Francisco Bay. The chlorine contact time was approximately one hour before dechlorination. Available chlorine was exposed to organics in the wastewater in addition to a small amount of ammonia added to the wastewater stream after nitrification but before multi-media filtration.

Primary sludge and thickened secondary sludge was mixed in 16 floating roof anaerobic digesters. The sludge residence time in the digesters was approximately 30 days. Sludge from the digesters was stored for several years in lagoons which cover 400 acres at the SJSCWP. Approximately 85 dry tons/day of sludge were dried in on-site drying beds before being disposed of to sludge piles. An average of 1.5 million cubic feet/day of digester gas was being produced, nearly all of which was used to run engines in order to generate power for the plant. In turn, engine cooling water was used to heat sludge in the digesters.

Liquid-phase sampling of the influent stream from 1984 to 1986 indicated high average concnetrations of several PTOCs. For instance, during six 24-hour composite samples drawn during the noted period, the average concentrations for methylene chloride, perchloroethylene, and toluene were 104.0, 48.0, and 159.0 µg/l, respectively. Aside from chloroform (10.7 µg/l), 1,1,1 trichloroethane (4.0 µg/l), and trichloroethylene (11.0 µg/l), all other PTOCs were reported to be below detection limit in the influent stream. However, the detection of bromodichloromethane, and a high average concentration of chloroform in the effluent stream suggested the formation of THMs as a result of chlorination. Finally, influent samples were reportedly drawn after grit removal. Thus, some PTOC volatilization could have occurred prior to sampling.

The emissions of PTOCs were most likely from aerated processes such as the primary effluent channel, and activated sludge and nitrification aeration basins. The latter might not be a significant source, since if volatilization occurred it probably occurred to a great extent in the activated sludge basins. Additional emissions could have occurred as

185

digester gases excaped from the floating roof digesters, and THMs vola-
tilized following chlorination.  If gas-phase sampling is to be com-
pleted in the future, it is recommended that emissions from the aerated
channel, aerated activated sludge basins, chlorine contact chambers, and
digester roofs be investigated.


## East Bay Municipal Utility District WWTF (August 19, 1986)

The East Bay Municipal Utility District WWTF (EBMUB) was managed by
the East Bay Municipal Utility District.  It was located on the North-
west boundary of Oakland, near the eastern edge of the San Francisco Bay
Bridge.  It served the cities of Alameda, Berkeley, Emeryville, Oakland,
Piedmont, El Cerrito, Kensington, and a small area of Richmond.  In
total, 567,000 residential customers, and over 20,000 business and
industrial users, discharged an annual average flow of approximately
eighty million gallons of wastewater per day.  Industrial users contri-
buted approximately 10% of the total flow.  As of 1985, 91 of those
users were subject to the EPA's categorical standards for industries.
Included in the list, with the number of facilities indicated in
parentheses, were industries involved with electroplating (35), metal
molding and casting (19), metal finishing (14), pharmaceuticals (7), and
iron and steel (5).

The EBMUD operated a secondary treatment facility.  The influent
was pre-chlorinated as an odor control measure.  Five bar screens were
operated in parallel inside of a covered facility.  Air from the
facility was vented through a chlorine spray scrubber before being
discharged to the atmosphere.  After screening, wastewater was pumped to
up to five gravity-flow grit tanks in parallel.  The wastewater flowed
over a weir at the end of each tank.  During storms, up to eight aerated
grit tanks could be employed as needed.  From the grit tanks, the waste-
water was clarified using a maximum of sixteen primary clarifiers in
parallel.  Primary effluent was conveyed in an aerated, covered channel,
where it fed into a pure-oxygen activated sludge system.  The activated
sludge reactors were covered, and involved eight four-stage trains which

186

utilized submerged turbine mixer/spargers for oxygen transfer. The mixed liquor recycle channel was aerated for particle suspension. Twelve final clarifiers were used to collect secondary sludge. Secondary effluent was chlorinated and later dechlorinated using sulfur dioxide. The effluent outfall was composed of a 1.75 mile long partially-open channel followed by a 1.1 mile long conveyance line leading to a discharge at the bottom of San Francisco Bay. A 700 foot length of diffuser was employed.

An average of 1850 dry tons of sludge was disposed of each month. Approximately 75% of the sludge was trucked to landfills, and 25% was mixed with woodchips and composted for commercial use. Primary sludge was pumped directly to anaerobic digesters. Secondary sludge was thickened by centrifuge before being mixed with primary sludge in the digesters. Ten high-rate, floating roof digesters were being used, each with an eight day sludge residence time. Digested sludge was dewatered by centrifuge and vacuum filters before being disposed of to landfills or to the on-site composting area. The 1.2-1.4 million cubic feet per day of digester gas was burned in three large engines which supplied up to 50% of the facility's power requirements. Waste heat was utilized to heat digesters, sludge conveyance pipes, and buildings at the plant.

The EBMUD maintained a well-equipped laboratory which allowed for relatively extensive priority pollutant analyses for samples drawn from the influent, effluent and sludge streams. Liquid-phase influent sampling completed from 1984 to 1986 indicated relatively high average concentrations of several PTOCs, including benzene, chloroform, methylene chloride, perchloroethylene, and toluene. In addition, average chloroform concentrations in the effluent stream were approximately equal to those in the influent stream. Bromodichloromethane was also infrequently detected in the effluent stream, and never detected in the influent stream. Finally, sampling for PTOCs in dewatered sludge indicated some accumulation of ethylbenzene and toluene.

Previous gas-phase sampling of activated sludge off-gases and the air above the mixed-liquor recycle channel were completed by the staff

of the EBMUD. However, all of the PTOCs were observed to be below detection limit.

A number of processes could have contributed to PTOC emissions from the EBMUD WWTF. Those included the large weirs on the gravity grit chambers, vented activated sludge off-gases, the aerated mixed-liquor recycle channel, floating roof digesters, and sludge composting. Emissions from grit tank weirs could be addressed using either gas sampling above the weir or pre-weir and post-weir liquid-phase sampling. Additional gas-phase sampling is needed to verify the previous results regarding emissions from the aerated recycle channel and activated sludge basins.


## Recommendations for Future Sampling

It is recommended that extensive future sampling be completed at the JWPCP, to investigate the difference between estimated uncontrolled emissions and measured controlled emissions, and to study the relative stripping efficiencies of control devices at removing PTOCs from off-gas streams. A complete study would include liquid-phase sampling for PTOCs in the JWPCP's influent and effluent streams, as well as in the influent and effluent streams of several processes; bar screens, grit chambers, primary clarifiers, and pure-oxygen activated sludge reactors. Waste-water flowrates should either be measured or obtained from plant records. During the same time period that liquid-phase samples are drawn, gas-phase PTOC concentrations and off-gas flowrates should be measured in the air spaces above individual processes, as well as at the exit vents of caustic scrubbers and activated carbon filters. It would also be desireable to account for wastewater residence times in each process stream. Aerated channels, sludge composting operations, and pure-oxygen activated sludge reactors should also be investigated as emissions sources.

In the remainder of this appendix, recommendations are made for studying emissions from individual treatment processes that are most conducive to both volatile emissions and sampling.

Primary Treatment:   Because PTOC concentrations are generally the highest as they enter treatment facilities, bar screens, grit chambers, and primary clarifiers require further attention as potential sources of PTOC emissions.   As noted above, simultaneous liquid and gas-phase measurements of concentrations and flowrates would be desireable.   The Sunnyvale WWTF and the East Bay MUD WWTF both utilize bar screens enclosed in buildings.   Each would provide suitable sampling conditions. The East Bay MUD WWTF also employs grit chamber effluent weirs which should be considered for sampling, as the weirs are characterized by several feet of free-falling water, a condition conducive to volatilization.   The JWPCP utilizes covered primary clarifiers and enclosed, aerated grit chambers which should be further studied as PTOC emissions sources.   Because grit chambers at the San Jose-Santa Clara WPCP and the East Headworks at the Hyperion Treatment Plant (HTP) are not aerated, and because PTOC mass loadings into those two facilities have been relatively high, PTOC concentrations in the primary clarifiers of those two systems may be high enough to cause significant volatile emissions.   It is recommended that they be considered for future sampling.

Aerated Transport Channels:   Aerated primary transport channels may be significant sources of PTOC emissions.   In addition to the JWPCP, other MWTPs that utilize aerated transport channels include the HTP, the San Jose-Santa Clara WPCP, and the East Bay MUD WWTF.   The Aerated channels at the JWPCP and the East Bay MUD WWTF are covered and more conducive to off-gas sampling than are the channels at the other two plants.

Biological Reactors:   Conventional and pure-oxygen activated sludge (AS) systems should be considered for future sampling of PTOCs in both the liquid and gas phases.   Of the eight plants that were visited, the Sacramento Regional WWTF, the East Bay MUD WWTF, and the JWPCP employ pure-oxygen AS systems.   That latter differs from the former two in that it utilizes surface, rather than submerged, oxygenation.   Both types of oxygenation should be studied in order to gain a better understanding of their PTOC stripping efficiencies.   Because the East Bay MUD WWTF has been subjected to higher PTOC loadings than has the Sacramento Regional WWTF, it may be preferable for comparison with the JWPCP's pure-oxygen

AS system. In addition, the HTP will be converted to a pure-oxygen AS plant in the future. Thus, it affords the opportunity to complete sampling of PTOC emissions from both conventional and pure-oxygen AS systems at the same facility. The San Jose-Santa Clara WPCP also utilizes conventional AS treatment.

Chlorination Systems: To study the emissions of chloroform following chlorination, influent and effluent streams, and the air upwind, above, and downwind of chlorine contact chambers should be sampled. Of the eight MWTPs that were visited, the four that appeared to generate the greatest amount of chloroform were the Sacramento Regional WWTF, the East Bay MUD WWTF, the San Jose-Santa Clara WWTF, and the Sunnyvale WWTF. The latter two may be the most conducive to volatile emissions, as both the chlorine contact chambers and the effluent outfall systems are open to the atmosphere.

Digesters: A great deal of uncertainty exists regarding emissions from digesters. However, high concentrations of some PTOCs have been observed in digester gases. Component analyses of digester gases, and gas-phase sampling at the openings of floating roof digesters and pressure-relief valves could lead to a better understanding of the importance of digesters as PTOC emissions sources. Based upon the amount of digester gas produced, PTOC mass loadings, and the type of digesters utilized, digesters at the JWPCP, the HTP, and the San Jose-Santa Clara WPCP are recommended for future sampling.

Ambient Sampling: As noted in Section B of this report, the HTP is recommended for ambient sampling, particularly at the eastern border of the plant. During periods of onshore breezes, simultaneous measurements to the west of the plant would be desirable to distinguish concentrations attributed to the HTP from background PTOC levels.

Other Plants to Consider: Only eight MWTPs were visited as part of this study. Uncontrolled emissions estimates indicated that three other MWTPs that were not visited may be significant sources of PTOC emissions. Those plants are the Terminal Island Treatment Plant, the

Palo Alto WWTF, and the OCSD WWTF #2. It is recommended that those facilities be visited and studied to indicate whether or not future sampling is warranted.

APPENDIX H:  TEST (A Refined Emissions Model)

# Modeling the Emissions of Volatile and Potentially Toxic Organic Compounds From Municipal Wastewater Treatment Plants

Richard L. Corsi
Daniel P.Y. Chang
Edward D. Schroeder
Qingzeng Qiu


Department of Civil Engineering
University of California at Davis
Davis, California  95616

## INTRODUCTION

Occurrences of potentially toxic organic compounds (PTOCs) in the influent streams of municipal wastewater treatment plants (MWTPs) are of concern for several reasons. Such compounds may contaminate sludge, interfere with biological treatment processes, endanger the health of treatment plant employees, and cause adverse effects to sensitive effluent receiving waters. Because of their affinity for the gaseous phase, volatile PTOCs (VTOCs) have been the focus of recent studies regarding emissions from MWTPs.[1-3] Volatile PTOCs that are frequently detected in the influent streams of MWTPs include benzene, chloroform, ethylbenzene, methylene chloride, perchloroethylene, toluene, 1,1,1-trichloroethane, and trichloroethylene.

Because of the cost and experimental difficulties associated with VTOC emissions measurements, the application of semi-empirical mass transport models is an attractive and valuable method to study the emissions associated with wastewater treatment. Models can be used to estimate emissions from entire treatment trains or from individual treatment processes. The resulting emissions estimates can then be used for emissions inventories, as input into transport models, or to analyze the effects of treatment modifications on the fate of organic contaminants.

This paper discusses methods used to model the distribution of VTOCs in MWTPs. The development of a user-oriented model to predict VTOC emissions throughout entire treatment trains is then described. Individual treatment processes and the competition among removal mechanisms are emphasized.

## TRANSPORT AND REMOVAL OF VTOCS DURING WASTEWATER TREATMENT

The primary transport and removal mechanisms for organic contaminants in wastewater are volatilization, adsorption and removal in sludge streams, biodegradation, and pass-through to receiving waters. In addition, formation of organic contaminants can occur during wastewater treatment. To provide readers unfamiliar with wastewater treatment some background regarding the systems to be modeled, each of the removal and formation mechanisms is briefly described below.

### Volatilization

Several treatment processes have characteristics that are conducive to the volatilization of VTOCs. For instance, high concentrations of contaminants are first exposed to the atmosphere at uncovered primary treatment processes such as bar screens and grit removal tanks. While the hydraulic residence times in such processes are low, the bars and racks on screening systems induce turbulence at the surface of the wastewater. Furthermore, grit tanks are often aerated, thus increasing the potential for stripping to the atmosphere. Residence times in primary clarifiers are generally much longer than those in screening systems or grit tanks. The large open clarifier surfaces and flow over clarifier weirs can lead to VTOC emissions.[4]

Secondary treatment processes such as trickling filters and activated sludge systems present additional opportunities for volatilization. In trickling filters, wastewater is contacted with biological organisms adhering to rock or plastic media. To promote efficient biodegradation of organic contaminants, large surface areas are exposed to reduce mass transfer resistance. In order to supply the aerobic organisms with oxygen, air is either actively blown or allowed to rise through the filter media by drafts induced by natural temperature gradients. Activated sludge systems and aerated waste lagoons also promote volatilization because both are aerated or oxygenated and have relatively long residence times.

Other treatment processes where volatilization can occur include aerated conveyance channels, rotating biological contactors, overland flow systems, and equalization basins.

Removal in Sludge Streams

Organic compounds can adsorb to suspended solids and biomass with subsequent removal in primary and secondary clarifiers. A previous study indicated that adsorption and removal of VTOCs in primary sludge streams is significantly greater than removal in waste activated sludge streams.[5] This may be due to higher concentrations during primary treatment, as well as efficient stripping as a result of aeration in secondary systems. The adsorption of individual organic compounds to solids found in wastewater is not well understood. However, octanol/water partition coefficients have been used to rank VTOCs according to their relative affinity for adsorption.[5] It was concluded from analysis of raw mass flow data that removal in sludge streams typically accounts for less than five percent of the total removal of VTOCs throughout an entire treatment train.[6]

Biodegradation

Biochemical oxidation of organic contaminants occurs at secondary and advanced treatment processes such as trickling filters, waste lagoons, activated sludge systems, oxidation ponds, rotating biological contactors, overland flow systems, and wetland systems. However, little is known regarding the bio-oxidation efficiency of VTOCs during municipal wastewater treatment. Laboratory research has indicated that several VTOCs (i.e., benzene, chlorobenzene, ethylbenzene, and toluene) can be efficiently bio-oxidized under the appropriate conditions.[7,8] However, such research is typically completed using high contaminant concentrations (> 10 mg/l) and steady-state contaminant feeds, conditions which are necessary to maintain acclimated microbial populations. Volatile PTOC concentrations in municipal wastewaters rarely exceed 0.1 mg/l, and slug discharges are common. MWTPs are not believed to meet the conditions that are necessary for acclimation, and thus efficient bio-oxidation of VTOCs is not expected to occur. Some degradation in unacclimated systems is expected to occur as a result of co-metabolism by bacteria that utilize other organic material as their carbon source.[9] For most of the VTOCs the average percent degraded in

unacclimated secondary treatment facilities has been reported to be between 0.0 and 20%, as opposed to values as high as 74%, for benzene, in acclimated systems.[10]

## Formation

Pre-chlorination for odor control and post-chlorination for disinfection can lead to the formation of trihalomenthanes (THMs) such as bromodichloromethane, dibromochloromethane, and chloroform. The ratio of average THM mass loadings in effluent streams to the mass loadings in influent streams is typically greater than 1.0 for those MWTPs that post-chlorinate, and much less than 1.0 in those MWTPs that do not post-chlorinate.[6,11] The factors that affect the formation of THMs during municipal wastewater treatment are complex, not well understood, and were not treated in the present modeling effort.

## Pass-Through

The VTOCs that enter a MWTP or that form during the treatment process, and that are not removed by one of the removal mechanisms described above, are passed through the treatment system and discharged in the effluent stream. An analysis of data compiled from previous studies indicated that the average percent pass-through (100% - percent removed) for VTOCs is typically less than 20%.[6] The fate of VTOCs following pass-through is not well documented. No attempt was made to model VTOCs which passed through a MWTP.

## VTOC DISTRIBUTION MODELS

The simplest predictive distribution models (PDMs) are based upon the assumption of steady-state conditions. While such conditions are typically not satisfied at MWTPs, steady-state PDMs can be valuable in order to assess the effects of treatment plant modifications on the fate of VTOCs. Furthermore, existing data are insufficient to establish concentration distributions as input into more complex transient models. The following analysis is based upon the assumption of steady-state conditions. Models are presented for continuous flow stirred-tank reactors (CFSTRs), plug-flow reactors (PFRs), and trickling filters. A brief discussion of approaches to estimating model parameters is then given.

## CFSTRs

The concentration "C" of a VTOC in a CFSTR is assumed to be equal to the effluent concentration. This simplifies the distribution model, particularly for the case when a portion of the treated flow is recycled. For a CFSTR the steady-state effluent concentration, "$C_e$", is estimated by

$$C_e = C_i/\{1.0 + r(k_v + k_b + k_s)\}, \tag{1}$$

where $C_i$ is the influent concentration, r is the hydraulic residence

time (volume of process/wastewater flowrate), and $k_v$, $k_b$, and $k_s$ are the rate constants for removal by volatilization, biodegradation, and adsorption to sludge, respectively. The CFSTR model can be used to estimate VTOC losses from well-mixed systems, which can include aerated lagoons and aeration basins.

PFRs

Plug-flow reactors are characterized by ideal mixing in the lateral direction and no mixing in the longitudinal direction. A simplified method for modeling transport in PFRs is to treat the PFR as a series of successive CFSTRs. The effluent concentration from the PFR can then be calculated as

$$C_e = C_i / \{1.0 + (r/n)(k_v + k_b + k_s)\}^n, \qquad (2)$$

where $C_i$, $r$, $k_v$, $k_b$, and $k_s$ are as defined previously, and n is the number of CFSTRs used to model the PFR. Equation 2 can be used to estimate VTOC losses from grit removal tanks, clarifiers, aeration basins, conveyance channels, and other systems with negligible mixing in the longitudinal direction. When effluent from a PFR is recycled, an iterative procedure is required to solve the equation because the concentration is not uniform throughout the reactor.

Trickling Filter Models

For this study, a model for the removal of VTOCs in trickling filters was assumed to have a form similar to models which are used to predict reductions in biochemical oxygen demand (BOD). A simplified exponential model is

$$C_e = C_i \exp\{-(k_v + k_b + k_s)[pAh/(Q + pQ)]\}, \qquad (3)$$

where p is the porosity of the filter media, A is the cross-sectional area of the filter, h is the depth of the filter, Q is the wastewater flowrate, and all other variables are as described previously. For systems with recycle, Equation 3 must be modified using an "effective" influent concentration $C_i'$ such that

$$C_i' = (C_i + bC_e)/(1 + b), \qquad (4)$$

where b is the fraction of the incoming flow recycled from the effluent to the influent stream (recycle ratio). An iterative solution algorithm is then required.

Estimating $k_v$

Values for $k_v$ are typically estimated by calculating the mass transfer coefficient for oxygen (reaeration rate), "$k_o$", and then applying the relationship

197

$$k_v = a'k_0, \tag{5}$$

where $a'$ is the transfer rate proportionality coefficient. The basis for a constant $k_v/k_0$ is found in the classical two-film, penetration, or surface renewal theories of mass transfer across an air-water interface.[12] The two latter theories describe highly agitated conditions better than the former. Two-film theory is commonly used for less-agitated conditions. Taking the ratio of the theoretical fluxes for two high-volatility compounds (e.g., a VTOC and oxygen) causes the dependence of wastewater parameters such as temperature and viscosity to cancel, leaving only the physical properties (i.e., diffusion coefficient) of the two compounds. For two-film theory $a'$ is equal to the ratio of the VTOC to oxygen diffusion coefficients. For penetration and surface renewal theories, $a'$ is equal to the square root of the ratio of the VTOC to oxygen diffusion coefficients. Experiments have verified that the values of $a'$, estimated using the above theories, typically lie between 0.55 and 0.65 for most of the VTOCs.[12,13]

Empirical methods have been proposed to estimate values of $k_0$, and an extensive review of those methods has been completed.[14] Most of the methods were developed for natural systems such as ponds, streams, and rivers. However, they have been used successfully to model mass transfer in wastewater treatment systems.[4] For surface aerated systems the value of $k_0$ is commonly taken to be the area-weighted average of mass transfer rates for non-agitated and agitated regions. The non-agitated regions can be treated as natural systems as noted above. To estimate mass transfer coefficients in the agitated regions, empirical models have been developed. Those models typically require knowledge of aerator characteristics, such as power rating, efficiency, and oxygen transfer rate, that are often available from the manufacturer of the aerator.

For bubble aeration, $k_v$ is dependent upon the degree of saturation of rising air bubbles. A method has been developed to estimate the product of the hydraulic residence time and $k_v$ for use in Equation 1.[13] Model requirements include the ratio of the gas to liquid flowrates, the dimensionless Henry's law coefficient, and the type of bubbles (i.e., coarse, medium, or fine).

For those systems that are characterized by radial flow (RF), PFR models can be used along with mass transfer coefficients obtained by integrating $k_v$ or $k_0$ equations in the radial direction. Such models have been used for radial flow clarifiers.

Estimating $k_b$

Bio-oxidation rates for VTOCs have not been extensively reported.[15,16] The bio-oxidation rates that have been reported for VTOCs are believed to overestimate the removals caused by biodegradation. The reason for overestimation is because the rates are commonly based upon laboratory experiments completed under conditions required to maintain biological acclimation to the VTOCs. Large uncertainties are associated with the extrapolation of those values to field conditions.

Estimating $k_S$

Few models exist to estimate adsorption to solids and biomass. Empirical models have been developed to estimate the partitioning of VTOCs between the wastewater and activated sludge.[4,17] However, the models are limited because they do not allow for time variations, or they are based upon laboratory studies that suppressed other removal mechanisms.

## INTEGRATED EMISSIONS MODEL

### General

An integrated emissions model (TEST; Toxic Emissions during Sewage Treatment) was developed in order to estimate VTOC emissions from entire wastewater treatment systems. The individual process models described in the previous section, in addition to several less commonly used models, were incorporated into the TEST model. The TEST model is user-oriented, and flexible in its ability to model user-specified treatment configurations. An option flow diagram for the TEST model is shown Figure 1. Initial input requirements include the choice of VTOCs to be modeled. Following the initial input segment, treatment processes are selected in sequence until the entire treatment train is modeled. Processes can be specified to be in series or in parallel. The effluent concentrations from individual processes are used as influent concentrations in the nearest downstream processes. The process options are described below.

The grit chamber option is used to estimate emissions from either aerated or non-aerated grit removal tanks. In either case, plug flow is assumed and modeled using a series of successive CFSTRs. Volatilization is assumed to be the only removal mechanism.

The clarifier option allows for either plug or radial flow to be modeled. Emissions from either primary or secondary clarifiers can be estimated. The user may choose to enter adsorption rate constants if they are available.

An option to estimate emissions from conveyance channels is also included. Emissions from aerated channels can be modeled. Regardless of the degree of aeration, plug flow is assumed and modeled using successive CFSTRs.

The trickling filter submodel is based upon Equation 3. In addition to the physical specifications of the trickling filter, the user must input a volatilization rate for each VTOC based upon a range specified on the model menu. Bio-oxidation and adsorption rates may be input interactively. The trickling filter option also allows for recycle of the effluent flow. If recycle is used, an iterative procedure is required with the user having to prescribe an initial estimate for the effluent concentration of each VTOC.

The activated sludge model allows several user options. The system can be modeled as a CFSTR or a PFR. Surface or bubble aeration can be prescribed. For bubble aeration, coarse, medium, or fine bubble diffuser systems can be analyzed. Uniform and tapered aeration options are available. Bio-oxidation and adsorption rates are entered by the user. If a PFR with recycle is modeled, an iterative solution is required.

Other treatment processes can be "constructed" during the model execution by specifying the appropriate reactor models and requirements for aeration.

Following the analysis of one process, the user than specifies the next process to be analyzed. Once all of the processes in the treatment train have been analyzed, process specifications, concentrations, removal efficiencies, and emissions for the selected VTOCs at each individual treatment process are output.

Example Application

To exemplify the use of the TEST model, an example application is provided. A simplified treatment configuration was chosen as depicted in Figure 2. The treatment processes that were involved included an aerated grit tank, followed by two rectangular clarifiers (sedimentation basins) in parallel, three CFSTR activated sludge aeration basins in parallel, and three secondary clarifiers in parallel. Specifications for each process are also listed in Figure 2. Benzene and vinyl chloride were analyzed using an influent concentration of 100 µg/l for each. Bio-oxidation rates of 0.005 hours$^{-1}$ were selected for the activated sludge systems. Adsorption was assumed to be insignificant. An influent flowrate of 2.2 m$^3$/sec (50 million gallons per day) was assumed.

The predicted emission rates and removal efficiencies are provided for each individual process in Figure 2. For both benzene and vinyl chloride, most of the total removal occurred in the activated sludge aeration basins. The percent removal was significantly greater for vinyl chloride, which has a much higher Henry's law constant than benzene. For each VTOC, greater than 99% of the total removal in the aeration basins was attributed to volatilization which clearly dominated bio-oxidation as the primary removal mechanism. Removal in each of the clarifiers was relatively insignificant. Removals in the aerated grit chambers were greater than removals in the clarifiers. However, because the aeration rates and hydraulic residence times in grit chambers are typically very low, emissions from those devices appear to be much lower than emissions from activated sludge aeration basins. The overall removal efficiencies for benzene and vinyl chloride were 32% and 75%, respectively. Emissions throughout the entire treatment train amounted to 6'.1 kg/day for benzene and 14.1 kg/day for vinyl chloride.

## SUMMARY

A model (TEST) has been developed to predict the distribution of organic contaminants during municipal wastewater treatment. The model was exercised in an example application which exemplified the significance of aerated secondary treatment processes as emissions sources. For VTOCs, the primary removal mechanism appears to be volatilization. Further validation will be required, but even at this stage TEST can be used to predict emissions of VTOCs throughout entire treatment systems. Moreover, the relative importance of specific treatment processes can be studied and the effects of process modifications as emission control measures can be assessed. The model has been delivered to the California Air Resources Board for further evaluation.

## ACKNOWLEDGEMENTS

## DISCLAIMER

"The statements and conclusions in this paper are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

# REFERENCES

1. California Air Resources Board, <u>Source Tests for Vinyl Chloride and Other VOCs at Sewage Treatment Plants</u>, memorandum to D.C. Simeroth, P. Ouchida and K. Jones, 1985.

2. V.S. Dunovant, C.S. Clark, S.S. Que Hee, V.S. Hertzberg, and J.G. Trapp, "Volatile organics in the wastewater and airspaces of three wastewater treatment plants," <u>Journal of the Water Pollution Control Federation, 58(9):</u> 886 (1986).

3. P.A. Lurker, C.S. Clark and V.J. Elia, "Atmospheric release of chlorinated organic compounds from the activated sludge process," <u>Journal of the Water Pollution Control Federation, 54(12):</u> 1566 (1982).

4. C.C. Allen, D.A. Green, J.B. White and J.B. Coburn, <u>Preliminary Assessment of Air Emissions From Aerated Waste Treatment Systems at Hazardous Waste Treatment Storage and Disposal Facilities,</u> U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Office of Research and Development, Cincinnati, Ohio, 1986.

5. G. Dixon and B. Bremen, <u>Technical Background and Estimation Methods for Assessing Air Releases from Sewage Treatment Plants,</u> Versar, Inc., memorandum to F. Reinhardt, 1984.

6. D.P.Y. Chang, E.D. Schroeder and R.L. Corsi, <u>Emissions of Volatile and Potentially Toxic Organic Compounds From Wastewater Treatment and Collection Systems,</u> Draft Report Submitted to the California Air Resources Board, 1987.

7. D.F. Kincannon, E.L. Stover, V. Nichols and D. Medley, "Removal mechanisms for toxic priority pollutants," <u>Journal of the Water Pollution Control Federation, 55(2):</u> 157 (1983).

8. C.T. Lawson and S.A. Siegrist, "Removal mechanisms for selected priority pollutants in activated sludge systems," <u>Proceedings of the ASCE Environmental Engineering Division Specialty Conference, 1981 National Conference on Environmental Engineering,</u> F.M. Saunders, Ed.: 356 (1981).

9. C.J. Kim and W.J. Maier, "Acclimation and biodegradation of chlorinated organic compounds in the presence of alternate substrates," <u>Journal of the Water Pollution Control Federation, 58(2):</u> 157 (1986).

10. U.S. Environmental Protection Agency, <u>Report to Congress on the Discharge of Hazardous Wastes to Publicly Owned Treatment Works,</u> EPA/530-SW-86-004, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C., 1986.

11. U.S. Environmental Protection Agency, Fate of Priority Pollutants in Publicly Owned Treatment Works, vol. 1, EPA 440/1-82/303, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C., 1982.

12. J.H. Smith, D.C. Bomberger, Jr. and D.L. Haynes, "Prediction of the volatilization rates of high-volatility chemicals from natural water bodies," Environmental Science and Technology, 14(11): 1332 (1980).

13. P.V. Roberts, C. Munz, P. Dandliker and C. Matter-Muller, Volatilization of Organic Pollutants in Wastewater-Model Studies, EPA-600/S2-84-047, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Cincinnati, Ohio, 1984.

14. R.G. Thomas, Volatilization from Water, Chapter 15 in Hardbook of Chemical Property Estimation Methods, W.J. Lyman et al., Ed., McGraw-Hill Book Co., New York, 1982.

15. J.W. Patterson and P.S. Kodukala, "Biodegradation of hazardous organic pollutants," Chemical Engineering Progress, 77(4): 48 (1981).

16. W.J. Weber, B.E. Jones and L.E. Katz, "Fate of toxic organic compounds in activated sludge and integrated PAC systems," Water Sci. Tech., 19: 471 (1987).

17. J.W. Blackburn, W.L. Troxler, K.N. Truong, R.P. Zink, S.C. Meckstroth, J.R. Florance, A. Groen, G.S. Sayler, R.W. Beck, R.A. Minear, A. Breen and O. Yagi, Organic Chemical Fate Prediction in Activated Sludge Treatment Processes, EPA/600/S2-85/102, U.S. Environmental Protection Agency, Water Engineering Research Laboratory, Cincinnati, Ohio, 1985.
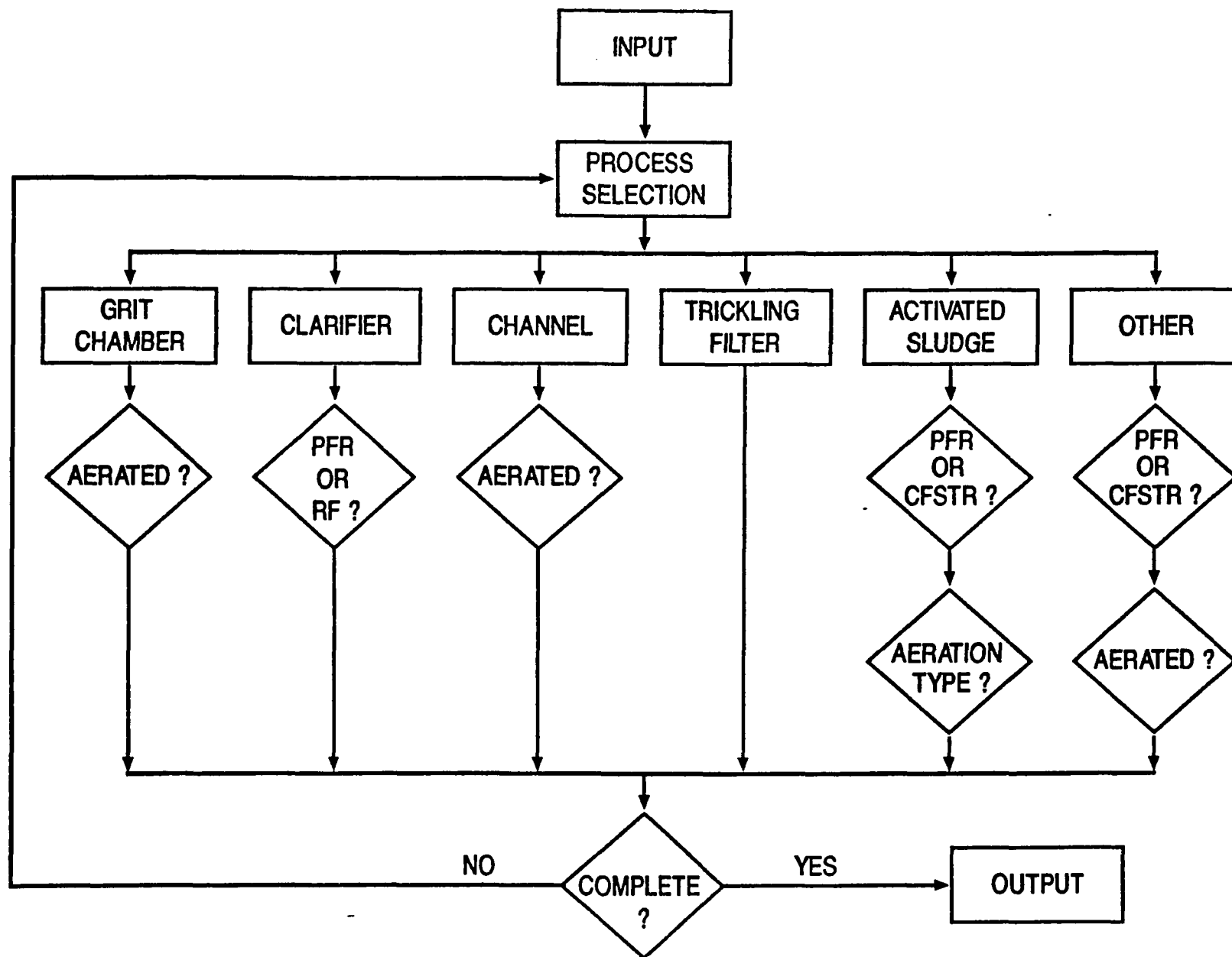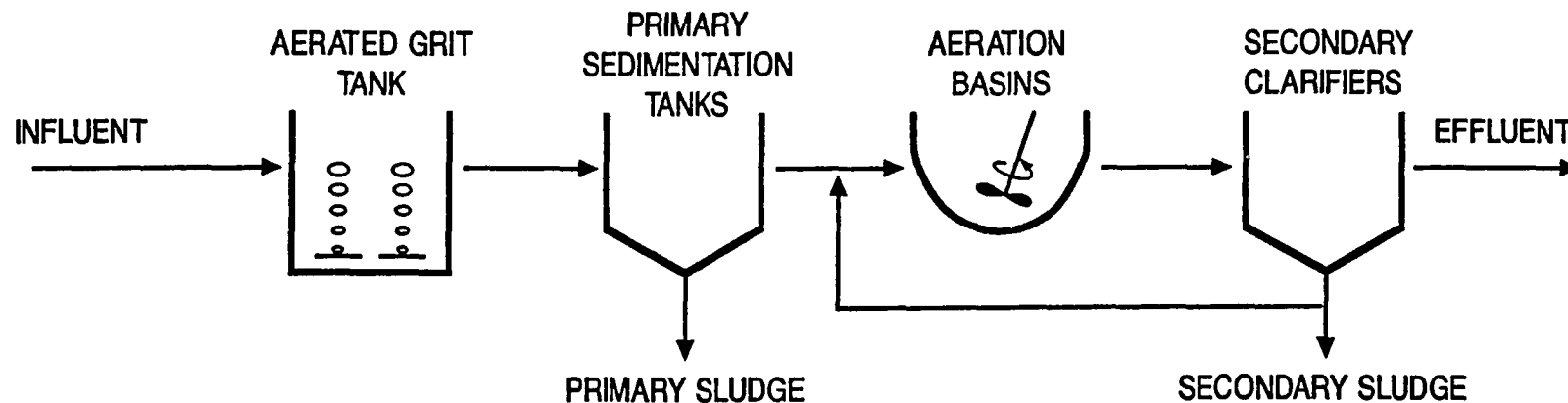
FIGURE 1. OPTION FLOW DIAGRAM FOR THE TEST MODEL

INFLUENT → AERATED GRIT TANK → PRIMARY SEDIMENTATION TANKS → AERATION BASINS → SECONDARY CLARIFIERS → EFFLUENT

PRIMARY SLUDGE

SECONDARY SLUDGE

| INFLUENT | GRIT TANK | PRIMARY SED. TANKS | AERATION BASINS | SECONDARY CLARIFIERS |
|---|---|---|---|---|
| Flow: 2.2 $m^3$/sec | Depth: 3.5 m | Rectangular | CFSTR | Rectangular |
| | Width: 8.0 m | Two in parallel | Three in parallel | Three in parallel |
| Benzene: 100 $\mu$g/l | Length: 25.0 m | Depth: 4.0 m | Volume: 7000 $m^3$ | Depth: 4.0 m |
| Vinyl | Aeration: 0.08 $m^3$/sec | Width: 14.0 m | Aeration: 1.4 $m^3$/s | Width: 14.0 m |
| chloride: 100 $\mu$g/l | HRT: 0.09 hours | Length: 80.0 m | HRT: 2.66 hours | Length: 80.0 m |
| | | HRT: 1.14 hours | | HRT: 1.71 hours |

| | E (kg/day) | % REM | E (kg/day) | % REM | E (kg/day) | % REM | E (kg/day) | % REM |
|---|---|---|---|---|---|---|---|---|
| Benzene | 0.2 | 0.9 | 0.01 | 0.04 | 5.9 | 31.0 | 0.01 | 0.04 |
| Vinyl chloride | .6 | 3.3 | 0.01 | 0.04 | 13.5 | 73.9 | 0.00 | 0.04 |

FIGURE 2. EXAMPLE APPLICATION USING THE TEST MODEL. HRT - HYDRAULIC RESIDENCE TIME, E - EMISSION RATE (KG/DAY), AND % REM - PERCENT OF EACH VTOC REMOVED ACROSS THE PROCESS