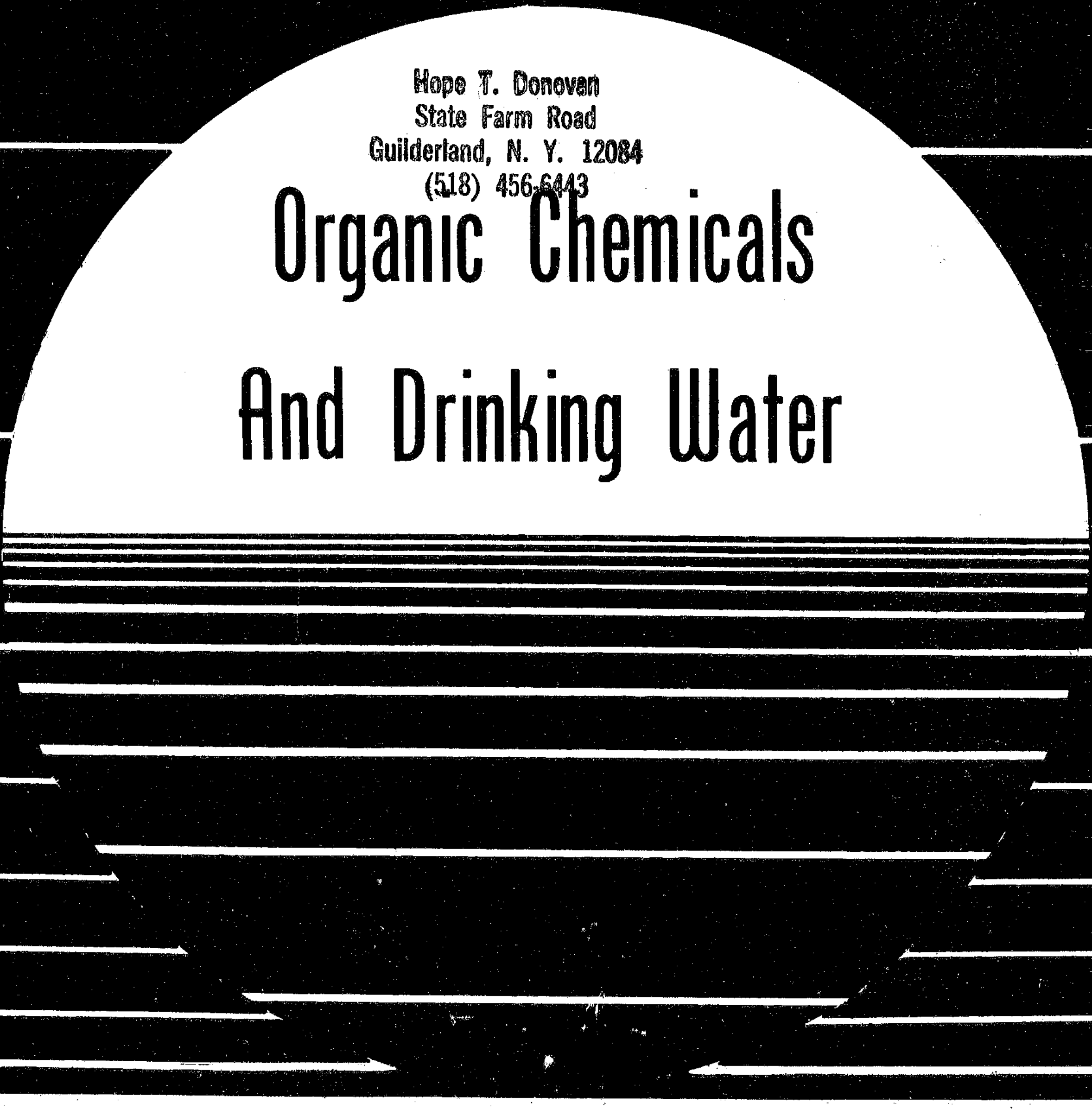


Organic Chemicals And Drinking Water

NEW YORK STATE DEPARTMENT OF HEALTH

Organic Chemicals And Drinking Water

●

- Status Report: Drinking Water Quality
- Discussion: The Meaning of Risk
- Standards: A Rational Basis for Establishing Drinking Water Limits
- Control: Cost Assessment of Control Techniques
- Strategy: Alternative Implementations

Nancy K. Kim, Ph.D.
Daniel W. Stone, P.E.

ACKNOWLEDGMENT

Although the responsibility for the contents of this report rests with the authors, we have received valuable assistance during the course of its preparation.

We would like to gratefully acknowledge the contributions of Peter Smith, P.E., to the Implementation Section and Philip Taylor, M.D., to the Relative Risk Section. Data submitted by other agencies include the Industrial Survey Data by John Pulaski, P.E. and the Hazardous Spills Data by Ronald Maylath, P.E. both of the New York State Department of Environmental Conservation, and Cost Assessment Data by Mr. Robert Clark of the United States Environmental Protection Agency.

G. Wolfgang Fuhs, Dr. Nat. Sci. and Leo Hetling, P.E., Ph.D., among others, offered valuable criticisms of the initial drafts of the report.

The authors also express gratitude to those who have spent hours in manuscript preparation, namely, Mrs. Eileen Jones, Ms. Robin Ritterman, Mrs. Kathleen Harris and Ms. Mary Ann Datri.

TABLE OF CONTENTS

Page

LIST OF ABBREVIATIONS VII

LIST OF APPENDICES IX

LIST OF TABLES XI

LIST OF FIGURES XIII

EXECUTIVE SUMMARY 1

INTRODUCTION 3

Federal Control Procedures 3
State Health Department Concerns 5

CHARACTERIZATION OF ORGANIC CHEMICAL WATER QUALITY PROBLEMS IN N.Y.S. 6

Department of Environmental Conservation Industrial Chemical Survey 6
Environmental Spills 7
Water Quality Data - Federal Surveys 8
Water Quality Data - Nassau and Suffolk Counties' Surveys 9
Water Quality Data - State Health Department Surveys 10
Summary 12

DISCUSSION OF RELATIVE RISK 14

Risk Ratios 14
Voluntary and Involuntary Risks 15
Acceptability of Risk 17

METHODS OF ESTIMATING RISKS FROM ORGANIC CHEMICALS IN DRINKING WATER 19

General Considerations 19
Epidemiological Studies 21
Animal Studies 21
Carcinogenesis - Statistical Methods 22
No-Observed-Adverse-Effect Level 23
The Use of Chemical Similarities in a Toxicological Evaluation 38
Formation of Class Values 39

TABLE OF CONTENTS (CONTINUED)

Page

CONTROL OF SYNTHETIC ORGANIC CHEMICAL CONTAMINATION AT PUBLIC WATER SYSTEMS 46

- Source Control 46
- Groundwater Development 47
- Aeration 48
- Granular Activated Carbon Treatment 49
- Summary 51

BENEFIT OF REDUCING RISK 53

- Benefit Formula 53
- Cost Benefit Relationship 56
- Summary 57

STRATEGIES FOR MANAGING SYNTHETIC ORGANIC CHEMICALS IN DRINKING WATER 61

- Mandated Minimum Treatment - All Systems 61
- Mandated Minimum Treatment - Larger Water Systems 62
- Treatment of Contaminated Water Systems 62
- Risk Advisory 63
- Controlling Contaminants 63
- Follow Federal Standards 63

ISSUES ON WHICH THE HEALTH DEPARTMENT IS REQUESTING COMMENT 64

REFERENCES 66

APPENDICES 69

LIST OF ABBREVIATIONS

ADI	Acceptable Daily Intake
COD	Chemical Oxygen Demand
DEC	Department of Environmental Conservation (NYS)
DOH	Department of Health (NYS)
EPA	Environmental Protection Agency (U.S.)
FDA	Food and Drug Administration (U.S.)
g	see gram
GAC	granular activated carbon
GPM	gallons per minute
gram (g)	A unit of mass, the amount of matter in a substance; similar to the weight of an object; 454 grams = 1 pound
KW-HR	kilowatt hours
ℓ	see liter
LD 50	Lethal dose for 50% of the animals tested; usually preceded by species and route of administration (i.e. oral rat LD 50)
liter (ℓ)	A unit of volume; 1 liter = 1.06 quarts
MCL	maximum contaminant level
mg	see milligram
MGD	million gallons per day
micro (μ)	A factor denoting one millionth (1/1,000,000 = 10^{-6})
microgram (μg)	one millionth of a gram (10^{-6}g) see ppb
milligram (mg)	one thousandth of a gram (10^{-3}g) see ppm
NA	not analyzed

LIST OF ABBREVIATIONS (CONTINUED)

NAS	National Academy of Sciences
ND	not detected
NIPDWR	National Interim Primary Drinking Water Regulations
NOMS	National Organics Monitoring Survey
NORS	National Organics Reconnaissance Survey
NYS DEC	New York State Department of Environmental Conservation
NYS DOH	New York State Department of Health
OSHA	Occupational Health and Safety Administration
PCBs	Polychlorinated biphenyls
pH	A measure of the acidity or alkalinity of a solution. The pH scale ranges from 0-14; less than 7 indicates acidity; greater than 7 indicates alkalinity; equal to 7 indicates neutrality.
ppb	parts per billion, a unit of concentration; in this case, for water, approximately equal to μg/ℓ (micrograms per liter)
ppm	parts per million, a unit of concentration; in this case, for water, approximately equal to mg/ℓ (milligrams per liter); 1 ppm = 1,000 ppb
PVC	Polyvinyl chloride
RFM	Rapid Fluorometric Method
SDWA	Safe Drinking Water Act
TOC	Total organic carbon
μ	see micro
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization

LIST OF APPENDICES

Appendix		Page
A.	New York State Department of Environmental Conservation - Industrial Chemical Survey	69
B.	U.S. Environmental Protection Agency - National Organics Reconnaissance Survey	79
C.	U.S. Environmental Protection Agency - National Organics Monitoring Survey	81
D.	Community Water Supply Wells Closed in Nassau and Suffolk Counties	87
E.	New York State Department of Health and U.S. Geological Survey Joint Study: Reconnaissance of Organic Contamination of N.Y.S. Aquifers	89
F.	State and Local Health Department Response to Consumer Complaints Outside Long Island	95
G.	Finished Water Quality Data for Poughkeepsie and Waterford	97
H.	Finished Water Quality Data for the City of Niagara Falls	103
I.	Cost Estimate for Development of New Groundwater Sources of Supply	109
J.	Cost Assessment of Aeration Stripping Towers	113
K.	Cost Assessment of Granular Activated Carbon Post Contactors	121
L.	Organic Chemicals Removed by Aeration or Granular Activated Carbon	129

LIST OF TABLES

Table		Page
1	Methods of Determining Risk	1
2	Risk of Fatality by Various Causes	1
3	Comparative Annual Treatment Costs in Dollars per Household	1
4	National Interim Primary Drinking Water Regulations	4
5	Areas of the State Where More Than Ten Million Pounds of a Class of Compound are Used, Manufactured or Stored	6
6	Counties in Which More Than 1,000 Gallons of Gasoline were Spilled in 1978	7
7	Counties Which Experienced Three or More Hazardous Material/ Toxic Substance Spills in 1978	8
8	Number of Wells Found to Contain Synthetic Organic Chemicals, Nassau County - 4/28/78	9
9	Organic Chemicals Detected in Community Water Supply Wells, Nassau County - 4/28/78	9
10	Number of Systems Found to Contain Synthetic Organic Chemicals, Upstate New York - 10/78	10
11	The Ten Most Commonly Found Organic Chemicals Detected in Public Water System Wells - 10/78	11
12	Community Water Systems Which use Surface Sources of Supply - October 1977	11
13	Risk Ratios and the Corresponding Number of Illnesses Per Year Per 18 Million People	14
14	Leading Causes of Death, New York State, 1974-1977	15
15	Estimated Lifetime Risk of Death for Persons in New York State by Selected Events	16
16	Estimated Lifetime Risk of Mortality from Respiratory Cancer in Smokers	17

LIST OF TABLES

Table — Page

17 Criteria for Data Selection from Bioassays to Set Contaminant Levels of Chemical Carcinogens using Statistical Methods 24

18 Cancer Risks from Chronic Exposure to Chemicals in Drinking Water Using the Guess, Crump and Deal Extrapolation Procedure (GLOBAL) 25

19 Guidelines for Contaminant Levels in Drinking Water as a Function of Statistical Confidence Limits for a Cancer Risk of 1 x 10^{-6} 32

20 Toxicity of Toxaphene 35

21 Maximum Contaminant Levels (MCL) in Drinking Water Based on Toxicity, Acceptable Daily Intake (ADI), and No-Adverse-Effect Levels 36

22 Chemical Classes 44

23 Cost of Groundwater Source Development 47

24 Cost of Construction, Operation and Maintenance of Aeration Towers 49

25 Cost of Construction, Operation and Maintenance of GAC Post Contactors 51

26 Concepts or Principles Used in Estimating the Value of Reducing the Probability of Death 54

27 Comparisons of Some Empirical Estimates for Values of Reducing the Probability of Death 55

LIST OF FIGURES

Figure — Page

1 Public Water Supply Wells Known to be Contaminated with Synthetic Organic Chemicals - March 1979 13

2 LD50 of Aliphatic Alcohols Based on Number of Carbons 41

3 Vapor Pressure of Aliphatic Alcohols Based on Total Number of Carbons 42

4 Octanol/Water Partition Coefficients (P) of Aliphatic Alcohols Based on Total Number of Carbons 43

5 Comparison of Costs for Source Development or Treatment 52

6 Annual Per Capita Costs and Benefits for Removing Chloroform from Drinking Water 58

7 Annual per Capita Costs and Benefits for Removing Tetrachloroethylene from Drinking Water 59

8 Annual Per Capita Costs and Benefits for Removing Chloroform from Drinking Water Assuming Exposure Through Ingestion and Inhalation 60

TABLE 1

Methods of Determining Risk

Method	ADVANTAGES	DISADVANTAGES
Cancer-Risk Calculations	Can relate a numerical risk to a dose.	Can only be used for carcinogenic compounds with dose-response data. May be applied to other effects in the future.
No-Observed-Adverse-Effect Levels	Gives a fairly reliable assessment for an acceptable daily intake.	Needs multi-dose, long-term toxicity data.
Chemical Similarities	Provides a guideline for a chemical which has not been studied extensively for toxicological effects, provided data is available for a chemically similar compound.	Assumptions made, but provides a more defensible value than the class system.
Class Values	Provides a qualitative measure of the toxicity of many compounds.	Based on trends within a chemical class. Method may involve a high level of uncertainty.

EXECUTIVE SUMMARY

The manufacture and use of synthetic organic chemicals is widespread throughout New York State, and as a result these chemicals have and are likely to continue to contaminate sources of drinking water. The presence of these chemicals in public water supplies presents a risk to the health of the consumer. An estimate of this risk can be obtained by using extrapolation procedures and scientific judgement to interpret toxicological data from animal studies and epidemiological studies on working populations (Table 1). The data in Table 2 show that the magnitude of this risk is roughly comparable to many other common voluntary or involuntary risks.

TABLE 2

Risk of Fatality by Various Causes

ACCIDENT TYPE	CHANCE PER LIFETIME
Hurricanes	2.8×10^{-5}
Lightning	3.5×10^{-5}
Air Travel	70.0×10^{-5}
Drowning	230.0×10^{-5}
Motor Vehicles	1750.0×10^{-5}
0.16 μg/ℓ PCB in Drinking Water	0.1×10^{-5}
11 μg/ℓ Vinyl Chloride in Drinking Water	11.0×10^{-5}

A variety of engineering methods including development of new uncontaminated supplies, aeration and granular activated carbon treatment, can be used to control the concentrations of synthetic organic chemicals in drinking water. The cost, practicality and efficiency of these engineering measures vary widely. (Table 3).

TABLE 3

Comparative Annual Treatment Costs in Dollars per Household*

PLANT SIZE	GROUNDWATER DEVELOPMENT	AERATION	GRANULAR ACTIVATED CARBON
0.1 MGD	$40	$29	$ --
1.0 MGD	12	12	133
10.0 MGD	--	3	57
50.0 MGD	--	3	31

*Assume three people per household

A variety of regulatory postures could be adopted by New York State to provide a basis for controlling the level of synthetic organic chemicals in the state's drinking water. The following are some examples of strategies which could be used as stated or combined in a logical manner:

1. Require all public water systems in the state to install the best available treatment technology.
2. Require the larger public water systems in the state to install the best available treatment technology.
3. Require treatment to reduce or eliminate contaminants in only those systems whose water presents an unacceptable level of risk from organic compounds. Determining an unacceptable level of risk requires a public policy judgement.
4. Advise the public of the levels in and the risk associated with their drinking water and allow them to decide if the risk is acceptable or unacceptable.
5. Attempt to control contamination by restricting the use or by strictly regulating the manufacture, use and disposal of organic chemicals.
6. Adopt the Federal standards and/or regulations when they are promulgated.

Although the policy which will finally be adopted requires scientific input, the selection of this policy is partly a public decision involving a balancing of acceptable involuntary risk against increased regulation and cost. Public comments and suggestions are thus required before a final strategy for regulating synthetic organic chemicals in drinking water can be adopted.

INTRODUCTION

Organic chemicals are used extensively in our technological society. When handled properly, organic chemicals enhance the quality of life, but when improperly used or discarded, these chemicals will adversely effect human health.

The purpose of this report is to provide background information related to the development of a policy to control the contamination of drinking water with organic chemicals. The report includes a summary of the Environmental Protection Agency's strategy to control synthetic organic chemicals in drinking water; a description of the meaning of risks; a proposed methodology to establish risks for organics; an estimation of the problem in New York State; and finally, an assessment of the costs for removing organics from drinking water. The New York State Department of Health welcomes comments and suggestions regarding this report from any interested party. These comments will be used to establish a policy for controlling organic chemicals in drinking water. Several possible implementation strategies and specific issues on which the Health Department is requesting comments and guidance are listed at the conclusion of the report.

Federal Control Procedures

As a first step in controlling the risks imposed on society by organic chemicals in drinking water, Congress passed the Safe Drinking Water Act (SDWA) in 1974. One of the ultimate goals of this Act was to publish regulations establishing maximum contaminant levels (MCL) for various compounds in drinking water. Carrying out details of this Act is the jurisdiction of the Environmental Protection Agency (EPA). Congress also directed EPA to commission a study which would propose methods for establishing these regulations. This study was carried out by the National Academy of Sciences. One hundred days after the National Academy of Sciences submitted its report, EPA was to propose drinking water regulations. The National Academy of Sciences submitted its report entitled "Drinking Water and Health" on June 20, 1977 and EPA proposed organic drinking water regulations on February 9, 1978 but has yet to promulgate these as regulations.

While waiting for the completion of this study, EPA promulgated the National Interim Primary Drinking Water Regulations (NIPDWR) for four chlorinated hydrocarbons and two chlorophenoxy acids. The Environmental Protection Agency also specified that surface source community water systems were to monitor distributed water for these organic chemicals at three year intervals. Table 4 provides a list of these chemicals with the associated maximum contaminant levels (MCL).

In 1978, EPA proposed amendments to the NIPDWR to expand its control over synthetic organic chemicals in drinking water and thereby demonstrate the preventive philosophy underlying SDWA. EPA's position is that long term exposure to even low levels of organic chemicals poses a significant health risk and should be controlled.

TABLE 4

National Interim Primary Drinking Water Regulations

ORGANIC CHEMICAL	MCL (mg/ℓ)
Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalene	0.0002
Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis(p-methoxyphenyl)ethane)	0.1
Toxaphene ($C_{10}H_{10}Cl_8$ - Technical chlorinated camphene, 67-69% chlorine)	0.005
Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxyacetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	0.01

This position is complicated because certain trace contaminants are formed as by-products during chemical disinfection which is practiced by community water suppliers. Chlorine, used in the disinfection process, may react with naturally occurring organic substances to produce other compounds. The compounds known as trihalomethanes are some of the most frequently formed by-products of chlorination.

The SDWA endeavors to protect public health by establishing maximum contaminant levels and setting monitoring requirements or by requiring application of a generally available treatment. EPA has determined that a maximum contaminant level (100 microgram/liter) and a monitoring requirement are feasible for total trihalomethanes; however, similar policies are not realistic for the myriad of synthetic organic chemicals used in our highly technical society.

To date, more than 700 specific synthetic organic chemicals have been identified in various drinking water supplies in the United States. These chemicals reach water from industrial and municipal wastewater discharges, urban and rural runoff into surface waters, ground infiltration from landfills, defective sewer lines and runoff from vegetation bleached with chemicals. The concentration of any specific synthetic organic chemical in drinking water is likely to be very small; however, consideration must be given to the long term aggregate health effect of the ingestion of perhaps several hundred compounds.

EPA's position is that the large number of potential synthetic organic chemical contaminants in drinking water makes monitoring a water system for the presence of each economically impractical. For this reason EPA is considering requiring a treatment technique instead of establishing MCL's and monitoring requirements. The presently preferred treatment technique is adsorption of contaminants by granular activated carbon (GAC) which is the best broad spectrum treatment currently available for removing synthetic organic chemicals. This treatment requirement should result in facilities which, when adequately designed and operated, will reduce the public health risk from drinking water contaminated with synthetic organic chemicals.

State Health Department Concerns

The Federal organic chemical regulations published in the Federal Register in February, 1978 will be reproposed by EPA. Indications are that the new proposed regulations will apply principally to community water systems located along designated stretches of streams. These streams have either large numbers of point source discharges from major industries and/or municipalities, or the streams are shipping routes for industrial or agricultural chemicals. The State will also be permitted to designate other stream reaches of special concern. As will be shown in subsequent sections of this report, most of the community water systems which are now known to be contaminated with synthetic organic chemicals are not located along these streams. Public health protection may indicate that all users of community water systems be subjected to regulations so that any significant risk can be eliminated regardless of the community location or size.

CHARACTERIZATION OF ORGANIC CHEMICAL WATER QUALITY PROBLEMS IN NEW YORK STATE

This section of the report summarizes available drinking water quality data and data from other programs of the Departments of Health and Environmental Conservation. These programs are designed to investigate or control chemical discharges to the environment.

Department of Environmental Conservation Industrial Chemical Survey

In 1977 the Department of Environmental Conservation conducted an Industrial Chemical Survey to determine types and amounts of organic chemicals used, stored or manufactured by industries in New York State. This survey did not quantify the amounts of chemicals discharged. However, these data do show chemical usage by county; and a correlation would be expected to exist between the use of organic compounds and their disposal or discharge.

Appendix A contains seven maps of New York State showing the use and distribution of seven classes of organic chemicals: Halogenated Hydrocarbons, Halogenated Organics (other than hydrocarbons), Pesticides, Aromatic Hydrocarbons, Substituted Aromatics (other than hydrocarbons and non-halogenated), Ketones and Aldehydes and Plastics. These data are further summarized in Table 5 which shows areas of the state that use more than ten million pounds of one or more compound class per county. As can be seen, large quantities of organic compounds are used throughout New York State.

TABLE 5

Areas of the State Where More Than Ten Million Pounds of a Class of Compound are Used, Manufactured or Stored

CLASS	AREA						
	Buffalo	Capital District	Long Island	Lower Hudson Valley	Syracuse	Metropolitan New York City	Rochester
Halogenated hydrocarbons	X	X			X		
Halogenated organics	X						
Pesticides	X	X					X
Aromatic hydrocarbons	X	X	X				
Substituted aromatics	X	X	X	X			
Ketones and Aldehydes				X			
Plastics		X	X	X	X	X	

Environmental Spills

The 1978 spill summary of oil and hazardous material/toxic substances was recently completed by the Department of Environmental Conservation, Division of Pure Waters. These data show that in 1978 2,032,697 gallons of gasoline were reported spilled in 255 separate events. Of this, a total of 50,400 gallons of gasoline were recovered and recycled. Table 6 lists counties in which more than 1,000 gallons of gasoline were spilled.

TABLE 6

Counties in Which More than 1,000 Gallons of Gasoline were Spilled in 1978

COUNTY	NUMBER OF SPILLS	VOLUME OF SPILLS (Gallons)	VOLUME CLEANED UP (Gallons)
Albany	8	1,004	0
Broome	1	3,700	3,000
Cayuga	3	12,050	9,500
Chautauqua	2	1,100	0
Chemung	1	3,500	3,500
Chenango	6	3,151	50
Dutchess	2	1,950	0
Erie	21	8,287	0
Essex	1	2,000	0
Herkimer	1	3,000	0
Jefferson	13	4,902	50
Monroe	17	7,644	25
Nassau	27	99,019	30,220
Niagara	7	4,140	0
Onondaga	8	5,510	50
Ontario	6	1,135	0
Orange	4	8,110	0
Suffolk	33	782,625	1,975
Ulster	5	2,200	0
Westchester	15	5,005	2,000
New York City (all)	21	1,067,146	0
Total	202	2,027,178	50,370

Table 7 lists the number of hazardous material/toxic substance spills other than gasoline reported to DEC in 1978. Some examples of the types of toxic or hazardous material spilled are sodium cyanide, acetone, chromic acid, heavy metal sludge, hydrocarbon waste, paint, pesticides, dry cleaning solvents and PCB's. More specific data regarding the spills of these materials can be obtained from DEC.

Hazardous material/toxic substance spills cannot be entirely eliminated in a highly technological society. In recognition of this, regulatory agencies must maintain vigilant surveillance of the environment and water supplies to ensure that

TABLE 7

Counties Which Experienced Three or More Hazardous Material/Toxic Substance Spills in 1978

COUNTY	NUMBER OF SPILLS	VOLUME OF SPILLS (Gallons)	VOLUME CLEANED UP (Gallons)
Albany	7	11,255	255
Erie	9	1,712	5
Livingston	3	4,101	0
Monroe	10	4,274	452
Nassau	9	11,450	0
Niagara	8	13,050	7,540
Ontario	3	101	0
Orange	3	15,720	0
Schenectady	4	355	90
Steuben	4	60	10
Suffolk	6	3,704	50
Warren	3	100,055	0
Westchester	5	190	0
New York City (all)	25	24,081	0
Total	99	190,108	8,402

the public health is not subjected to significant risks.

Water Quality Data - Federal Surveys

Between 1975 and 1977, the U.S. Environmental Protection Agency conducted surveys to characterize the organic chemical contamination of the nation's drinking water systems. The National Organics Reconnaissance Survey (NORS) for halogenated organics in drinking water included three New York State public water systems: New York City, Buffalo, and Rhinebeck. Each of these systems uses surface supply sources. In addition to the trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane and bromoform) formed during chlorination, each sample was analyzed for the synthetic chemicals 1,2-dichloroethane and carbon tetrachloride. The results of this survey are contained in Appendix B. Each of the sampled public water systems were found to contain total trihalomethanes at concentrations ranging between 24 and 61 µg/ℓ. 1,2-Dichloroethane was found in both the raw and treated water of Rhinebeck at concentrations of 3 and 2 µg/ℓ, respectively; this compound was not in the other two public water systems sampled. Carbon tetrachloride was not identified in any of the samples collected.

In 1976 and 1977, EPA conducted the National Organics Monitoring Survey (NOMS). Four public water systems in New York State were included: Poughkeepsie, Waterford, Syracuse and Buffalo. These systems use surface supply sources. Samples were analyzed for 27 specific organic chemicals in addition to five general organic indicators. Except for the trihalomethane series and the general organic chemical indicators (total organic carbon, chemical oxygen demand and carbon chloroform extract), results for individual compounds were less than 1.8 µg/ℓ. The results of these analyses are provided in Appendix C.

Water Quality Data - Nassau and Suffolk Counties' Surveys

In 1976 synthetic organic chemicals were discovered in some public water supply wells in Nassau County. As a result of these findings, State and County resources were used to sample and analyze water from each well used as a source for community water systems. Wells were tested for six synthetic organic chemicals: tetrachloroethylene, 1,1,2-trichloroethylene, chloroform, 1,1,1-trichloroethane, carbon tetrachloride and trifluorotrichloroethane. The distribution of results by the sum of these contaminants is provided in Table 8.

TABLE 8

Number of Wells Found to Contain Synthetic Organic Chemicals Nassau County - 4/28/78

SUM OF CONTAMINANT LEVELS (µg/ℓ)	NUMBER OF WELLS
<10	384
10 - <20	10
20 - <50	13
50≤	14

The most commonly found contaminants in public water supply wells in Nassau County are listed in Table 9. These data show that tetrachloroethylene and 1,1,2-trichloroethylene were found in 15 percent and 13 percent, respectively, of the sampled wells. As will be shown subsequently, these contaminants were also found in many other wells in upstate New York.

TABLE 9

Organic Chemicals Detected in Community Water Supply Wells Nassau County - 4/28/78

CONTAMINANT	WELLS TESTED	WELLS POSITIVE	PERCENT POSITIVE	MAXIMUM LEVEL DETECTED (µg/ℓ)
Tetrachloroethylene	372	57	15	375
1,1,2-Trichloroethylene	372	50	13	300
Chloroform	372	41	11	67
1,1,1-Trichloroethane	372	33	9	310
Carbon Tetrachloride	372	20	5	21
Trifluorotrichloroethane	372	4	1	135

A sampling program for organic chemicals in water supplies began in Suffolk County during this same period. As of December 8, 1978 500 separate community water supply wells in Suffolk County were analyzed for organic chemical contamination. As was the case in Nassau County, trichloroethylene and tetrachloroethylene were frequently found in these wells. Based on these data, 13 community water supply wells in Suffolk County and 23 community water supply wells in Nassau County were closed. A list of these closures is provided in Appendix D.

Water Quality Data - State Health Department Surveys

In 1978 the State Health Department contracted with the United States Geological Survey (USGS) to study groundwater supplies for 112 organic chemical contaminants. Thirty public water systems were sampled during the summer and fall of 1978. A summary of the results of this program is contained in Appendix E. A total of 47 samples from 39 wells were collected. Every well tested was found to contain some synthetic organic chemical contamination. Table 10 shows the number of systems containing synthetic organic chemicals as a function of the sum of the contamination.

TABLE 10

Number of Systems Found to Contain
Synthetic Organic Chemicals
Upstate New York - 10/78

SUM OF CONTAMINANT LEVELS (μg/ℓ)	NUMBER OF SYSTEMS
<10	5
10 - <20	12
20 - <50	7
50 - <150	3
150≤	3

The ten most commonly found contaminants in public water supply wells in this study are shown in Table 11. These data show that bis(2-ethylhexyl)phthalate, toluene and di(n-butyl)phthalate were found in 92, 85, and 54 percent of the wells sampled.

State and local health departments respond to consumer reports of taste and odor problems in public and private water systems by investigating complaints, sampling water, conducting sanitary surveys to determine the potential source or sources of contamination and advising and informing consumers of available methods to safeguard their health. In some cases, the legislature has appropriated funds to correct the problem by extending nearby community water systems into the area of contamination.

To date, eight separate contamination incidents involving PCB's, trichloroethylene, tetrachloroethylene and 1,1,1-trichloroethane have been investigated by the Health Department outside Long Island. Additionally, up to 150 separate instances of gasoline contamination of public and private water supply wells have occurred in New York. Appendix F contains a summary of these investigations.

TABLE 11

The Ten Most Commonly Found Organic Chemicals
Detected in Public Water System Wells - 10/78

CONTAMINANT	WELLS TESTED	WELLS POSITIVE	PERCENT POSITIVE	MAXIMUM LEVEL DETECTED (μg/ℓ)
Bis(2-ethylhexyl)phthalate	39	36	92	170.0
Toluene	39	33	85	10.0
Di-n-butyl phthalate	39	21	54	470.0
Trichloroethylene	39	18	46	19.0
Ethylbenzene	39	17	44	40.0
Diethyl phthalate	39	13	33	4.6
Trichlorofluoromethane	39	11	28	13.0
Anthracene/Phenanthrene	39	7	18	21.0
Benzene	39	6	15	9.6
Butyl benzyl phthalate	39	5	13	38.0

During the fall of 1977, the State Health Department sampled distributed water from 420 surface source community water systems for the six pesticides and herbicides contained in the State and Federal drinking water regulations. In no instance was a detectable concentration of these contaminants found. Table 12 summarizes these data.

TABLE 12

Community Water Systems Which Use
Surface Sources of Supply
October 1977

CONTAMINANT	NUMBER OF SAMPLES	DETECTION LIMIT (μg/ℓ)	MAXIMUM CONTAMINANT LEVEL (μg/ℓ)	NUMBER OF ANALYSES WITH MORE THAN THE DETECTION LEVEL
Endrin	400	0.02	0.2	0
Lindane	400	0.04	4.0	0
Methoxychlor	400	1.0	100.0	0
Toxaphene	400	1.0	5.0	0
2,4-D	400	0.5	100.0	0
2,4,5-TP	400	0.1	10.0	0

The finished water of Poughkeepsie and Waterford has been analyzed for a variety of organic compounds during the last nine years. Both of these communities obtain their raw water from the Hudson River. The vast majority of the organic compounds for which analyses were run were present at concentrations less tha 5 µg/ℓ or were not detected. The exceptions were chloroform (maximum 190 µg/ℓ) and bromodichloromethane (maximum - 18 µg/ℓ), both probably by-products of chlorination. The results of these studies are given in Appendix G.

The finished water of Niagara Falls has been analyzed for typical industrial organic chemicals periodically during the past two years. Again, the contaminants present at the highest concentrations were the trihalomethanes (maximum - chloroform 43 µg/ℓ), by-products of chlorination. The remaining compounds for which analyses were run were either not detected or present at low concentrations (maximum - 1,2,3,4-tetrachlorobenzene - 6.54 µg/ℓ). The results of these studies are given in Appendix H.

Summary

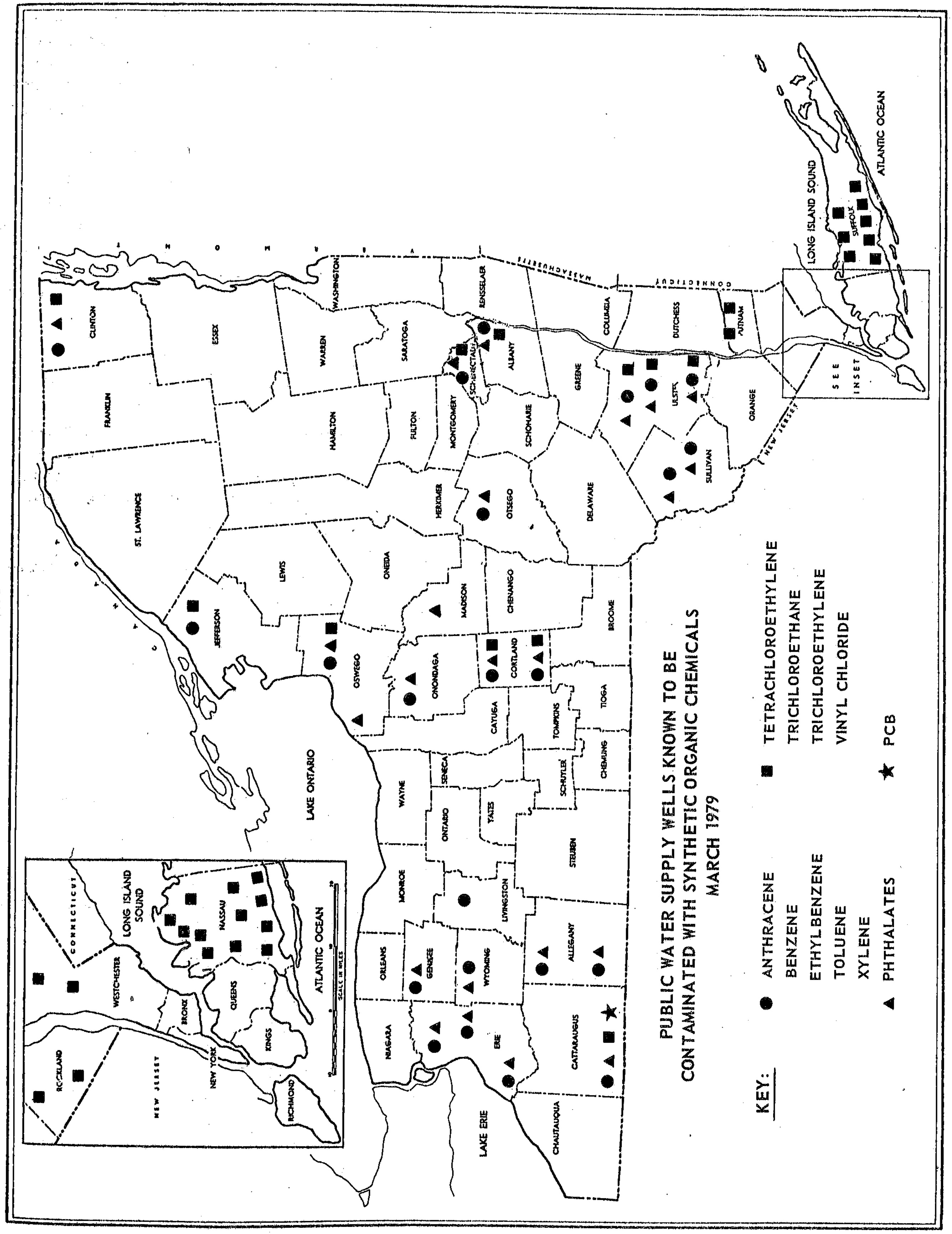
Data from the Department of Environmental Conservation indicate that extremely large quantities of synthetic organic chemicals are manufactured, used or stored throughout New York State. DEC's spill summary for 1978 shows that many accidental discharges of hazardous material and toxic chemicals occur in New York State each year.

The total impact of these events on drinking water quality is unknown. Available water quality surveys do indicate that:

1. Extensive groundwater quality studies on Long Island have documented the contamination of numerous drinking water supply wells with organic chemicals.
2. Water quality studies in upstate New York have documented organic chemical contamination of many public and private water supply wells.
3. The pesticides and herbicides (endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5-TP Silvex) are generally not found in surface source community water systems.

The attached Figure 1 shows the location of public and private water supply wells which are contaminated with synthetic organic chemicals. These data show that contamination is widespread and not restricted to a particular area of the State.

FIGURE 1



PUBLIC WATER SUPPLY WELLS KNOWN TO BE
CONTAMINATED WITH SYNTHETIC ORGANIC CHEMICALS
MARCH 1979

DISCUSSION OF RELATIVE RISK

This section will provide an explanation of risk ratios, background on the meaning of risk as applied to everyday life, and observations on the acceptability of risk. Risk ratios provide a quantitative description of the probability of a hazard associated with a particular event or exposure and thereby provide society with a measuring device for making decisions concerning the acceptability of an event or exposure.

Risk Ratios

Throughout this report, the term risk or risk ratios will be used as the unit of measure of the probability of a particular adverse effect occurring to an individual over a lifetime. The average lifetime in New York State is assumed to be 70 years. Table 13 provides several examples of risk ratios and the associated number of illnesses expected per year for a population of 18 million (approximately the population of New York State) assuming an average lifetime of 70 years.

TABLE 13

Risk Ratios and the Corresponding Number of Illnesses
Per Year Per 18 Million People

RISK RATIO			NUMBER OF ILLNESSES
ENGLISH	DECIMAL	EXPONENTIAL	PER YEAR PER 18 MILLION PEOPLE
One per ten	0.1	10^{-1}	25,000
One per hundred	0.01	10^{-2}	2,500
One per thousand	0.001	10^{-3}	250
One per ten thousand	0.0001	10^{-4}	25
One per hundred thousand	0.00001	10^{-5}	2.5
One per million	0.000001	10^{-6}	.25

At first, a risk of one per million, one per hundred thousand or even one per ten thousand appears small. Society would probably not even notice twenty-five additional cases of illness resulting from an exposure of 18 million people unless they occurred in a cluster. However, these events certainly would be noticed by the twenty-five directly affected, their friends, relatives and business associates.

Table 14 shows the risk of death from the five leading causes in New York State for the period 1974-77. These lifetime risks are substantial, being two in one hundred or greater with cardiovascular disease having the highest risk of approximately 0.27.

TABLE 14

Leading Causes of Death
New York State
1974 - 1977

CAUSE OF DEATH	NUMBER DEATHS/YEAR	ESTIMATED LIFETIME RISK	RISK RATIOS
Cardiovascular disease	70,413	27 in 100	0.27
Cancer	36,297	14 in 100	0.14
Stroke	13,700	5 in 100	0.05
Pneumonia	5,716	2 in 100	0.02
Accidents	5,592	2 in 100	0.02

Table 15 lists other causes of death with the approximate lifetime risks. In comparison to cardiovascular disease, cancer, stroke, pneumonia and accidents, the risk of death from these events is very small.

Voluntary and Involuntary Risks

Distinguishing between voluntary and involuntary risk is necessary in understanding risk and making judgments on the acceptability of risk. Governmental representatives are unable to prevent individuals from voluntarily subjecting themselves to risks. A classic example of a voluntary acceptance of risk is cigarette smoking. Numerous studies have shown that smoking dramatically increases an individual's risk of contracting respiratory cancer or emphysema. Table 16 shows the lifetime risk of death from respiratory cancer in smokers. These data show that as little as one two-thousandths of a cigarette per day is equivalent to a 10^{-6} lifetime risk of death from cancer. Additionally, smokers have a risk of approximately 0.075 to 0.2 for contracting emphysema.

Driving automobiles is an action undertaken by society and involves an acceptance of risk. In 1978, 2,551 people died and 266,442 people were injured in New York State as a result of traffic accidents. Therefore, the lifetime risk of death from vehicle traffic in New York State for 1978 was .01 and the accepted lifetime risk of injury from vehicle traffic in New York State for 1978 was 1.04. The probability of anyone being injured in an automobile accident during his or her lifetime is over 100 percent. Driving automobiles can be a voluntary acceptance of risk (pleasure driving) or involuntary (necessary means of transportation).

Clearly, people who smoke cigarettes or travel in automobiles accept the relatively high risks associated with these activities as a trade-off against certain benefits.

TABLE 15

Estimated Life Time Risk of Death for Persons in New York State By Selected Events*

1 IN A MILLION OR 10^{-6}

- Diphtheria
- Acute Polio
- Rubella (German measles)
- Melanoma
- Vitamin D deficiency
- Ricketts
- Passenger on railroad hit by train
- Passenger on a commercial air-craft

1 IN ONE HUNDRED THOUSAND OR 10^{-5}

- Gas gangrene
- Hemophilia
- Pedestrian hit by bicycle
- Anesthesia complication of surgery
- Lightning
- Cataclysm (hurricane, flood, tornado, earthquake, etc.)
- Bites and Stings (Venomous animals or insects)

1 IN TEN THOUSAND OR 10^{-4}

- Electrocution
- Fall out of building
- Hit by falling object
- Firearm accident
- Excessive cold
- Accidental poisoning with drug or medicine
- Fall from ladder or scaffold

*Estimate is based on the number of deaths in New York State recorded for each cause by the New York State Health Department, Office of Biostatistics, for the years 1974 to 1977. 1×10^{-6} risk represents events occurring from 0-5 times in that 4 year time; 1×10^{-5} risk represents events occurring from 6-50 times during the 4 years; and 1×10^{-4} risk represents events occurring 51-500 times during the 4 years. A four year period for recording of events was selected because with the population of New York State (1977 estimate 17,924,000), just over 70 million person years of observation are accrued each 4 years; therefore, events occurring once every four years correlate with a risk of one in a million for a lifetime.

New York State Dept. of Health

TABLE 16

Estimated Lifetime Risk of Mortality from Respiratory Cancer in Smokers

RISK	NUMBER OF CIGARETTES PER DAY
1 in a million ($1x10^{-6}$)	1/2,000 or 0.0005
1 in a hundred thousand ($1x10^{-5}$)	1/200 or 0.005
1 in ten thousand ($1x10^{-4}$)	1/20 or 0.05
2 in a thousand ($2x10^{-3}$)	1 or 1
4 in a hundred ($4x10^{-2}$)	20 or 1 pack

People are also subjected to a number of involuntary risks associated with every day life. For the purpose of this discussion, involuntary risk shall be defined as an unavoidable risk to which the population or part of it is subjected. Examples of involuntary risk are those associated with drinking contaminated water, breathing polluted air and being in hurricanes, tornadoes or lightning storms. In general, individuals cannot control the quality of the water they drink or the air they breathe because choices for reducing the risk inherent in drinking water or breathing ambient air are either not available or impractical.

Acceptability of Risk

The development of a methodology to calculate the risk associated with a given dose provided impetus to society and scientists to define a level of acceptable risk. In 1961, Mantel and Bryan[1] defined "virtual safety" as being a risk of 1 in 100 million for a lifetime. In addition, FDA[2] believes that a risk of 1 in 1 million for a lifetime can probably be considered an insignificant public health concern.

According to the New York Times[3], Baron Rothschild, a former Director of Britain's Central Advisory Council for Science and Technology, has suggested that the acceptable level of risk from any beneficial activity should be approximately equivalent to the risk associated with death from a vehicular accident. If this were accepted for drinking water in New York, approximately 2,500 deaths per year in the State would occur from drinking contaminated water.

Comar[4] suggests that some guidelines could be established in dealing with risks:

1. Eliminate all voluntary or involuntary risks that have no benefit and are avoided without great cost.
2. Eliminate any large risk, say 10^{-4} or greater, that does not carry clearly overriding benefits.
3. Ignore any small risk, say 10^{-5} or less, that does not fall under number 1 above.

4. Actively study risks falling between these limits and do not proceed with an action until the benefits and the risks of the action are carefully evaluated.

An additional illustration of the difficulties in determining what level of risk and to whom a risk is acceptable is given by William E. Burrows[5] in a recent article in the New York Times Magazine. Mr. Burrows states

> "When a newscaster says that 'the quality of air today is acceptable,' to whom is he or she referring? What is acceptable to the taxi driver who must earn a living with his automobile is not necessarily acceptable to the asthmatic breathing the fumes -- except at the moment when the asthmatic having a seizure, needs the taxi in order to get to a hospital; then the taxi and its wake of noxious vapors become eminently acceptable to driver and passenger alike."

Determining the level of acceptable risk is not a scientific decision. This decision must be made by society or by public officials who are directly responsible to society.

METHODS OF ESTIMATING RISKS FROM ORGANIC CHEMICALS IN DRINKING WATER

The New York State Department of Health has generally followed the toxicological procedures given by the National Academy of Sciences in the publication entitled "Drinking Water and Health"[6] when calculating risks associated with contaminant levels in drinking water. The following section provides a technical summary of that methodology along with some additional procedures which have been developed within the Department. More detailed information can be obtained from the publication "Drinking Water and Health."[6]

General Considerations

One major obstacle in a discussion of risk stems from the difficulty in quantifying risk. To date, a predictive risk (as distinguished from an observed risk) has been calculated only for carcinogenic compounds. Using cancer-risk extrapolation calculations, an exposure level for a compound can be associated with an excess lifetime cancer incidence. Numerous other toxic effects beside carcinogenic effects can be produced by exposure to chemicals including teratogenic effects, mutagenic effects, polyneuropathy, central nervous system disorders, liver damage, blood disorders, and many others. So far, no numerical expression for risk has been developed which can relate the probability of producing these types of adverse effects with a dose.

The Department has used four methods for determining risk and setting guidelines. They are (1) dose-response extrapolations from animal studies for carcinogenic compounds, (2) the use of no-observed-adverse-effect levels for non-carcinogens, (3) chemical correlations, and (4) class values. The first two methods are established procedures. The last two are used when very little toxicological data are available, and these methods are not easily defined or characterized. Most of the methods rely on animal experiments; however, epidemiological studies are considered whenever possible. Various concepts such as threshold levels, safety or uncertainty factors, acceptable daily intake, etc., will be discussed.

Any method used to set a guideline should account for the possible lifetime exposure of a diverse population to a substance. Therefore, the difference between acute and chronic toxicity should be stressed. Acute toxicity is defined as adverse effects occurring shortly after the administration of a single dose or multiple doses of a substance. Many people consider death as a major or only consequence of acute toxicity. However, other effects such as damaged skin from an acid burn would also be considered an acute toxic effect. A chronic toxic effect is defined as an injury that persists because it is irreversible or progressive or because the rate of injury is greater than the rate of repair during a prolonged exposure period. Chronic exposure is the frequent or continuous ingestion of a substance over a long time.

Since drinking water standards must consider a lifetime exposure of the public to a substance, the primary concern must be with possible chronic effects. The animal studies which are most relevant for determining chronic effects are those lasting for a lifetime or half-lifetime of a species. A 90-day study, sometimes termed a sub-acute toxicity study and usually conducted on rodents, is a classical toxicological test which approaches the shortest time period that is considered acceptable or desirable.

Subgroups of the population may be at a higher risk from a chemical than others. The fetus, newborn, the ill, and those with some inborn genetic error are some of these groups. The fetus is in a developmental stage and many of the liver, kidney and metabolic processes may not be functioning at all or to the same degree as in adults. Those with some genetic trait, e.g. sickle-cell anemia, may react more violently to a chemical. The toxicity of a chemical will even vary with sex. Benzene is more toxic to females than males probably as a result of hormonal differences. The newborn in most mammalian species has different absorption characteristics than the older members of the same species. With age, the membranes of the gastro-intestinal tract develop some discriminatory ability which affects the amount of some substances entering the body by ingestion. In addition, the bacterial content of the stomach and intestinal tract is not the same as found in older members of the species. These characteristics may lead to major differences in absorption for the newborn which could put them at a higher risk than the general population.

An individual is exposed to many chemicals at any given time from air, water and food. When this happens, the combined action of the chemicals can be[7]

(a) independent - when the chemicals produce different effects or have different modes of action;

(b) additive - when the magnitude of an effect or response produced by two or more chemicals is numerically equal to the sum of the effects or responses that the chemicals would produce individually;

(c) more than additive - often called potentiation or synergism;

(d) less than additive (antagonism, inhibition).

The results of these combinations cannot be disregarded. However, the number of possible interactions between n substances is, in general, $2^n - n - 1$. For example, the number of possible interactions between just 5 different chemicals is 26. Moreover, these potentially synergistic mixtures have been studied to a lesser degree than individual chemicals. The possibility that this area will be studied thoroughly within the near future is inconceivable. Therefore, we recognize that these effects do exist and that they do have potentially serious consequences. Hopefully, by taking a conservative approach with cancer-risk calculations and uncertainty factors, any synergistic effect will be minimized. For a given situation, the chemical interactions are considered when possible; however, setting guidelines which consider all possible situations and interactions is impracticable.

Epidemiological Studies

Epidemiological studies attempt to quantify risk by comparing two populations, one of which has been exposed to a substance and one which has not. These studies do supply the percentage of a group which may expect to see some effect from an exposure. However, major problems exist in using epidemiological studies as a basis for a guideline. Some of these are:

1. Exposure levels are difficult to determine since contaminant levels may have been extremely variable or may not have been measured because of the accidental nature of the exposure.

2. If the use of a substance is widespread, a control group may not be readily available.

3. A population that is exposed only to one substance at any given time is difficult to find. This is illustrated by the studies on chromium workers who have a high incidence of lung and nasal cancer. Chromium ore is processed to obtain a product; during this procedure, the workers are exposed to many chromium compounds and various impurities. Therefore, establishing a definitive cause and effect relationship for a specific compound is difficult.

4. Many epidemiological studies are conducted on working populations comprised, for the most part, of healthy adult males. These results may not be directly applicable to a varied human population.

5. Epidemiology is mainly a diagnostic tool rather than a predictive one. The studies which are needed must be able to predict a safe level rather than determine levels which are found to cause adverse effects.

Animal Studies

The appropriateness of applying animal studies to humans can be questioned because of the differences that exist between species. In addition, for any one study the genetic pool of the animals is usually very similar because the animals are inbred; this is not true for the human population. Differences in other processes such as metabolism, exposure, distribution, storage, excretion, reabsorption, etc., exist; however, very little information is usually known about these processes, and taking them into consideration is difficult.

A number of generalizations can be made concerning the differences in risk between animals and humans caused by the size differential. Generally speaking, the larger animal will have a lower metabolic rate and slower distribution of chemicals throughout his system. For a larger animal, more cells exist which may be susceptible to some adverse effect. In addition, for the same dose (expressed in milligram per kilogram of body weight), human cells are exposed to a substance for a much longer time than those of smaller animals. Anticancer drug studies have shown that the dose effective in a human is approximately 1/12th of the dose effective in a mouse, 1/6 of the dose effective in a rat, and 1/2 to 1/3 of the dose effective in a dog or monkey. It must be emphasized that this is on a weight/weight (milligram per kilogram) basis. These differences in susceptibility between species are reduced if the dose is expressed in units of weight per body surface area (milligram per square meter). These facts tend to indicate that a substance may be less toxic in smaller animals than in man.

Despite these limitations, animal experiments do provide data from which a dose-response relationship can be defined. This is almost impossible to do using epidemiological studies. Therefore, the National Academy of Sciences, the World Health Organization, the Food and Drug Administration and others have used the results of animal studies when providing health advisory statements.

Carcinogenesis - Statistical Methods

Some theories of cancer induction assume that a threshold level exists. A threshold level is an exposure level below which no toxic effect is observed because body mechanisms are capable of protecting a person from injury. However, NAS and FDA have recommended that threshold levels not be used for several reasons. The exact mechanism of carcinogenesis is unknown. The existence or non-existence of a threshold level has never been proven. If one cellular change can lead to a malignant transformation and a lethal cancer, a threshold level will not exist. Even if thresholds do exist, different segments of the population will have different thresholds. Factors such as sex, age, race or previous medical history can separate humanity into groups with different threshold levels. Therefore, the prudent approach would be to assume that no threshold value exists.

Tracing the history and development of statistical methods of risk estimation from cancer studies helps to increase the understanding of the procedures used today. The Department uses two different statistical methods. One was developed from the Armitage-Doll[8,9,10] model of carcinogenesis (GLOBAL by Guess, Crump and Deal)[11]; the second is the log-probit method developed by Mantel and Bryan[1]. The history and development of the first method will be traced.

Iversen and Arley[12,13] developed one of the first statistical models for carcinogenicity. This theory states that the probability of a cell being transformed to a cancer cell is a linear function of the amount of carcinogen present. After the initial event, the development of the tumor is assumed to be independent of the presence of the carcinogen. This method is commonly referred to as the one-hit model, and the mathematical implications are that the number of tumors within a lifetime depends on the total dose of the carcinogen and not on the pattern of exposure.

Nordley[14] and Stocks[15] added to this theory by introducing the concept that more than one change may be necessary before a single cell is transformed into a cancer cell. The probabilities of each of these changes are assumed equal and proportional to time and to the concentration of the carcinogen. If the number of changes which must occur is set equal to six or seven, then an age-specific, cancer-incidence rate is obtained which is proportional to the 6th or 7th power of age and a cancer incidence is obtained which is proportional to the 6th or 7th power of the concentration of the carcinogen. The correlation between age and cancer incidence and the 6th or 7th power of age is consistent with what is found in animals and humans. However, the correlation between cancer incidence and the 6th or 7th power of the concentration of the carcinogen is not observed in either human or animal studies.

Armitage and Doll[8,9,10] used this model but allowed different probabilities for each transformation. Some of the transformations would depend on the presence of the carcinogen and some would not. This resulted in a model that was consistent with tumor incidence and rates of formation found in animal and human studies.

With the advent of cancer-risk calculations which associate a given risk with a given dose, a safe or an acceptable level of risk had to be established. In 1961, Mantel and Bryan[1], in developing their dose-response calculation, defined "virtual safety" as being a risk of 1 in 100 million for a lifetime at a statistical assurance level of 99%. (The chances of the true calculated dose being less than the calculated dose is one out of one hundred when a statistical assurance level of 99% is used.) In the FDA criteria and procedures for evaluating assays for carcinogenic residues[2], the recommended method for determining an acceptable residue level of a carcinogenic compound uses the Mantel-Bryan extrapolation procedure. In addition, the Commissioner of FDA believes that a risk level of 1 in 1 million for a lifetime at a statistical assurance level of 99% can probably be considered as an insignificant public health concern. The National Academy of Sciences used the Guess, Crump and Deal extrapolation procedure when recommending methodology for determining maximum contaminant levels in drinking water. The Academy did not set an acceptable risk but used a confidence level of 95% in stating a risk for one μg/liter of a substance.

The Department of Health uses the method of Armitage and Doll, computerized by Guess, Crump and Deal (GLOBAL), to set guidelines for carcinogenic compounds. The Department has been using as an insignificant risk the value of 1 in 1 million for a lifetime at a statistical assurance level of 95%. Table 17 outlines the procedure for analyzing the data supplied by bioassays. Table 18 gives the results of cancer-risk calculations for some compounds and shows the drinking water concentrations which correspond to several risk values. Table 19 shows how the drinking water concentration varies as a function of statistical assurance level at a risk of 1 in 1 million.

No-Observed-Adverse-Effect Level

For non-carcinogens a guideline can be calculated from a no-observed-adverse-effect level. If this level is assumed to exist, then the existence of a threshold level follows. For a multidose experiment, the highest level which does not produce a toxic effect is the no-observed-adverse-effect level and is used to set a guideline. In determining a no-observed-adverse-effect level, the following information should be used[16].

(a) Biochemical aspects, including the kinetics of absorption, tissue distribution and excretion, biological half-life, effects on enzymes, metabolism, etc.

(b) Special studies - carcinogenicity, mutagenicity, neurotoxicity, potentiation, reproduction, teratogenicity, etc.

(c) Acute toxicity - LD 50's and other similar studies, mainly involving single doses in several species of experimental animals.

(d) Short-term studies, which generally include the classical sub-acute 90-day toxicity test. These studies generally extend from weaning to sexual maturity, usually 3 months in rodent species and 1-2 years in dogs or monkeys.

TABLE 17

Criteria for Data Selection from Bioassays to Set Contaminant Levels of Chemical Carcinogens using Statistical Methods

Several sets of data, based on species, sex, tumor and location, may be generated. Doses are extrapolated for each data set, and the following rules are used to determine safe levels:

1. Data from any one tumor cannot be duplicated; i.e., one data set referring to leukemias while another set, for the same group of experimental animals, referring to leukemias and lymphomas. If this is the case, the most significant data is used.

2. Compare extrapolated dose levels for different data sets of the same group of experimental animals (i.e., male rats). Any values greater than the lowest dose (most sensitive data set) by more than one order of magnitude are discarded. The mean of all other doses within the same experimental group is calculated.

3. Extrapolated doses must include both males and females. If males and females of the same species are analyzed as separate experimental groups, the extrapolated doses must be combined. After step 2, the mean value of the male and female dose levels is taken.

4. If more than one species has been tested, results should be compared. If any species is less sensitive than the most sensitive by more than one order of magnitude its data is not used. The mean value of the dose levels of the most sensitive species is calculated. This is regarded as the maximum contaminant level.

TABLE 18

Cancer Risks from Chronic Exposure to Chemicals in Drinking Water Using the Guess, Crump and Deal Extrapolation Procedure (GLOBAL)

Compound	Allowed µg/l[1] for the lower 95% confidence limit on safe dose for three risk values			Reference (source of data)
	1×10^{-4}	1×10^{-5}	1×10^{-6}	
Aflatoxin B_1	0.01	.001	.0001	Wogan, et al., Food Cosmet. Toxicol. 12, 681 (1974)
Aldrin	0.3	.03	.003	NCI[2], 1978 (#C00044)
2-Aminoanthraquinone	524.0	52.4	5.24	NCI, 1978 (#C01876)
4-Aminobiphenyl	2.6	.26	.026	Clayson, et al., Brit. J. Cancer 21, 755 (1965)
3-Amino-9-ethyl-carbazole hydrochloride	35.0	3.5	.35	NCI, 1978 (#C03043)
1-Amino-2-methyl-anthraquinone	105.0	10.5	1.05	NCI, 1978 (#C01901)
4-Amino-2-nitro-phenol	410.0	41.0	4.10	NCI, 1978 (#C03963)
2-Amino-5-nitro-thiazole	44.0	4.4	.44	NCI, 1978 (#C03065)
o-Anisidine hydro-chloride	170.0	17.0	1.70	NCI, 1978 (#C03747)
Auramine	18.0	1.8	.18	Bouser, et al., Brit. J. Cancer 10, 653 (1956)
Azinphosmethyl	12.0	1.2	.12	NCI, 1978 (#C00066)

Compound	Allowed μg/l[1] for the lower 95% confidence limit on safe dose for three risk values			Reference (source of data)
	1 x 10^{-4}	1 x 10^{-5}	1 x 10^{-6}	
α-BHC	33.0	3.3	.33	Ito, et al., J. Natl. Cancer Inst. 54, 801 (1975)
β-BHC	12.0	1.2	.12	Thorpe and Walker, Food Cosmet. Toxicol. 11, 433 (1973)
Benzidine	4.0	.4	.04	Vesselinovich, et al., Cancer Res. 35, 2814 (1975)
Bis (2-chloroethyl) ether	310.0	31.0	3.1	Innes, et al., J. Natl. Cancer Inst. 42, 1101 (1969)
Carbon tetrachloride	450.0	45.0	4.5	NAS, Drinking Water and Health, 1977
Chloramben	1500.0	150.0	15.0	NCI, 1978 (#C00055)
Chlordane	3.2	.32	.032	NCI, 1976 (#C00099)
Chlorobenzilate	715.0	71.5	7.15	NCI, 1978 (#C00408)
Chloroform	29.0	2.9	.29	NAS, Drinking Water and Health, 1977
4-Chloro-o-phenylene-diamine	233.0	23.3	2.33	NCI, 1978 (#C03292)
Chlorothalonil	1917.0	191.7	19.17	NCI, 1978 (#C00102)
5-Chloro-o-toluidine	105.0	10.5	1.05	NCI, 1979 (#C02051)
m-Cresidine	0.8	0.08	0.008	NCI, 1978 (#C02993)
Cupferron	180.0	18.0	1.80	NCI, 1978 (C03258)

Compound	Allowed μg/l[1] for the lower 95% confidence limit on safe dose for three risk values			Reference (Source of data)
	1 x 10^{-4}	1 x 10^{-5}	1 x 10^{-6}	
Dapsone	38.0	3.8	.38	NCI, 1977 (#C01718)
p,p'-DDE	9.0	.9	.09	NCI, 1978 (#C00555)
DDT	4.0	.4	.04	NAS, Drinking Water and Health, 1977
1,2-Dibromo-3-chloropropane	3.7	.37	.037	NCI, 1978 (#C00500)
1,2-Dibromoethane	48.0	4.8	.48	NCI, 1978 (#C00522A)
2,7-Dichlorodibenzo-p-dioxin	1045.0	104.5	10.45	NCI, 1979 (#C03667B)
Dicofol	21.0	2.1	.21	NCI, 1978 (#C00486)
Dieldrin	0.3	.03	.003	Walker, et al., Food Cosmet. Toxicol. 11, 415 (1972)
N,N'-Diethylthio-urea	16.0	1.6	.16	NCI, 1979 (#C03816)
2,3-Dimethoxybenzidine-4,4'-diisocyanate	2080.0	208.0	20.80	NCI, 1979 (#C02175)
4-Dimethylamino-stilbene	.3	.03	.003	Port, et al., Oncology 33, 66 (1976)

Compound	Allowed $\mu g/l^1$ for the lower 95% confidence limit on safe dose for three risk values 1×10^{-4}	 1×10^{-5}	 1×10^{-6}	Reference (Source of data)
Dimethylnitrosamine	1.0	.1	.01	Terracini, et al., Brit. J. Cancer 21, 559 (1967)
1,4-Dioxane	311.0	31.1	3.11	NCI, 1978 (#C03689B)
Direct Black 38	29.0	2.9	.29	NCI, 1978 (#C54557)
Direct Blue 6	44.0	4.4	.44	NCI, 1978 (#C54579)
Direct Brown 95	48.0	4.8	.48	NCI, 1978 (#C54568)
p,p'-Ethyl DDD	467.0	46.7	4.67	NCI, 1979 (C02868)
ETU	23.0	2.3	.23	NAS, Drinking Water and Health, 1977
Heptachlor	1.0	.1	.01	NAS, Drinking Water and Health, 1977
Hexachlorobutadiene	42.0	4.2	.42	Dow Chemical Co. Report, 1976
Hydrazine sulfate	26.0	2.6	.26	J. Natl. Cancer Inst. 41, 331 (1968)
IPD	7.3	.73	.073	NCI, 1978 (#C01547)
Isophosphamide	3.8	.38	.038	NCI, 1977 (#C11638)
Isonicotinic acid hydrazine	180.0	18.0	1.8	J. Natl. Cancer Inst. 41, 331 (1968)
Kepone	1.0	.1	.01	NAS, Drinking Water and Health, 1977
Metepa	4.8	.48	.048	Bull. WHO 34, 317 (1966)

Compound	Allowed $\mu g/l^1$ for the lower 95% confidence limit on safe dose for three risk values 1×10^{-4}	 1×10^{-5}	 1×10^{-6}	Reference (Source of data)
2-Methyl-1-nitro-anthraquinone	2.2	.22	.022	NCI, 1978 (#C01923)
N-Methyl-N-nitroso-aniline	4.2	.42	.042	Brit. J. Cancer 18, 265 (1964)
Mirex	9.2	.92	.092	Ulland, et al., J. Natl. Cancer Inst. 58, 133 (1977)
2-Naphthylamine	9.4	.94	.094	Bonser, et. al., Brit. J. Cancer 6, 412 (1952)
Nitrilotriacetic acid ($Na_3NTA \cdot H_2O$)	1300.0	130.0	13.0	NCI, 1977 (#C01445)
5-Nitroacenaphthene	59.0	5.9	.59	NCI, 1978 (#C01967)
5-Nitro-o-anisidine	320.0	32.0	3.20	NCI, 1978 (#C01934)
Nitrofen	33.0	3.3	.33	NCI, 1978 (#C00420)
2-Nitro-p-phenylene-diamine	444.0	44.4	4.44	NCI, 1979 (#C03941)
p-Nitrosodiphenylamine	499.0	49.9	4.99	NCI, 1979 (#C02244)
N-Nitrosopyrrolidine	1.4	.14	.014	Preussmann, et al., Z. Krebsforsch 90, 161 (1977)
5-Nitro-o-toluidine	88.0	8.8	.88	NCI 1978 (#C01843)
Parathion	4.5	.45	.045	NCI, 1979 (#C00226)

Compound	Allowed $\mu g/l^1$ for the lower 95% cofidence limit on safe dose for three risk values			Reference (source of data)
	1×10^{-4}	1×10^{-5}	1×10^{-6}	
PCB (1260)	16.0	1.6	.16	Kimbrough, et al., J. Natl. Cancer Inst. <u>55</u>, 1453 (1975)
Phenazopyridine hydrochloride	533.0	53.3	5.33	NCI, 1978 (#C01672)
Phenesterin	14.0	1.4	.14	NCI, 1978 (#C01558)
Phenytoin	52.0	5.2	.52	IARC Monographs, Vol. 13
Piperonyl sulfoxide	31.0	3.1	.31	NCI, 1979 (#C02824)
Pivalolactone	410.0	41.0	4.10	NCI, 1978 (#C04126)
Propyleneimine	11.0	1.1	.11	Ulland, et al., Nature <u>230</u>, 460 (1971)
p-Quinone dioxime	110.0	11.0	1.10	NCI, 1979 (#C03850)
Safrole	240.0	24.0	2.40	Long, E. L., Arch. Path. <u>75</u>, 595 (1963)
Sterigmatocystin	.03	.003	.0003	Zwicker, et.al., Food Cosmet. Toxicol. 12, 491 (1974)
Sulfallate	48.0	4.8	.48	NCI, 1978 (#C00453)
1,1,2,2-Tetrachloroethane	37.0	3.7	.37	NCI, 1978 (#C03554)

Compound	Allowed $\mu g/l^1$ for the lower 95% confidence limit on safe dose for three risk values			Reference (source of data)
	1×10^{-4}	1×10^{-5}	1×10^{-6}	
Tetrachloroethylene	220.0	22.0	2.20	NCI, 1976 (#C04580)
o-Toluidine Hydrochloride	267.0	26.7	2.67	NCI, 1979 (#C02335)
1,2,2-Trichloroethane	46.0	4.6	.46	NCI, 1978 (#C04579)
Trichloroethylene	460.0	46.0	4.6	NAS, <u>Drinking Water and Health</u>, 1977
2,4,6-Trichlorophenol	497.0	49.7	4.97	NCI, 1979 (#C02904)
Trimethylphosphate	506.0	50.0	5.06	NCI, 1978 (#C03781)
Trimethylthiourea	40.0	4.0	.40	NCI, 1979 (#C02186)
Urethane	4.3	.43	.043	Port, et al., Oncology <u>33</u>, 66 (1976)
Vinyl Chloride	110.0	11.0	1.10	Maltoni, et al., Gli Ospedali della Vita <u>2</u>, 65 (1975)

---

[1] An intake of two liters of water per day would produce one excess cancer death per lifetime for 10,000, 100,000 and 1,000,000 population (assuming 70 kg body weight).

[2] National Cancer Institute Bioassay (NCI number given in parenthesis).

TABLE 19

Guidelines for Contaminant Levels in Drinking Water as a Function of Statistical Confidence Limits for a Cancer Risk of 1×10^{-6}*

COMPOUND	MAXIMUM CONTAMINANT LEVELS IN μg/ℓ**				
	50%	75%	90%	95%	99%
1,2-Dibromoethane (Mice - Male, Female)	0.80	0.57	0.50	0.47	0.42
Parathion (Rats - Male, Female)	0.71	0.053	0.047	0.044	0.040
Piperonyl Sulfoxide (Mice - Male, Female)	0.49	0.36	0.32	0.31	0.27

*based on an intake of 2 liter/day and 70 kilogram body weight
**lower confidence limits on safe dose

(e) Long-term studies - usually 80 weeks in mice, 2 years in rats. Multi-generational studies may belong in this category, depending on the duration of the treatment received by each generation.

(f) Observations in man - mainly observations in individuals having had occupational or accidental exposure; this also includes studies with volunteers under specific conditions.

The no-observed-adverse-effect level is expressed as a dose in milligrams per kilogram and decreased by a safety or uncertainty factor. This is multiplied by the average weight of a man, 70 kilograms, to obtain an acceptable daily intake or ADI.

The use of safety factors or uncertainty factors in deriving an acceptable daily intake for a chemical leads to some arbitrariness since there is no rigid set of rules for establishing the magnitude of this factor. Historically, a safety factor of 100 has been used by the FDA in connection with a no-effect level. However, most of these substances have been studied for toxicological effects to a greater extent than the average organic chemical. Other scientific groups have used safety factors along with general guidelines for establishing their magnitude. The World Health Organization has set acceptable daily intakes for pesticides. The following excerpt, taken from one of their publications[16], discusses the complexities involved in determining a safety factor.

> Once a no-effect level in one or several animal species has been identified and agreed upon by the majority of the experts, the problem of extrapolating from a safe level found in animals to a safe level for human intake has to be accomplished. This is generally done by the application of a safety factor to the no-effect level found in animals. No hard and fast rule can be made with regard to the magnitude of this safety factor, since many aspects have to be considered, such as species differences, individual variations, incompleteness of available data, and a number of other matters such as considerations of the fact that pesticide residues may be ingested by people of all ages throughout the whole lifespan, that they are eaten by the sick as well as the healthy, and that there are wide variations in individual dietary patterns.
>
> Whatever the safety factor employed in extrapolating from animals models to the human situation, the factors chosen will necessarily always be arbitrary ones. This fact underlines the complexity of assessing health hazards of chemicals, even when the best available means are used, and it shows that a degree of uncertainty always accompanies any toxicological decision.

In 1975 a list of WHO recommended acceptable daily intakes and their safety factors was compiled. The safety factors ranged from 6 to 2,500 with a mean of 254 and a median of 100. In the same article, five different cases distinguished by the quality and quantity of available toxicological data were presented[17].

1. The no-effect level chosen and the experimental study from which it has been selected is clearly stated.

2. A no-effect level has been demonstrated in only one animal species.

3. A same-effect level has been demonstrated in more than one animal species. In this case the safety factor construed has been indicated in all species for which the no-effect level has been shown.

4. No-effect levels have been demonstrated in more than one animal species. In this case, it was taken that the no-effect level that served as a basis for the ADI has been the one demonstrated in the most sensitive species.

5. A no-effect level has been demonstrated in one or more animal species and significant data on human safe levels have also been demonstrated. In this case it was taken that the no-effect level in the most sensitive animal species served as a basis and the no-effect level in human subjects has been used for lowering the safety factor commonly applied to animal no-effect levels.

The NAS study used 3 different safety or uncertainty factors. Their guidelines are as follows[6]:

1. Valid experimental results from studies on prolonged ingestion by man, with no indication of carcinogenicity.

Uncertainty Factor = 10

2. Experimental results of studies of human ingestion not available or scanty (e.g., acute exposure only). Valid results of long-term feeding studies on experimental animals or in the absence of human studies, valid animal studies on one or more species. No indication of carcinogenicity.

Uncertainty Factor = 100

3. No long-term or acute human data. Scanty results on experimental animals. No indication of carcinogenicity.

Uncertainty Factor = 1000

The range in uncertainty factors for 39 substances studied by the NAS is 10 to 1000 with a mean of 713 and a median of 1000; i.e., an uncertainty factor of 1000 is used in over half of the cases. The Health Department has been following the standards of the NAS when establishing safety factors for compounds.

An example of an acceptable daily intake calculation is given in Table 20. Guidelines for acceptable contaminant levels in drinking water for two different percentages of ADI's are given in Table 21. The remaining percentage of the daily intake could come from air, food, or skin absorption.

TABLE 20

Toxicity of Toxaphene*

Species	Duration of Study	Dosage Levels and No. of Animals Per Group	Highest No-Adverse-Effect Level or Lowest-Minimal-Effect Level	Effect Measured	Reference
Rat	9 months	50 ppm (12 animals)		Slight liver change in animals	18
Rat	9 months	200 ppm (12 animals)		Distinct liver change in 6 months	18
Dog	44 days	160 ppm (2 animals)		Change in kidney tubules and liver parenchyma	19
Dog	106 days	160 ppm (2 animals)			19
Rat	2 yr	25 ppm. 100 ppm. and 400 ppm	25 ppm (1.25 mg/kg)[c,d]	No adverse effect liver change	20

Using an uncertainty factor of 1,000, the suggested no-adverse-effect level in drinking water is calculated as follows:

$$\frac{1.25}{1000} = 0.00125 \text{ mg/kg/day(ADI)}, 0.00125 \times 70^{a} \times 0.1^{b} = 0.0088 \text{ mg/liter}$$

---

[a] Assume average weight of human adult = 70 kg.
[b] Assume average daily intake of water for man = 2 liters, and that 20 percent of total intake is from water.
[c] Value from which the suggested no-adverse-effect level was calculated.
[d] Assume weight of rat = 0.4 kg and average daily food consumption of rat = 0.02 kg.
*Taken from Safe Drinking Water Committee of the National Research Council. 1977. Drinking Water and Health. (National Academy of Sciences, Washington, D.C. p.602.

TABLE 21

Maximum Contaminant Levels (MCL) in Drinking Water Based on Toxicity, Acceptable Daily Intake (ADI), and No-Adverse-Effect Levels*

COMPOUND	20% OF ADI MCL μg/LITER	1% OF ADI MCL μg/LITER	UNCERTAINTY FACTOR
Alachlor	700.0	35.0	1000
Aldicarb	7.0	0.35	100
Amiben	1750.0	88.0	1000
Atrazine	150.0	7.5	1000
Benefin	700.0	35.0	1000
Bromacil	88.0	4.4	1000
Butachlor	70.0	3.5	1000
Captan	350.0	18.0	1000
Carbaryl	574.0	29.0	100
2,4-D	88.0	4.4	1000
Diazinon	14.0	0.7	10
Dicamba	8.8	0.44	1000
Disulfoton	0.7	0.035	100
Ferbam	88.0	4.4	1000
Folpet	1120.0	56.0	1000
Hexachlorophene	7.0	0.35	1000
Malathion	140.0	7.0	10
Maneb	35.0	1.8	1000
MCPA	8.8	0.44	1000
Methoxychlor	700.0	35.0	100
Methyl Methacrylate	700.0	35.0	1000
Methyl Parathion	30.0	1.5	10
Nitralin	700.0	35.0	1000
Paraquat	60.0	3.0	1000
Pentachlorophenol	21.0	1.1	1000
Phorate	0.7	0.035	100
Propachlor	700.0	35.0	1000
Propanil	140.0	7.0	1000
Propazine	325.0	16.0	1000
Simazine	1505.0	75.0	1000
2,4,5-T	700.0	35.0	100
TCDD	7×10^{-5}	3.5×10^{-6}	100
Thiram	35.0	1.8	1000
Toxaphene	8.8	0.44	1000
2,4,5-TP	5.3	0.26	1000
Trifluralin	700.0	35.0	100
Zineb	35.0	1.8	1000
Ziram	88.0	4.4	1000

*Assumed intake of 2 liters per day and a 70 kilogram body weight

Partially taken from Drinking Water and Health, National Academy of Sciences, Washington, D.C., 1977.

The Use of Chemical Similarities in a Toxicological Evaluation

From the above descriptions, obviously, the first two methods for setting a guideline are the methods of choice; however, they require a substantial amount of toxicological data. For many compounds, adequate toxicological data cannot be found, and even the most common measurement of toxicity, the oral-rat LD 50 has not been determined. Two methods which will be discussed in this and the following section have been developed to apply to those compounds. Because of the very nature of their derivation, these methods involve a number of assumptions, and therefore many doubts can be expressed about the appropriateness of their use. However, if these methods were not used, the only other choice would be to give no answer and either completely eliminate human intake of these chemicals through water or allow unlimited intake. The last alternatives seem equally undesirable and less acceptable than using a method which is based on the best, although incomplete, knowledge (available today) to arrive at some decision.

One example of using chemical similarity involves the phosphonate compounds which are widely used in industrial formulations for preventing boiler scale accumulation. HEPD, (1-hydroxyethylidene) bisphosphonic acid, is an organic phosphonate compound also used in the treatment of Paget's disease and in bone scanning techniques. Because HEDP has been prescribed for the treatment of a disease, some human, chronic, toxicological data is available that can be used to set a guideline. A guideline for another, similar compound, TePMEDA or N,N-tetraphosphonomethylethylenediamine, was needed. This compound has been tested for use in bone scanning techniques but has not been administered to humans over a long period. However, a limited amount of biochemical information is available including sites of deposition in the body and organ distribution. Since these processes are similar for both compounds, the same guideline was suggested by the Department for each. This technique is only useful if there are two chemically, very similar compounds, one of which has been studied at least to the extent that some level of acceptable chronic exposure can be established.

A second example of this type of analysis was used to answer the question "Should vinyl fluoride be considered a carcinogen?". If the literature is searched for data concerning the carcinogenic potential of vinyl fluoride in animals or man, very little information is found. However, much more data are available for vinyl chloride and vinyl bromide. Several specific literature references can be used to develop a reasonable response to this question.

One study[21] has shown that vinyl bromide and vinyl chloride give positive results in a mutagenetic study involving a bacteria strain. This study also demonstrated the formation of an epoxide metabolic intermediate with both chemicals by trapping it with a trapping agent, 4-nitro(4-benzyl)pyridine.

The metabolism of vinyl chloride has been studied in detail. Evidence exists that vinyl chloride is metabolized by the mixed function oxidase systems in the liver to chloroethylene oxide which is further oxidized to chloroacetaldehyde and finally to chloroacetic acid.

A study[22] in rats compared the acute toxicities of ethane, ethene, vinyl fluoride, vinyl chloride, and vinyl bromide at four dose levels. Two liver function tests were measured: serum alanine-α-ketoglutarate transaminase (SAKT) and liver non-protein sulfhydryl expressed as glutathione sulfide (GSH). The SAKT values showed a dose dependent increase for all compounds measured except ethane implying that liver damage is dose dependent. The GSH values were all elevated except for the measurements involving ethane. Other metabolic studies have shown that GSH is initially depleted during vinyl chloride metabolism and that a rebound effect follows. The GSH levels are lowered when a radical species is formed which usually occurs during epoxide formation. In addition, the liver pathology of these compounds was very similar. The authors concluded that the double bond was more important in contributing to the toxic effects of these compounds than the halogen substituent.

After considering the above studies, the conclusion was reached that vinyl fluoride has a high probability of being carcinogenic. This has not been proven experimentally, but the available evidence supports this hypothesis.

Formation of Class Values

Millions of organic compounds exist. Very few of these compounds have been studied thoroughly, if at all, for toxicological effects. Performing all the tests which are deemed necessary for a complete toxicological evaluation would be very expensive and time consuming. For example, 1.5 to 3 million dollars and 3 years are needed to complete an adequate carcinogenic study on 2 species of animals for one compound. Conducting all the tests on each of the existing organic compounds in order to establish a guideline is economically and physically impossible.

The Department has begun to establish a system for regulating compounds using chemical properties. The compounds that had been found in drinking water prior to the summer of 1977 were examined for available toxicological data and were arranged into classes depending on the functional groups present in the molecules. All the data that could be found in secondary sources for any compound in one of these classes were assembled. The data included were oral-rat LD 50 values, drinking water standards developed by the World Health Organization or any other country, and Threshold Limit Values proposed by OSHA or the American Conference of Governmental and Industrial Hygienists. Other general ideas such as metabolism and the possible bioaccumulation in man of a class of compounds were also considered. A guideline for drinking water was based on the more toxic members of each class. Compounds shown to be more toxic than the majority of the class were given separate guidelines. This approach is useful in obtaining a first approximation of the toxicity of a particular compound and seems reasonable when very little or no toxicological information is available for a compound.

The derivation and possible scientific validation of the class value for aliphatic alcohols will be given as an example. In Figure 2, the oral-rat LD 50 values for aliphatic alcohols are plotted versus total carbons in the molecule. The observed trend may be related to the physical-chemical properties of the compounds.

The explanation for the variation may involve the absorption and excretion characteristics of these compounds. For example, the percentage absorbed by the gastrointestinal tract may decrease as the total carbons in the alcohol increases. Also exhalation by the lungs is a possible route of excretion; the compounds with high vapor pressures, corresponding to those alcohols with fewer carbons, may be exhaled rapidly without being metabolized. The combination of these two processes may explain the observed trend in oral-rat LD 50 values. Graphs of vapor pressure and log (octanol/water) partition coefficients, which may measure absorption and excretion properties, are also presented (Figures 3 and 4). Table 22 gives the eleven classes of compounds which have been analyzed in this manner and their corresponding recommended drinking water levels.

A second example of the use of this procedure involves four compounds which are derivatives of hexachlorocyclopentadiene. None of the compounds had enough toxicological information to set a guideline on the basis of cancer-risk calculations or no-observed-adverse-effect levels. One compound had been implicated as a metabolite of heptachlor or dilor (two pesticides which are hexachlorocyclopentadiene derivatives). For another, some information from acute toxicity studies and from a few limited, chronic toxicity studies was available. The other two compounds were chemically similar to hexachlorocyclopentadiene and other common diene pesticides which have been studied extensively. A guideline was set for these compounds by examining the standards that had been set for other halogenated diene pesticides and using the more restrictive members of the group. The diene pesticide standards used were based on no-observed-adverse-effect levels.

FIGURE 2

LD50 OF ALIPHATIC ALCOHOLS BASED ON NUMBER OF CARBONS

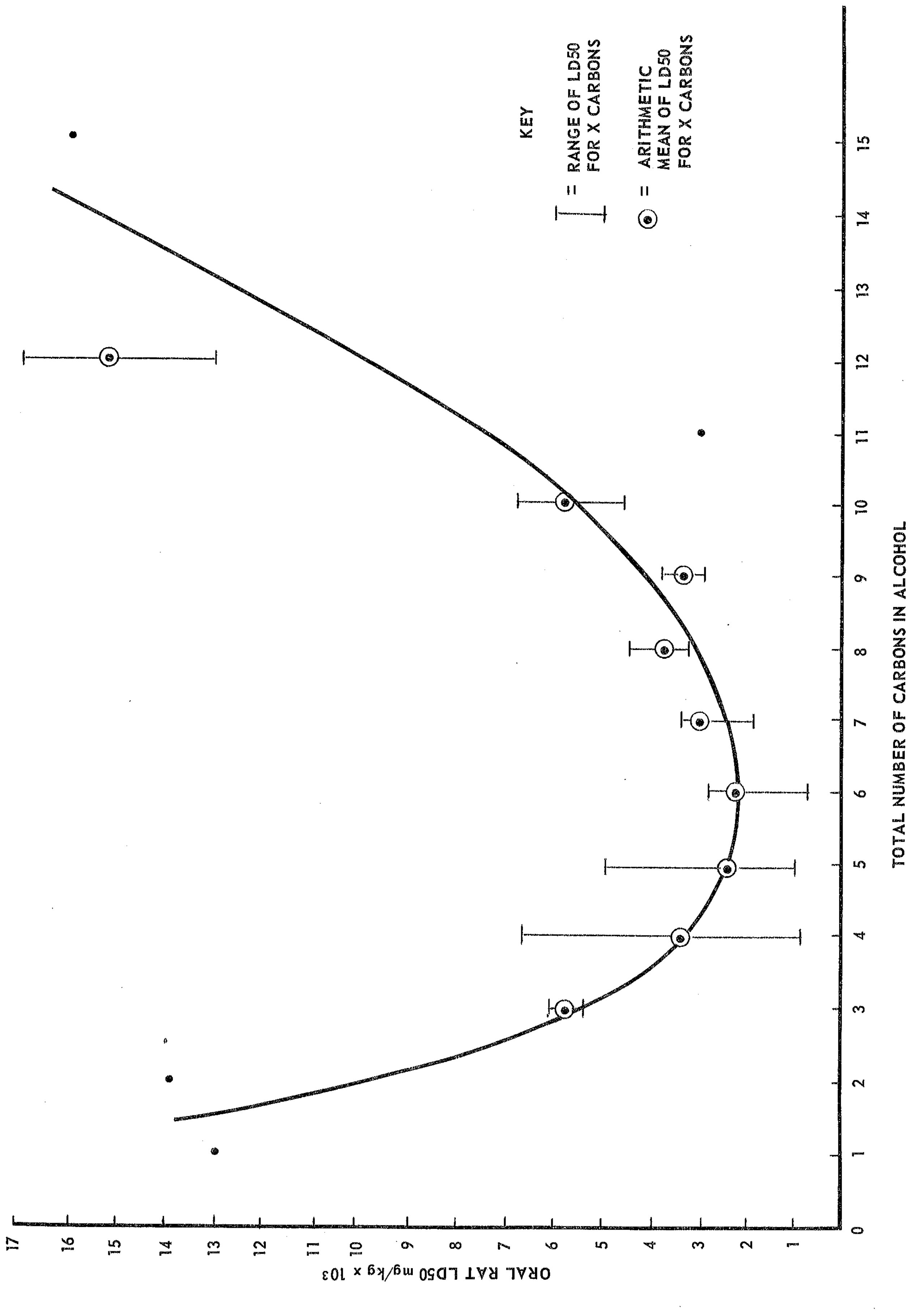


FIGURE 3

VAPOR PRESSURE OF ALIPHATIC ALCOHOLS BASED ON TOTAL NUMBER OF CARBONS

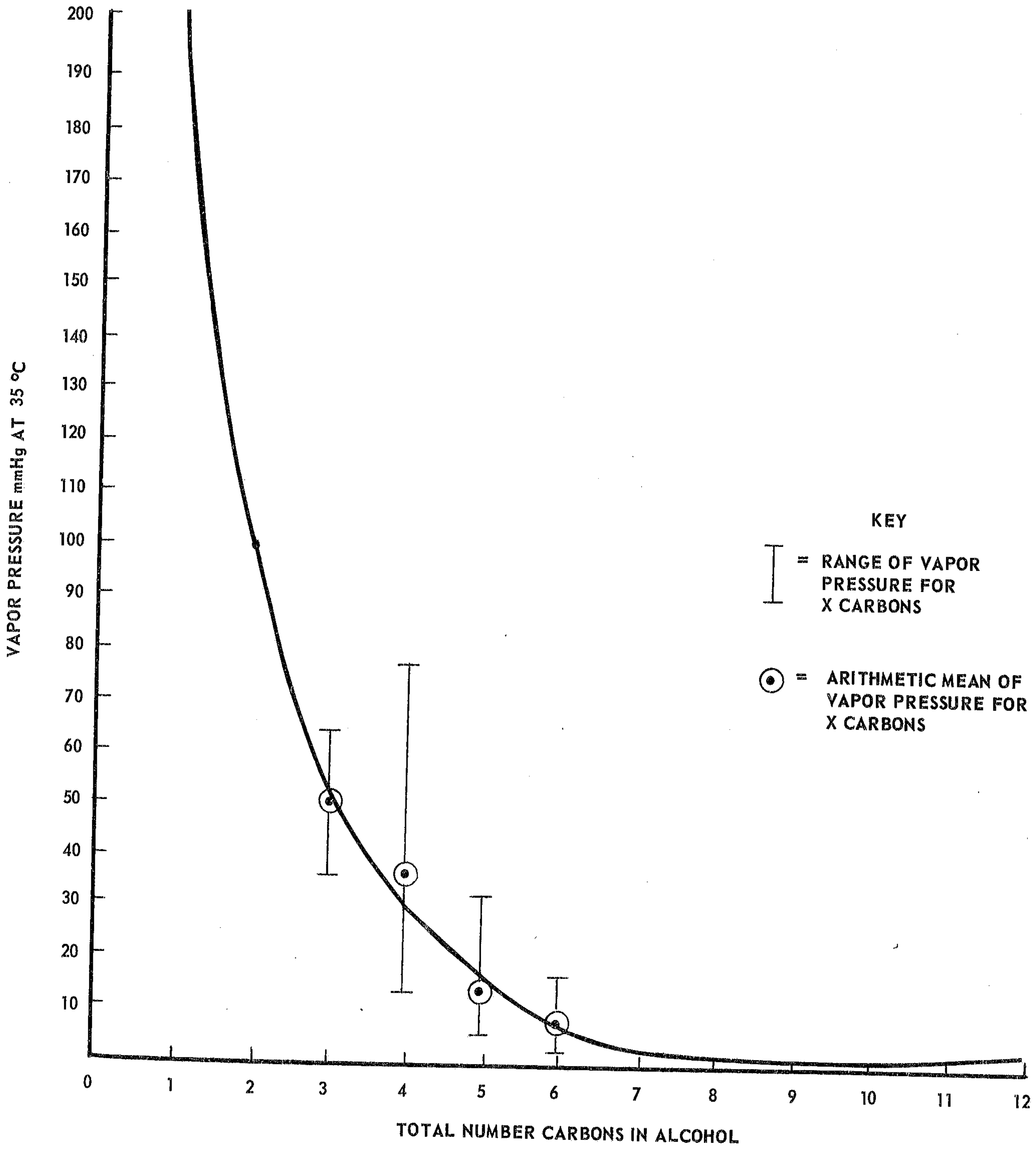


FIGURE 4

OCTANOL/WATER PARTITION COEFFICIENTS (P) OF ALIPHATIC ALCOHOLS BASED ON TOTAL NUMBER OF CARBONS

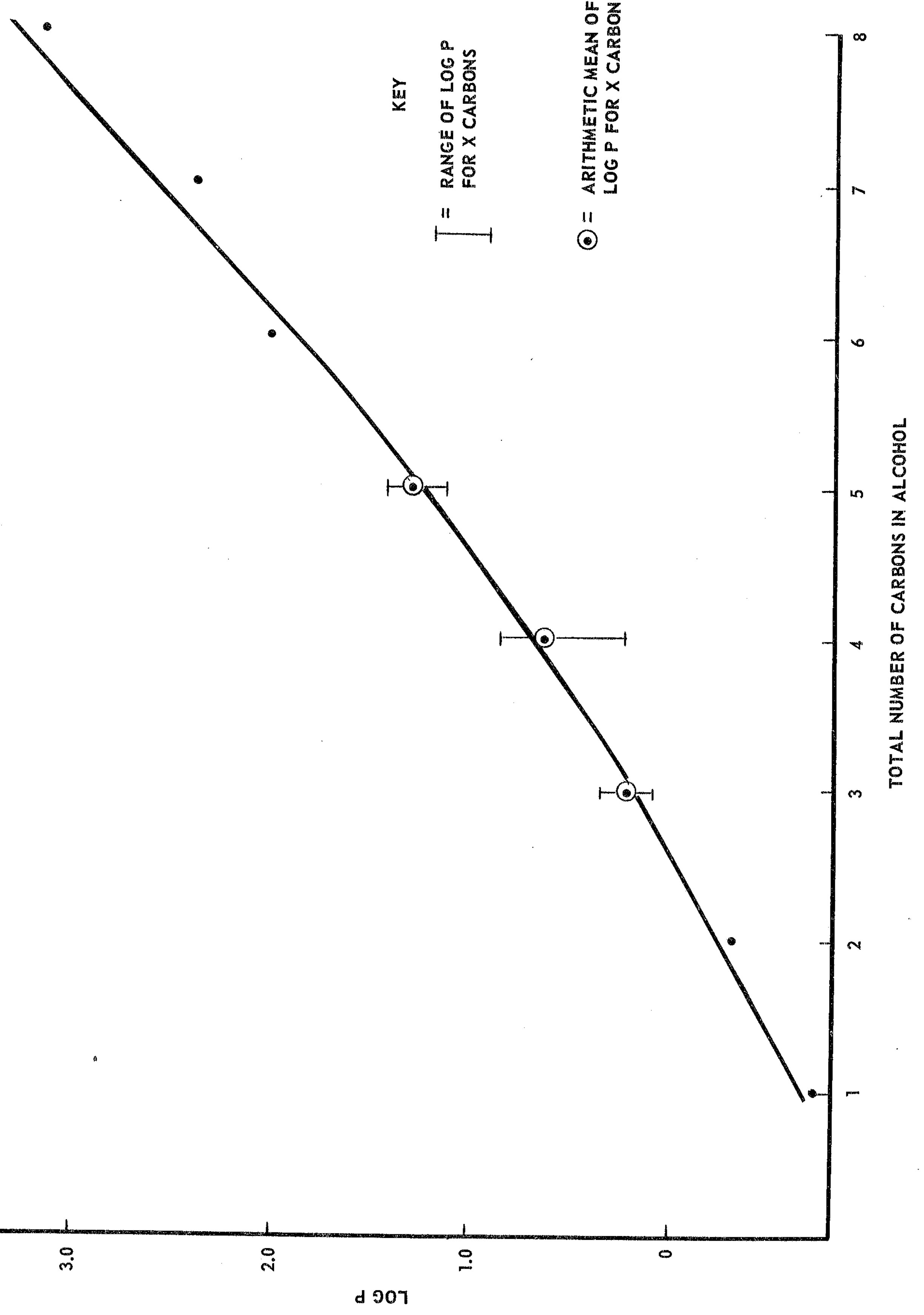


TABLE 22

Chemical Classes

CHEMICAL CLASS & DEFINITION	EXAMPLES	MICROGRAM PER LITER
Acyclic Alkanes - Compound having the general formula C_nH_{2n+2}	Pentane Octane 2-Ethylhexane	100
Acyclic Saturated Aliphatic Alcohols - Compounds having the general formula $C_nH_{2n+1}OH$	Propanol 2-Methyl-2-butanol Methyl isobutyl carbinol	50
Acyclic Saturated Aliphatic Aldehydes - Compounds having the general formula $C_nH_{2n}O$ with the carbonyl group on a terminal carbon atom	Propanal 2-Ethylbutanal Pentanal	50
Exception:	Formaldehyde	10
Acyclic Saturated Aliphatic Ketones - Compounds having the general formula $C_nH_{2n}O$ with the carbonyl group on a non-terminal carbon atom	Methyl ethyl ketone 2-Pentanone Di(t-butyl) ketone	50
Acyclic Saturated Aliphatic Esters - Compounds having the general formula $R\overset{\overset{O}{\|}}{C}OR'$ (R, $R'=C_nH_{2n+1}$)	Ethyl acetate Methyl propionate Amyl acetate	100
Exception:	Methyl formate	75
Acyclic Saturated Halogenated Aliphatics - Compounds containing C,H, and X (X = F, Cl, Br, and/or I) having the general formula $C_nH_yX_z$, where $y + z = 2n+2$	Bromochloromethane s-Butylbromide 1,1-Dibromo-5,5-dichloropentane	50
Acyclic Substituted Unsaturated Aliphatics - A straight or branched chain unsaturated compound containing one of the following functional groups: halogen, aldehyde, nitrile	Acrolein 1-Chloropropene Acrylonitrile	2

CHEMICAL CLASS & DEFINITION	EXAMPLES	MICROGRAM PER LITER
Acyclic Hydrocarbon Substituted Benzenes - Benzene or any acyclic hydrocarbon substituted phenyl compound	Xylene Isopropylbenzene Tetramethylbenzene	50
Exception:	Benzene	1
Acyclic Hydrocarbon Substituted Halobenzenes - A derivative of benzene containing C,H, or X (X=F, Cl, Br, or I) which has at least one halogen atom attached to the ring and which may or may not have straight or branched chain hydrocarbon substituents.	o-Chlorostyrene Hexabromobenzene 3-Chloro-5-Bromotoluene	10
Phthalates - Esters of o-phthalic acid	Benzylbutylphthalate Bis(2-ethylhexyl)phthalate Dimethylphthalate	100
Polycyclic Aromatic Hydrocarbons - Hydrocarbons which contain two or more condensed aromatic nuclei in which certain carbon atoms are common to two or more rings, and their hydrocarbon derivatives.	Naphthalene Azulene 3-Methylindene	10
Exception:	Benzo(α)pyrene	0.2

These values should not be used for a compound belonging to a class if other toxicological data indicate a lower value is necessary to arrive at an acceptable risk.

CONTROL OF SYNTHETIC ORGANIC CHEMICAL CONTAMINATION AT PUBLIC WATER SYSTEMS

This section of the report addresses two alternatives to water suppliers for controlling synthetic organic chemical contamination of public water systems:

1. Control of contaminants at their source.
2. Development of alternate sources or treatment of water from existing sources before distribution to the public.

Source Control

Water suppliers should seek out the best available water sources for future development. Suppliers should be in a position to exercise some control over these sources to ensure the continued availablility of drinking water in adequate quantity and quality to their customers.

Section 1100 of the Public Health Law provides the statutory basis for the Department of Health to adopt Watershed Rules and Regulations to protect sources of water supplies from contamination. Traditionally, Watershed Rules and Regulations have been used to protect drinking water supplies from conventional sources of contamination such as inadequately treated sewage. The statutory base has sufficient breadth to allow suppliers to control other land use practices such as storage of toxic chemicals, terrestrial or aquatic application of pesticides or herbicides, land use practices which may deleteriously affect water quality and solid waste storage areas. The Health Department is reviewing these procedures and will provide guidance to water suppliers in developing proposals for improved, up-to-date Watershed Rules and Regulations.

The Department of Environmental Conservation has responsibility under the State Pollution Discharge Elimination System and Water Classification System to protect the water resources of the state for their best use. All waters of the state are classified, and nonsaline groundwater is considered to be the best source of drinking water. In 1978 the Department of Environmental Conservation promulgated strict groundwater quality and effluent limitation standards (Part 703) to protect groundwater.

The widespread manufacture, transport and use of synthetic organic chemicals make 100% effective source control unlikely. In some cases source control techniques cannot be applied because groundwater is already contaminated. Groundwater normally moves very slowly through aquifers. Once contaminated, decades or perhaps centuries will pass before the water can once again be used for consumption without treatment.

Surface sources of supply usually are not affected for long periods of time from a single contamination incident because the flow in the river or stream and even in most lakes is rapid enough for the contaminated water to move past an intake. However, surface source systems in general are stressed more frequently than ground source systems. Accidental spills, illegal discharges, in-place toxic site releases and other nonpoint discharges from rural and urban areas may, on a regular basis, degrade the quality of surface sources of supply.

If the source or sources of contamination cannot be identified and/or eliminated, the supplier of water has two remaining options. These options are to abandon the source and obtain a new source of supply or to treat the water so that it does not pose an unacceptable risk to health.

Groundwater Development

Appendix I provides an assessment of the cost of developing replacement groundwater supply sources. Data for this Appendix were obtained using project submission reports available in the Health Department's files. Costs were not adjusted for inflation. However, all of the data were from wells developed in 1974 or later. Additionally, a site specific cost of 0 to 25% was added to account for extenuating circumstances such as streams and road crossings or inordinately long transmission lines. Standby power was an added cost for the two largest wells. The inclusion of these costs increased the price of the 0.9 MGD sources by 0.6 cents per 1,000 gallons produced. Table 23 summarizes this assessment. For comparative purposes costs for each project were reduced to cents per 1,000 gallons produced.

TABLE 23

Cost of Groundwater Source Development

WELL YIELD (MGD)	COSTS (CENTS PER 1000 GAL. TREATED)
0.1	20.0
0.5	6.15
0.7	4.59
0.9*	5.54
1.0*	6.02

*Includes 0.6 cents per 1000 gal. treated for standby power

These costs for development of new supply sources assume that nearby sources are available. If nearby sources are not available, the cost of source development can escalate drastically.

Aeration

Henry's Law states that the equilibrium concentration of a solute in air is directly proportional to the concentration of the solute in water at a given temperature. This law, therefore, controls the relative concentration of a volatile substance in water and air as follows:

$$c_{air} = k\, c_{water}$$

where, c_{air} = concentration in air

c_{water} = concentration in water

k = Henry's Law constant (temperature dependent).

The Henry's Law constant is a measure of the solubility of the contaminant in water and its volatility. If a continuous supply of uncontaminated air is brought in contact with water containing a volatile synthetic organic chemical, the substance will be removed from the aqueous phase in accordance with Henry's Law. The rate at which a volatile compound is removed from water by aeration depends on several kinetic factors:

(a) the air to water ratio

(b) the contact time

(c) the temperature of the water and the air.

Increases in a, b, and c will increase the efficiency of removal. In view of both kinetic and solubility considerations, aeration is likely to be effective in New York State for removing synthetic organic chemicals from groundwater which has a relatively constant temperature of approximately 50°F and from surface water during the warmer seasons. This method may not be effective for surface source systems in winter when ambient water temperature is near 32°F.

Aeration has been used by the water industry for many years to reduce taste and odor problems and to remove dissolved gases. Aeration equipment typically consists of spray aerators, stepped aerators and aeration basins using submerged diffusers or surface aerators. Recently, stripping towers have been used by the wastewater industry to remove ammonia.

The aeration towers at the Orange County Water District (California) advanced wastewater treatment plant are reported to be as effective as activated carbon in removing synthetic organic contaminants when air to water ratios of 3000:1 are applied. The Environmental Protection Agency reports that trichloroethylene, carbon tetrachloride and tetrachloroethylene were reduced in bench tests by 98% when air to water ratios of 8:1 were applied for a contact time of 10 minutes. Under the same conditions, chloroform concentrations were reduced by 60%. This information suggests that aeration may be a cost effective method for reducing the concentration of and the health risk associated with synthetic organic chemicals in drinking water.

Appendix J is a cost assessment of synthetic organic chemical removal using aeration stripping towers. Estimated construction costs are for rectangular towers with 16 feet of PVC media and an overall tower height of 22 feet. Towers are constructed on a reinforced concrete basin which acts as a pump well. Forced draft countercurrent air flow is provided with air to water ratios of 22.5 to 1. Higher air to water ratios can be achieved by increasing the size of the fan and/or the power supply for the fan and would result in higher operating costs. Table 24 summarizes this cost assessment; for comparative purposes, costs for each project were reduced to cents per 1000 gallons treated. As in the case of groundwater source development costs, a site specific cost of 0-25% was added.

TABLE 24

Cost of Construction, Operation and Maintenance of Aeration Towers

TREATMENT CAPACITY (MGD)	COSTS (CENTS PER 1000 GAL. TREATED)
0.1	14.5
0.5	9.7
1.0	5.9
10.0	1.7
50.0	1.3

Granular Activated Carbon Treatment

The two major types of interactions that bind a dissolved impurity (adsorbate) to an adsorbing surface (adsorbent) are Van der Waal's forces (also known as physical adsorption) and chemical adsorption. The adsorbate is capable of moving within the adsorbent when physical adsorption takes place. On the other hand, in chemical adsorption the organic compound is often irreversibly bound to a specific site on the adsorbent. In general, the bond between the adsorbent and the adsorbate is greater with chemical adsorption.

Removal of trace organic impurities from water by activated carbon adsorption is thought to involve a three step mechanism. The first step is transportation through a surface film to the exterior of the adsorbent. The second step is pore diffusion involving movement within the pores of the adsorbent. The third step is adsorption onto the interior pore and capillary surfaces of the adsorbent. In continuous flow systems, such as granular activated carbon (GAC) post contactors, film diffusion is usually the rate-limiting mechanism. In the design of GAC post contactors, the empty bed contact time is the most important factor in determining removal effectiveness for a particular compound.

Seven general rules which affect the adsorption of organic compounds are:

1. As the adsorbent surface area increases, the rate of adsorption increases.
2. As the concentration of adsorbate increases, the rate of adsorption increases.

3. Adsorption from solution increases with decreasing solubility.

4. Adsorption increases within a homologous series of compounds as molecular weight increases.

5. Adsorption increases with decreasing pH.

6. As the temperature of water increases, the rate of adsorption increases.

7. As the temperature of water increases, the efficiency of adsorption decreases.

Powdered activated carbon has been used in New York for taste and odor control for many years. The water industry and state regulatory officials are less familiar with the use of GAC as an adsorbent for synthetic organic chemicals. EPA is confident that GAC is the best broad spectrum synthetic organic chemical adsorber presently available.

EPA suggests that two methods are available for installing GAC in public water systems: (a) replace existing sand filter beds with GAC and (b) install GAC post contactors. In recent years the trend to increase flow rates through gravity filters has significantly reduced the available empty bed contact time if replacement is used. Other factors such as operational problems in replacing the GAC media in gravity filters and abrasion of the GAC media during backwash reduce the usefulness of this treatment method. In conclusion, GAC treatment can best be provided with GAC post contactors.

Appendix K is a cost assessment of synthetic organic chemical removal using GAC post contactors. Pressure carbon contactors are used for plants with flow rates up to 20 MGD. The costs of the 50 and 100 MGD plants are estimated for gravity carbon contactors.

The following design criteria were used for both the gravity and pressure contactors:

Construction - steel

Hydraulic loading rate - 5 GPM/ft^2

Operation - downflow

Empty bed contact time - 18 min.

Backwash pumping rate - 12 GPM/ft^2

Each type of contactor is enclosed in a suitable building. Energy costs for operation and maintenance of the building, contactors, pumps and multiple hearth furnace area are included in the estimates. Table 25 summarizes the cost assessment. For comparative purposes, costs for each project were reduced to cents per 1000 gallons treated. As with the other alternative treatment techniques, site specific costs of 0 to 25% were added. Selection of this treatment method should be made only after pilot studies are performed to determine the efficiency of removal and precise cost estimates are calculated.

TABLE 25

Cost of Construction, Operation and Maintenance
of GAC Post Contactors

TREATMENT CAPACITY (MGD)	COSTS (CENTS PER 1000 GAL. TREATED)
1	67.1
10	28.5
20	22.5
50	15.4
100	13.7

Summary

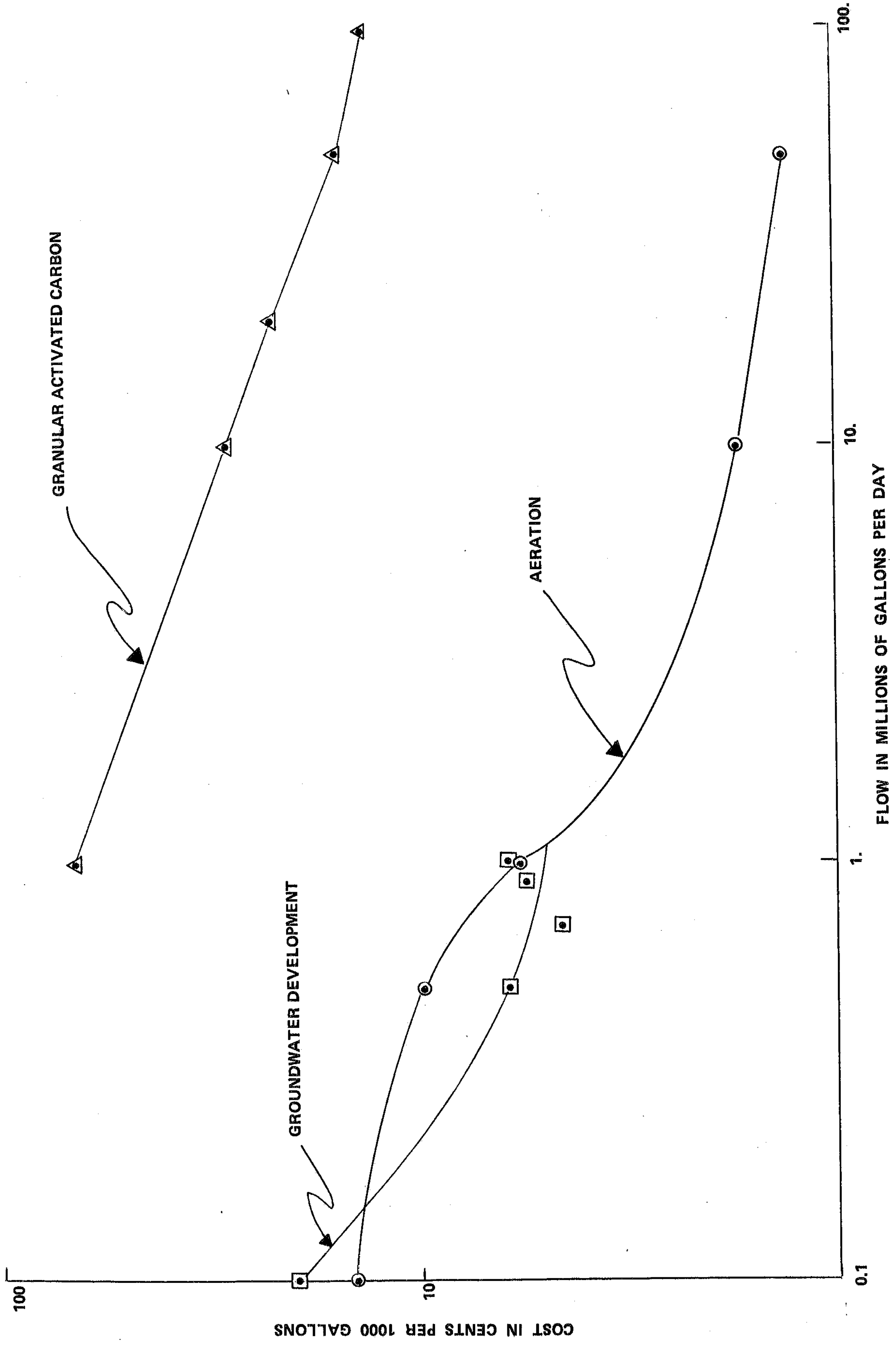
The decision to seek a new source of supply or install one of several treatment methods is complex and depends on a variety of factors. These factors include the size of the system, the nature and extent of the contamination, the availability of other sources, and fiscal constraints. Rapidly changing technologies further complicate the issues.

Appendix L provides a list of synthetic organic chemicals which can be removed from water using aeration, and a list of synthetic organic chemicals which have been reported in the literature to be absorbed on granular activated carbon. These lists are provided for guidance only. Before a treatment method is selected, site specific pilot studies must be performed to determine the suitability of the treatment method and the design criteria.

Figure 5 is a graph of the cost of controlling the sythetic organic chemical problem in cents per 1000 gallons vs. flow in million gallons per day. These data show that aeration is the least expensive treatment technique for systems larger than 1 MGD and less than 0.15 MGD. For systems that are between 0.15 and 1.0 MGD, the development of a new groundwater source may be more economical. If the contaminant cannot be removed by aeration, then the higher cost GAC treatment may have to be used.

FIGURE 5

COMPARISON OF COSTS FOR SOURCE DEVELOPMENT OR TREATMENT



BENEFIT OF REDUCING RISK

In 1978 the National Academy of Sciences prepared an economic analysis of removing chloroform from drinking water. In making this analysis, the "cost of risk" had to be established. Despite justifiable moral and philosophical objections, this dilemma must be confronted if economic assessments are to be made. In practice, implicit judgements about the value of life are very often made by individuals and governments at all levels. These judgements are necessary so that the greatest benefit is obtained from limited resources.

Table 26 describes four concepts and principles used in estimating the value of reducing the probability of death. The basis for each method and some of its weaknesses are provided. None of these methods provide an exact scientific basis for establishing an economic value of reducing the probability of death, but they are valuable in establishing boundary conditions on which decisions can be made.

Table 27 provides six empirical estimates of the value of reducing the probability of death. Estimates range from $49,226 to $1,000,000 with most of the values between $200,000 and $300,000. Some of these will be used later to describe one method of evaluating the benefit of reducing the risk of death.

Benefit Formula

An estimate of the benefit in reducing the risk from organic chemicals in drinking water can be obtained from the following formula:

$$B = (r_1/70) \times (v)$$

where, B = per capita benefit in dollars per year

r_1 = per capita lifetime risk estimate

v = assumed economic value of preventing a death

70 = average life expectancy

and,

$$r_1 = .85\ C \times V \times r$$

where, .85 = the assumed efficiency of treatment

C = initial concentration of the organic chemical in drinking water ($\mu g/\ell$)

TABLE 26

Concepts or Principles Used in Estimating the Value of Reducing the Probability of Death

Method	Basis	Weaknesses
Discounted Value of Individual Production	Assess the worth of an individual's future production. Future production is discounted because it is generally believed that future production is less valuable than present production.	Defines value of death prevention in terms of an individual's production. Method will undervalue lives of housewives, elderly, unemployed and underemployed. Does not account for the amount of production the individual consumes. No allowance is made for social values or the utility of life to an individual.
Extrapolation From Risk Premiums	The differences between wages of workers in "safe" versus hazardous occupations are related to an empirical measure of the actual risk of death. Results show how workers compute, perceive and require compensation for accepting higher risks.	Downward bias may be inherent in this method because the attitude and concern towards risk of workers in hazardous occupations may be less than that of the general population. The long delay between exposure and illness may diminish the workers response to the actual risks at hand.
Cost of Illness and Human Suffering	In addition to loss of earnings, estimates should include costs of: medical treatment, unemployment and distress and hardship to family and friends by taking into account lengths of illness and amount of physical and economic support required.	These factors are very difficult to measure.
Pareto Improvement Principle	Action is worthwhile if it can benefit some without harming anyone else. This principle can also apply if an action can sufficiently improve conditions for some so that they can compensate others and thereby improving the total aggregate. In practice, this shows an individual's willingness to pay for avoiding a given risk. It may also be interpreted as the minimum payment demanded to maintain one's welfare at a given level after exposure to a health risk.	Measurements of the actual change in one's well being are difficult to quantify.

TABLE 27

Comparisons of Some Empirical Estimates for Values of Reducing the Probability of Death

Researcher	Value per life saved	Basis of estimate	Comment
Carlson (1963)	$200,000 to $1,000,000	U.S. expenditure for deference compensation to pilots flying high risk situation.	Biased upward because it involves relatively young people with a long life expectancy.
Schelling (1965)	10 to 100 times yearly income of head of household for family member	--------	Applies to a specific death, not generalized risk of death.
Thaler and Rosen (1975)	$200,000 ± 60,000 per individual per lifetime	Assessed earnings of high risk jobs (one death per 1000 workers).	Does not consider what family and friends would pay to save their life.
Bailey (1975)	286,000 value of reducing probability of death by 100%	Adjusted Thaler and Rosen method: separates risk of death from risk of injury, also considers risk avoidance, income, tax and third party effects.	---------
Cooper and Rise (1976)	$49,226 per death from Neoplasms	Divide total cost of neoplasm in 1972 by number of deaths from this cause. Cost estimate includes: morbidity, prevention, detection, treatment, rehabilitation, training and capital for these activities.	Needs adjustment per Bailey (1975)
NAS (1978)	$210,814	Cooper and Rice (1976) adjusted per Bailey (1975).	

From: Chloroform, Carbon Tetrachloride, and other Halomethanes: An Environmental Assessment National Academy of Sciences, Washington, D.C. 1978.

V = daily per capita intake of water (ℓ/day)

r = lifetime risk for an oral dose of 1 μg/day

Assumptions for the above calculations were:

(1) The result of exposure to the organic compound is death; curable illness is not considered.

(2) Risk is constant for any age throughout life.

(3) The average life expectancy is 70 years.

(4) Constant lifetime consumption of water is 1.95 liters per day.

(5) Treatment efficiency is 85%.

(6) Values of preventing one death range from $100,000 to $1 million.

Cost Benefit Relationship

Applying the preceding equation to chloroform and tetrachloroethylene yields Figures 6 and 7 for various levels of contamination and assumed economic values of preventing death. Also plotted on these figures is the cost of treatment, including source replacement, aeration and GAC, from the previous section of this report. For concentrations to the right of the intersection of the cost and benefit curves, treatment is economical. For concentrations to the left of the intersection of the cost and benefit curves, treatment is not economical. For example, these data (Figure 6) support a decision to institute aeration treatment for systems larger than 10 MGD whenever chloroform is present in concentrations greater than about 50 μg/ℓ if the economic value of life is assumed to be $500,000. Similarly, the data in Figure 7 support a decision to institute aeration treatment for systems larger than 50 MGD whenever tetrachloroethylene is present in concentrations greater than 160 μg/ℓ if an economic value of life is assumed to be $1,000,000. Treatment of smaller systems cannot be justified based on these data. An innovative, efficient technology which can be applied to synthetic organic chemical removal from small systems needs to be developed.

If both tetrachloroethylene and 1,1,2-trichloroethane are present in the water supply and can be removed by the same treatment process, then the benefit would be at least additive. The dashed plot on Figure 7 represents this additive benefit.

So far, only the increased risk from drinking the water has been incorporated in the benefit curve. Chloroform and tetrachloroethylene are both volatile compounds and will be released into the indoor air which people will breathe. These compounds will contribute to the total body burden by ingestion and inhalation. The following assumptions were made in calculating the amount of chloroform inhaled per day from this source by an individual: (1) a family of four, (2) each person uses 50 gallons of water per day, (3) the air space in the house is 350 m^3 ($\sim$12,400 cu. ft.), (4) 5 air changes per day in the house, (5) 50% of the compound enters the vapor stage, (6) 15 m^3 is the average daily respiratory volume, and (7) 70% of an inhaled dose is retained. The benefit curve in Figure 8 is calculated for both the air and water contributions of chloroform to the total body burden. The benefit is approximately double that for water ingestion only. For example, a decision to institute aeration treatment for systems larger than 10 MGD is supported whenever chloroform is present in concentrations greater than about 25 μg/ℓ if the economic value of life is assumed to be $500,000.

Summary

This method is provided to promote discussion and to provide some options for the boundary conditions available in making treatment decisions. Several points are worthy of emphasis:

1. The water quality surveillance studies conducted to date indicate that if a water supply is contaminated, it is usually contaminated with more than one synthetic organic chemical.

2. The assumption that the total risk from the chemicals in the water supply would be at least equal to the sum of the independent risks seems reasonable; however, one treatment method may not always deal effectively with all of them.

The above analysis is also limited by a variety of factors such as rapidly changing technologies, changing economic and social values, variations in actual cost from site to site, lack of scientifically precise data and inability of the simplified models to reflect actual conditions. Because of these factors, this procedure must not be construed as a precise methodology for arriving at a final decision but rather as providing some additional insight into the problem of selecting an optimum regulatory strategy.

FIGURE 6

ANNUAL PER CAPITA COSTS AND BENEFITS FOR REMOVING CHLOROFORM FROM DRINKING WATER

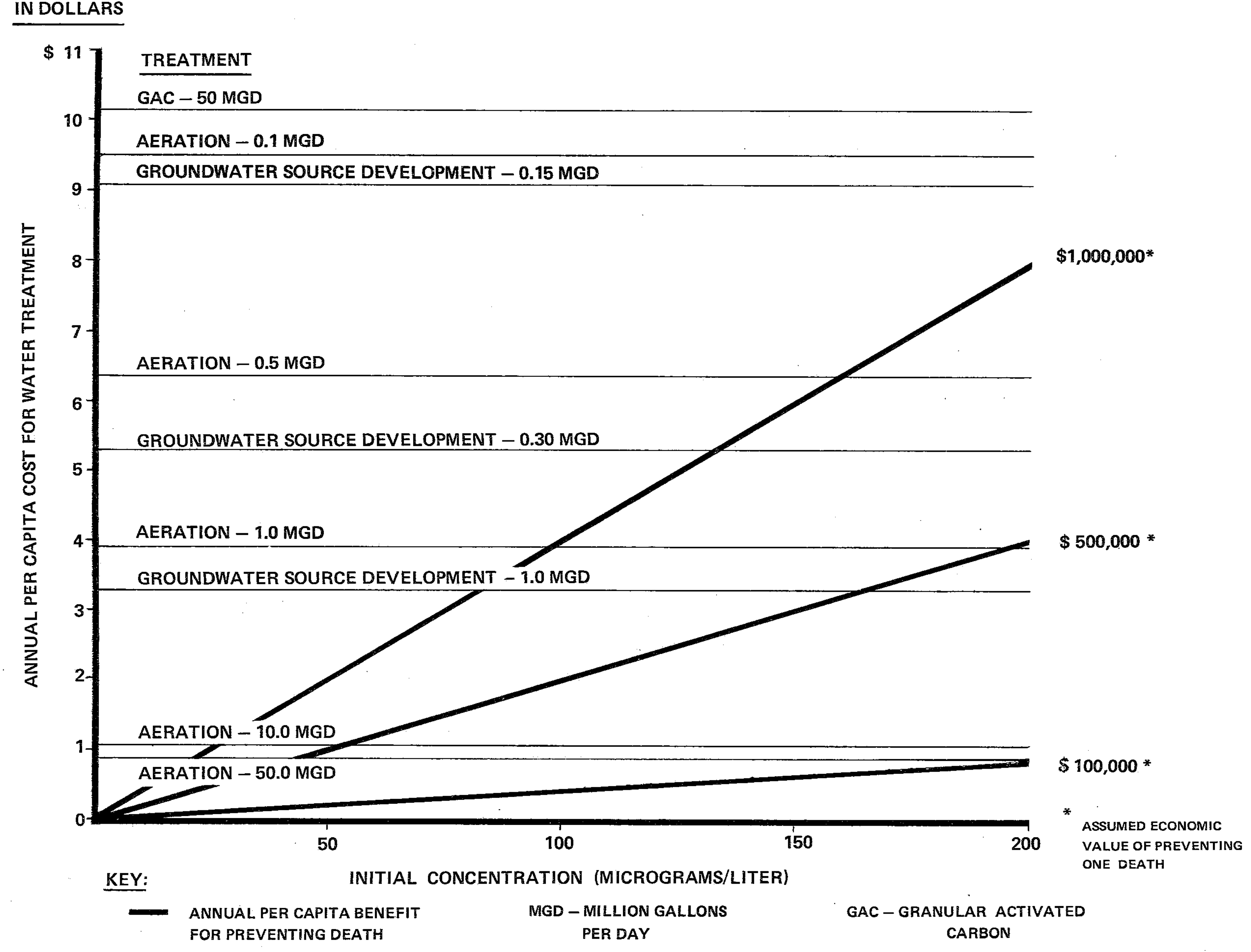


FIGURE 7

ANNUAL PER CAPITA COSTS AND BENEFITS FOR REMOVING TETRACHLOROETHYLENE FROM DRINKING WATER

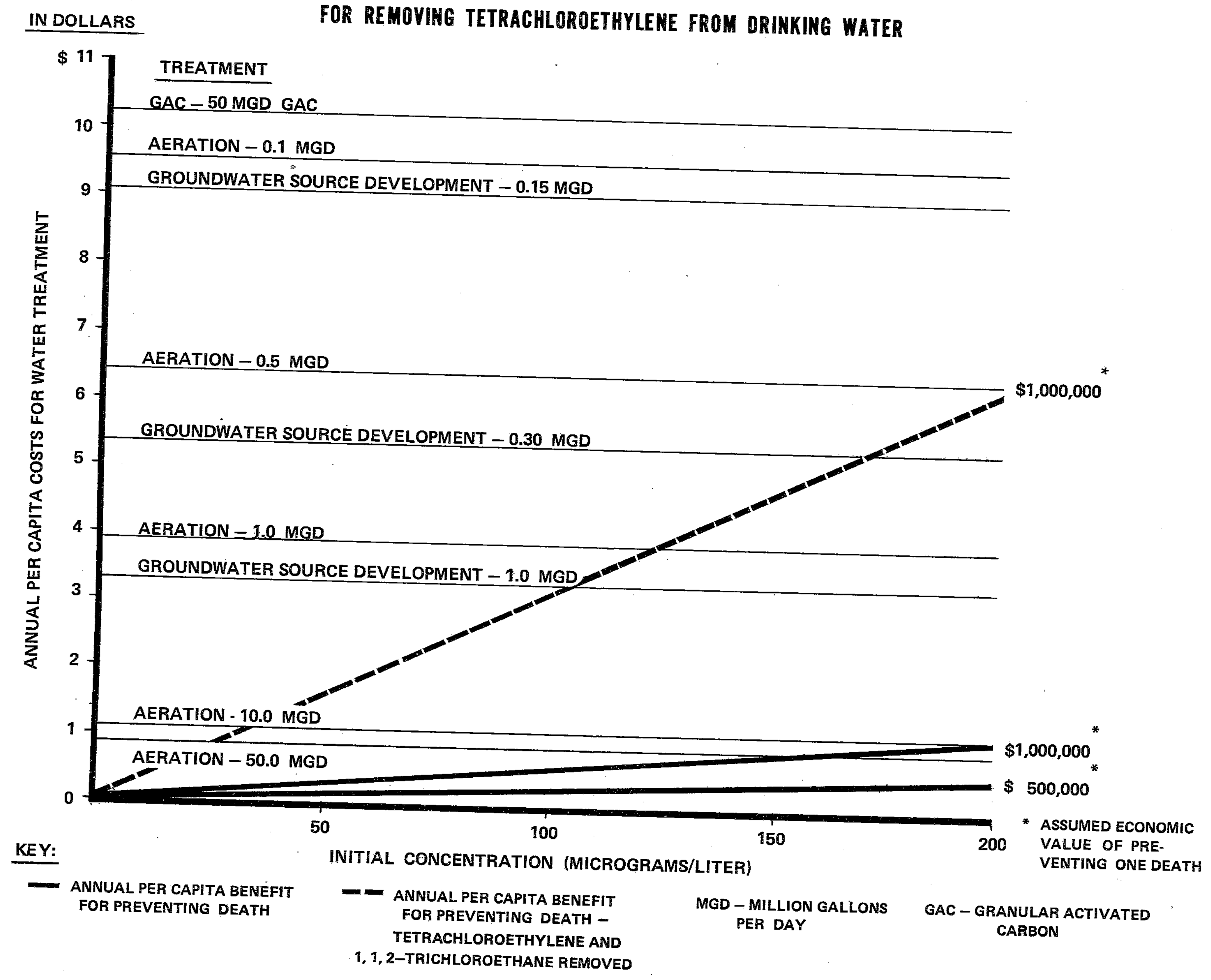
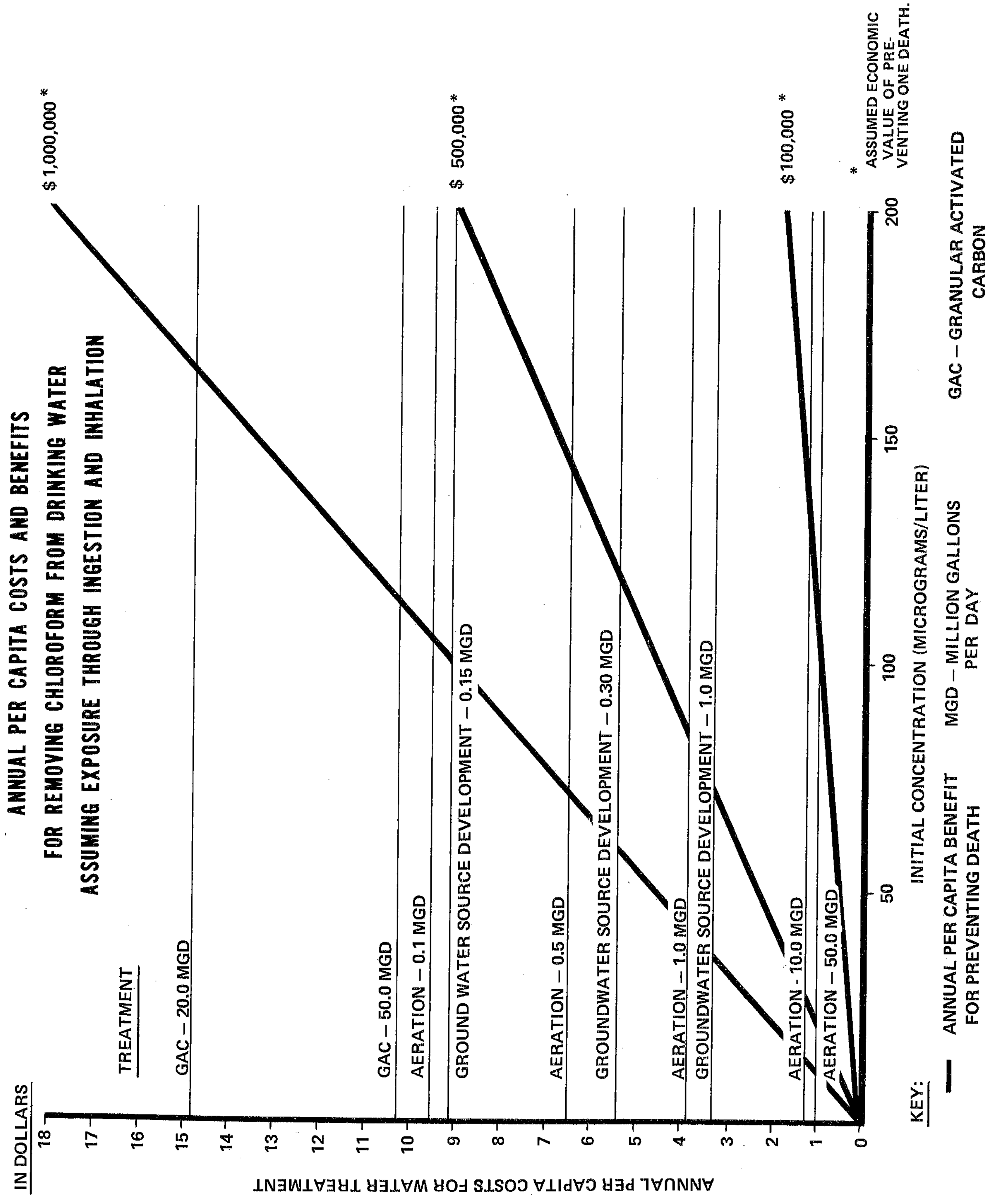


FIGURE 8

ANNUAL PER CAPITA COSTS AND BENEFITS FOR REMOVING CHLOROFORM FROM DRINKING WATER ASSUMING EXPOSURE THROUGH INGESTION AND INHALATION



STRATEGIES FOR MANAGING SYNTHETIC ORGANIC CHEMICALS IN DRINKING WATER

Ultimately, the State of New York will be required to establish a strategy regarding organic chemicals in drinking water. This strategy will require regulations and standards which prescribe conditions under which a contaminated or a potentially contaminated water system may be used. The reduction or elimination of contamination from a water system can be accomplished in three general ways:

1. use alternative sources of water which contain concentrations of organic chemicals below some established maximum contaminant level,
2. remove the source of contamination so that the concentrations of organic chemicals are below some established maximum contaminant level, or
3. remove contaminants to some level by treatment.

A number of strategies could be used to regulate the levels of organic chemicals in public water systems in New York State. While some of these strategies are theoretically applicable to individual and commercial sources of drinking water, they are primarily intended for the larger community water systems serving the public on a regular basis. Historically, the state's overall strategy has been that the uncontaminated source of water, when available, is always most desirable.

Mandated Minimum Treatment - All Systems

The physiological effects of many organic chemicals are unknown, the capacity to test for many contaminants is extremely limited, and the use of organic chemicals is widespread throughout the state. For these reasons, the best available treatment technology could be required in all public water systems in New York State. This would require the installation of an acceptable treatment system, such as granular activated carbon, and could be phased in over a reasonable time schedule. The largest or most vulnerable supply could be required to complete installation first.

This strategy, while serving as the ultimate in prevention, would likely be prohibitively expensive in certain water supplies in the state. For some supplies, the nature of the source, the watershed protection or the absence of substantial contamination makes this strategy difficult to justify; public acceptance would be difficult to obtain. Nevertheless, such a requirement would relieve the state and local health agencies, as well as the water suppliers, of the burden of monitoring for the myriad of potential toxic organic substances which may at any time invade any water supply.

Mandated Minimum Treatment - Larger Water Systems

Another similar alternative would require, as a minimum, the best available treatment at all public water systems serving a large population (e.g., 75,000 or greater). This strategy would not only protect the vast majority of the citizens of New York State by eliminating organics from the preponderance of drinking water consumed each day, but it would also apply to the supplies that are most susceptible to contamination, either because they obtain their water from very large and difficult to control surface watersheds or from high production, extremely vulnerable groundwater sources. Additionally, the cost of providing treatment per user would be considerably reduced by the economies of scale. The operation and maintenance of the treatment process at large supplies would be more reliable since larger systems normally have better operating talent.

Treatment of Contaminated Water Systems

The most traditional strategy is requiring treatment of supplies known to be contaminated or known to have a strong potential for contamination based on the evaluation of the water source. For as long as health departments have been requiring treatment processes, water supplies have been required to remove objectionable constituents from water. This approach could simply be expanded to synthetic organic contaminants by the development of a series of finished water standards for organic chemicals. Because some risk is associated with the ingestion of organic chemicals, such a policy requires an implicit or explicit acceptance of a level of risk. An accepted level of involuntary risk must be decided upon before such standards can be calculated.

A major weakness of this requirement is that each water supplier in the state would have to continuously monitor its water sources for all synthetic organic chemicals which could potentially contaminate the supply. The number of organic chemicals of concern seems to grow with each succeeding week. The technology for measuring these compounds at low levels is, in many cases, not available and, where available, is extremely expensive. A second weakness is that changing toxicological information will necessitate changes in standards.

A practical variation of this strategy would be to allow the water supplier to select one option from a number of alternatives when synthetic organic chemicals are found in unacceptable concentrations. Some of the options which are available include: (1) developing a new uncontaminated source, (2) blending an uncontaminated source with the regular source to dilute the contaminant concentration to an acceptable level, (3) permitting the temporary inactivation of the supply until the source of contamination can be found, stopped and removed through pumping or contaminant recovery, (4) activating a strong interconnection with an approved adjoining public water system. The most cost effective alternatives in many situations will probably be a combination of two or more of these alternatives.

Risk Advisory

The presence of low levels of organic contaminants normally increases the risk of illness only slightly. Most water used in a typical household is not ingested and probably does not impose a significant threat to one's health. Therefore, at certain levels of contamination, the consumer could be advised of the risk, water ingestion could be restricted, or another source, such as bottled water, could be used. This, in effect, would be changing one's exposure from involuntary to voluntary.

Controlling Contaminants

Although the awareness of exposure to organic contaminants has increased during the past several years, probably some level of exposure has existed among some of our population for a number of years. Obviously, the number and quantity of chemicals to which the consumer of drinking water is potentially exposed is growing at a rapid rate. A strategy for the long-term reduction in exposure is the identification and risk assessment of all harmful chemicals and either the ultimate elimination of their use or the "cradle to grave" control of these chemicals to the point that they will be eliminated as a threat to our water supply.

Recent federal and state regulatory strategies are rapidly moving in this direction. However, because of the widespread transport and use of synthetic organic chemicals, their presence will probably not be completely eliminated from water supplies by source control.

Follow Federal Standards

EPA plans to develop some standards for organic chemicals in drinking water within the next year. National contaminant levels for specific chemicals may be established or treatment may be required when a serious contamination is present. Although statements have been made that such regulations would be promulgated during the early fall of 1979, this goal may not be reached. The easiest role for the state as a regulator would be to wait for EPA to mandate a standard and follow their lead.

The degree of control established by EPA would probably be based on a nationwide need to reduce the exposure of the public at large to organic chemicals. We, in New York State, produce, consume and dispose of much greater quantities of synthetic organic chemicals than the national average; therefore, our exposure is greater, and the need for more stringent regulations may be indicated. In addition, population densities in such areas as Long Island and the Niagara Frontier, where very great volumes of chemicals are produced, used and disposed of, may have exposures which are manyfold greater than the national average. The degree of control imposed by EPA which would meet some national health goals may not be acceptable in New York State.

ISSUES ON WHICH THE HEALTH DEPARTMENT IS REQUESTING COMMENT

Any interested party is encouraged to provide comments on this report to assist the Health Department in developing a control strategy for organic chemicals. This control strategy must adequately protect the public health while taking into account technological and scientific limitations. Comments should be sent to:

Peter J. Smith, P.E.
New York State Department of Health
Bureau of Public Water Supply
Tower Building, Room 482
Governor Nelson A. Rockefeller Empire State Plaza
Albany, New York 12237

The Health Department is particularly interested in comments on the following areas but will welcome comments on any issue:

1. What regulatory strategy should the Department of Health adopt to control the level of synthetic organic chemicals in drinking water?

2. Considering that the exposure is involuntary, what should be the definition of unacceptable, acceptable and insignificant risk from drinking water?

3. Are the methods presented here for establishing risks associated with drinking water acceptable? Should there be limitations for their use, modifications or additions? What is an appropriate magnitude of the safety or uncertainty factor? What percentage of the acceptable daily intake should be allowed in drinking water?

4. Based on these methods of risk assessment, should the Department adopt enforceable drinking water standards at specific levels of acceptable risk for all organic compounds known to be carcinogenic or toxic?

5. What criteria can be used to identify and segregate chemicals into groups:

   (a) for which standards need to be adopted,
   (b) for which guidelines will suffice, and
   (c) for which no regulation is needed?

6. If toxicological data are not available for a compound, is the concept of using classes of compounds or extrapolating data from one specific compound to another reasonable?

7. Should regulatory agencies concentrate their efforts on controlling organic chemicals at the point of discharge or at the point of water withdrawal? Both?

8. Are the cost estimates for groundwater source development, aeration and GAC treatment reasonably accurate?

9. Are there any other existing or developing technologies that might significantly change the cost and efficiency of removing organics from drinking water?

10. If standards are adopted, should they only apply to large community water systems or to all water systems?

11. Should the Health Department undertake research to evaluate application of treatment technology to remove synthetic organic chemicals from drinking water or defer this effort to the Federal Government or the water industry?

12. Should society as a whole pay for the additional cost of water treatment or should the cost of treatment be borne by the operators (and therefore the customers)?

Comments on these and any other matters regarding this subject will be accepted until February 29, 1980.

REFERENCES

1. Mantel, N. and Bryan, W.R. 1961. Safety testing of carcinogenic agents. Journal of the National Cancer Institute, 27(2):455-470.

2. Food and Drug Administration. February 22, 1977. Food producing animals. Federal Register, 42(35):10412-10437.

3. Anonymous article, Scientists Debate Acceptable Risk, New York Times, 1979.

4. Comar, C.L., Risk: A Pragmatic De Minimis Approach, Science, 203, 319, January 26, 1979.

5. Burrows, W.E., The Cancer Safety Controversy, New York Times, March 25, 1979.

6. Safe Drinking Water Committee of the National Research Council. 1977. Drinking Water and Health, National Academy of Sciences, Washington, D.C.

7. World Health Organization. 1978. Environmental Health Criteria 6: Principles and methods for evaluating the toxicity of chemicals, Part I. World Health Organization, Geneva, p.29.

8. Armitage, P. and Doll, R. 1954. The age distribution of cancer and a multi-stage theory of carcinogenesis. British Journal of Cancer, 8:1-12.

9. Armitage, P. and Doll, R. 1957. A two-stage theory of carcinogenesis in relation to the age distribution of human cancer. British Journal of Cancer, 11:161-169.

10. Armitage, P. and Doll, R. 1961. Stochastic models for carcinogenesis. In Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability, 4:19-38. University of California Press, Berkeley and Los Angeles.

11. Crump, K.S., Guess, H.A., and Deal, K.L. 1972. Confidence intervals and test of hypotheses concerning dose response relations inferred from animal carcinogenicity data. Biometrics, 33:437-451.

12. Iversen, S. and Arley, N. 1950. On the mechanism of experimental carcinogenesis. Acta Pathologica et Microbiologica Scandinavica, 27: 773-803.

13. Arley, N. and Iversen, S. 1952. On the mechanism of experimental carcinogenesis. VI. Hit theory interpretation of some experiments of Berenblum and Shubik. Acta Pathologica et Microbiologica Scandinavica, 31:164-171.

REFERENCES (CONTINUED)

14. Nordling, C.O. 1953. A new theory on the cancer-inducing mechanism. British Journal of Cancer, 7:68-72.

15. Stocks, P. 1953. A study of the age curve of the stomach in connection with a theory of the cancer producing mechanism. British Journal of Cancer, 7:407-417.

16. Vettorazzi, G. and Miles-Vettorazzi, P. 1975. Safety evaluation of chemicals in food: toxicological data profiles for pesticides. 1. Carbamate and organophosphorous insecticides used in agriculture and public health. Progress in standardization: 3. World Health Organization, Geneva, p. 4 and p. 6.

17. Vettorazzi, G. 1975. Toxicological decisions and recommendations resulting from safety assessment of pesticides. Critical reviews in Toxicology, Goldberg, L., ed. CRC Press, Inc., Cleveland, Ohio, pp. 125-183.

18. Ortega, P., W. J. Hayes, Jr., and W. F. Durham. 1957. Pathological changes in the liver of rats after feeding low levels of various insecticides. Arch. Pathol. 64:614-622.

19. Lackey, R. W., 1949. Observations on the acute and chronic toxicity of toxaphene in the dog. J. Ind. Hyg. Toxicol. 31:117-120.

20. Fitzhugh, O. G., and A. A. Nelson. 1951. Comparison of chronic effects produced in rats by several chlorinated hydrocarbon insecticides. Fed. Proc. 10:295.

21. Bartsh, H., Malaveille, C., Barbin, A., Planche, G. and Montesano, R. 1976. Aldylating and mutagenic metabolites of halogenated olefins produced by human and animal tissues. Proceedings of the American Association for Cancer Research, 17-17.

22. Conolly, R. B., Jaeger, R. J., and Szabo, S. 1978. Acute hepatotoxicity of ethylene, vinyl fluoride, vinyl chloride, and vinyl bromide after Aroclor 1254 pretreatment. Experimental and Molecular Pathology, 28:25-33.

APPENDIX A

New York State Department of Environmental Conservation

Industrial Chemical Survey

This Appendix contains maps showing a county by county distribution of the amount of seven classes of organic chemicals used, stored or manufactured in New York.

These data do not show the locations of organic chemical discharges to the environment.

APPENDIX A-1

Industrial Chemical Survey
Classes of Compounds

- Pesticides (Includes herbicides, algaecides, blocides, slimicides and mildewcides)

Aldrin/Dieldrin
Chlordane and metabolites
DDT and metabolites
Endosulfan/Thiodan & metabolites
Endrin and metabolites
Heptachlor and metabolites
Malathion
Methoxychlor
Parathion
Toxaphene
Sevin
Kelthane
Diazinon
Dithane
Carbaryl
Silvex
Dithiocarbamates
Maneb
Dioxathion
Tandex/Karbutilate
Carbofurans
Pentac
Folpet
Dichlone
Rotenone
Lindane/Isotox
Simazine
Methoprene
Pesticides not specified above

- Aromatic Hydrocarbons

Benzene
Toluene
Xylene
Biphenyl
Naphthalene
Ethylbenzene
Styrene
Acenaphthene
Fluoranthene
Aromatic hydrocarbons not specified abov

- Halogenated Hydrocarbons

Methyl chloride
Methylene chloride
Chloroform
Carbon tetrachloride
Freon/Genatron
Other halomethanes
1,1,1-Trichlorethane
Other haloethanes
Vinyl fluoride
Vinyl chloride
Dichloroethylene
Trichloroethylene
Tetrachloroethylene
Chlorinated propane
Chlorinated propene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Chlorinated benzene
Chlorinated toluene
Fluorinated toluene
Polychlorinated naphthalene
Dechloprane ($C_{10}Cl_{12}$)
Hexachlorocyclohexane (BHC)
Halogenated hydrocarbons
not specified above

- Halogenated Organics (other than hydrocarbons)

Phosgene
Methyl chloromethyle ether
Bis(chloromethyl) ether
Other chloralkyl ehters
Benzoyl chloride
Chlorothymol
Chlorinated phenol
Chlorinated cresols or xylenols
Chlorendic acid
Chloroaryl ethers
Dichlorophene or hexachlorophene
Chlorinated aniline (including methylene bis (2-chloraniline))
Dichlorobenzidine
Chlorinated diphenyl oxide
Chlorinated toluidine
Kepone ($C_{10}Cl_{10}O$)
Dichlorovinyl sulfonyl pyridine
Chloropicrin
Trichloromethyl thio-phthalimide
Trichloro-propylsulfonyl pyridine
Tetrachloro-methylsulfonyl pyridine
Tetrachloro-isophthalonitrile
Halogenated organics not specified above

- Ketones and Aldehydes

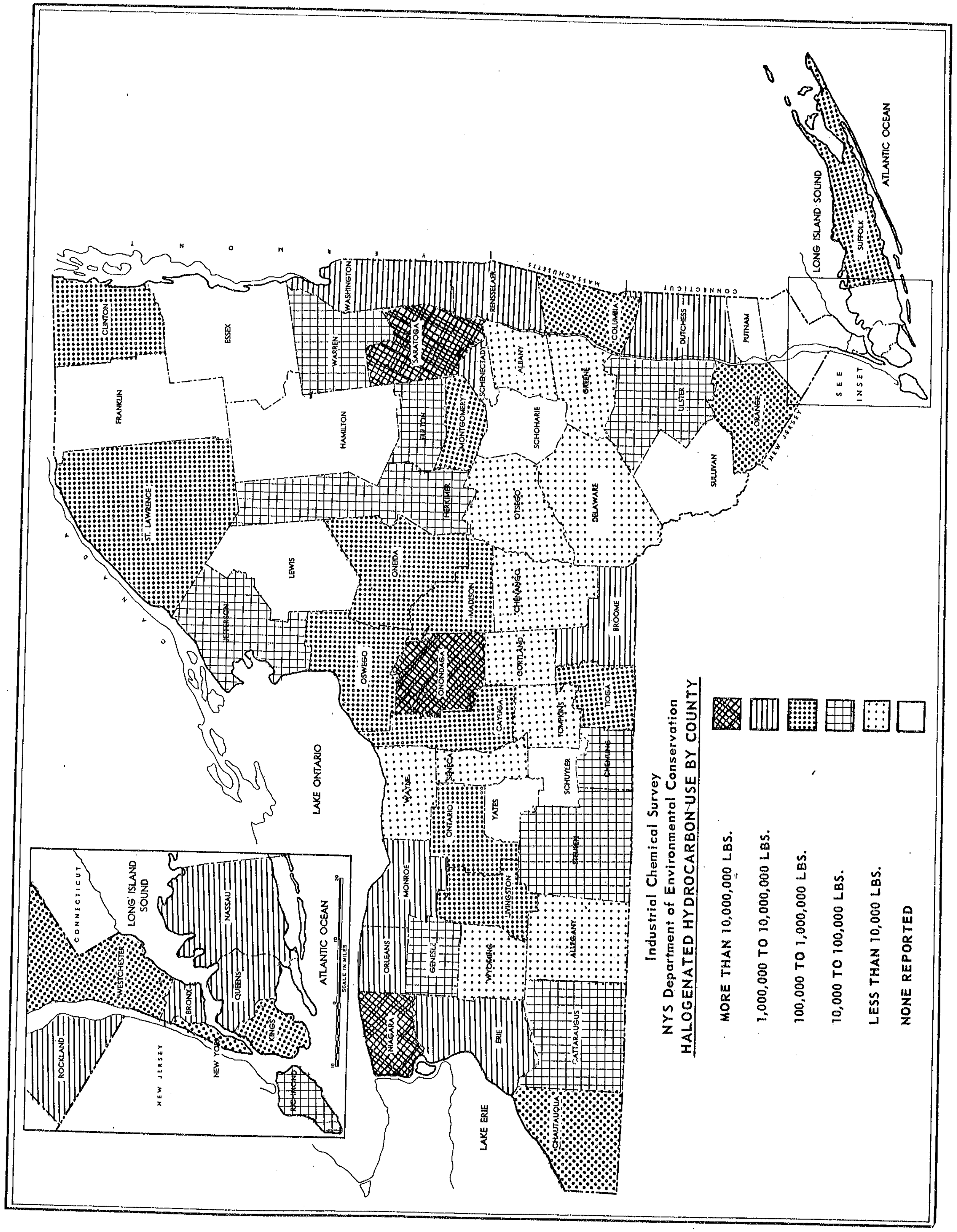
Acetone
Methyl Ethyl Ketone (MEK)
Formaldehyde
Methyl Isobutyl Ketone (MIBK)
Acetaldehyde
Benzaldehyde
Not Specified Above

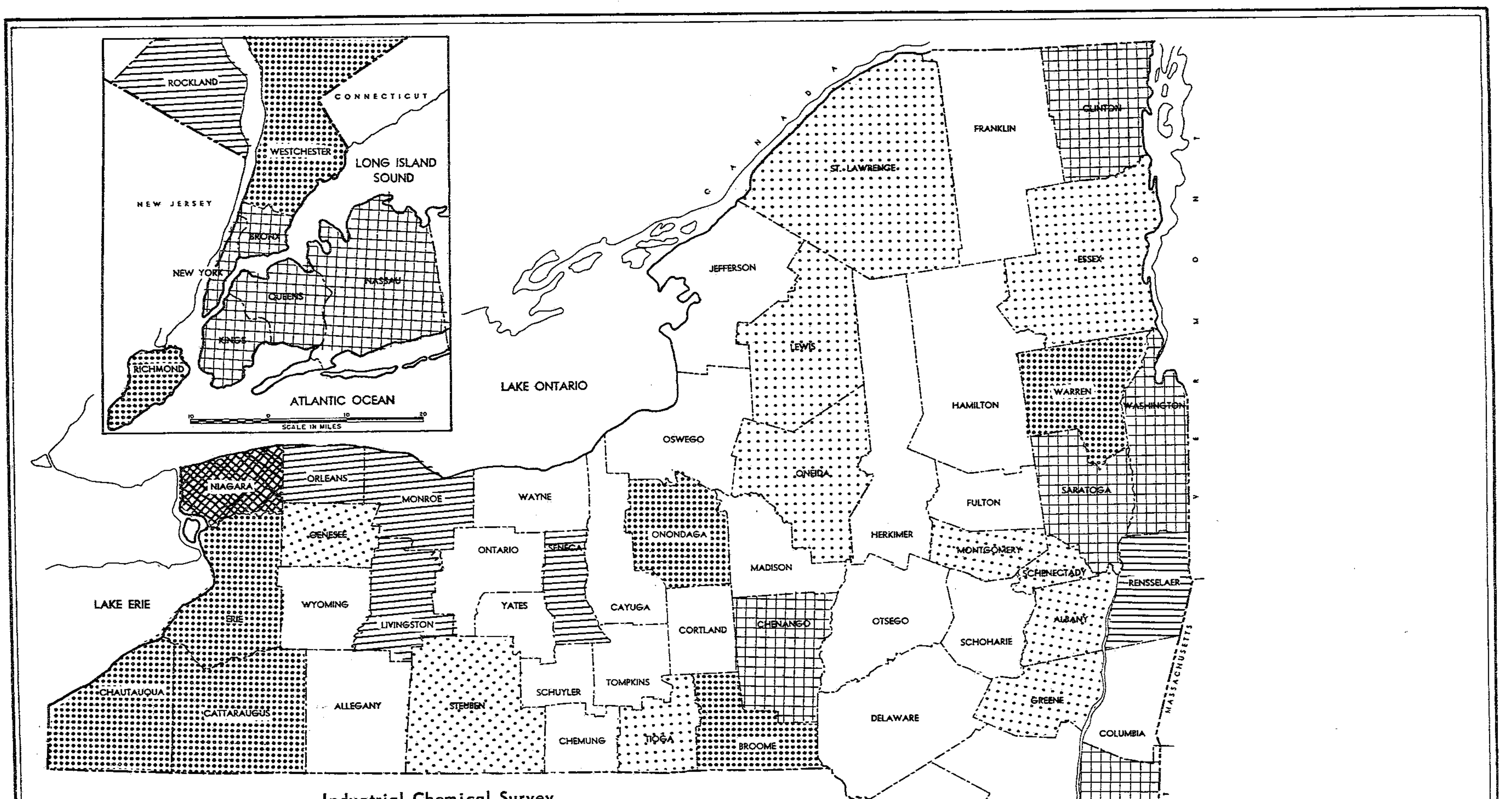
- Substituted Aromatics (other than hydrocarbons and non-halogenated)

Phenol, cresol, or xylenol
Catechol, resorcinol, or hydroquinone
Nitrophenols
Nitrobenzenes
Nitrotoluenes
Aniline
Toluidines
Nitroanilines
Nitroanisole
Toluene diisocyanate
Dimethylaminoazobenzene
Benzoic Acid (and Benzoate salts)
Phthalic, isophthalic or terephthalic acid
Phthalic anhydride
Phthalate esters
Phenoxyacetic acid
Phenylphenols
Nitrobiphenyls
Aminobiphenyls (including benzidine)
Diphenylhydrazine
Naphthylamines
Carbazole
Acetylaminofluorene
Dyes and organic pigments
Pyridine
Substituted aromatics not specified above

- Plastics

Poly Vinyl Chloride
Poly Styrene
Not specified

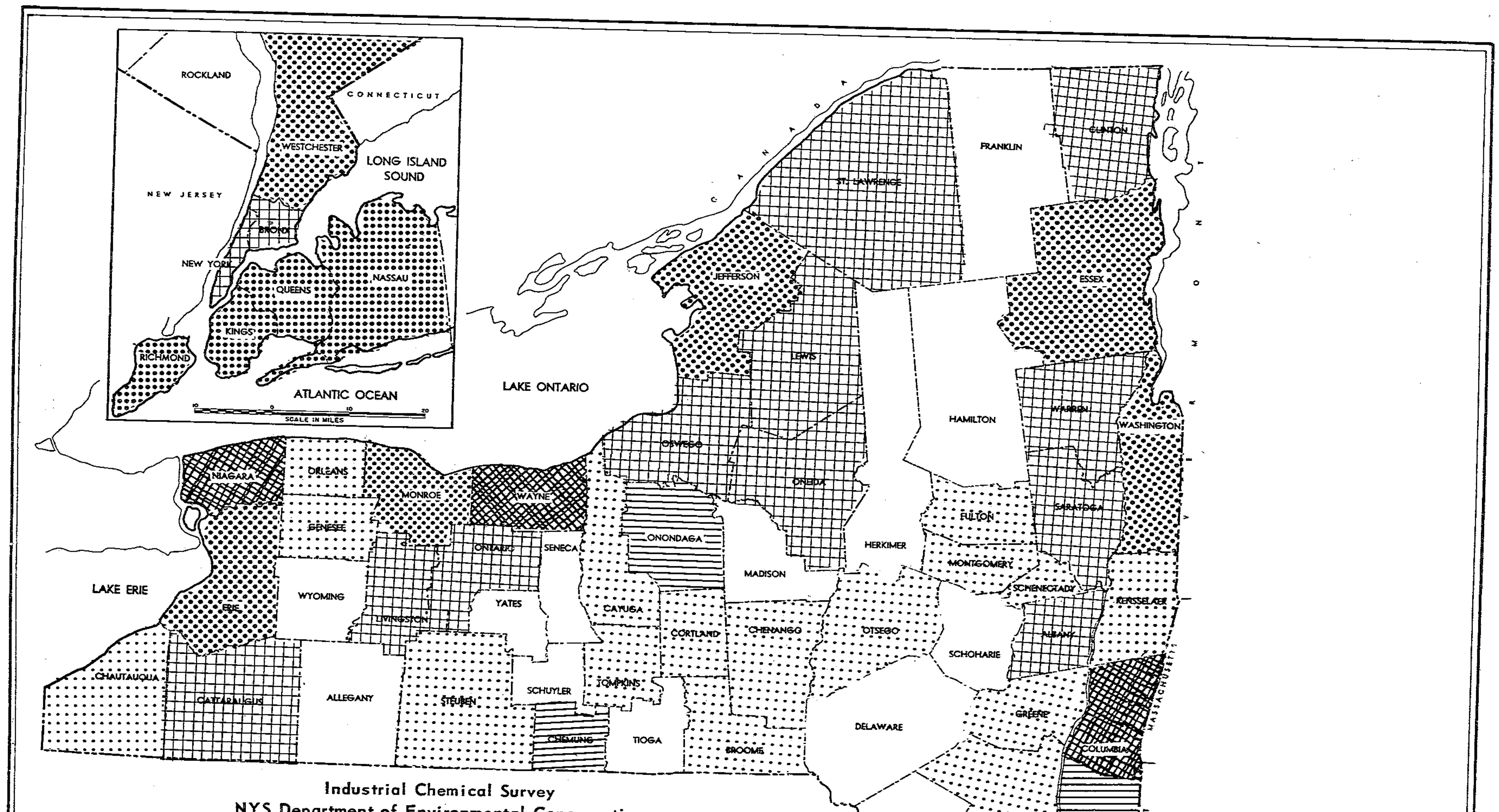




Industrial Chemical Survey
NYS Department of Environmental Conservation

HALOGENATED ORGANICS (OTHER THAN HYDROCARBONS) USE BY COUNTY

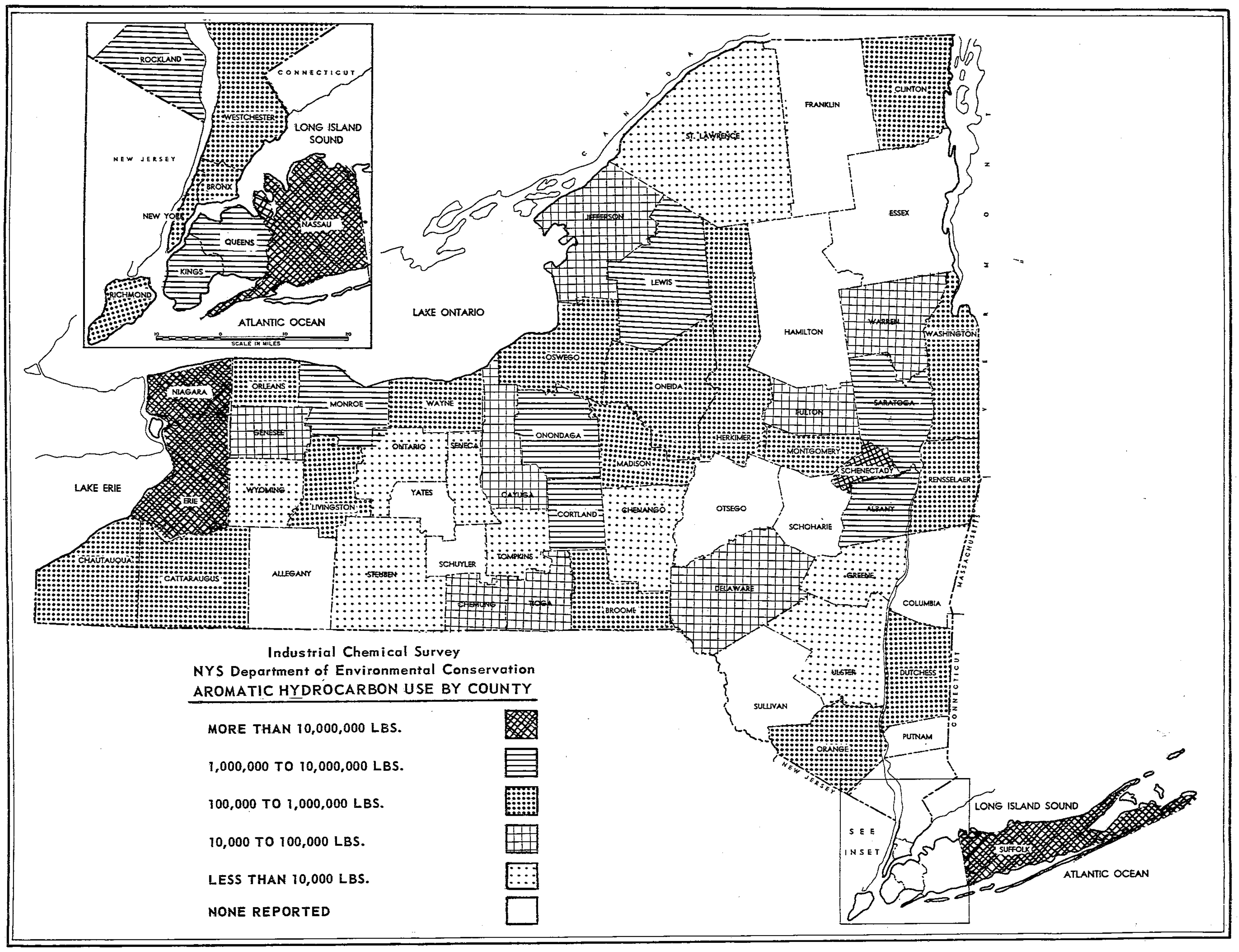
MORE THAN 10,000,000 LBS. ▩
1,000,000 TO 10,000,000 LBS. ▤
100,000 TO 1,000,000 LBS. ▓
10,000 TO 100,000 LBS. ▦
LESS THAN 10,000 LBS. ░
NONE REPORTED ☐

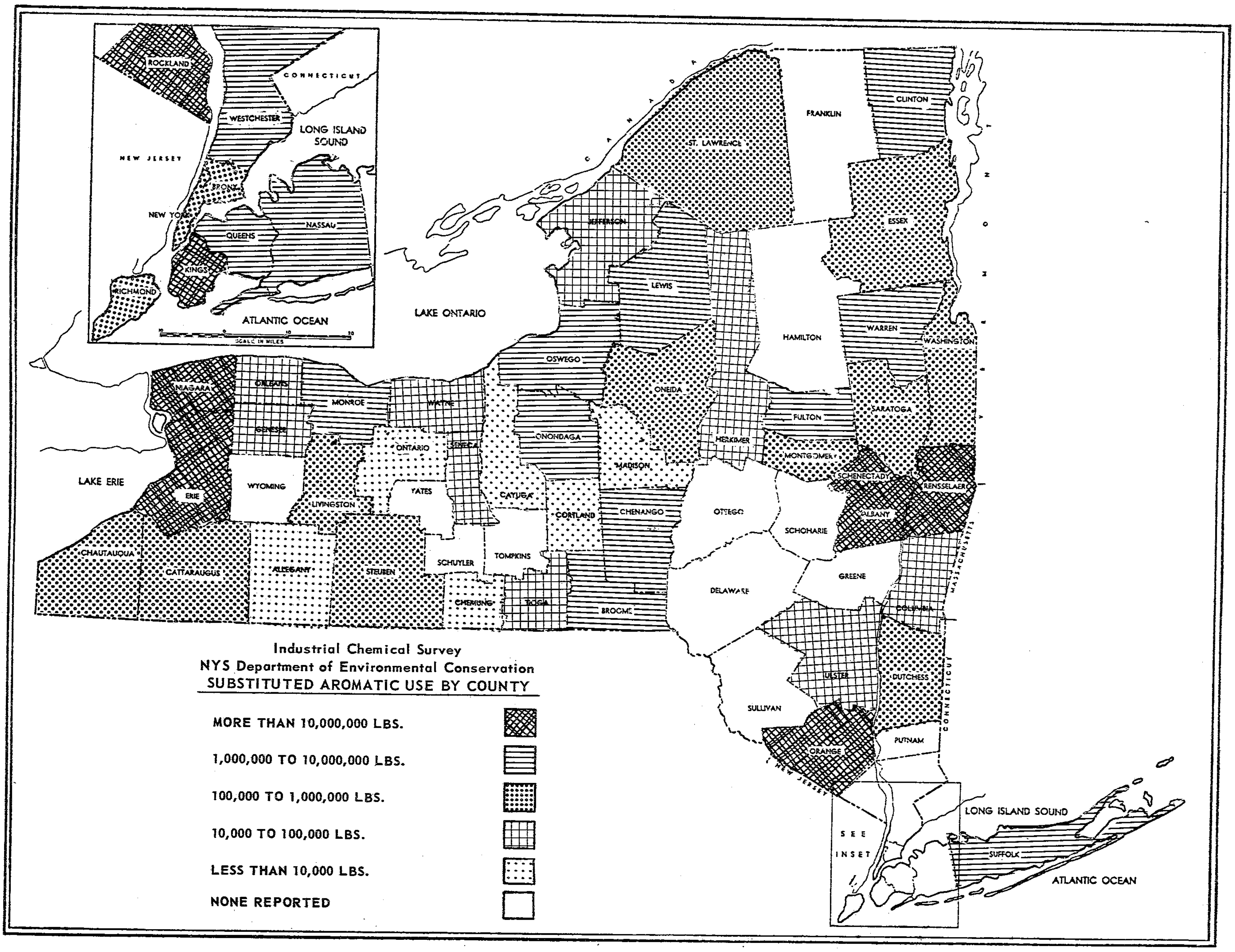


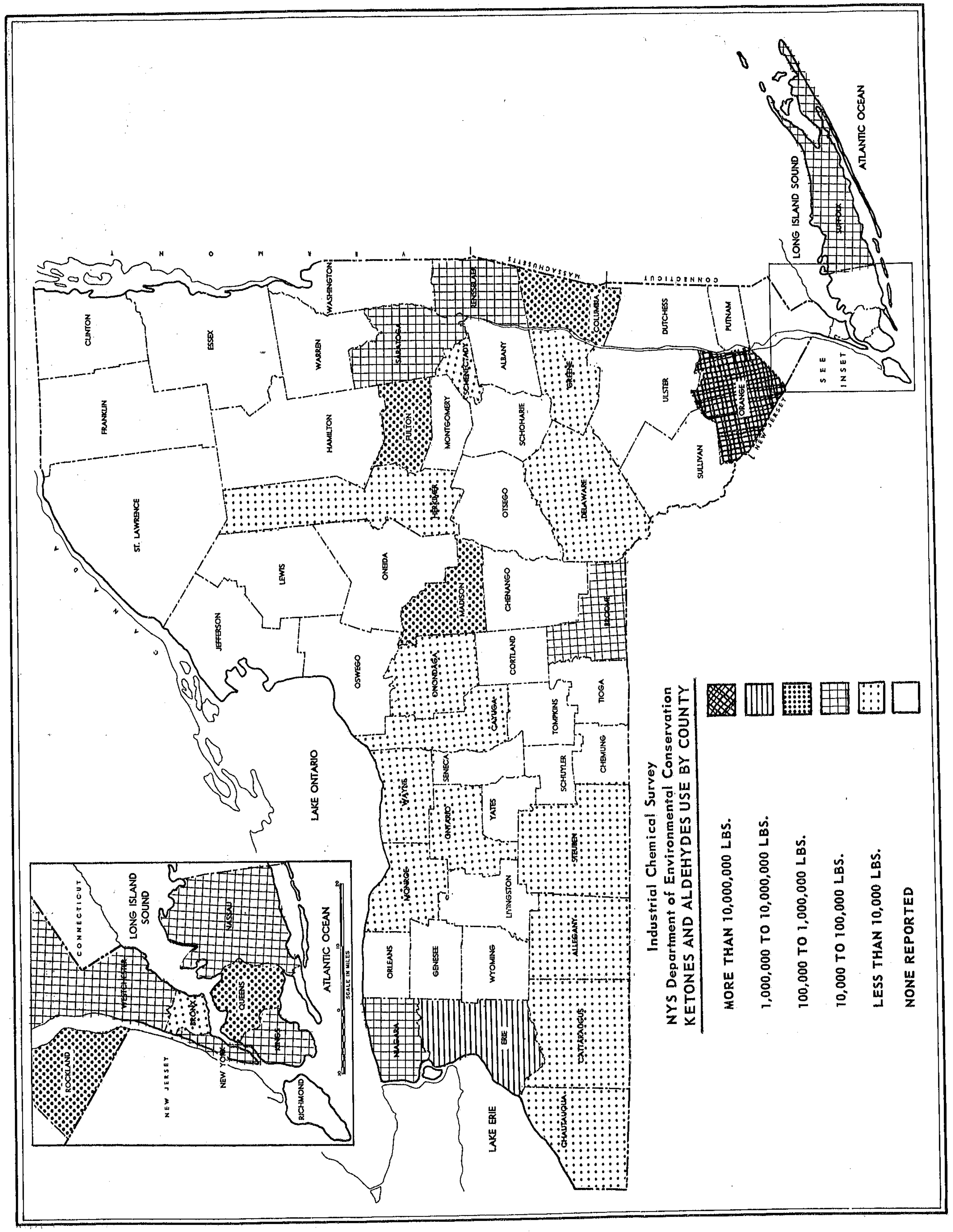
Industrial Chemical Survey
NYS Department of Environmental Conservation

PESTICIDE USE BY COUNTY

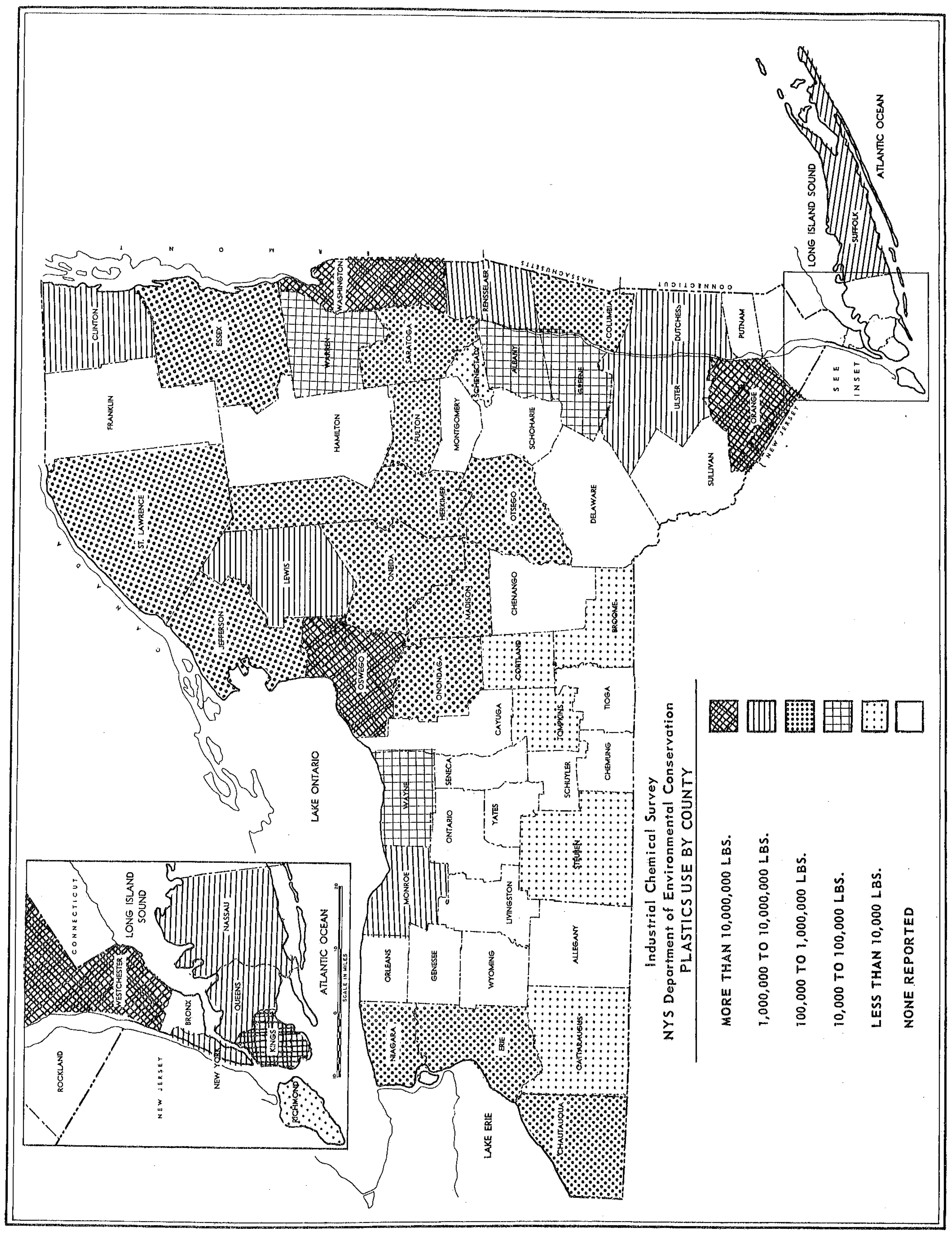
MORE THAN 10,000,000 LBS. ▩
1,000,000 TO 10,000,000 LBS. ▤
100,000 TO 1,000,000 LBS. ▓
10,000 TO 100,000 LBS. ▦
LESS THAN 10,000 LBS. ░
NONE REPORTED ☐


Industrial Chemical Survey
NYS Department of Environmental Conservation
AROMATIC HYDROCARBON USE BY COUNTY


Industrial Chemical Survey
NYS Department of Environmental Conservation
SUBSTITUTED AROMATIC USE BY COUNTY



Industrial Chemical Survey
NYS Department of Environmental Conservation
KETONES AND ALDEHYDES USE BY COUNTY



Industrial Chemical Survey
NYS Department of Environmental Conservation
PLASTICS USE BY COUNTY

APPENDIX B

U.S. Environmental Protection Agency

National Organics Reconnaissance Survey for
Halogenated Organics in Drinking Water

Water Quality Data for Systems Sampled in New York State

APPENDIX B -1

U.S. Environmental Protection Agency
National Organics Reconnaissance Survey for Halogenated Organics in Drinking Water

Water Quality Data for Systems Sampled in New York State

Contaminant	New York City Croton Reservoir Raw	New York City Croton Reservoir Finished	Buffalo Lake Erie Raw	Buffalo Lake Erie Finished	Rhinebeck Hudson River Raw	Rhinebeck Hudson River Finished
1. Chloroform µg/ℓ	NF	22	NF	10	0.3	49
2. Bromodichloromethane µg/ℓ	NF	7	NF	10	NF	11
3. Dibromochloromethane µg/ℓ	NF	0.9	NF	4	NF	1
4. Bromoform µg/ℓ	NF	NF	NF	NF	NF	NF
5. 1,2-Dichloroethane µg/ℓ	NF	NF	NF	<.02	3	2
6. Carbon Tetrachloride µg/ℓ	NF	NF	NF	NF	NF	NF
7. Nonvolatile Total Organic Carbon mg/ℓ	3.0	2.5	2.6	1.7	3.5	1.6
8. Total Trihalomethanes (sum 1-4) µg/ℓ	NF	29.9	NF	24	0.3	61

NF - NOT FOUND

APPENDIX C

U.S. Environmental Protection Agency

National Organics Monitoring Survey

Water Quality Data for Systems Sampled in New York State

List of abbreviations used in this appendix:

ICED - samples were shipped iced, stored at 2-8°C for 1-2 weeks

Terminal - samples were shipped at ambient temperature, stored at 20-25°C for 3-6 weeks

Quenched - samples were preserved with sodium thiosulfate, shipped at ambient temperature, stored at 20-25°C for 3-6 weeks

NA - Not analyzed

ND - Value was below detection limit, the number following the ND is the detection limit times 1000

All results are µg/l except: carbon chloroform extract, nonpurgeable TOC & COD which are in mg/l and ultraviolet absorbance in absorbance units and emission fluorescence scan which is in RFM units.

APPENDIX C-1

U.S. Environmental Protection Agency
National Organics Monitoring Survey

Poughkeepsie (C), Hudson River

Parameter	1	2	3	4	5
Sampling Period	3/76-4/76	5/76-7/76	5/76-7/76	11/76-1/77	11/76-1/77
Sampling Characteristic	ICED	Terminal	Quenched	Terminal	Quenched
Chloroform	50.	73.	NA	NA	NA
Bromodichloromethane	10.8	18.	NA	NA	NA
Dibromochloromethane	1.2	2.2	NA	NA	NA
Bromoform	ND5000	ND300	NA	NA	NA
Dichloroiodomethane	NA	present	NA	NA	NA
1,2-Dichloroethane	ND2000	1.8	NA	NA	NA
Carbon Tetrachloride	ND2000	.25	NA	NA	NA
Methylene Chloride	ND2000	NA	NA	NA	NA
Vinyl Chloride	NA	ND100	NA	NA	NA
1,1,2-Trichloroethane	ND2000	.06	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	present	NA	NA	NA
Bis(2-chloro Ethyl) Ether	ND5000	ND10	NA	NA	NA
Bis(2-chloro Isopropyl) Ether	NA	ND10	NA	NA	NA
Benzene	NA	ND200	NA	NA	NA
P-Dichlorobenzene	ND1000	ND5	NA	NA	NA
M-Dichlorobenzene	NA	ND5	NA	NA	NA
O-Dichlorobenzene	NA	ND5	NA	NA	NA
1,2,4-Trichlorobenzene	ND1000	ND5	NA	NA	NA
2,4-Dichlorophenol	NA	NA	NA	NA	NA
Pentachlorophenol	NA	NA	NA	NA	NA
PCB's	NA	ND100	NA	NA	NA
Fluoranthene	NA	NA	NA	NA	NA
3,4-Benzofluoranthene	NA	NA	NA	NA	NA
1,12-Benzoperylene	NA	NA	NA	NA	NA
3,4-Benzopyrene	NA	NA	NA	NA	NA
Indeno(1,2,3-CD) Pyrene	NA	NA	NA	NA	NA
Carbon Chloroform Extract	.4	1.2	NA	1.21	1.
Nonpurgeable TOC	.9	3.37	NA	NA	NA
COD	4	NA	NA	NA	NA
Ultraviolet Absorbance	NA	0.032	NA	NA	NA
Emission Fluorescence Scan	3.0	11.5	NA	NA	NA

APPENDIX C-2

U.S. Environmental Protection Agency
National Organics Monitoring Survey

Waterford, Hudson R.

Parameter	1	2	3	4	5
Sampling Period	3/76-4/76	5/76-7/76	5/76-7/76	11/76-1/77	11/76-1/77
Sampling Characteristic	ICED	Terminal	Quenched	Terminal	Quenched
Chloroform	48.	86.	NA	120.	48.
Bromodichloromethane	ND1000	3.7	NA	5.0	2.6
Dibromochloromethane	13.	.31	NA	0.30	ND200
Bromoform	ND5000	ND300	NA	ND600	ND600
Dichloroiodomethane	NA	present	NA	ND	NA
1,2-Dichloroethane	ND2000	ND1000	NA	ND2000	ND1000
Carbon Tetrachloride	ND3000	ND200	NA	ND400	ND400
Methylene Chloride	ND3000	NA	NA	NA	NA
Vinyl Chloride	NA	.10	NA	NA	NA
1,1,2-Trichloroethane	ND1000	.34	NA	0.20	0.30
Tetrachloroethylene	NA	present	NA	0.49	0.66
1,1,1-Trichloroethane	NA	present	NA	ND400	ND400
Bis(2-chloro Ethyl) Ether	ND5000	ND10	NA	ND10	NA
Bis(2-chloro Isopropyl) Ether	NA	ND10	NA	ND10	NA
Benzene	ND800	1.8	NA	1.0	NA
P-Dichlorobenzene	ND1000	.007	NA	ND5	NA
M-Dichlorobenzene	NA	ND5	NA	ND5	NA
O-Dichlorobenzene	NA	ND5	NA	ND5	NA
1,2,4-Trichlorobenzene	ND1000	ND5	NA	ND5	NA
2,4-Dichlorophenol	.04	NA	NA	NA	NA
Pentachlorophenol	.04	NA	NA	NA	NA
PCB's	1.4	0.2	NA	0.20	NA
Fluoranthene	.01	NA	NA	NA	NA
3,4-Benzofluoranthene	ND30	NA	NA	NA	NA
1,12-Benzoperylene	ND50	NA	NA	NA	NA
3,4-Benzopyrene	ND30	NA	NA	NA	NA
Indeno(1,2,3-CD) Pyrene	ND50	NA	NA	NA	NA
Carbon Chloroform Extract	.7	0.9	NA	1.4	NA
Nonpurgeable TOC	1.8	3.54	NA	3.6	NA
COD	NR	NA	NA	NA	NA
Ultraviolet Absorbance	NA	0.043	NA	NA	NA
Emission Fluorescence Scan	4.2	12	NA	NA	NA

APPENDIX C-3

U.S. Environmental Protection Agency
National Organics Monitoring Survey

Syracuse (C)

Parameter Sampling Period Sampling Characteristic	1 3/76-4/76 ICED	2 5/76-7/76 Terminal	3 5/76-7/76 Quenched	4 11/76-1/77 Terminal	5 11/76-1/77 Quenched
Chloroform	8.6	22.	NA	15.	1.6
Bromodichloromethane	8.6	7.	NA	5.5	0.28
Dibromochloromethane	ND1000	2.9	NA	2.1	ND200
Bromoform	ND5000	ND300	NA	ND600	ND600
Dichloroiodomethane	NA	present	NA	ND	NA
1,2-Dichloroethane	ND1000	ND500	NA	ND1000	ND100
Carbon Tetrachloride	ND1000	ND200	NA	ND400	ND400
Methylene Chloride	ND1000	NA	NA	NA	NA
Vinyl Chloride	NA	ND100	NA	NA	NA
1,1,2-Trichloroethane	ND1000	ND30	NA	ND200	ND300
Tetrachloroethylene	NA	NA	NA	ND200	ND200
1,1,1-Trichloroethane	NA	NA	NA	ND400	ND400
Bis(2-chloro ethyl)Ether	ND5000	ND10	NA	ND10	NA
Bis(2-chloro Isopropyl)Ether	NA	ND10	NA	ND10	NA
Benzene	ND2200	ND100	NA	NA	NA
P-Dichlorobenzene	ND1000	ND5	NA	0.01	NA
M-Dichlorobenzene	NA	ND5	NA	ND5	NA
O-Dichlorobenzene	NA	ND5	NA	ND5	NA
1,2,4-Trichlorobenzene	ND1000	ND5	NA	ND5	NA
2,4-Dichlorophenol	ND10	NA	NA	NA	NA
Pentachlorophenol	.12	NA	NA	NA	NA
PCB's	ND120	ND100	NA	ND100	NA
Fluoranthene	ND10	NA	NA	NA	NA
3,4-Benzofluoranthene	ND30	NA	NA	NA	NA
1,12-Benzoperylene	ND50	NA	NA	NA	NA
3,4-Benzopyrene	ND30	NA	NA	NA	NA
Indeno(1,2,3-CD)Pyrene	ND50	NA	NA	NA	NA
Carbon Chloroform Extract	.5	1.5	NA	0.5	NA
Nonpurgeable TOC	2.8	1.3	NA	1.3	NA
COD	7	NA	NA	NA	NA
Ultraviolet Absorbance	NA	0.019	NA	NA	NA
Emission Fluorescence Scan	1.0	2.5	NA	NA	NA

APPENDIX C-4

U.S. Environmental Protection Agency
National Organics Monitoring Survey

Buffalo (C), Lake Erie

Parameter Sampling Period Sampling Characteristic	1 3/76-4/76 ICED	2 5/76-7/76 Terminal	3 5/76-7/76 Quenched	4 11/76-1/77 Terminal	5 11/76-1/77 Quenched
1. Chloroform	NA	16.	3.5	16.0	2.9
2. Bromodichloromethane	NA	9.5	1.6	10.0	0.74
3. Dibromochloromethane	NA	6.3	1.3	7.0	1.4
4. Bromoform	NA	.57	ND300	ND600	ND600
5. Dichloroiodomethane	NA	NA	NA	ND	NA
6. 1,2-Dichloroethane	NA	ND500	NA	ND1000	ND100
7. Carbon Tetrachloride	NA	ND200	NA	ND400	ND400
8. Methylene Chloride	NA	NA	NA	NA	NA
9. Vinyl Chloride	NA	ND100	NA	NA	NA
10. 1,1,2-Trichloroethane	NA	ND30	NA	ND200	ND300
11. Tetrachloroethylene	NA	NA	NA	ND200	ND200
12. 1,1,1-Trichloroethane	NA	NA	NA	ND400	ND400
13. Bis(2-chloro ethyl) Ether	ND500	ND10	NA	ND10	NA
14. Bis(2-chloro Isopropyl) Ether	NA	ND10	NA	ND10	NA
15. Benzene	ND1100	ND100	NA	NA	NA
16. P-Dichlorobenzene	NA	ND5	NA	ND5	NA
17. M-Dichlorobenzene	NA	ND5	NA	ND5	NA
18. O-Dichlorobenzene	NA	ND5	NA	ND5	NA
19. 1,2,4-Trichlorobenzene	ND1000	ND10	NA	ND5	NA
20. 2,4-Dichlorophenol	ND10	NA	NA	NA	NA
21. Pentachlorophenol	.09	NA	NA	NA	NA
22. PCB's	ND120	ND200	NA	ND100	NA
23. Fluoranthene	ND10	NA	NA	NA	NA
24. 3,4-Benzofluoranthene	ND30	NA	NA	NA	NA
25. 1,12-Benzoperylene	ND50	NA	NA	NA	NA
26. 3,4-Benzopyrene	ND30	NA	NA	NA	NA
27. Indeno(1,2,3-CD) Pyrene	ND50	NA	NA	NA	NA
28. Carbon Chloroform Extract	.6	0.8	NA	0.9	NA
29. Nonpurgeable TOC	1.9	2.0	NA	2.3	NA
30. COD	4	NA	NA	NA	NA
31. Ultraviolet Absorbance	NA	0.035	NA	NA	NA
32. Emission Fluorescence Scan	3.2	6.5	NA	NA	NA

APPENDIX D

Community Water Supply Wells Closed
Due to Synthetic Organic Chemical Contamination
in
Nassau and Suffolk Counties

APPENDIX D-1

Public Water Supply Wells - Nassau County
Closed as of 3/22/79 due to Synthetic Organic Contamination

Supply Name	Well No.	Location	Population Served	Contaminants Detected
Bethpage W.D.	6-1, 9	Bethpage	32,000	1,1,2 Trichloroethylene Tetrachloroethylene
Hicksville W.D.	3-1, 5-1	Hicksville	57,000	Vinyl chloride 1,1,1 Trichloroethane
(V) Farmingdale	2-1	Farmingdale	8,000	1,1,2 Trichloroethylene
Plainview W.D.	3-1	Plainview	40,000	1,1,2 Trichloroethylene 1,1,1 Trichloroethane
So. Farmingdale W.D.	1-1 6-1, 6-2	Plainedge Massapequa	49,200	1,1,1 Trichloroethane 1,1,2 Trichloroethylene
Jericho W.D.	10	Jericho	55,000	1,1,1 Trichloroethane
L.I. Water Corp.	1-15	Roosevelt	259,000	1,1,1 Trichloroethane
City of Glen Cove	21, 20, 22, 1s, 2s	Glen Cove	28,000	1,1,2 Trichloroethylene Tetrachloroethylene
Manhasset-Lakeville W.D.	12	Lake Success	43,000	1,1,2 Trichloroethylene Tetrachloroethylene
Garden City Park W.D.	5	Garden City Park	24,000	Tetrachloroethylene
(V) Hempstead	6	Hempstead	42,000	1,1,2 Trichloroethylene
Jamaica W.S.	28 16	Elmont New Hyde Park	127,000	1,1,2 Trichloroethylene Tetrachloroethylene
New York Water Supply Corp.	2s	No. Wantagh	169,000	1,1,1 Trichloroethane Dibromochloroethane
Roosevelt Field W.D.	3	Garden City Est.	-	1,1,2 Trichloroethylene

Public Water Supply Wells - Suffolk County
Closed as of 3/15/79 due to Synthetic Organic Contamination

Supply Name	Well Field	Well No.	Location	Population Served
Suffolk County Water Authority	Albany Ave.	1,2,3	Amityville	900,000
	Meade Dr.	1,2	Center Port	
	Locust Ave.	2,3	Bohemia	
	Oval Dr.	1,2	Central Islip	
	Lincoln Ave.	1	Islip	
E. Farmingdale W.D.		2-1	E. Farmingdale	7,000
S. Huntington W.D.		2	E. Huntington	51,000
University Garden Apts.		1	Nesconset	Unknown

1,1,1-Trichloroethane, Trichloroethylene and/or Tetrachloroethylene were detected in these wells at 50 ug/l or greater.

APPENDIX E

New York State Department of Health

and

United States Geological Survey

Joint Study

Reconnaissance of Organic Contamination of New York State Aquifers

Selected Water Sampling Sites Outside Long Island

June 1978 - October 1978

APPENDIX E-1

New York State Department of Health
and
United States Geological Survey
Cooperative Agreement

List of Contaminants for which Each Sample was Analyzed

1. Volatile Organics

Chloromethane
Dichlorodifluoromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Trichlorofluoromethane
1,1-Dichloroethylene
1,1-Dichloroethane
Trans-1,2-Dichloroethylene
Chloroform
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon tetrachloride
Bromodichloromethane
Bis(chloromethyl) ether
1,2-Dichloropropane
Trans-1,3-Dichloropropene
Trichloroethylene
Dibromochloromethane
Bis-1,3-Dichloropropene
1,1,2-Trichloroethane
Benzene
2-Chloroethylvinyl ether
Bromoform
1,1,2,2-Tetrachloroethane
Toluene
Chlorobenzene
Ethylbenzene

2. Acids

2-Chlorophenol
Phenol
2,4-Dichlorophenol
2-Nitrophenol
P-chloro-m-cresol
2,4,6-Dimethylphenol
2,4-Dinitro-o-cresol
4-Nitrophenol
Pentachlorophenol
2,4,6-Trichlorophenol

3. Base Neutrals

1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachloroethane
1,2-Dichlorobenzene
Bis(2-Chloroisopropyl)ether
Hexachlorobutadiene
1,2,4-Trichlorobenzene
Naphthalene
Bis(2-chloroethoxy)methane
2-Chloronaphthalene
Acenaphthylene
Acenaphthene
Isophorone
Fluorene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
2,4-Dinitrotoluene
N-nitrosodiphenylamine
Hexachlorobenzene
4-Bromophenyl phenyl ether
Phenanthrene
Anthracene
Di-n-octylphthalate
2,3,7,8-Tetrachlorodibenzo-p-dioxin
Dimethyl phthalate
Diethyl phthalate
Fluoranthene
Pyrene
Di-n-butyl phthalate
Benzidine
Butyl benzyl phthalate
Chrysene
Bis(2-ethylhexyl)phthalate
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(g,h,i)perylene
N-nitrosodimethylamine
N-nitrosodi-n-propylamine
4-Chlorophenyl phenyl ether
3,3'-Dichlorobenzidine
Aldrin
Dieldrin
Chlordane (tech. mixture)
4,4' - DDT
4,4' - DDE (p,p'-DDE)
4,4' - DDD (p,p' - TDE)
Alpha-endosulfan
Beta-endosulfan
Endosulfan sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide
Alpha-BHC
Beta-BHC
Gamma-BHC (lindane)
Delta-BHC
PCB-1242 (Aroclor 1242)
PCB-1254 (aroclor 1254)
PCB-1221 (Aroclor 1221)
PCB-1232 (Aroclor 1232)
PCB-1248 (Aroclor 1248)
PCB-1260 (Aroclor 1260)
PCB-1016 (Aroclor 1016)
Toxaphene

APPENDIX E-2

Reconnaissance of Organic Contamination of New York State Aquifers
Selected Water Sampling Sites

County	Supply Name	Contaminant	Sum of Concentration of Contaminants µg/ℓ	Population Served
Albany	(V) Green Island	Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Ethyl benzene Toluene Trichloroethylene	20	3,600
Albany	(T) Guilderland Guilderland Water Department	Bis(2-ethylhexyl)phthalate Toluene	10	10,000
Albany	Latham Water District	Bis(2-ethylhexyl)phthalate Toluene Trichloroethylene	12	75,000
Allegany	(V) Bolivar	Toluene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Butylbenzyl phthalate Diethyl phthalate Anthracene/phenanthrene	16	1,450
Allegany	(V) Cuba	Toluene Bis(2-ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Anthracene/phenanthrene	16	1,700
Cattaraugus	Felmont Oil Co.	Toluene Trichloroethylene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Anthracene	16	Unknown
Clinton	(T) Plattsburgh Salmon River Water District	1,1,1-Trichloroethane Toluene Ethylbenzene Bis(2-ethylhexyl)phthalate	10	25
Cortland	(C) Cortland	Benzene Bis(2-ethylhexyl)phthalate Diethyl phthalate Di-n-butyl phthalate Ethyl benzene Phenanthrene Toluene Trichloroethylene	39	22,000

APPENDIX E-3

Reconnaissance of Organic Contamination of New York State Aquifers
Selected Water Sampling Sites

County	Supply Name	Contaminant	Sum of Concentration of Contaminants µg/ℓ	Population Served
Cortland	(T) Cortlandville	Anthracene Bis(2-ethylhexyl)phthalate Diethyl phthalate Di-n-butyl phthalate Ethyl benzene Toluene Trichloroethylene	56	2,700
Cortland	(V) Homer Newton Water Works	Anthracene Bis(2-ethylhexyl)phthalate Diethyl phthalate Di-n-butyl phthalate Ethyl benzene Trichloroethylene	164	4,242
Erie	(V) Alden	Toluene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Butylbenzyl phthalate Diethyl phthalate Di-n-octyl phthalate Anthracene/phenanthrene Anthracene	14	3,000
Erie	(V) No. Collins	Toluene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Diethyl phthalate Di-n-octyl phthalate Anthracene/phenanthrene	28	1,675
Erie	(V) Springville	Toluene Trichlorofluoromethane Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Butylbenzyl phthalate Diethyl phthalate Di-n-octyl phthalate Anthracene/phenanthrene	222	5,000
Genesee	(C) Batavia	Toluene Trichlorofluoromethane Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Diethyl phthalate	12	17,800

APPENDIX E-4

Reconnaissance of Organic Contamination of New York State Aquifers
Selected Water Sampling Sites

County	Supply Name	Contaminant	Sum of Concentration of Contaminants µg/ℓ	Population Served
Jefferson	Fort Drum	Ethyl benzene Toluene Trichloroethylene	2	Unknown
Madison	(V) Cazenovia	Trichlorofluoromethane Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate	2	2,700
Onondaga	(V) Baldwinsville	Toluene Bis(2-ethylhexyl)phthalate	4	6,000
Oswego	(C) Fulton	Benzene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Toluene Trichloroethylene Trichlorofluoromethane	15	15,000
Oswego	(V) Phoenix	Carbon tetrachloride Bis(2-ethylhexyl)phthalate	16	2,600
Putnam	(V) Brewster	Benzene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Ethyl benzene 1,1,2,2-Tetrachloroethane Tetrachloroethylene Toluene Trans-1,2-dichloroethylene Trichloroethylene	290	2,000
Putnam	(T) Carmel	Bis(2-ethylhexyl)phthalate Diethyl phthalate Di-n-butyl phthalate Ethyl benzene Phenol Tetrachloroethylene Toluene Trichloroethylene 2,4,6-Trichlorophenol	12	1,500
Saratoga	Shenendehowa Central School	Bis(2-ethylhexyl)phthalate Toluene Trichloroethylene Trichlorofluoromethane	21	9,000
Schenectady	(C) Schenectady	Bis(2-ethylhexyl)phthalate Toluene Trichloroethylene	46	86,000

APPENDIX E-5

Reconnaissance of Organic Contamination of New York State Aquifers
Selected Water Sampling Sites

County	Supply Name	Contaminant	Sum of Concentration of Contaminants μg/ℓ	Population Served
Schenectady	(T) Rotterdam	Ethyl benzene Phenol Toluene Trichloroethylene	4	24,000
Sullivan	(T) Tusten Narrowsburgh Water District	Ethylbenzene Bis(2-ethylhexyl)phthalate	33	1,100
Sullivan	(T) Liberty White Sulfur Springs Water District	Bis(2-ethylhexyl)phthalate	1	500
Ulster	(V) Ellenville	Bis(2-ethylhexyl)phthalate Bromodichloromethane Chloroform Ethyl benzene Toluene Trichloroethylene Trichlorofluoromethane	21	5,000
Ulster	Kingsvale Water (near city of Kingston)	Bis(2-ethylhexyl)phthalate Chloroform Ethyl benzene Phenol Tetrachloroethylene Toluene Trichloroethylene Trichlorofluoromethane	91	250
Ulster	(T) Ulster	Bis(2-ethylhexyl)phthalate Ethyl benzene Phenol Toluene Trichloroethylene Trichlorofluoromethane	16	6,000
Wyoming	(V) Arcade	Toluene Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Diethyl phthalate Anthracene/phenanthrene	14	1,980

APPENDIX F

State and Local Health Department Response to Consumer Complaints Outside Long Island

Public and Private Wells with Detectable Levels of Synthetic Organic Contaminants

APPENDIX F-1

Public and Private Water Supply Wells with Detectable Levels of Synthetic Organic Contaminants

(Outside Long Island)

County	Supply Name	Contaminant	Sum of Concentrations of Contaminants µg/ℓ	Population Served
Cattaraugus	(V) Allegany	PCB	--	2,200
Livingston	(V) Caledonia	Gasoline Benzene Toluene Xylene	200	2,400
Putnam	(V) Brewster	Tetrachloroethylene Trichloroethylene	200	2,000
Putnam	(V) Mahopac	Tetrachloroethylene	160	Unknown
Rockland	(V) Suffern	1,1,1 Trichloroethane	170	9,500
Rockland	(T) West Nyack	Trichloroethylene	3,000 to 20,000	
Statewide	Individual wells 150 estimated incidents	Benzene Toluene Xylene	20 to 3,000	Unknown
Westchester	(T) No. Castle Hamlet of Armonk	Tetrachloroethylene Trichloroethylene	100 to 2,800	Unknown
Westchester	Bedford W.D. #1	Tetrachloroethylene	100	8,000

APPENDIX G

Finished Water Quality Data for Poughkeepsie and Waterford

This Appendix gives the concentrations of some organic compounds in finished drinking water for two cities which obtain their raw water from the Hudson River.

APPENDIX G-1

Finished Water Analysis
Poughkeepsie

Source: Hudson River
Data: US Geological Survey

all results in µg/ℓ

Compound	7/71	10/71	4/72
aldrin	0	0	0
chlordane	0	0	0
DDD	0	0	0
DDE	0	0	0
DDT	0	0	0
dieldrin	0	0	0
endrin	0	0	0
heptachlor	NA	0	0
heptachlorepoxide	0	0	0
lindane	NA	0	0
methoxychlor	0	0	0
toxaphene	0	0	0
diazinon	0	0	0.06
ethion	0	0	0
malathion	0	0	0
methylparathion	0	0	0
methyltrithion	0	0	0
trithion	0	0	0
2,4 - D	0	0	0
2,4,5 - T	0	0	0
silvex	0	0	0
PCB's	NA	NA	0
phenols	5.0	NA	0

APPENDIX G-2

Finished Water Analysis
Poughkeepsie

Source: Hudson River
Data: NYS Dept. of Health

all results in µg/ℓ

Compound	6/78	7/6/78 (plant)	7/6/78 (dist.)	12/78 (plant)	12/78 (dist.)
bromodichloromethane	7	18	14	18	17
bromoform	LT 5	LT 5	LT 5	LT 5	LT 5
chloroform	44	190	160	50	50
chlorodibromomethane	LT 5	LT 5	LT 5	LT 5	LT 5
carbon tetrachloride	LT 5	LT 5	LT 5	LT 5	LT 5
tetrachloroethylene	LT 5	LT 5	LT 5	LT 5	LT 5
trichloroethane	LT 5	LT 5	LT 5	LT 5	LT 5
trichloroethylene	LT 5	LT 5	LT 5	LT 5	LT 5

APPENDIX G-3

Finished Water Analysis
Waterford Water Company

Source: Hudson River
Data: US EPA

All results in μg/ℓ

Compound	2/4/76	7/8/76	12/8/76	2/24/78
acetone	NA	ND	NA	NA
benzene	1.4	1.8	1.0	4.7
bromodichloromethane	3.9	3.7	5.0	ND
chlorobenzene	NA	ND	0.56	ND
chloroform	22	86	120	NA
dibromochloromethane	0.1	0.31	0.30	NA
dichloroethylene isomer	NA	ND	NA	NA
dichloroiodomethane	NA	ND	NA	NA
tetrachloroethylene	NA	ND	0.49	NA
tetrahydrofuran	NA	ND	NA	NA
toluene	2.7	ND	19	3.3
1,1,1-trichloroethane	0.1	ND	NA	NA
trichloroethylene	0.1	0.34	0.20	NA
xylene isomer	1.0	ND	ND	0.94
carbon tetrachloride	0.1	NA	NA	NA
bromoform	0.1	NA	NA	NA
ethyl benzene	NA	NA	0.42	0.21

APPENDIX G-4

Finished Water Analysis
Waterford Water Company

Source: Hudson River
Data: NYS Health Dept.

All results in μg/ℓ

Compound	9/30/77	5/78	7/13/78	9/18/78	11/10/78	11/28/78	1/23/79
benzene	NA	NA	NA	NA	NA	NA	LT 1
bromodichloromethane	NA	4	5	LT 2	7	9	7
bromoform	NA	LT 5	LT 5	LT 5	LT 5	LT 5	LT 5
carbon tetrachloride	NA	LT 5	LT 5	LT 5	LT 5	LT 5	LT 2
chloroform	NA	65	62	14	70	50	39
chlorotoluene	NA	NA	NA	NA	NA	NA	LT 10
α - chlorotoluene	NA	NA	NA	NA	NA	NA	LT 10
dibromochloromethane	NA	LT 5	2	LT 5	LT 5	LT 5	LT 2
monochlorobenzene	NA	NA	NA	NA	NA	NA	LT 10
tetrachloro ethylene	NA	LT 2.5	LT 2	LT 2	LT 2	LT 2	LT 2
toluene	NA	NA	NA	NA	NA	NA	1
trichloroethane	NA	LT 2	LT 2	LT 2	LT 2	LT 2	LT 2
trichloroethylene	NA	LT 5	LT 5	LT 5	LT 5	LT 5	LT 4
vinyl chloride	NA	NA	NA	NA	NA	NA	LT 1
xylene	NA	NA	NA	NA	NA	NA	1
Total PCB	0.8	NA	NA	NA	NA	NA	NA

NA - not analyzed
LT - less than the detection limit

APPENDIX H

Finished Water Quality Data
for the City of Niagara Falls

This Appendix gives the concentrations of some organic compounds in finished drinking water for Niagara Falls which obtains its raw water from the Niagara River.

APPENDIX H-1

Finished Water Analysis
Niagara Falls (C)

Source: Niagara River (West Branch)

Data: U.S. Geological Survey

All Data in µg/liter

Compound	11/70	7/71	10/71	4/72	6/74	9/74
Aldrin	0	0	0	0	0	0
Chlordane	NA	0	0	0	0	0
DDD	0	0	0	0	0	0
DDE	0	0	0	0	0	0
DDT	0	0	0	0	0	0
Dieldrin	0	0	0	0	0	0
Endrin	0	0	0	0	0	0
Heptachlor	0	0	0	0	0	0
Heptachlor Epoxide	NA	0	0	0	0	0
Lindane	0	0	0	0	0	0
Toxaphene	NA	0	0	0	0	0
Methoxychlor	NA	0	0	0	0	0
Diazinon	NA	0	0	0	0	0
Ethion	0	0	0	0	0	0
Malathion	0	0	0	0	0	0
Methyl Parathion	0	0	0	0	0	0
Methyl Trithion	NA	0	0	0	0	0
Parathion	0	0	0	0	0	0
Trithion	0	0	0	0	0	0
2,4-D	0	0	0	0	0	0
2,4,5-T	0	0	0	0	0	0
Silvex	0	0	0	0	0	0
PCB's	NA	NA	NA	0	0	0
PCN's	NA	NA	NA	NA	0	0

APPENDIX H-2

Finished Water Analysis
Niagara Falls (C)

Source: Niagara River (West Branch)
Data: New York State Department of Health

All data in µg/liter

Compound	9/77	7/78	4/26/79	Plant 12/12/78	Dist. 12/12/78	8/25/78
Trichlorobenzenes	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene	NA	NA	NA	NA	NA	NA
Monochlorotoluenes	NA	NA	LT 1.0	NA	NA	NA
Tetrachlorobenzenes	NA	NA	NA	NA	NA	NA
Lindane	LT 0.04	NA	LT 0.05	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	NA	NA	NA
2,3,5-Trichlorophenol	NA	NA	NA	NA	NA	NA
Hexachlorobenzenes	NA	NA	LT 0.05	NA	NA	NA
Mirex	LT 0.01	NA	LT 0.01	NA	NA	NA
Chloroform	NA	43	NA	30	22	32
Bromoform	NA	LT5	NA	LT5	LT5	LT5
Bromodichloromethane	NA	21	NA	13	14	17
Chlorodibromomethane	NA	LT2	NA	5	5	6
Carbontetrachloride	NA	LT5	NA	LT5	LT5	LT5
1,1,1-Trichloroethane	NA	LT5	NA	LT5	LT5	LT5
Trichloroethylene	NA	LT5	NA	LT5	LT5	LT5
Tetrachloroethylene	NA	2	NA	LT2	LT2	LT2
Monochlorobenzene	NA	NA	LT 1.0	NA	NA	NA
Methoxychlor	LT 1.0	NA	NA	NA	NA	NA
Endrin	LT 0.02	NA	NA	NA	NA	NA
2,4-D	LT 0.5	NA	NA	NA	NA	NA
Toxaphene	LT 1.0	NA	NA	NA	NA	NA
Silvex	LT 0.1	NA	NA	NA	NA	NA
Total PCB	NA	NA	NA	NA	NA	LT 0.05

APPENDIX H-3

Finished Water Analysis
Niagara Falls (C)

All values are reported as parts per billion (µg/ℓ) and have been corrected for a field bank.

Compound	11/1/78	2/22/79	3/19/79[5]	4/12/79[6]	5/14/79[7]	6/11/79
Trichlorobenzenes	0.83[2]	0.43	1.9	0.70	0.36	0.09
1,2-Dichlorobenzene	<0.07	<0.05	0.18	0.093	0.01	0.01
1,4-Dichlorobenzene	<0.30	<0.05	0.18	0.015	0.01	0.01
Hexachlorocyclopentadiene	N/D[3]	0.2	0.30	0.10	<0.04	<0.05
Monochlorotoluenes	N/D	<0.05	<0.01	0.16	0.06	0.01
Tetrachlorobenzenes	4.0	0.76	0.56	0.65	1.01	0.37
Lindane	0[4]	<0.05	<0.01	<0.01	<0.01	<0.01
Hexachlorobutadiene	0.09	0.51	0.059	0.049	0.13	0.03
2,3,5-Trichlorophenol	0[4]	<0.05	<0.01	<0.01	<0.01	<0.01
Hexachlorobenzenes[1]						0.01
Mirex[1]						<0.01

[1] Compound was added to the monthly monitoring profile beginning July, 1979.

[2] Value reflects concentration of only the 1,2,3 isomer of trichlorobenzene.

[3] N/D indicates that the designated compound is not shown to be present above the noise level of the output signal.

[4] Compound was not included in the analytical protocol.

[5] Initiation of "Operation Clean" began with high pressure water scouring of the chemical pretreatment channels 3/19/79.

[6] Spring clean up program in shoreshaft, intake and forebays began 4/19/79 and terminated 4/27/79.

[7] Values represent the average of the initial and verification of GC/MS run following an equipment malfunction.

APPENDIX H-4

Finished Water Analysis
Niagara Falls (C)

Source: Niagara River (West Branch)

Data: Carborundum Laboratories

All data in µg/liter

Compound	a 8/23/78	a,b 8/27/78	c 8/23/78	c 8/25/78	c 9/5/78	c 9/15/78	c 10/16/78	b,c,d 11/1/78	2/22/79	3/19/79	4/12/79	5/14/79	6/11/79
Trichloroethylene	LT 0.4	0.050	3.2	4.4	4.0	5.4	3.2	0.13	NA	NA	NA	NA	NA
Toluene	LT 0.1	0.005	0.25	0.36	0.26	0.6	0.18	0.02	NA	NA	NA	NA	NA
Tetrachloroethylene	LT 0.4	2.7	2.1	2.4	2.1	1.8	1.5	2.40	NA	NA	NA	NA	NA
Monochlorobenzene	LT 0.1	0.085	LT 0.1	LT 0.1	LT 0.1	LT 0.1	LT 0.1	0.13	NA	NA	NA	NA	NA
Monochlorobenzotrifluoride	LT 0.2	NA	0.1	LT 0.2	LT 0.2	LT 0.2	LT 0.1	NA	NA	NA	NA	NA	NA
Monochlorotoluene	LT 0.1	NA	0.17	0.16	0.27	0.07	0.04	ND	LT 0.05	LT 0.01	0.16	0.06	0.01
Dichlorobenzotrifluoride	NA	NA	0.21	LT 0.4	LT 0.04	LT 0.2	1.0	NA	NA	NA	NA	NA	NA
Dichlorobenzenes	0.2	NA	0.18	0.02	0.26	LT 0.3	LT 0.2	LT 0.2	LT 0.1	0.36	0.108	0.02	0.02
Dichlorotoluenes	0.3	NA	LT 0.3	LT 0.3	LT 0.3	0.3	LT 0.3	NA	NA	NA	NA	NA	NA
Trichlorobenzenes	1.5	NA	1.5	1.4	1.3	1.3	0.8	0.83	0.43	1.9	NA	0.36	NA
Hexachlorobutadiene (C-46)	0.1	NA	0.13	0.12	0.08	0.1	0.3	0.09	0.51	0.059	0.70	0.13	0.09
Tetrachlorobenzenes	1.7	NA	1.7	1.3	1.2	1.1	0.5	4.0	0.76	0.56	0.049	1.01	0.03
Hexachlorocyclopentadiene (C-56)	0.31	NA	0.31	LT 0.2	0.26	LT 0.2	LT 0.1	ND	0.2	0.30	0.65	LT0.04	0.37
Mirex	LT 0.2	NA	LT 0.2	LT 0.2	LT 0.3	NA	LT 0.9	NA	NA	NA	0.10	NA	LT 0.05
Benzene	NA	0.89	NA	NA	NA	NA	NA	0.05	NA	NA	NA	NA	NA
Carbontetrachloride	NA	0.20	NA	NA	NA	NA	NA	0.43	NA	NA	NA	NA	LT 0.01
1,1,1-trichloroethane	NA	LT 0.33	NA	NA	NA	NA	NA	1.10	NA	NA	NA	NA	NA
Chloroform	NA	17	NA	NA	NA	NA	NA	21.0	NA	NA	NA	NA	NA
1,1-dichloroethylene	NA	0.22	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Ethylbenzene	NA	0.025	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Methylenechloride	NA	0.64	NA	NA	NA	NA	NA	0.80	NA	NA	NA	NA	NA
Bromoform	NA	0.37	NA	NA	NA	NA	NA	0.20	NA	NA	NA	NA	NA
Dichlorobromomethane	NA	55	NA	NA	NA	NA	NA	14.0	NA	NA	NA	NA	NA
Trichlorofluoromethane	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorodibromomethane	NA	22.0	NA	NA	NA	NA	NA	3.7	NA	NA	NA	NA	NA
Hexachlorocyclohexane (BHC) Lindane	NA	NA	0.27	0.26	0.41	0.39	LT 0.1	NA	LT 0.05	LT 0.01	LT0.01	LT0.01	LT 0.01
Trichlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	LT 0.05	LT 0.01	LT0.072	LT0.01	LT 0.01
Hexachlorobenzenes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01

a	grab sample from filter plant IA
b	with sodium thiosulfate added
c	grab sample from new valve vault
d	72 hour composite
e	preliminary cleanup began 3/19/79. Forebay cleanup began 4/19/79 - Terminated 4/27/79

APPENDIX H-5

Finished Water Analysis
Niagara Falls (C)

Source: Niagara River

Data: Recra Research, Inc.

Compound	4/11/79	4/18/79
Octachlorocyclopentene	0.18	0.51
1,2-dichlorobenzene	LT 0.01	LT 0.01
1,4-dichlorobenzene	LT 0.01	LT 0.01
hexachlorocyclopentadiene	LT 0.01	LT 0.01
hexachlorobenzene	0.57	0.39
Mirex	0.03	LT 0.01
Lindane	1.9	1.66
1,2,4-trichlorobenzene	0.89	LT 0.01
1,2,3-trichlorobenzene	0.38	0.26
1,3,5-trichlorobenzene	LT 0.01	0.76
1,2,3,4-tetrachlorobenzene	1.5	6.54
1,2,4,5-tetrachlorobenzene	0.68	LT 0.01
1,2,3,5-tetrachlorobenzene	LT 0.01	LT 0.01
hexachlorocyclobutene	0.20	LT 0.01

APPENDIX I

Cost Estimate for the Development of New Groundwater Sources of Supply

This Appendix includes capital cost estimates for the development of replacement groundwater supply sources. The estimates are based on the worth of the dollar in the year designated and adjustments for inflation are necessary. An allowance for site specific costs ranging from 0-25% is made. These cost estimates should be used only in making preliminary approximations of the actual costs.

References:

1. Gummerman, R.C., et al. "Estimating Costs for Water Treatment Efficiency," US EPA, EPA-600/12-78/182, August, 1978.
2. New York State Department of Health, Bureau of Public Water Supply, files.

APPENDIX I-1

Cost Estimate for Development of New Groundwater Sources of Supply

Parameter	Plant A	B	C	D	E
Design					
year developed	1974	1974	1975	1976	1974
yield, GPM	70	350	500	600	700
number of wells	1	1	1	1	2
well type	drilled	Gravel Pack	Gravel Pack	Drilled	Gravel Pack
well diameter, in.	10	16 x 12	18 x 12	16	16 x 12
well depth, ft.	40	50	80	68	50
pump type	Submersible	Turbine	Turbine	Turbine	Turbine
standby power kw	-	-	-	150	75
Installed Costs					
ground water exploration	10,000	10,000	10,000	10,000	10,000
building and access road	15,000	25,000	30,000	30,000	40,000
well development	5,000	16,000	20,000	15,000	32,000
pump(s) with motor(s)	3,500	8,000	5,500 *	14,000	16,000
standby power	-	-	-	20,000	22,000
inside piping	3,300	7,000	4,500	5,415	11,000
chlorination	1,000	1,500	1,500	9,000**	7,000
telemetry	4,000	4,000	4,000	1,200	5,000
electrical	2,500	4,000	4,000	15,000	5,500
heat & ventilation	1,500	3,000	3,000	5,000	5,000
detention time	-	-	-	-	10,000
transmission line (500'@$20/ft)	10,000	10,000	10,000	10,000	10,000
Total Construction Costs	55,800	88,500	92,500	134,615	173,500
contingencies @ 5%	2,790	4,260	4,625	6,730	8,675
subtotal	58,590	92,760	97,125	141,345	182,175
engineering @ 10%	5,580	9,276	9,712	14,134	18,217
subtotal	64,170	102,036	106,337	155,479	200,392
legal fiscal and administrative	2,800	4,000	4,100	5,100	6,100
subtotal	66,970	106,036	110,937	160,579	206,492
interest during construction	1,200	2,100	2,200	3,800	5,000
subtotal	68,170	108,136	113,137	164,379	211,492
site specific costs 0-25%	0 - 17,042	0-27,034	0-28,284	0 - 41,094	0 - 52,873
Total Capital Cost	68,170 - 85,212	108,136-135,171	113,137 -141,421	164,379-205,473	211,492-264,365

* Well developed for 500 GPM but 200 GPM Turbine and motor initially installed

** Corrosion control, no chlorination

APPENDIX I-2

Summary: Total Annual Increased Costs for Replacement Groundwater Source

	Plant A	B	C	D	E
Well yield, GPM	70.	350.	500.	600.	700.
Operating Costs	Assume operating costs of replacement source equals operating cost of previous source, therefore, no increase in operating costs.				
Capital Costs	78,000.	120,000	128,000	185,000.	235,000.
Debt. Service 20 yrs@7%	7,362.	11,327	12,083	17,462.	22,181.
Total Increased Cost per year	7,362.	11,327	12,083	17,462.	22,181.
Cents per 1000 gal. treated $\frac{\text{cost/yr.}(0.1)}{365 \times \text{MGD}}$	20.0	6.15	4.59	5.54	6.02

APPENDIX J

Cost Assessment of Aeration Stripping Towers

This Appendix includes capital and operating cost estimates of aeration stripping towers for five plant sizes ranging from 0.1 MGD to 50 MGD. These cost estimates should only be used in making preliminary first approximations of the actual costs.

References:

1. Gummerman, R.C., et al. Unpublished additions to "Estimating Costs for Water Treatment as a Function of Size and Treatment Efficiency," US EPA-600/12-78/182, August, 1978.
2. Culp, R.L. and Culp, G.L., Advanced Wastewater Treatment, New York: Van Nostrand Reinhold Company, 1971.
3. Process Manual for Nitrogen Control, US EPA Technology Transfer, October, 1975.
4. Argo, D.G., Control of Organic Chemical Contaminants in Drinking Water, Presented at Seminar: Control of Organic Chemical Contaminants in Drinking Water, Philadelphia, PA, January, 1979.
5. Unpublished correspondence with Robert M. Clark, Chief of Economic Analysis Activities, US EPA, Cincinnati, Ohio.

APPENDIX J-1

Design Criteria for Aeration Stripping Towers

Design Criteria		Plant				
		A	B	C	D	E
Design Capacity	MGD	.13	.67	1.35	13.50	67.50
Ave. Daily Production	MGD	.084	.42	.84	8.40	42.00
Ave. Day Max. Month	MGD	.10	.50	1.00	10.00	50.00
Population Served		463	2,317	4,635	46,350	231,750
Min. Surface Area[1]	ft^2	3.85	19.29	38.50	385.80	1,929.00
Number of Towers[2]		1	1	1	2	2
Tower Plan Dimensions	ft x ft	2 x 2	4 x 5	6 x 7	14 x 14	32 x 32
Adjusted Surface Area	ft^2	4.	20.	42.	392.	2,048.
Adjusted Application Rate	GPM/ft^2	17.36	17.36	16.53	17.71	16.95
Overall Tower Height	ft	22.00	22.00	22.00	22.00	22.00
Depth of Tower Pack	ft	16.00	16.00	16.00	16.00	16.00
Volume of Tower Pack	ft^3	68.00	320.00	672.00	6,272.00	32,768.00
Supply Pumping	GPM	69.40	347.20	694.40	6,944.00	34,722.00
Air to Water Ratio	-	22.5:1	22.5:1	22.5:1	22.5:1	22.5:1
Contact Time	Min.	6.89	6.89	7.24	6.75	7.06

[1] Assume 18 GPM/ft^2 of Tower Pack

$$\text{Surface Area} = \frac{\text{Ave. Day Max. Month (MGD)}}{\text{1440 Min/Day} \quad 18\ \text{gal/ft}^2\text{/min.}}$$

[2] Select number and diameter of towers to equal surface area.

APPENDIX J-2

Summary: Total Annual Operating Cost for Aeration Stripping Towers

COSTS	Plant				
	A	B	C	D	E
Ave. Day Max. Month MGD	.1	.5	1.0	10.0	50.0
Labor Operation	910.0	910.0	910.0	1,820.0	3,640.0
Electricity	682.0	1,508.0	2,951.0	24,856.0	123,826.0
Labor Maintenance	940.0	1,230.0	1,520.0	3,100.0	8,100.0
Material Maintenance	1,000.0	1,000.0	1,350.0	2,000.0	7,200.0
Laboratory Analyses	-	10,000.0	10,000.0	10,000.0	10,000.0
Total Operating Cost	3,532.0	14,648.0	16,731.0	41,776.0	152,766.0
Capital Cost	18,500.0	33,500.0	53,000.0	215,000.0	890,000.0
Debt Service, 20 yrs.@ 7%	1,746.0	3,162.0	5,002.0	20,293.0	84,000.0
Operating Costs	3,532.0	14,648.0	16,731.0	41,776.0	152,766.0
Total Cost Per Year	5,278.0	17,810.0	21,733.0	62,069.0	236,766.0
Cents per 1000 gal. treated	14.46	9.75	5.95	1.70	1.29

$$\frac{\text{Cost/yr.} \quad (0.1)}{365 \text{ x (Ave. Day Production)}}$$

APPENDIX J-3

Plant A
Cost Estimate for Aeration Stripping Tower - 0.1 MGD

Unit Process	Construction $	Process Energy KW - HR	Maintenance Material $/yr	Maintenance Labor hr/yr
Stripping Towers	10,450.	--	--	--
Induced Draft Fan	--[1]	9,500.	500.	44.0
Supply Pumps	2,000.	10,000.	500.	50.0
Subtotal	12,450.	19,500.	1,000.	94.0
Subsurface considerations	0.			
Standby Power	0.			
Total Construction Cost	12,450.			
General Contractor Profit @ 15%	1,867.			
Subtotal	14,317.			
Engineering @ 10%	1,431.			
Pilot Plant Studies	--			
Subtotal	15,748.			
Legal, Fiscal, Adm.	700.			
Interest during Construction @ 10%	150.			
Total Capital Cost	16,598.			
Site Specific Costs 0-25%	4,149.			
Final Capital Costs	16,598. - 20,747.			

[1] Construction Cost for fan included in tower cost

APPENDIX J-4

Plant B
Cost Estimate for Aeration Stripping Tower - .5 MGD

Unit Process	Construction $	Process Energy KW - HR	Maintenance Material $/yr	Maintenance Labor hr/yr
Stripping Towers	20,100.	--	--	--
Induced Draft Fan	--[1]	10,600.	500.	48.0
Supply Pumps	2,200.	32,500.	500.	75.0
Subtotal	22,300.	43,100.	1,000.	123.0
Subsurface considerations	0.			
Standby Power	0.			
Total Construction Cost	22,300.			
General Contractor Profit @ 15%	3,345.			
Subtotal	25,645.			
Engineering @ 10%	2,564.			
Pilot Plant Studies	--			
Subtotal	28,209.			
Legal, Fiscal, Adm.	1,500.			
Interest during Construction @ 10%	400.			
Total Capital Cost	30,109.			
Site Specific Costs 0-25%	7,527.			
Final Capital Costs	30,109. - 37,636.			

[1] Construction Cost for fan included in tower cost

APPENDIX J-5

Plant C
Cost Estimate for Aeration Stripping Tower - 1.0 MGD

Unit Process	Construction $	Process Energy KW - HR	Maintenance Material $/yr	Maintenance Labor hr/yr
Stripping Towers	31,000.	--	--	--
Induced Draft Fan	--[1]	19,000.	550.	52.0
Supply Pumps	5,000.	65,318.	800.	100.0
Subtotal	36,000.	84,318.	1,350.	152.0
Subsurface considerations	0.			
Standby Power	0.			
Total Construction Cost	36,000.			
General Contractor Profit @ 15%	4,320.			
Subtotal	40,320.			
Engineering @ 10%	4,032.			
Pilot Plant Studies	--			
Subtotal	44,352.			
Legal, Fiscal, Adm.	2,000.			
Interest during Construction @ 10%	700.			
Total Capital Cost	47,052.			
Site Specific Costs 0-25%	16,763.			
Final Capital Costs	47,052. - 58,815.			

[1] Construction Cost for fan included in tower cost

APPENDIX J-6

Plant D
Cost Estimate for Aeration Stripping Tower - 10.0 MGD

Unit Process	Construction $	Process Energy KW - HR	Maintenance Material $/yr	Maintenance Labor hr/yr
Stripping Towers	140,000.	--	--	--
Induced Draft Fan	--[1]	68,000.	1,000.	110.
Supply Pumps	65,000.	642,180.	1,000.	200.
Subtotal	205,000.	710,180.	2,000.	310.
Subsurface considerations	0.			
Standby Power	0.			
Total Construction Cost	205,000.			
General Contractor Profit @ 15%	24,600.			
Subtotal	229,600.			
Engineering @ 10%	22,960.			
Pilot Plant Studies	10,000.			
Subtotal	262,560.			
Legal, Fiscal, Adm.	7,300.			
Interest during Construction @ 10%	9,000.			
Total Capital Cost	278,860.			
Site Specific Costs 0-25%	69,715.			
Final Capital Costs	278,860. - 348,575.			

[1] Construction Cost for fan included in tower cost

APPENDIX J-7

Plant E
Cost Estimate for Aeration Stripping Tower - 50 MGD

Unit Process	Construction $	Process Energy KW - HR	Maintenance Material $/yr	Maintenance Labor hr/yr
Stripping Towers	420,000.	--	--	--
Induced Draft Fan	--[1]	327,000.	3,200.	310.
Supply Pumps	150,000.	3,210,900.	4,000.	500.
Subtotal	570,000.	3,537,900.	7,200.	810.
Subsurface considerations	0.			
Standby Power	0.			
Total Construction Cost	570,000.			
General Contractor Profit @ 15%	68,400.			
Subtotal	638,400.			
Engineering @ 10%	63,840.			
Pilot Plant Studies	30,000.			
Subtotal	732,240.			
Legal, Fiscal, Adm.	15,000.			
Interest during Construction	42,000.			
Total Capital Cost	789,240.			
Site Specific Costs 0-25%	197,310.			
Final Capital Costs	789,240. - 986,550.			

[1] Construction Cost for fan included in tower cost

APPENDIX K

Cost Assessment of Granular Activated Carbon Post Contactors

This Appendix includes capital and operating cost estimates of GAC Post Contactors for five plant sizes ranging from 1 MGD to 100 MGD.

References:

1. Gummerman, R.C., et al., "Estimating Costs for Water Treatment as a Function of Size and Treatment Efficiency," US EPA, EPA-600/12-78/182, August, 1978.

APPENDIX K-1

Design Criteria for Post Filtration Granular Activated Carbon Contactors

Design Criteria		Plant				
		A	B	C	D	E
Design Capacity	MGD	1.35	13.5	27.0	67.5	135.0
Ave. Daily Production	MGD	.84	8.4	16.8	42.0	84.0
Ave. Day Max. Month	MGD	1.	10.	20.	50.	100.
Population Served		4635.	46,350.	92,700.	231,750.	463,500.
Min. Surface Area	ft^2	138.8	1,388.8	2,777.7	6,944.4	13,888.8
Min. Required Carbon Volume[1]	ft^3	1,666.6	16,666.6	33,333.3	84,333.3	166,666.6
Number of Contactors[2]		3.	10.	12.	11.	20.
Diameter of Contactors	ft	10.	14.	18.	30.	30.
Adjusted Surface Area/(n-1)units	ft^2	157.1	1,385.4	2,799.2	7,068.6	13,430.3
Adjusted Application Rate	GPM/ft^2	4.42	5.01	4.96	4.91	5.17
Adjusted Depth	ft	10.6	12.06	11.94	11.82	12.44
Adjusted Carbon Volume/n units	ft^3	2,497.5	18,564.	36,460.	91,905.	175,866.
Supply pumping[3]	GPM	694.	6,944.	13,888.	34,722.	69,444.
Backwash Pumping[4]	GPM	942.	1,847.	3,053.	8,482.	16,964.
Mul. Hearth Furnace Area[5]	ft^2	19.8[8]	198.8	397.8	994.6	1,988.9
Initial Carbon Charge/(n-1)units[6]	lbs	49,957.	501,225.	1,002,658.	2,506,519.	5,012,191.
Initial Carbon Charge/unit	lbs	24,978.	55,695.	91,150.	250,651.	263,799.
Total Carbon Charge[7]	lbs	74,935.	556,921.	1,093,808.	2,757,171.	5,275,990.
Makeup Carbon per year	lbs	20,979.	210,514.	421,116.	1,052,737.	2,105,120.

[1] Assume EBCT = 18 min., Application Rate 5 GPM/ft^2 Therefore carbon Depth = 12'

$$\text{Surface Area} = \frac{\text{Ave. Day Max Month (MGD) gal/day}}{\text{1440 min/day } 5\ gal/ft^2/min.} =$$

Carbon Volume = Surface Area X Depth =

Buffer Stock = Volume of one Contactor

[2] Select number and diameter of contactors to equal surface area.

[3] Operating head 35'

[4] One backwash per day for 10 min. duration 12 GPM/ft^2. Two backwashes per day for 100 MGD plant

[5] Furnace area based on regeneration every two months, a carbon density of 30 lbs/ft^3. A hearth loading of 70 lbs/ft^2/day and 40 percent downtime. Adjusted loading rate = 70 lbs/ft^2/day (.6) = 42 lab/ft^2/day.

[6] Carbon density = 30 lbs/ft^3

[7] One backup contactor is provided and contains buffer carbon but is not used during normal operation.

[8] Not economical for onsight regeneration.

APPENDIX K-2

Summary: Total Annual Operating Cost for Granular Activated Carbon Post Contactors

Operating Costs	Plant				
	A	B	C	D	E
Ave. Day Max. Month MGD	1.	10.	20.	50.	100.
Labor Operation	24,000.	48,000.	96,000.	96,000.	128,000.
Electricity	9,636.	58,710.	86,620.	180,027.	348,114.
Natural Gas	*	27,300.	52,000.	106,600.	213,200.
Maintenance Labor	2,400.	8,000.	11,900.	22,700.	41,200.
Maintenance Material	2,800.	15,700.	26,500.	39,000.	59,000.
Replacement Carbon	14,000.	120,000.	220,000.	600,000.	1,050,000.
Laboratory Analyses	20,000.	20,000.	20,000.	20,000.	20,000.
Insurance For Furnace	3,000.*	11,000.*	16,000.*	28,000.*	40,000.*
Off Site Regeneration Contract	44,960.	-	-	-	-
Total Operating Costs	120,796.	308,710.	529,020.	1,092,327.	1,899,514.
Capital Cost	900,000.	6,000,000.	9,000,000.	13,500,000.	24,250,000.
Debt Service, 20 yrs. @ 7%	84,953.	566,357.	849,536.	1,274,304.	2,289,028.
Operating Costs	120,796.	308,710.	529,020.	1,092,327.	1,899,514.
Total Cost Per Year	205,749.	875,067.	1,378,556.	2,366,631.	4,133,542.
Cents Per 1000 gal. Treated $\frac{\text{cost/yr.(0.1)}}{\text{365 x (Ave. Day Production)}}$	67.10	28.54	22.48	15.43	13.66

* Extrapolated Estimate From "Revised Economic Analysis of Proposed Regulations on Organic Contaminants in Drinking Water", U.S.E.P.A., July 5, 1978.

APPENDIX K-3

Plant A
Cost Estimate for Post Filtration Carbon Adsorbers - 1.0 MGD Plant

Unit Process	Construction $	Electrical Energy KW-HR Building	Electrical Energy KW-HR Process	Natural Gas scf/yr	Maintenance Material $/yr	Maintenance Labor hr/yr
Contactors	250,000.	210,000.	1,100.		1,800.	2,000
Carbon Charge	47,000.					
Supply and Backwash Pumping	300,000.*	--	64,218.		1,000.	400
Carbon Regeneration	Contract with regional facility for regeneration					
Makeup Carbon	--	--	--	--	14,000.	--
Subtotal	597,000.	210,000.	65,318.		16,800.	2,400
Subsurface considerations	0.					
Standby Power	0.					
Total Construction Costs	597,000.					
General Contractor Profit	71,640.					
Subtotal	668,640.					
Engineering @ 10%	66,864.					
Subtotal	735,504.					
Legal, Fiscal, Adm.	16,000.					
Interest during Construction @ 10%	42,000.					
Total Capital Cost	793,504.					
Site Specific Costs 0-25%	198,376.					
Final Capital Costs	793,504. - 991,880.					

*Extrapolated estimates from "Revised Econimic Impact Analysis of Proposed Regulation on Organic Contaminants in Drinking Water," U.S. EPA, July 5, 1978.

APPENDIX K-4

Plant B
Cost Estimate for Post Filtration Carbon Adsorbers - 10 MGD Plant

Unit Process	Construction $	Electrical Energy KW-HR Building	Electrical Energy KW-HR Process	Natural Gas scf/yr	Maintenance Material $/yr	Maintenance Labor hr/yr
Contactors	1,200,000.	550,000.	7,000.		6,900.	3,200
Carbon Charge	310,000.					
Supply and Backwash Pumping	770,000.*	--	642,180.		1,800.	800
Carbon Regeneration	1,700,000.	30,000.	430,000.	21,000,000.	7,000.	4,000
Makeup Carbon	--	--	--	--	120,000.	--
Subtotal	3,980,000.	580,000.	1,079,180.	21,000,000.	135,700.	8,000
Subsurface considerations	0.					
Standby Power	0					
Total Construction Costs	3,980,000.					
General Contractor Profit	398,000.					
Subtotal	4,378,000.					
Engineering @ 10%	437,800.					
Subtotal	4,815,800.					
Legal, Fiscal, Adm.	43,000.					
Interest during Construction @ 10%	460,000.					
Total Capital Cost	5,318,800.					
Site Specific Costs 0-25%	1,329,700.					
Final Capital Costs	5,318,800 - 6,648,500					

*Extrapolated estimates from "Revised Economic Impact Analysis of Proposed Regulations on Organic Contaminants in Drinking Water," U.S. EPA, July 5, 1978.

APPENDIX K-5

Plant C
Cost Estimate for Post Filtration Carbon Adsorbers - 20 MGD Plant

Unit Process	Construction $	Electrical Energy KW-HR Building	Electrical Energy KW-HR Process	Natural Gas scf/yr	Maintenance Material $/yr	Maintenance Labor hr/yr
Contactors	2,400,000.	950,000.	15,000.		14,000.	4,200
Carbon Charge	640,000.					
Supply and Backwash Pumping	854,000.*	--	1,284,360.		3,000.	1,200
Carbon Regeneration	2,200,000.	38,000.	600,000.	40,000,000.	9,500.	6,500
Makeup Carbon	--	--	--	--	220,000.	--
Subtotal	6,094,000.	988,000.	1,899,360.	40,000,000.	246,500.	11,900
Subsurface considerations	0					
Standby Power	0					
Total Construction Costs	6,094,000.					
General Contractor Profit	609,400.					
Subtotal	6,703,400.					
Engineering @ 10%	670,340.					
Subtotal	7,373,740.					
Legal, Fiscal, Adm.	57,000.					
Interest during Construction @ 10%	690,000.					
Total Capital Cost	8,120,740.					
Site Specific Costs 0-25%	2,030,185.					
Final Capital Costs	8,120,740. - 10,150,925.					

*Extrapolated estimates from "Revised Economic Impact Aanlysis of Proposed Regulations on Organic Contaminants in Drinking Water," U.S. EPA, July 5, 1978.

APPENDIX K-6

Plant D
Cost Estimate for Post Filtration Carbon Adsorbers - 50 MGD Plant

Unit Process	Construction $	Electrical Energy KW-HR Building	Electrical Energy KW-HR Process	Natural Gas scf/yr	Maintenance Material $/yr	Maintenance Labor hr/yr
Contactors	3,200,000.	1,900,000.	26,000.		13,000.	5,100
Carbon Charge	1,300,000.					
Supply and Backwash Pumping	1,000,000.*	--	3,210,900.		6,000.	2,000
Carbon Regeneration	3,400,000.	54,000.	810,000.	82,000,000.	20,000.	15,600
Makeup Carbon	--	--	--	--	600,000.	--
Subtotal	8,900,000.	1,954,000.	4,046,900.	82,000,000.	639,000.	22,700
Subsurface considerations	0					
Standby Power	0					
Total Construction Costs	8,900,000.					
General Contractor Profit	890,000.					
Subtotal	9,790,000.					
Engineering @ 10%	979,000.					
Subtotal	10,769,000.					
Legal, Fiscal, Adm.	68,000.					
Interest during Construction	1,100,000.					
Total Capital Cost	11,937,000.					
Site Specific Costs 0-25%	2,984,250.					
Total Capital Costs	11,937,000. - 14,921,250.					

*Extrapolated estimates from "Revised Economic Impact Analysis of Proposed Regulations on Organic Contaminants in Drinking Water," U.S. EPA, July 5, 1978.

APPENDIX K-7

Plant E
Cost Estimate for Post Filtration Carbon Adsorbers - 100 MGD Plant

Unit Process	Construction $	Electrical Energy KW-HR Building	Electrical Energy KW-HR Process	Natural Gas scf/yr	Maintenance Material $/yr	Maintenance Labor hr/yr
Contactors	5,700,000.	3,400,000.	54,000.		17,000.	8,000
Carbon Charge	2,500,000.					
Supply and Backwash Pumping	1,280,000.*	--	6,421,800.		12,000.	3,000
Carbon Regeneration	6,800,000.	108,000.	1,620,000.	164,000,000.	30,000.	30,200
Makeup Carbon	--	--	--	--	1,050,000.	--
Subtotal	16,280,000.	3,508,000.	8,095,800.	164,000,000.	1,080,000.	41,200
Subsurface considerations	0					
Standby Power	0					
Total Construction Costs	16,280,000.					
General Contractor Profit	1,465,200.					
Subtotal	17,745,520.					
Engineering @ 10%	1,774,520.					
Subtotal	19,519,720.					
Legal, Fiscal, Adm.	90,000.					
Interest during Construction	2,150,000.					
Total Capital Cost	21,759,720.					
Site Specific Costs 0-25%	5,439,930.					
Total Capital Costs	21,759,720. - 27,199,650.					

*Extrapolated estimates from "Revised Economic Impact Analysis of Proposed Regulations on Organic Contaminants in Drinking Water," U.S. EPA, July 5, 1978.

APPENDIX L

Organic Chemicals Removed by
Aeration or Granular Activated Carbon

Two lists of organic compounds are contained in this Appendix. The first is a list of those organic compounds which are likely to be removed using aeration. The second is a list of organic compounds which have been reported in the literature as being absorbed on granular activated carbon. Site specific pilot studies to select the most suitable treatment and to establish design criteria must be conducted for each proposed use of these methods.

APPENDIX L-1

Synthetic Organic Compounds Likely to be removed by Aeration

Aromatic

Benzene
Toluene
Naphthalene
Biphenyl
Benzo(a)pyrene
Dibenzanthracene
20-Methylcholanthrene

Alkene Derivatives

Acrolein
Acrylonitrile
Allyl alcohol
Cyclopentadiene

Small Halogenated Hydrocarbons

Bromoform
Methyl bromide
Carbon tetrachloride
Chloroform
Dibromochloromethane
Bromodichloromethane
Methylene chloride
Freon 11
Freon 12
Ethylene dibromide
Trichloroethane
Dichloroethane
Trifluorotrichloroethane
DBCP
Tetrachloroethylene
Trichloroethylene
Dichloroethylene
Vinylidene chloride
Vinyl chloride
Sodium fluoroacetate

APPENDIX L-2

Organic Compounds that have been Reported in the Literature to be Adsorbable on Granular Activated Carbon

A-camphanone
Acetone
Acetophenone
Acetylene dichloride
Aldrin
Acrylonitrile
Baygon
Benzene
Benzocaine
Benzoic acid
α-BHC
Bis-(2-chloroethyl) ether
Bis-(2-chloroisopropyl) ether
Bromobenzene
Bromochlorobenzene
Bromodichloromethane
Bromoform
Bromophenyl phenyl ether
Butyl benzene
Carbon tetrachloride
Chlorobenzene
Chloro ethyl ether
Chloroform
Chlorohydroxybenzophenone
Chloronitrobenzene
Chloropyridine
2,4 D
DDT

Dibrom
Dibromobenzene
Dibromochloromethane
Dichlorobenzene
1,2-Dichloroethane
Dichloroethyl ether
Dieldrin
Di(2-ethylhexyl) phthalate
Di-isobutyl carbinol
Dimethoxy benzene
Dimethoate
Dimethyl sulfoxide
Di(n-butyl) phthalate
m-Dinitrobenzene
2,4-Dinitrophenol
2,6-Dinitrotoluene
Diquat
Diuon
Docosane
Eicosane
Endo-2-camphanol
Endosulfan
Endrin
2,4,5-T (ester)
Ethyl benzene
2-Ethylhexanol
Exo-2-camphanol

APPENDIX L-3

Gasoline
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachloroethane
Hexadecane
1-Isobromobenyl-4-isopropyl benzene
(1,2 isomer)
Isocyanic acid
Isophorone
Juglone
Kerosene
Lindane
Linuron
Malathion
p-Menth-1-en-8-ol
o-Methoxy phenol
α-methyl benzyl alcohol
Methyl biphenyl
Methyl chloride
2-Methyl-5-ethyl pyridine
Methoxychlor
MS-222
Naphthalene
Nitrobenzene
p-Nitrophenol
Octadecane
Oil (fuel)
Paraquat
Parathion
PCB
Pentachlorobiphenyl
Phenols
Phenylacetic acid
Phenyl ether
Phenyl methyl carbinol
Propionic acid
Propyl benzene
Pyridine
Rotenone
Sevin
Simazine
Strychnine
Styrene
Telodrin
Tetrachlorobenzene
Tetrachlorobiphenyl
Tetrachloroethylene
Tetraline
Toluene
Toxaphene
Triazine
Trichlorobiphenyl
1,1,2-Trichloroethane
3-Trifluoromethyl-4-nitrophenol (TFM)
Xylene