New Jersey Drinking Water Quality Institute

Maximum Contaminant Level Recommendations for Hazardous Contaminants in Drinking Water

March 26, 1987

Submitted to:
New Jersey Department of Environmental Protection

State of New Jersey
DRINKING WATER QUALITY INSTITUTE
DIVISION OF WATER RESOURCES
CN 029
TRENTON, NEW JERSEY 08625

26 March 1987

Commissioner Richard T. Dewling
Department of Environmental Protection
CN 402
Trenton, New Jersey 08625

Dear Commissioner:

I am pleased to submit on behalf of the Institute its recommendations for maximum contaminant levels in drinking water. The processes by which these levels were derived are described in the Institute report presented on the following pages.

We appreciate the diligence and competence of those in the Departments of Health and, especially, Environmental Protection who designed and supervised studies, evaluated information, prepared reports and otherwise provided essential staff services to the Institute.

The variety of chemicals produced and the extent of their use have been increasing remarkably in recent years. The sensitivity of our measurement techniques has been improving. One of the results of these trends is more widespread evidence of low-level contamination of our environment. Some of these chemicals may bring more harm than benefit but no one is empowered to make that a binding judgment. In time the public interest may penetrate the system that decides which chemicals are to be made and delivered to the environment.

As you know better than we do, an element of our environment which is vulnerable, and is of paramount public concern, is the quality of our drinking water supplies. Under the terms of the N.J. Safe Drinking Water Act, the Institute is directed to recommend to you maximum contaminant levels for chemicals listed in the law.

Available knowledge of the effect of these chemicals upon human health is incomplete. For many of the chemicals we seek to regulate there probably is no level below which they are harmless. We have observed the statutory criteria, considered the most current and best health-effects information, determined analytical sensitivities, and evaluated existing water treatment technologies. From this review we have developed health-based numbers, practical quantitation levels, and maximum contaminant levels. Generally our MCL values are more conservative than those proposed by the EPA. In some cases, the recommended MCL is considerably higher than the health-based number, reflecting analytical limitations. We decided that in an enforceable regulation persons cannot be held to a performance standard that cannot reliably be measured in our best laboratories. As sensitivity improves, the MCL should be lowered in these cases.

In the course of our work, we have been assured that usable, costly treatment techniques exist to remove these contaminants to concentrations below the recommended levels. The application of treatment where it is needed should bring these contaminant levels as close as possible to the goal of zero.

Institute members hope that these recommendations will assist you in the difficult task of preparing the necessary regulations.

We intend to submit at a later date recommendations concerning chemicals not listed in the statute, the conduct of the safe drinking water program, and needed changes in the law.

Sincerely,

Richard J. Sullivan
Chairman

RJS:jeb

PREFACE

The New Jersey Drinking Water Quality Institute (Institute) is a fifteen member body created by the amendments to the New Jersey Safe Drinking Water Act ("Act") (N.J.S.A. 58:12A-1 et seq., P.L. 1977, c.224, as amended and supplemented by P.L. 1983, c.443). Six members serve ex officio and include representatives of the New Jersey Department of Environmental Protection, the New Jersey Department of Health, and the Water Supply Advisory Council. Nine members are appointed, three by the Speaker of the General Assembly, three by the President of the Senate, and three by the Governor, and represent major water purveyors, the academic scientific community, and the public.

This document presents the Institute recommendations for maximum contaminant levels to the Commissioner of the Department of Environmental Protection for a list of twenty-two hazardous contaminants listed in the amendments to the Act. This completes one of the tasks of the Institute. Future activities of the Institute include the development of a list of contaminants for which testing will be required.

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ACKNOWLEDGEMENTS

The New Jersey Drinking Water Quality Institute (Institute) would like to acknowledge the active participation and technical support of the New Jersey Department of Environmental Protection (NJDEP) and New Jersey Department of Health (NJDOH) personnel in the development of the Institute's recommendations.

The Institute would like to recognize the following NJDEP personnel who prepared this document: Leslie McGeorge, Deputy Director, Office of Science and Research; Sandra Krietzman, Principal Environmental Specialist, Bureau of Safe Drinking Water, Division of Water Resources; Jeff Oxenford, Research Scientist, Office of Science and Research; Robert Hazen, Manager of the Risk Assessment Unit, Office of Science and Research; and the staff of the Risk Assessment Unit, Office of Science and Research.

Significant contributions were made by several other NJDEP staff. The Health-based Support Documents, included in this report as appendices, were written by Debra A. Berger, Lubow Jowa, Gloria B. Post, Paul A. Richter, Alfred J. Sargente, and Stephen Shiboski, of the Office of Science and Research staff. The treatment report was prepared by Paul Schorr and Vincent Monaco of the Bureau of Safe Drinking Water, Division of Water Resources. Barker Hamill, Bureau Chief, Bureau of Safe Drinking Water and William Whipple, Assistant Director, Water Supply and Watershed Management Element of the Division of Water Resources are also acknowledged for their significant contributions to the work of the Drinking Water Quality Institute, as well as Steve Jenniss, Jerry Fagliano and Kathleen Cunningham of the NJDOH. This document and the appendices were typed by Sarah Royce and Michelle Gaston of the Bureau of Safe Drinking Water, and Karen Funari and Theresa Raymond of the Office of Science and Research.

EXECUTIVE SUMMARY

Overview

Over the past ten to fifteen years, the vulnerability of our nation's potable water supplies to organic pollutant contamination has become increasingly evident through a variety of drinking water quality evaluation surveys and reports of specific contamination cases. Volatile organic chemicals (VOCs) have received particular attention due to their potential adverse health effects, their potential to contaminate groundwater supplies, and the relative ease of analytical detection of these substances. Concern has also centered around certain chlorinated organics such as polychlorinated biphenyls and chlorinated pesticides, primarily due to their persistence in the environment and their toxicity.

In the past, a number of New Jersey potable water supplies have been demonstrated to be contaminated with generally low levels of VOCs and chlorinated organic contaminants. The State Safe Drinking Water Act (P.L.1983, c.443) was amended in 1984 (A-280 amendments) to assure that all New Jersey public community water supplies would be monitored on a routine basis for a specified list of twenty-two VOCs and chlorinated organics, many of which are among the most commonly detected organic contaminants in drinking water. The comprehensive nature of the New Jersey A-280 monitoring requirements is more extensive than those of any other known state or federal drinking water programs.

The A-280 amendments also mandate the establishment of maximum contaminant levels (MCLs) for the twenty-two specified contaminants. Additional hazardous contaminants are to be evaluated for possible inclusion by regulation in the A-280 monitoring and standard setting process. Maximum contaminant levels are to be set for carcinogenic contaminants at levels which would lead to the development of cancer in no more than one in one million persons ingesting the contaminant over a lifetime, within the limits of medical, scientific and technological feasibility. The MCLs for noncarcinogens are to be established, within the limits of practicability and feasibility, at levels which eliminate all adverse physiological effects following ingestion. Additional statuatory guidance regarding the state MCLs is that in no case shall the New Jersey standards be any less stringent than corresponding federal standards, and standards need not be established for any hazardous contaminant until the presence of the substance has been detected by tests required by the A-280 amendments. The owner or operator of each water system, upon receipt of test results that confirm that an MCL has been violated, must bring the water into compliance with the MCL within a year. The U.S. Environmental Protection Agency has proposed but not yet adopted standards for eight of the A-280 contaminants.

The amendments established the New Jersey Drinking Water Quality Institute (Institute) to provide external input into the

overall A-280 program, the specific generation of maximum contaminant levels, and the selection of additional contaminants. This Institute consists of 15 members from the public, the academic community, the state's water purveyors, and two state agencies. A listing of Institute representatives is provided in Appendix A. This report summarizes the initial set of recommendations from the Institute to the Commissioner of the New Jersey Department of Environmental Protection. These recommendations are centered around the activities undertaken by the Institute to establish MCLs for the initial list of contaminants.

To derive the MCLs, the Institute evaluated three key elements: health effects, analytical methodologies and their reliability, and water treatment capabilities. Adverse health effects were evaluated initially by categorizing the contaminants according to the level of evidence of human carcinogenicity. Quantitative risk assessments were then conducted based on selected sensitive health endpoints to establish health-based levels in drinking water. Standard analytical methods available for 16 of the 22 compounds were evaluated through laboratory studies and an examination of available U.S. Environmental Protection Agency data. Based upon a review of the detection and quantitation information provided, practical quantitation levels were developed. Practical quantitation levels are concentrations at which quantitation can be achieved within defined limits of uncertainty. Two treatment technologies, air stripping and granular activated carbon contacting, were also investigated for the 16 contaminants. The Institute determined that it was technologically feasible and practicable to remove these A-280 organics from drinking water.

Recommendations

Based upon the deliberations of the Institute members, specific recommendations for the A-280 program have been developed and are presented in the accompanying document. The following list is intended to highlight the most significant recommendations:

1. Institute recommended MCLs for lifetime exposure to contaminants in potable water are:

Contaminant	MCL (ug/l)
1) Benzene	1
2) Carbon Tetrachloride	2
3) Chlordane	0.5
4) Chlorobenzene	4
5) o-Dichlorobenzene	600
m-Dichlorobenzene	600
p-Dichlorobenzene	6
6) 1,2-Dichloroethane	2
7) 1,1-Dichloroethylene	2
8) cis-and trans-1,2-Dichloroethylene	10

9)	Methylene Chloride	2
10)	Polychlorinated Biphenyls	0.5
11)	Tetrachloroethylene	1
12)	Trichlorobenzenes	8
13)	1,1,1-Trichloroethane	26
14)	Trichloroethylene	1
15)	Vinyl Chloride	5
16)	Xylenes	44

MCLs could not be established for the following contaminants specified in the A-280 amendments because of the lack of current standardized analytical methodology: ethylene glycol, formaldehyde, n-hexane, kerosene, and methyl ethyl ketone.

2. The Institute recognizes that the toxicological database for these chemicals is a constantly evolving set of information, and that new advances in analytical methodologies for the detection of organics in potable water may occur in the future. Maximum contaminant levels were set for some chemicals at concentrations above the health-based goals. Such MCLs were established at the lowest reliable quantitation levels based on presently available methodologies. For these reasons, it is recommended that the Institute re-evaluate the MCLs at least every three years to reflect the most current technical information.

3. In addition to reporting values at or above the practical quantitation levels determined by the Institute, the levels at which quantitation can be achieved with acceptable uncertainty, laboratories should be required to report any level of contamination between the practical quantitation levels and the individual laboratory's method detection limits (MDL). These results should be qualified as estimated values. This reporting is of particular importance for chemicals for which the health-based goal is below the practical quantitation level.

4. A standardized procedure should be identified for the determination of MDLs by all A-280 laboratories. Laboratories should be required to determine MDLs for each instrument at a set frequency.

5. Due in part to the fact that kerosene is actually a mixture of a variety of hydrocarbon compounds, the Institute recommends that kerosene be removed from the original list of 22 contaminants. An MCL for one component of kerosene, benzene, has been recommended.

LIST OF ABBREVIATIONS

A-280 - Assembly Bill 280 (1984 Amendments to the New Jersey Safe Drinking Water Act, N.J.S.A. 58:12A-1 *et seq*. (P.L. 1983, c.443)

ACS - American Chemical Society

ADI - Acceptable Daily Intake

BSDW - Bureau of Safe Drinking Water

GC - Gas Chromatography

GC/MS - Gas Chromatography/Mass Spectrometry

kg - kilogram

LOAEL - Lowest Observed Adverse Effect Level

MCL - Maximum Contaminant Level

MDL - Method Detection Limit

mg - milligram

NJDEP - New Jersey Department of Enviromental Protection

NJDOH - New Jersey Department of Health

NOAEL - No Observed Adverse Effect Level

OSR - Office of Science and Research

PCWS - Public Community Water Supply (i.e. a water supply that serves more than 25 people or 15 service connections on a year-round basis).

PCB - Polychlorinated Biphenyl

ppb - Part Per Billion (equivalent to ug/l in water)

PQL - Practical Quantitation Level

QC - Quality Control

RUDES - Rutgers University Department of Environmental Science

U.S.EPA - United States Environmental Protection Agency

VOC - Volatile Organic Chemical

2a List - The list of 22 hazardous contaminants contained in

Section 2.a. of the 1984 Amendments to the N.J. Safe Drinking Water Act, A-280.

2b List - A list of hazardous contaminants to be developed in accordance with Section 2.b. of the 1984 Amendments to the N.J. Safe Drinking Water Act.

ug - microgram

I. INTRODUCTION

A. Background

Throughout the 1970s and early 1980s, concern over the possible contamination of potable water supplies was heightened as a result of numerous reports on the detection of a variety of potentially toxic organic pollutants in the nation's water supplies. In 1976, the U.S. Environmental Protection Agency (U.S.EPA) released a compilation of data revealing that more than 1,200 organic compounds had been found in a variety of water types worldwide (Shackelford and Keith, 1976). As of 1984, Stacha and Pontices reported that more than 700 organic contaminants had been specifically identified in U.S. drinking water supplies.

Although a broad array of organic contaminants have been detected in potable water supplies, attention has been directed toward volatile organic chemicals (VOCs), due to their potential health risks, their potential for groundwater contamination and the fact that many drinking water surveys have been targeted to the analysis of this type of contaminant (Shackelford and Cline, 1986). Volatile organics are a class of synthetic chemicals with low molecular weights. Such commonly known solvents and raw materials as trichloroethylene, benzene and vinyl chloride are examples of volatile organic substances. Analyses of groundwater supplies throughout the nation (U.S.EPA Groundwater Supply Survey 1980 - 1981, Westrick et al., 1983) and in New Jersey (Tucker, 1981) have demonstrated the vulnerability of a significant number of supplies to contamination with generally low levels of volatile organic pollutants.

As a result of findings such as these, the federal government began its lengthy efforts to set standards, or maximum contaminant levels (MCLs), for volatile organics in drinking water. The first federal announcement of an intent to regulate these contaminants came in 1982, with a U.S.EPA Advanced Notice of Proposed Rulemaking for volatile organics (U.S.EPA, 1982). This initial notice was only a first step in a very time-consuming process to set MCLs, and was restricted to a small group of 13 volatile contaminants. Five years later, as of the beginning of 1987, this U.S.EPA process has not yet resulted in the setting of an MCL for any volatile organic compound in drinking water.

B. A-280 Amendments

Due, in part, to the lack of standard-setting activity on the federal level, and in the wake of numerous reported detections of organic pollutants in New Jersey water supplies (Tucker, 1981 and Division of Water Resources, Bureau of Safe Drinking Water historical data files), the legislature adopted and the Governor signed into law amendments to the State Safe Drinking Water Act in 1984. These amendments, commonly referred to as "A-280" (P.L.1983, c.443), mandated the periodic testing of delivered water at public community water supplies (PCWS) for a specified

list primarily of volatile organic hazardous contaminants. Monitoring for A-280 contaminants on a semi-annual basis has now been required of New Jersey PCWS since early 1985. A comprehensive report on the initial round of sampling results was released in 1986 (NJDEP, 1986b).

Also required by A-280, was the adoption of MCLs by the Commissioner of the Department of Environmental Protection for each of the specified contaminants. The list of 22 compounds (plus isomers) for which MCLs are to be established is provided in Table 1. This group of chemicals has been referred to as the "2a" list because of its location in Section 2.a. of the amendments. All of the contaminants on this list are volatile organics with the exceptions of chlordane, kerosene, ethylene glycol, and polychlorinated biphenyls (PCBs). Most of the volatile organics selected by the Legislature had previously been detected in New Jersey potable water supplies, and as well the nonvolatile compounds, chlordane and PCBs (Tucker, 1981). The A-280 amendments also call for the future adoption of an additional list of hazardous contaminants (referred to as the "2b" list) which is to include pesticides, other synthetic organics and metals, and the setting of MCLS for these.

Table 1
A-280 2a Contaminants List

1. Benzene
2. Carbon Tetrachloride
3. Chlordane
4. Chlorobenzene
5. Dichlorobenzene(s)
6. 1,2-Dichloroethane
7. 1,1-Dichloroethylene
8. cis-1,2-Dichloroethylene
9. trans-1,2-Dichloroethylene
10. Ethylene Glycol
11. Formaldehyde
12. n-Hexane
13. Kerosene
14. Methyl Ethyl Ketone
15. Methylene Chloride
16. Polychlorinated Biphenyls (PCBs)
17. Tetrachloroethylene
18. Trichlorobenzene(s)
19. 1,1,1 - Trichloroethane
20. Trichloroethylene
21. Vinyl Chloride
22. Xylene(s)

C. Drinking Water Quality Institute

In order to provide external recommendations to the Commissioner of the New Jersey Department of Environmental Protection (NJDEP) on various aspects of the A-280 program, the amendments established an advisory group in the NJDEP called the Drinking Water Quality Institute (Institute). The Institute was charged with providing recommendations for the following: development of the MCLs, development of the 2b contaminants list, development of appropriate analytical testing methodologies, and review of general NJDEP activities related to the safe drinking water program. The amendments provided the Institute with the technical services of the state agencies (including NJDEP and N.J. Department of Health (NJDOH)) and other commissions or agencies.

As provided by the statute, the Institute is comprised of 15 members, 6 of whom are ex officio representatives of NJDEP, NJDOH, and the Water Supply Advisory Council, and 9 of whom are appointed representatives of the water purveyors, the academic scientific community, and the public. Members serving in appointed positions are to be selected by the Governor, President of the Senate and Speaker of the General Assembly. Following this procedure, all initial members were appointed to the Institute by January, 1985. A complete listing of current Institute members is given in Appendix A.

The first meeting of the Institute was held in March of 1985 and meetings of this advisory body have generally followed a regular monthly schedule. Subsequent to the initial meeting, three Subcommittees were formed to effectively carry out the mandates of the Institute in a timely manner. The work of the Subcommittees revolved around the need to develop information in three critical areas for MCL derivation: health effects, analytical quantitation limits, and water treatment capabilities.

The three Subcommittees and their responsibilities are:

1) Lists and Levels - development of health-based maximum contaminant levels and a 2b list of additional hazardous contaminants

2) Testing - development of appropriate analytical techniques, reliable quantitation limits, and frequencies of testing.

3) NJDEP Program - review of NJDEP activities undertaken in accordance with the Safe Drinking Water Act, and consideration of water treatment issues.

All Institute meetings are open to the public. Technical support has been provided to the Institute by representatives of the NJDEP Office of Science and Research (OSR) and Bureau of Safe Drinking Water (BSDW), and the NJDOH. As described later in this document, NJDEP personnel also frequently provided the Institute with detailed results of a number of external research evaluations related to the establishment of the MCLs.

D. Document Content and Organization

This document presents the product of the deliberations of the Drinking Water Quality Institute, and conveys the Institute's initial recommendations to the NJDEP Commissioner. It is anticipated that these recommendations will serve as the main technical support for NJDEP's regulations pursuant to the A-280 amendments. The document is organized according to the activities of the three Subcommittees: health-based considerations, analytical considerations, and treatment considerations. The resultant derivation and application of MCLs follows these sections, and the document concludes with additional recommendations of the Institute. Additional detailed technical reports and evaluations are presented for reference in the appendices.

II. HEALTH EFFECTS CONSIDERATIONS FOR MCL DERIVATION

A. Requirements Under A-280

The A-280 amendments to the New Jersey Safe Drinking Water Act require health effects considerations in the establishment of maximum contaminant levels for each of 22 organic compounds (plus isomers). Health effects are considered for the purposes of risk assessment either as cancer or other adverse physiological effects. The A-280 amendments state that within certain feasibility limits, the maximum contaminant levels for carcinogens, other than those resulting from compounds with public health benefits (e.g. disinfecting agents), shall permit cancer in no more than one in one million persons ingesting that chemical for a lifetime. The MCLs for noncarcinogens, and those carcinogens resulting from compounds with public health benefits, shall eliminate within the limits of practicability and feasibility, all adverse physiological effects which may result from ingestion.

B. The Risk Assessment Process

1. Background

Health-based MCLs were developed by conducting risk assessments on the 22 compounds (including isomers) specified in the A-280 amendments. The risk assessment methodology followed generally accepted procedures including those recommended by U.S.EPA (1984c, 1985d, 1986), as well as those recommended by risk assessment experts associated with other government agencies, scientific institutions, and environmental consulting firms.

Chemicals were first classified as carcinogens or noncarcinogens for the purposes of risk assessment according to the U.S.EPA proposed categorization for carcinogens (U.S.EPA, 1985d). U.S.EPA has categorized chemicals according to the weight of evidence for human carcinogenicity in Groups A thru E as shown and defined in Table 2. Risk assessments were performed using the three category approach for setting recommended MCLs as described in U.S.EPA, 1985d.

Category I includes Groups A and B, Category II includes Group C, and Category III includes Groups D and E. Category I includes those chemicals which are known or probable human carcinogens with strong evidence of carcinogenicity. Risk assessments for these chemicals were based on carcinogenic effects. Those chemicals in Category II with equivocal evidence of carcinogenicity were treated as noncarcinogens with an additional uncertainty factor of 10 to account for their unclear carcinogenicity status (U.S.EPA, 1985d). Category III chemicals were considered noncarcinogens because of either inadequate or no evidence of carcinogenicity.

Table 2

U.S.EPA Categorization of Weight of Evidence for Human Carcinogenicity*

Group A: Human carcinogen -
Sufficient evidence from human epidemiological studies.

Group B: Probable human carcinogen -
Group B1: Limited evidence from human epidemiological studies.

Group B2: Sufficient evidence from animal studies and inadequate or no data from human epidemiological studies.

Group C: Possible human carcinogen -
Limited evidence of carcinogenicity from animal studies in the absence of human data.

Group D: Not classifiable as to human carcinogenicity -
Inadequate human and animal evidence for carcinogenicity or no data available.

Group E: Evidence of noncarcinogenicity for humans -
No evidence for carcinogenicity in at least two adequate animal tests or in both adequate human epidemiological and animal studies.

* (based on U.S.EPA, 1986)

Studies used in quantitative risk assessment were chosen to represent, as closely as possible, the human exposure conditions of interest. Therefore, studies in which animals were exposed by an oral route were preferred to those where exposure was by an inhalation route. Long term exposures were preferred over short term exposures because effects occurring with lifetime exposure are pertinent for the MCL development under A-280.

One of either two general risk assessment procedures was used depending on the carcinogenicity classification of the chemical. These are discussed in detail below.

2. Noncarcinogens

Health-based risk assessments for noncarcinogens (Categories II and III) were performed to develop health-based maximum contaminant levels (MCLs) at which no adverse physiological effects would be expected to result from lifetime exposure. Risk assessments for noncarcinogens were based on the assumption that a threshold for such effects exists, below which such effects should not occur.

The process involved in developing health-based MCLs for noncarcinogens is outlined in Table 3. The first step involved review of the scientific literature and evaluation of all human and animal studies in which adverse effects related to exposure were reported. All noncarcinogen health-based risk assessments were based on studies in experimental animals with the exception of methyl ethyl ketone, which was based on effects observed in humans. The study most appropriate for risk assessment was chosen after considering the route of exposure, the duration of exposure, and the dose at which adverse effects were observed.

As mentioned previously, the oral route is preferable for extrapolation to human drinking water exposure. When no adequate oral study was reported, studies using inhalation exposure were considered. Studies in which the compound was administered by injection were not considered appropriate for risk assessment.

Chronic exposure studies (greater than 10% of the lifespan, or approximately three to six months in rodents, Chan et al., 1984) were preferable to subchronic studies (less than 10% of the lifespan). Studies evaluating effects of acute exposure were not considered appropriate for health-based MCL development.

In cases where a number of equally valid studies demonstrated adverse effects at different levels of exposure, the highest level at which no adverse effects were observed (NOAEL) which did not exceed any known lowest observed adverse effect level (LOAEL) was chosen. If no NOAEL had been demonstrated, the lowest reported LOAEL was used.

The dose to the experimental animals in mg/kg per day at the NOAEL (or LOAEL) of interest was then calculated. Specific

Table 3

Steps in Noncarcinogen Health-Based Level Development*

1. Select most appropriate study and endpoint.
2. Determine NOAEL (LOAEL).
3. Calculate dose to experimental animals in mg/kg per day.
4. Calculate human ADI by applying appropriate uncertainty factors.
5. Calculate drinking water health-based MCL using assumptions for human exposure.

*(see text for details)

calculations for each noncarcinogen can be found in Appendix B. For exposure by gavage, the administration of a dose of test chemical to experimental animals by a tube inserted into the animal's stomach, 100% absorption was assumed. For exposure in the food or drinking water, the dose in mg/kg was calculated from food or water consumption data, if given, or from standard assumptions for these parameters. For inhalation exposure, the dose to the experimental animals in mg/kg per day generally was calculated from the air concentration (mg/m^3), breathing rate (m^3 /day), and pulmonary absorption factor as described by Anderson et al., 1983. A conservative estimate for the pulmonary absorption fraction was used, based on available experimental data for the compound. For one chemical (1,1,1-trichloroethane), this method for dose conversion was not appropriate because inhalation exposure was continuous and saturation occurred. In this case, a pharmacokinetic model was used to estimate the dose to animals in mg/kg per day. For all dose calculations, if weights of the experimental animals were not reported, rats were assumed to weigh 0.35 kg and mice 0.03 kg (Anderson et al., 1983).

The next step in noncarcinogen health-based MCL development involved calculation of an ADI (acceptable daily intake) to humans by applying appropriate uncertainty factors to the animal dose in mg/kg per day. The application of uncertainty factors generally followed the recommendations of Dourson and Stara (1983), as shown in Table 4.

Finally, the health-based MCL was calculated from the ADI by assuming that an average adult male consumes two liters of water per day and weighs 70 kg. An exception to this assumption was made for one compound, xylene, for which the risk assessment was based on effects due to exposure during pregnancy. In this case, the average weight of an adult female, 60 kg, was used. It was further assumed that only 20% of the daily exposure to the compounds would come from drinking water and that the remaining 80% of exposure would result from other sources such as air and food (U.S.EPA, 1985d).

3. Carcinogens

Carcinogen risk assessments are based on the assumption that no threshold exists for carcinogenesis. This means that there is some risk of cancer following exposure to any dose of a carcinogen. Risk assessments for carcinogens (U.S.EPA Group I) were conducted in a manner consistent with the recommendations of the Carcinogen Assessment Group of U.S.EPA (Anderson et al., 1983; U.S.EPA, 1986). As required by the A-280 amendments, the health-based MCL is based on the level of a compound expected to result in no more than a one in one million lifetime additional cancer risk.

One in one million represents an extremely small lifetime additional cancer risk, and an increased incidence of this magnitude is not measurable in a population by epidemiological

Table 4

Uncertainty Factors Used in ADI Development

Factor	Application
10	To account for variation in sensitivity between members of a species. Used for extrapolation from human and animal studies.
10	To account for variations in sensitivity between different species. Used for extrapolation from chronic animal studies.
10	To account for less than chronic exposure. Used for extrapolation from subchronic studies.
1 - 10	To estimate a NOAEL from a LOAEL. Factor may vary depending on sensitivity of effect.
10	For compounds with equivocal evidence for carcinogenicity (U.S.EPA, 1985d). Used for Category II compounds.
1 - 10	Additional factor to account for uncertainties not addressed elsewhere may be applied when appropriate (eg. inadequacies in study, small number of animals/group).

techniques. To put this risk in perspective, the current lifetime cancer incidence in the U.S. is approximately one in three individuals (American Cancer Society, 1985). Therefore, an additional lifetime risk of one in one million will not measurably increase the total cancer incidence.

Mathematical models developed for the extrapolation of risks at very low doses from effects observed at the high doses used experimentally were employed as discussed below. The risk assessments were based on animal bioassay data for all compounds except benzene, which was based on human data.

Mathematical modeling was performed by K.S. Crump and Co. on animal bioassay and epidemiological data provided by the OSR Risk Assessment Unit (K.S. Crump, 1986a; 1986b). The study and endpoint most appropriate for risk assessment was selected based on design and conduct of the study, duration of exposure, and route of administration (oral preferable to inhalation, discussed previously). When more than one otherwise equally appropriate study or tumor type was reported, the most sensitive endpoint was chosen for MCL development. The incidence of benign and malignant tumors was considered in accordance with recent U.S.EPA Guidelines for Carcinogen Risk Assessment (1986).

The multistage model for high to low dose extrapolation was used for all risk assessments based on animal bioassays, with the exception of carbon tetrachloride. For carbon tetrachloride, the multistage-Weibull model was employed to adjust for premature mortality of the animals in the study selected for risk assessment (K.S. Crump, 1986a). For benzene, the relative risk model was applied to human epidemiological data (K.S. Crump, 1986b).

In calculating the doses to the experimental animals, conversions to mg/kg per day from inhalation exposure or exposure in the diet were performed as discussed for noncarcinogens above. Doses were adjusted when necessary for less than daily exposure frequency, less than lifetime exposure period, or early termination of experiment, as described in K.S. Crump, 1986. Assumptions for the weights of experimental animals were as previously described in the noncarcinogens section.

The dose to the experimental animal which would result in a lifetime extra risk of one in one million was extrapolated from the adjusted experimental dose with the multistage (or multistage-Weibull model). The conversion to the equivalent human dose was then made on an equivalent surface area basis. It was assumed that humans and animals are equally susceptible to the compound's carcinogenic effects.

The health-based MCL for drinking water was calculated from the 95% lower confidence limit on the dose projected to result in an extra risk of cancer of one in one million. Assumptions for daily human water consumption and average human weight were the same as for the noncarcinogens.

4. Uncertainties

Uncertainty is inherent in the risk assessment process, since risk assessment is utilized to predict health effects in humans at very low dose levels based upon toxicity observed mainly in experimental animals exposed under different conditions and usually at much higher doses. Two of the major contributions to uncertainty are the use of an animal model to predict human response, and the use of effects observed at high doses to predict responses at low levels encountered in the environment.

Differences in sensitivity to toxic effects between humans and experimental animals may arise from differences in metabolism, target site for toxicity, susceptibility of target site to disease, immunological response, hormonal status, and dietary factors.

The multistage model was used for carcinogens to estimate responses outside of the range which can be practically determined experimentally. This high-to-low dose extrapolation involves uncertainty which increases as the difference between the doses in the range of observation and predicted risk becomes greater. For noncarcinogens, the application of uncertainty factors results in health-based MCLs which are several orders of magnitude lower than the levels at which adverse effects are observed in experimental animals.

Other sources of uncertainty in the risk assessment process arise from variability in sensitivity among the human population resulting from genetic and environmental factors, extrapolation between different routes and time courses of exposure, and assumptions regarding the potential for human environmental exposure to the compound of interest (e.g. drinking water consumption).

A conservative approach was used in all aspects of the risk assessment process for both carcinogens and noncarcinogens, as discussed below. Therefore, the risk assessment procedures and assumptions are more likely to overestimate, rather than underestimate, the potential adverse effects of the compounds. This is a prudent approach since our knowledge of the potential effects of exposure to low levels of toxic chemicals is not complete. Humans were considered to be as sensitive as the most sensitive animal species tested, and the risk assessment was based on the most sensitive toxic endpoint reported (adverse physiological effect or carcinogenicity). Conservative assumptions were used for such parameters as pulmonary and gastrointestional absorption factors in experimental animals, human drinking water consumption, and fraction of total human exposures arising from drinking water.

High-to-low dose extrapolations for carcinogens and noncarcinogens were performed in a conservative manner. For

noncarcinogens, the application of safety factors resulted in health-based MCLs expected to be below the threshold for adverse effects for the most sensitive exposed individuals. For carcinogens, the multistage model was chosen for low-dose extrapolation, because it currently has the strongest scientific basis of any existing model (U.S.EPA, 1985a). The multistage model is conservative because it predicts a linear, nonthreshold, dose-response curve at low doses. Further conservatism is incorporated into the carcinogen risk assessment by using the 95% lower confidence limit on the dose giving one in one million risk, rather than the maximum likelihood estimate of the dose, for health-based MCL development. Therefore, one in one million is the plausible upper limit on risk from lifetime exposure at the health-based MCL. In other words, the risk at the health-based level is likely to actually be less than one in one million.

C. Health-Based MCL Support Document Development and Review

The Risk Assessment Unit in the Office of Science and Research had primary responsibility for development and preparation of Support Documents which present the background for, and calculation of the health-based MCL for each compound. Valuable input was also received from NJDOH personnel and members of the Drinking Water Quality Institute Lists and Levels Subcommittee in the review of these documents. OSR's Risk Assessment Unit staff contributing to this project included seven individuals with advanced degrees in toxicology, epidemiology, and statistics. Contracts were initiated with consultants by the staff to augment their own expertise and accelerate the data gathering process. The stages in the process of MCL development and review are summarized below.

An initial review of the relevant toxicologic literature for each compound was provided to the Office of Science and Research by ICAIR Life Systems Inc. (1985) in a report entitled "Assessment of Candidate Studies for Derivation of MCL Values for 22 Selected Drinking Water Contaminants". In addition to a literature review, the consultants performed a preliminary risk assessment to suggest a health-based MCL for each contaminant and recommended the most appropriate study and endpoint. They also provided copies of primary literature cited to the Office of Science and Research. The report was a useful preliminary review of previous work, and provided the foundation for further work.

For each chemical, the OSR Risk Assessment Unit staff performed a complete review of the relevant scientific literature independent of that done by ICAIR. The Support Documents are based on the literature published through July 1986, although more recently published information was considered in some instances. Contacts were maintained with knowledgeable individuals within the U.S.EPA's Office of Drinking Water, Carcinogen Assessment Group, and Office of Research and Development; the National Toxicology Program; and the National Academy of Sciences, as well as

researchers in industry and academia, to obtain information not available in the published scientific literature.

For all compounds, the choice of the most appropriate study and endpoint for health-based MCL development was made by the staff of the Risk Assessment Unit. For noncarcinogens, the quantitative risk assessments were carried out by Risk Assessment Unit staff. Most of the quantitative risk assessments for the compounds treated as carcinogens were performed by K.S. Crump and Company Inc. (1986a, 1986b), based on animal bioassay and human epidemiological data provided by the Office of Science and Research. In a few cases, quantitative risk assessments for carcinogens were performed by the Risk Assessment Unit when additional data became available. For each compound, K.S. Crump and Company carried out risk assessments based on several different studies and endpoints. The most appropriate risk assessment for MCL development was selected by the OSR staff.

The documents were presented to the Lists and Levels Subcommittee of the Drinking Water Quality Institute between January and July, 1986. After incorporation of the Subcommittee's comments and changes, the documents were accepted and transmitted to the full Drinking Water Quality Institute.

At this time, the documents were submitted to ICF Clement Associates, a consulting firm highly qualified in the area of risk assessment, for peer review. ICF Clement provided comment on the accuracy of information, appropriateness of study chosen for risk assessment, and risk assessment methodology on each individual Support Document and in a final report (ICF Clement, 1986). The documents were revised to incorporate the peer review comments as appropriate.

Additional comments were also received from consultants retained by the water supply industry on trichloroethylene, tetrachloroethylene and 1,2-dichloroethane (Environmental Medicine, Inc., 1986; Calabrese, 1986). These comments discussed some of the areas of controversy regarding the risk assessment for these chemicals and were reviewed by the Risk Assessment Unit, OSR and NJDOH.

After consideration of further comments submitted by the New Jersey Department of Health, the documents were modified and adopted in final form by the Lists and Levels Subcommittee in December 1986. Several specific issues will be mentioned in the introduction to the proposed Regulations in order to request public comment on areas of uncertainty.

D. Summary of Health-Based MCLs

Table 5 shows selected elements of the MCL risk assessments presented in detail as individual Support Documents in Appendix B. Health-based MCLs range from 0.013 ug/l for chlordane to 600 ug/l for ortho- and meta-dichlorobenzene. Eleven chemicals were

Table 5

Summary of Risk Assessments for Health-based MCL Development

Chemicals	Carcinogenicity Category*	Basis for Risk Assessment: Approach	Basis for Risk Assessment: Endpoint**	Health-based MCL (micrograms per liter)
Benzene	I	Relative Risk	Human Leukemia	0.15
Carbon tetrachloride	I	Multistage Weibull	Hepatocellular Carcinoma	0.39
Chlordane	I	Multistage	Hepatocellular Adenoma	0.013
p-Dichlorobenzene	I	Multistage	Renal Adenocarcinoma	6.1
1,2-Dichloroethane	I	Multistage	Hemangiosarcoma	0.29
Formaldehyde	I	Multistage	Nasal Squamous Cell Carcinoma	0.65
Methylene Chloride	I	Multistage	Hepatocellular Carcinoma and Adenoma	2.5
PCBs	I	Multistage	Hepatocellular Carcinoma	0.024
Tetrachloroethylene	I	Multistage	Hepatocellular Carcinoma	0.44
Trichloroethylene	I	Multistage	Hepatocellular Carcinoma and Adenoma	1.2
Vinyl Chloride	I	Multistage	Hepatocellular Carcinoma	0.084
Chlorobenzene	II	NOAEL	Liver Toxicity	4.6
1,1-Dichloroethylene	II	LOAEL	Liver Toxicity	1.0
o-Dichlorobenzene	III	LOAEL	Kidney Toxicity	600
m-Dichlorobenzene	III	LOAEL	Kidney Toxicity	600
cis-1,2-Dichloroethylene	III	LOAEL	Liver Toxicity	10
trans-1,2-Dichloroethylene	III	LOAEL	Liver Toxicity	10
Ethylene Glycol	III	NOAEL	Kidney toxicity	290
n-Hexane	III	LOAEL	Neural Response Time	33
Kerosene				none
Methyl Ethyl Ketone	III	LOAEL	Human Neuropathy	270
1,2,4-Trichlorobenzene	III	NOAEL	Liver Toxicity	8.6
1,1,1-Trichloroethane	III	LOAEL	Liver Toxicity	26
Xylenes	III	NOAEL	Embryotoxic and Developmental Effects	44

* U.S.EPA, 1985d

** Based on animal data unless otherwise specified.

treated as carcinogens in Category I, and eleven as noncarcinogens in Categories II and III. The predominant target organ for carcinogenic and noncarcinogenic effects was the liver. All risk assessments were based on data from experimental animals except for benzene and methyl ethyl ketone which were based on effects in humans.

No health-based MCL for kerosene is recommended at this time, because not enough relevant scientific information is currently available to allow for MCL development for this complex mixture. However, recommendations are made regarding the basis of future regulations for specific components of kerosene in the Kerosene Support Document (Appendix B, Section K) of this document. A recommendation that kerosene be removed from the 2a list is made in Section VII of this document.

III. ANALYTICAL CONSIDERATIONS FOR MCL DERIVATION

A. Analytical Methods

Analytical methods to be used for the determination of A-280 organic compounds in potable water samples must be sensitive, rapid, compound specific, commercially available and produce data that are accurate and reproducible. Methods have been developed by the U.S.EPA that satisfy these characteristics for sixteen of the A-280 compounds.

The current NJDEP "Regulations Governing Laboratory Certification and Standards for Performance," N.J.A.C. 7:18-1.1 et seq., amended in 1984, specify the use of the U.S.EPA "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater", 40 CFR Part 136, for the analysis of A-280 contaminants. These methods, first released in 1979, are commonly referred to as the 600 series methods. While designed for industrial and municipal wastewater matrices, the 600 series methods were used for the analysis of A-280 compounds in drinking water matrices because they represented the best available applicable methods. NJDEP methods currently approved for the analysis of A-280 compounds are listed in Table 6.

In June 1985, the U.S.EPA released "Methods for the Determination of Organic Compounds in Finished Drinking Water and Raw Source Water", commonly referred to as the 500 series methods (U.S.EPA, 1985b). These methods, designed for potable water matrices, are directly applicable to the analysis of many A-280 volatile organic chemicals (VOCs) and are listed as part of Table 10.

No approved NJDEP methods exist for the analysis of formaldehyde, n-hexane, kerosene, ethylene glycol, methyl ethyl ketone and cis-1,2-dichloroethylene in drinking water. Methods are being developed and validated by NJDEP for these compounds (see Section VII).

B. Limits of Detection and Quantitation

Analytical methods must be capable of detecting a compound and then measuring that compound within specified uncertainity limits. The lowest concentration level to which an analyte can be measured by an analytical method with confidence that the analyte concentration is greater than zero is commonly called the method detection limit (MDL). However, accurate and reproducible quantitation may not be achievable at this level. MDLs for a given analytical method may vary among laboratories and instruments, and also may be different from day to day on the same instrument used by the same operator.

In an effort to establish a defined level where instrumentation and daily analytical variations may be controlled to an acceptable standardized degree, the U.S.EPA established a

Table 6
NJDEP Approved Methods for
Analysis of A-280 Compounds

Compound	U.S. EPA Method
Benzene	602, 624
Carbon Tetrachloride	601, 624
Chlordane	608, 625
Chlorobenzene	602, 624
Dichlorobenzenes	601, 602, 625
1,2-Dichloroethane	601, 624
1,1-Dichloroethylene	601, 624
cis-1,2-Dichloroethylene	No Method
trans-1,2-Dichloroethylene	601, 624
Ethylene Glycol	No Method
Formaldehyde	No Method
n-Hexane	No Method
Kerosene	No Method
Methylene Chloride	601, 624
Methyl Ethyl Ketone	No Method
PCBs	608, 625
Tetrachloroethylene	601, 624
Trichlorobenzenes	612, 625
1,1,1-Trichloroethane	601, 624
Trichloroethylene	601, 624
Vinyl Chloride	601, 624
Xylenes	602, 503.1, 625

concept which has been termed the practical quantitation level (PQL). The PQL is the level where quantitation can be achieved with acceptable uncertainity among most laboratories.

It would not be possible to regulate a substance accurately at the MDL. The uncertainity of any reported value at the MDL is far too great to serve as an acceptable basis for regulatory action. The PQL, on the other hand, is a limit set above the MDL where confidence can be placed in the value of the results reported.

In the November 13, 1985 Federal Register the U.S.EPA proposed PQLs for nine VOCs. The PQLs were based on an evaluation of results of laboratory performance data from U.S.EPA and external sources, multi-laboratory method validation studies, and laboratory performance evaluation studies. Results of U.S.EPA and State laboratories performance on a series of laboratory performance evaluation studies are given in Table 7.

From the results shown in Table 7, the U.S.EPA determined that most laboratories could achieve acceptable results (within plus or minus 40% of the theoretical true value) for the designated VOCs at a concentration of 5 micrograms per liter (ug/l). Therefore, the agency proposed their PQLs at 5 ug/l for the seven VOCs included in the studies. The U.S. EPA also used a factor of 5 to 10 times the MDLs achieved by the best laboratory to support their conclusion that commercial laboratories could achieve these levels. The PQL for 1,1-dichloroethylene, which was not included in the laboratory performance evaluation studies, was also proposed at 5 ug/l "based upon its similarity in analysis (e.g., same analytical method, similiar chemical structure, and similiar GC retention times) to the VOCs" shown in Table 7 (U.S.EPA, 1985b). The PQL for vinyl chloride, which was also not included in the water pollution studies, was proposed at 1 ug/l with special considerations being placed on its analysis. The value of 1 ug/l for vinyl chloride was determined by multiplying the low end of the MDL range by a factor of 5.

The major limitation of the results presented in Table 7 was that the lowest concentration levels used in the performance evaluation studies were 5 ug/l or above for all compounds except 1,1,1-trichloroethane. Therefore, no data was provided to evaluate the ability of the laboratories to analyze samples at lower concentration levels accurately. The Institute requested that NJDEP investigate the possibility of performing a research study to provide them with information on the accuracy and precision of analyses at these low concentrations to derive MCLs for many of the A-280 compounds.

Table 7
U.S.EPA Results from Water Pollution Studies 8-11
(From U.S.EPA, 1985b)

	TV[1] (ug/l)	No. of labs	No. of labs outside +/- 20% TV	No. of labs outside +/- 40% TV
Benzene	7.10	31	12	6
	9.4	32	5	2
	14.1	28	5	1
	18.8	28	8	4
Carbon Tetrachloride	6.02	31	10	5
	10.5	35	6	2
	12.0	40	12	3
	16.9	37	7	2
1,2-Dichloroethane	6.43	35	11	3
	15.9	29	5	3
	17.1	34	3	0
	19.1	38	7	3
Trichloroethylene	4.99	30	6	3
	8.32	38	8	2
	12.0	36	8	2
	16.8	35	5	2
Tetrachloroethylene	6.08	38	11	5
	11.0	36	4	1
	12.2	30	6	4
1,1,1-Trichloroethane	1.61	39	16	9
	6.42	31	6	3
	7.96	35	8	2
	15.9	35	6	0
p-Dichlorobenzene	5.5	18	5	2
	11.0	18	5	4
	13.7	14	8	1

[1]TV="true" value or reference concentration.

C. Studies to Determine the Analytical Limitations

1. U.S.EPA - Water Supply Performance Evaluation Study #17

In Water Supply Performance Evaluation Study #17 (Gomez-Taylor, 1986), the U.S.EPA sent low level samples of nine VOCs to state and commercial laboratories to evaluate laboratory performance below 5 ug/l. The results of this study, which U.S.EPA released to OSR, indicated that the majority of the laboratories could achieve acceptable quantitation (within plus or minus 40% of the true value) for concentrations of approximately 2 to 5 ug/l for all VOCs included in the study except vinyl chloride. It was assumed that laboratories were using the 600 series methods for this study.

2. Rutgers University, Department of Environmental Sciences - Drinking Water Methods Validation Study

As previously stated, when the A-280 amendments were first passed, the only methods available for the measurement of volatile organic compounds in water were the U.S.EPA 600 series methods. To validate the application of these methods to drinking water and to develop methodologies for compounds without approved methods, a study was initiated by NJDEP with Rutgers University, Department of Environmental Sciences (RUDES). A major portion of this project was to develop MDLs for the A-280 contaminants in drinking water matrices as specified by U.S.EPA in 40 CFR part 136, Appendix B. This work was also to evaluate the effect of increasing the 600 series method's (for VOCs) sample purge volume in order to assess possible improvements in detection limits. The study was subsequently modified to evaluate the 500 series methods when these methods were released by the U.S.EPA. The use of the larger sample purge volume (25 ml versus 5 ml) was maintained. RUDES provided data on their laboratory's MDLs for Methods 502.1, 524.1, and 608. RUDES MDLs are shown in Table 8.

3. NJDEP - Practical Quantitation Level Study

At the request of the Testing Subcommittee a study was initiated by NJDEP with the N.J. A-280 certified laboratory community to evaluate their analytical performance on A-280 contaminants. The study, referred to as the PQL study, was designed to evaluate the precision and accuracy of analysis at low concentration levels of A-280 contaminants by certified laboratories, to give insight on the analytical methods being used, and to provide the information needed to determine the PQLs.

All 33 laboratories certified for A-280 analyses were asked to participate in the PQL study. The laboratories were instructed to analyze samples at 5 concentration levels using the 500 series methods for VOCs and method 608 for extractable compounds. All methods were to be performed exactly as written. At each concentration level, laboratories were required to run four

Table 8
MDLs Reported by Rutgers University
in Drinking Water Matrices (ug/l)

	Method 524.1		Method 502.1[1]		Method 608	
	SW[2]	GW	SW	GW	SW	GW
Benzene	.80	.07				
Carbon Tetrachloride	.22	.21	0.013	0.02		
Chlordane					.141	.054
Chlorobenzene	.50	.21				
1,2-Dichloroethane	.83	.72	.039	.030		
1,1-Dichloroethylene	.37	.34	.035	.053		
C+T-1,2-Dichloroethylene	.86	.18	.028	.026		
n-Hexane	.22	.32				
Methylene Chloride	.45	.81	.022	.015		
Methyl Ethyl Ketone	12.26	8.43				
PCBs (Aroclor 1254)					.131	.173
PCBs (Aroclor 1242)					.189	.185
Tetrachloroethylene	.34	.20	.087	.153		
1,1,1-Trichloroethane	.31	.27	.017	.019		
Trichloroethylene	.60	.28	.035	.047		
Vinyl Chloride	1.51	1.08				
1,4 + 1,2-Xylenes	.75	.22				
1,3-Xylene	.35	.20				

[1]25 ml sample purge volume was used for method 502.1

[2]SW = Surface Water
GW = Ground Water

replicates. The concentration levels chosen ranged from easily quantifiable levels, to levels around the MDLs given in the methods. Results were compared to the known values of the samples to determine accuracy. Precision was determined from the analysis of the replicates and from comparison of the mean values determined by each laboratory.

Along with the results of these samples, the laboratories were also required to report surrogate recoveries from each sample, daily calibration check and quality control (QC) check standards, daily blanks, initial precision and accuracy statements, calibration curves, and the MDLs for each analyte. MDLs were determined as specified by U.S.EPA in 40 CFR Part 136, Appendix B. This supporting documentation was required to allow NJDEP to evaluate the quality of the reported results.

One limitation of the study was that only 6 out of the 33 commercially certified laboratories participated. This low response occurred despite aggressive actions by NJDEP to encourage participation, including: a general certified laboratory meeting to describe the study, numerous letters and follow-up phone conversations with the laboratory personnel, and an offer of payment for a portion of the workload. Although the number of labs participating was low, this study represents a unique evaluation of analytical performance by the certified laboratories which are actually performing the A-280 analyses. This PQL study is far superior to the common reliance on only university or state laboratories to obtain this type of data.

Another limitation of this study was that it was necessary to send out samples to the laboratories in sealed glass ampules at high concentrations. The laboratories were asked to make a series of dilutions from these ampules. Some small errors would be expected to have been introduced during dilution procedures. The samples used were supplied by the U.S.EPA and are the best currently available. A review of the results did not indicate any substantial dilution errors. The samples used were supplied by the U.S.EPA and are the best currently available.

D. Derivation of the PQLs

Two approaches were used to derive the PQLs. Each approach yielded a range where an acceptable PQL could be set. Information from many other sources was used to support the PQLs. A detailed discussion describing how the PQL was determined for each compound is presented in Appendix C which supplements this document.

The first approach to determine the PQLs was to evaluate the results of the PQL study (see Table 9) for the 17 compounds included. Using three parameters calculated from the study data, precision and accuracy were evaluated at each concentration level. Accuracy was expressed as the percent difference between the laboratory determined mean and the true concentration of each sample. Acceptable accuracy was set at an average percent

Table 9
Summary of PQL Study Data

COMPOUND	SAMPLE #	TRUE VALUE (ug/l)	AVG LAB MEAN (ug/l)	AVG %STD REPS*	AVG %DIFF FROM TRUE VALUE**	%STD MEAN ***
VINYL CHLORIDE	1	50.8	55.73	17.99	62.39	80.85
	2	12.72	12.62	7.50	42.99	58.07
	3	5.08	3.94	23.32	34.78	49.48
	4	1.02	0.85	51.77	54.92	65.60
	5	0.2	0.24	26.17	82.70	78.86
TRICHLOROETHYLENE	1	17.5	18.45	9.27	14.78	18.04
	2	4.38	3.70	4.58	19.27	16.07
	3	1.75	1.42	7.25	27.26	34.47
	4	0.35	0.27	21.29	29.21	40.56
	5	0.07	0.04	31.90	64.42	110.29
TETRACHLOROETHYLENE	1	22.6	24.56	11.15	14.27	15.53
	2	5.65	4.95	7.63	18.57	12.37
	3	2.26	1.94	6.80	30.65	31.42
	4	0.45	0.35	19.97	53.21	51.18
	5	0.09	0.07	18.19	68.91	102.04
CHLOROBENZENE	1	15.8	15.77	9.21	16.80	27.77
	2	4	3.10	9.47	29.75	35.31
	3	1.58	1.31	11.85	34.20	47.12
	4	0.32	0.31	40.92	46.77	60.84
	5	0.06	0.10	38.45	165.92	146.88
METHYLENE CHLORIDE	1	9.11	11.03	9.15	24.02	13.76
	2	2.28	2.51	9.73	22.03	20.46
	3	0.91	1.10	12.62	34.58	33.05
	4	0.18	0.45	27.23	147.61	61.27
	5	0.04	0.30	23.97	717.87	74.22
CARBON TETRACHLORIDE	1	10.6	9.93	8.99	15.11	23.24
	2	2.65	1.89	5.47	28.59	23.24
	3	1.06	0.58	36.76	45.07	49.17
	4	0.21	0.12	28.60	46.02	51.32
	5	0.04	0.01	35.07	73.96	139.97
BENZENE	1	5.15	6.33	14.92	27.20	23.71
	2	1.29	1.41	9.08	23.94	28.09
	3	0.52	0.66	14.92	38.52	46.39
	4	0.1	0.16	37.72	66.61	31.94
	5	0.02	0.05	25.55	203.33	100.00

Table 9 (con't.)
Summary of PQL Study Data

COMPOUND	SAMPLE #	TRUE VALUE (ug/l)	AVG LAB MEAN (ug/l)	AVG %STD REPS*	AVG %DIFF FROM TRUE VALUE**	%STD MEAN ***
1,4-DICHLOROBENZENE	1	13.6	14.62	24.33	30.76	34.32
	2	3.4	3.16	8.46	35.61	45.80
	3	1.36	1.09	13.77	19.66	18.54
	4	0.27	0.26	26.80	73.91	100.88
	5	0.05	0.15	8.53	303.98	158.18
1,3-DICHLOROBENZENE	1	25.8	27.49	17.68	12.42	12.25
	2	6.45	6.03	13.56	21.78	26.45
	3	2.58	2.24	11.38	17.96	20.12
	4	0.52	0.35	34.25	52.39	78.99
	5	0.1	0.03	43.08	86.34	192.03
1,2-DICHLOROBENZENE	1	15.5	14.98	21.99	46.29	45.13
	2	2.8	3.05	15.15	36.10	46.87
	3	1.55	1.42	19.68	49.47	49.47
	4	0.22	0.46	29.38	191.82	127.66
	5	0.05	0.80	8.35	1813.92	191.12
1,1,1-TRICHLOROE-THANE	1	7.39	6.47	9.61	33.32	57.02
	2	1.85	1.58	7.62	22.84	24.94
	3	0.74	0.48	30.64	34.46	46.36
	4	0.15	0.17	53.98	23.79	36.28
	5	0.03	0.05	8.54	151.87	99.85
CHLORDANE	1	1.18	1.23	3.07	8.46	8.13
	2	0.59	0.63	2.97	5.17	0.80
	3	0.16	0.19	2.71	23.29	21.05
	4	0.06	0.09	7.61	50.42	22.22
	5	0.03	0.05	2.75	66.67	20.00
AROCLOR 1254 (PCBs)	1	0.97	0.92	7.59	14.69	16.04
	2	0.49	0.44	13.83	17.47	22.51
	3	0.32	0.30	15.70	35.75	39.15
	4	0.13	0.14	11.03	31.86	32.90
	5	0.07	0.09	29.56	45.64	24.00

* AVG % STD REPS - Average relative standard deviation of the four replicates
** AVG % DIFF FROM TRUE VALUE - Average % difference of the lab mean from the true value
*** % STD MEAN - Relative standard deviation of laboratory means

difference of all the laboratories mean values from the true values (AVG. % DIFF FROM TRUE VALUE) of less than 40%. Individual laboratory precision was evaluated using the percent relative standard deviation of the four replicates analyzed at each concentration level. Acceptable individual laboratory precision was set at an average relative standard deviation (AVG. % STD REPS) of less than 20%. Interlaboratory precision was evaluated using the percent relative standard deviation of the laboratory reported means (% STD MEAN). Acceptable interlaboratory precision was chosen to be less than 40%.

Using these three parameters it was possible to observe how well each laboratory and the group of laboratories could quantitate each compound over a wide concentration range. Individual laboratory precision indicated the consistency of results reported from individual laboratories and interlaboratory precision indicated the consistency among the laboratories. Accuracy, as expressed by the percent difference between the mean and true value, provided an indication of how close the values from laboratories were to the true values.

From the PQL Study, it was possible to determine the concentration range in which acceptable precision and accuracy can be achieved. Below that concentration range, one or all of the parameters fail to meet the acceptance criteria.

A second approach, used to further narrow down the concentration ranges and to support the PQL study results, was to multiply the RUDES and PQL study method detection limits by a factor. U.S.EPA proposed a factor of 5 to 10 times the MDL for determining the PQL (U.S.EPA, 1985b). The American Chemical Society (ACS) defines the MDL as 3 times the standard deviation of the analyte signal, and the limit of quantitation, similiar to the PQL, as 10 times the standard deviation (ACS, 1983). This yields a PQL approximately 3.3 times the MDL. These factors were applied to the PQL study MDLs and the RUDES MDLs. The RUDES data is extremely important because it is the only data derived using a drinking water matrix. All other results, including the PQL study, were derived using an organic free water matrix. Matrix effects become critical for low detection limits in Method 608, where an extraction procedure is required.

U.S.EPA data from Water Supply Performance Evaluation #17, when available, were also evaluated to determine the performance of U.S.EPA and State laboratories on low level volatile samples which were similiar to those used in the PQL study. Results were evaluated to determine the number of laboratories that achieved accuracy within +/-40%. If the new 500 series methods, instead of the 600 series methods, had been used, results may have been improved during Water Supply Performance Evaluation #17.

All the data described above were evaluated to determine each PQL. The PQL was then rounded off to the nearest whole number, except for chlordane and PCBs for which a PQL lower than 1 ppb

Table 10
Practical Quantitation Levels and Recommended
Analytical Methods for A-280 Compounds

COMPOUND	PQL(ug/l)	RECOMMENDED U.S.EPA METHODS*
Benzene	1	503.1, 524.1
Carbon tetrachloride	2	502.1, 524.1
Chlordane	0.5	608
Chlorobenzene	2	502.1, 503.1, 524.1
o-Dichlorobenzene	5	503.1, 524.1
m-Dichlorobenzene	5	503.1, 524.1
p-Dichlorobenzene	5	503.1, 524.1
1,2-Dichloroethane	2**	502.1, 524.1
1,1-Dichloroethylene	2**	502.1, 524.1
C+T-1,2-Dichloroethylene	2**	502.1, 524.1
Ethylene Glycol	No Method	----------
Formaldehyde	No Method	----------
n-Hexane	No Method	----------
Kerosene	No Method	----------
Methylene Chloride	2	502.1, 524.1
Methyl Ethyl Ketone	No Method	----------
PCBs	0.5	608
Tetrachloroethylene	1	502.1, 503.1, 524.1
Trichlorobenzene	5**	612
1,1,1-Trichloroethane	1	502.1, 524.1
Trichloroethylene	1	502.1, 503.1, 524.1
Vinyl Chloride	5	502.1, 524.1
Xylenes	2**	503.1, 524.1

*U.S.EPA has recently released methods 502.2 and 524.2. These methods are currently being considered for use by NJDEP in the A-280 monitoring program.

**Compounds not included in the PQL study.

could be established. These values were further discussed by analytical chemists who are actually performing these analyses to ensure that these levels were achievable. For compounds where little or no information on analytical performance was available, the PQLs were based on the similiarity in chemical structures to those compounds included in the PQL study. PQLs are given in Table 10.

E. Additional Recommendations

In the determination of PQLs, the Testing Subcommittee of the Institute reviewed a large quantity of analytical data and found a number of unanswered questions that need to be addressed in the near future. While the PQL is important for the comparison of data between laboratories, the MDL was found to be important for the assessment of individual laboratory performance. The Subcommittee found that the MDL is very instrument dependent and must be statistically derived by each laboratory for each instrument. However, it was noted that most laboratories never routinely statistically determined their own MDL, but rather relied on literature references or made their own non-statistical approximations. Several statistical approaches for establishing MDLs are available. The U.S.EPA procedure, stated in Appendix B to 40 CFR Part 136, was selected for usage in the RUDES and PQL studies due to its direct application to gas chromatographic techniques. However, even in this procedure, options are available to the analyst which could result in establishment of non-uniform MDLs among laboratories. These options will need to be standardized.

From the overall Testing Subcommittee assessment it is evident that laboratory testing standards need to be established in the following areas:

1. A standardized procedure (preferably the U.S.EPA method cited above) needs to be identified and if need be, standardized for the determination of MDLs by all A-280 testing laboratories;

2. A-280 certified laboratories must be required to determine the MDL for each instrument used for A-280 testing at a set frequency (i.e. once a year); and

3. A-280 certified laboratories should be required to report all data down to the statistically derived MDL. Analytical results occurring between the MDL and PQL should be qualified as estimated values. However, the data should still be reported to NJDEP.

To achieve the PQLs it is extremely important to use the best analytical methods available. The Testing Subcommittee, therefore, recommends the following analytical methods for the determination of A-280 compounds:

1. U.S.EPA 500 series methods should replace the 600 series methods for VOCs in potable water;

2. The 500 series methods were not evaluated for the analysis of the trichlorobenzenes, therefore, method 612 is recommended; and

3. U.S.EPA method 608 is recommended for the analysis of the extractable compounds, PCBs and chlordane. Method 625 should no longer be considered acceptable due to extremely high MDLs.

Recommended methods for each A-280 compound are given in Table 10.

Lastly, the Testing Subcommittee recommends that additional research be conducted to evaluate alternative analytical methods or modifications to existing methods for analyzing the A-280 compounds with health-based numbers lower than the PQLs established in this document. The long term goal should be to identify or develop methods with PQLs at or approaching the health-based numbers.

IV. TREATMENT CONSIDERATIONS

A. Responsibilities

The Program Subcommittee of the Institute was orginally delegated the responsibility of reviewing general NJDEP activities undertaken in accordance with the New Jersey Safe Drinking Water Act. After the Institute and three Subcommittees were formed and began discussing their respective issues, the treatment of water for the removal of A-280 contaminants began to emerge as an important consideration that was not being addressed by any Subcommittee. The questions that had to be answered were: 1) can volatile organics be removed from drinking water to meet the health-based criteria for carcinogenic and noncarcinogenic compounds; 2) what are the available technologies for removing the A-280 contaminants from drinking water; and 3) what are the economic considerations in removing the noncarcinogenic A-280 contaminants from drinking water. These issues are directly related to the feasibility criteria to be considered in setting standards for carcinogens and the feasibility and practicability criteria for noncarcinogens. The responsibility for addressing these questions was assigned to the Program Subcommittee.

B. Treatment Techniques and Feasibility

The Program Subcommittee investigated and agreed upon two technologies that can be used to remove the sixteen A-280 chemicals currently monitored. Aeration is one process whereby the A-280 VOCs dissolved in water are forced from the water into the air. Contactors provide the other technology that removes organic chemicals from water by chemical and physical attraction of the molecules to activated granular carbon. Packed aeration towers (air stripping) and granular activated carbon (GAC) contactors provide the best removal efficiencies for the A-280 organic contaminants among the available aeration and contactor processes. Table 11 provides the VOC removal efficiencies for the various treatment technologies; packed aeration towers and GAC contactors are shown to have the capacity for greater than or equal to 90% removal. Both technologies are available and have been used to reduce the concentrations of organic volatile and nonvolatile chemicals in drinking water in New Jersey. Both technologies also have a long history of use in the chemical process industry.

The nature of the organic compound to be removed from drinking water determines the appropriate treatment technique. Most of the A-280 organics under consideration are generally volatile and are amenable to aeration. The amount of a compound that may transfer from the water to the air may be calculated using Henry's Law (see Appendix D) for the design of treatment processes. The calculations are simplified when the organics dissolved in the water are at low concentrations, do not react with other dissolved compounds and are allowed to reach

Table 11
Treatment Technologies for VOC Reduction

Aeration	Reported Removal Efficiency
Packed Aeration Towers	90-99.9%
Multiple Tray Aeration	40-90%
Diffused Aeration	70-92%
Spray Aeration	75-90%
Air Lift Pumping	40-97%
Cascade Aeration	40-80%
Contactors	
Granular Activated Carbon Contactors (GAC)	>99%
Powered Activated Carbon Addition	50-90%
Synthetic Resin Contactors	>90%
Other Treatment Options	
Point of Use GAC	90->99%

[1] U.S.EPA, 1985e.

equilibrium with clean air at normal temperatures and pressures. These conditions can be approximated in actual practice. Therefore, the performance of air strippers may be predicted (Hand et al., 1986; Love et al., 1983; Gosset et al., 1985).

The relative ease of air stripping the A-280 contaminants is portrayed on Table 12. For organics that are weakly air stripped, such as 1,2-dichloroethane, a combination of air stripping and GAC contacting makes reduction feasible. It is not feasible to air strip either chlordane or PCBs. These compounds are readily adsorbed onto carbon.

Similarly, most of the A-280 organics are also adsorable onto granular activated carbon (GAC). GAC is specially treated carbon that has an enormous internal surface area on which organic molecules in the water can be adsorbed. Ideal conditions require that water temperature remain constant and that equilibrium between the adsorbed organics and those remaining in solution be reached. The mathematical relationship between the amount of organic compound in the water and the amount of organic compound adsorbed has been described (Dobbs and Cohen, 1980).

The relative ease of adsorption by GAC contacting is portrayed on Table 12. Weakly adsorbed organics may require a combination of air stripping and carbon adsorption. Vinyl chloride which is not feasible to adsorb is readily air stripped.

C. Cost Analysis and Practicability

The Program Subcommittee also reviewed economic factors and cost estimates for removing certain organics from drinking water. The A-?80 amendments contain specific wording to be used by the Institute to develop MCLs. The cost of treatment, which is a function of treatment efficiency in that it affects the 'practicability' of an MCL, may only be considered for noncarcinogens or those toxic chemicals that are disinfection by-products. A-280 hazardous contaminants presently classified as noncarcinogens include the following:

chlorobenzene	meta- and ortho-dichlorobenzene
1,2,4-trichlorobenzene	1,1,1-trichloroethane
1,1-dichloroethylene	cis- and trans-1,2-dichloroethylene
ethylene glycol	n-hexane
methyl ethyl ketone	xylenes

The practicability of achieving health-based levels was evaluated in terms of the size and cost of treatment facilities.

For the purposes of cost estimation, packed tower aeration treatment was used because the results of this treatment technique can be predicted. A U.S.EPA report on the removal of organics was used which provided cost estimates on air stripping only for various size treatment plants, converted to 1986 dollars (U.S.EPA, 1984e).

Table 12
Comparison of Two Treatment Technologies:
Removal of A-280 Contaminants

ORGANIC CHEMICAL	Carbon Adsorbability				Air Strippability			
	READILY	MODERATELY	WEAKLY	NOT	READILY	MODERATELY	WEAKLY	NOT
Benzene			X			X		
Carbon Tetrachloride			X		X			
Chlordane	X							X
Chlorobenzene			X		X			
p-Dichlorobenzene		X					X	
o-Dichlorobenzene		X				X		
m-Dichlorobenzene		X				X		
1,2-Dichloroethane			X				X	
1,1-Dichloroethylene			X		X			
cis-1,2-Dichloroethylene			X			X		
trans-1,2-Dichloroethylene			X			X		
Ethylene Glycol	----------NR*----------				----------NR----------			
Formaldehyde	----------NR----------				----------NR----------			
Kerosene	----------NR----------				----------NR----------			
Methyl Ethyl Ketone	----------NR----------				----------NR----------			
Methylene Chloride			X				X	
N-Hexane	----------NR----------				----------NR----------			
Polychlorinated Biphenyls	X							X
Tetrachloroethylene			X		X			

Table 12 (con't.)

ORGANIC CHEMICAL	Carbon Adsorbability				Air Strippability			
	READILY	MODERATELY	WEAKLY	NOT	READILY	MODERATELY	WEAKLY	NOT
1,1,1-Trichloroethane			X		X			
1,2,4-Trichlorobenzene		X					X	
Trichloroethylene			X		X			
Vinyl Chloride				X	X			
Xylenes			X			X		

*NR = Not Reported

References: Ashworth et al., 1986; Cummins, 1982a, 1982b, 1985; Gosset et al., 1985; Hand et al., 1986; Abrams and Medlar, 1986; Dobbs and Cohen, 1980; Love et al., 1983; U.S.EPA, 1984d.

Although cost considerations are only applicable for the noncarcinogens, the Program Subcommittee originally chose to estimate costs for removing two carcinogens (benzene and trichloroethylene) to 1 ppb and one noncarcinogen (1,1,1-trichloroethane) to 5 ppb, to reflect what the Subcommittee judged to be reasonable estimates of analytical capabilities and long-term health effect levels. Using this approach, an estimate of $54 million dollars in treatment costs for the affected supplies in N.J. was derived. An increase in water rates from $0.05 to $0.96 per 1,000 gallons was also estimated ($0.05 to $0.15 per 1,000 gallons increase for systems serving more than 100,000 people, $0.19 to $0.96 per 1,000 gallons for the smaller systems).

The Program Subcommittee reanalyzed cost data based on preliminary indications of what that Institute was considering adopting as MCLs (see Section V., Derivation of the MCLs). Five sets of A-280 monitoring data collected between December 1984 and December 1986 showed that 120 PCWS had reported results above the draft Institute recommended MCLs. However, all these results were not necessarily verified according to the Bureau of Safe Drinking Water policies set forth in the Drinking Water Guidance document (NJDEP, 1986a). The estimated total Statewide costs to remove A-280 contaminants to the draft Institute recommended MCLs is projected to be in the range of 50 to 70 million dollars, which is very similar to the first estimate.

In both cases, however, the cost estimates are approximate and do not take into account site specific data and other factors such as the cost of abandoning a supply, site and distribution improvements and cost of alternative supply. Costs will also be influenced by other factors directly related to the two technologies. Air strippers may emit unacceptable concentrations of volatile organic contaminants into the air, which may necessitate the use of vapor phase carbon to adsorb the organics being emitted. Costs for air stripping may double if vapor phase carbon is required to control air emissions. Granular activated carbon used for contaminated water adsorbs organics selectively and may subsequently release what it previously adsorbed, resulting in the organic breaking through the contactor and reentering the drinking water. To prevent breakthrough to unacceptable levels, water utilities have to replace the carbon. The frequency of replacing the carbon will significantly affect costs. Therefore, carbon usage and disposal may become important considerations in both air stripping and carbon contacting.

Practicability was considered by estimating the size and cost of treatment facilities, namely air strippers for various capacities and contaminant concentrations (U.S.EPA, 1984d; U.S.EPA, 1984e). A summary of available data for a hypothetical one million gallon per day packed aeration tower with a hypothetical influent concentration of 100 ppb for each noncarcinogen is presented in Appendix D. In summary, available studies and limited field data indicate the practicability of air

stripping, even for the not-so-strippable dichlorobenzenes and trichlorobenzene. A brief discussion of each of the noncarcinogens also appears in Appendix D.

D. Summary

It is technologically feasible and practicable to remove the A-280 volatile and readily adsorbable organics from drinking water. Specifically,

trichloroethylene	tetrachloroethylene
1,1-dichloroethylene	carbon tetrachloride
vinyl chloride	trans-1,2-dichloroethylene
1,1,1-trichloroethane	xylenes
benzene	dichlorobenzene(s)
methylene chloride	1,2-dichloroethane
trichlorobenzene(s)	PCBs
chlordane	

can be removed with either packed aeration towers or granular activated carbon contactors. There is insufficient data to draw a conclusion for the following:

methyl ethyl ketone	ethylene glycol
kerosene	formaldehyde
n-hexane	cis-1,2-dichloroethylene.

V. MAXIMUM CONTAMINANT LEVEL DERIVATION AND RECOMMENDATIONS

A. A-280 Statuatory Basis for Maximum Contaminant Levels

The A-280 amendments describe the process to be used in the establishment of MCLs. Maximum contaminant levels for the carcinogenic contaminants are to be established in a different manner than for the noncarcinogens. For the carcinogenic substances, MCLs are to be developed which "...permit cancer in no more than one in one million persons ingesting that chemical for a lifetime..." "...within the limits of medical, scientific and technological feasibility". The Institute interprets this language to mean that the MCLs for carcinogens should be set at the one in one million excess risk level unless it is not currently technically feasible to do so. Technical feasibility includes the capability of analytical instrumentation to detect and quantitate contaminants reliably in water, as well as the capability of water treatment processes to remove contaminants to the specified health-based levels. Cost is not a direct consideration in the evaluation of technical feasibility in this case.

A different process is described in the amendments for setting MCLs for noncarcinogenic contaminants. For these substances, MCLs should be derived which eliminate "...all adverse physiological effects from ingestion..." "...within the limits of practicability and feasibility". The Institute interprets practicability to mean that cost considerations should be evaluated in determining MCLs for noncarcinogens. Therefore, the Institute finds that MCLs for noncarcinogens should be set at the health-based levels unless it is not technically feasible to do so, or would present an overwhelming cost burden when compared to the cost of other commonly accepted water treatment practices.

The only additional statuatory guidance supplied to the Institute for the setting of MCLs is that in no case shall the State MCLs be less stringent than federal standards established by the U.S.EPA. As of the date that these recommendations are being prepared, no final federal MCLs are available for any of the A-280 2a list contaminants although proposed standards for eight A-280 compounds have been published (U.S.EPA, 1985c). A comparison of U.S.EPA standards to MCLs recommended by the Institute will have to be undertaken by NJDEP at the time that the final federal MCLs are promulgated. Any New Jersey MCL which exceeds a federal standard would have to be adjusted at that time.

B. Derivation of Recommended MCLs

As outlined above, the Institute required information on adverse health effects, as well as analytical and treatment capabilities to derive MCLs for each of the A-280 contaminants. In previous sections of this document, these three considerations were fully described and conclusions were presented. Section II contains the health-based levels for each contaminant, and Section

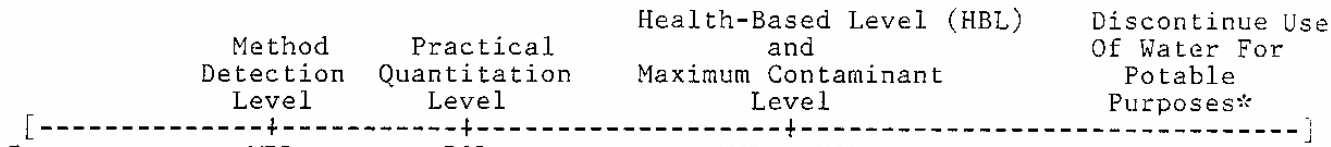
III provides the compound-specific practical analytical quantitation limits (PQLs). Treatment capabilities and cost figures are reviewed in Section IV.

After evaluating the health-based levels and the PQLs, the Institute found that treatment considerations were not the driving factors for the MCL determination for carcinogens or noncarcinogens. Therefore, the recommended MCLs were set based on health-effects and analytical considerations. If reliable quantitation could be achieved at the health-based levels, then the MCLs were set at the health-based concentrations. If it was determined that concentrations at the health-based goal level could not be reliably quantitated at this time, then MCLs had to be set at the PQL. The processes used to establish the MCLs for each contaminant are shown in Figures 1 and 2.

Table 13 lists all of the A-280 2a contaminants, corresponding health-based levels, PQLs and the MCLs derived as stated above. Maximum contaminant levels for a total of 19 compounds (including isomers) were derived, ranging in concentration from 0.5 to 600 ug/l. Recommended MCLs for the contaminants treated as carcinogens in the quantitative risk estimates (category I) ranged from 0.5 to 6 ug/l, and for the other chemicals (categories II and III), the range varied from 1 to 600 ug/l. Compounds in Table 13 are identified precisely as they appeared in the A-280 legislation; therefore, some isomers are listed separately, while others are combined. Section VI should be consulted for a further description of isomer-specific MCLs. Due to the wide range of values (0.013 to 600 ug/l) for the health-based levels among the various contaminants, two significant figures were provided instead of calculating the values to a defined decimal place. When a health-based level exceeded a PQL, an MCL was set at the health-based whole number. Health-based concentrations were rounded down in establishing the MCLs to be as protective of public health as possible (e.g. the chlorobenzene health-based number of 4.6 was rounded down to an MCL of 4 ug/l).

The U.S.EPA proposed MCLs for eight compounds are provided in Table 13 for comparison to the Institute recommended MCLs (U.S.EPA, 1985c). All of the U.S.EPA proposed MCLs are equivalent to or higher than those recommended here, with the exception of vinyl chloride. The proposed U.S.EPA MCL for vinyl chloride is more stringent than the Institute recommended value (1 versus 5 ug/l). If this federal standard is promulgated, NJDEP would be obligated to adopt the lower value although the NJDEP PQL study data does not support reliable quantitation at such a low level.

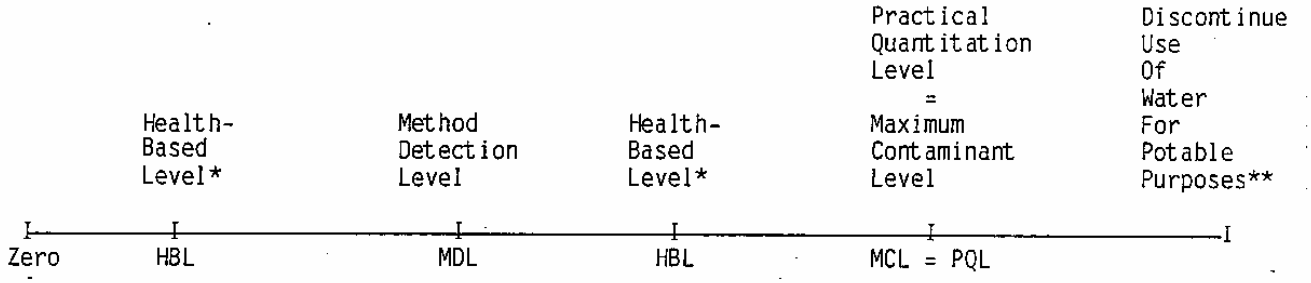
Figure 1
Derivation of MCLs: Contaminants
with Health-Based Levels
Greater Than the PQL and the MDL



Compounds:	Chlorobenzene	Methylene Chloride
	o-Dichlorobenzene	1,2,4-Trichlorobenzene
	m-Dichlorobenzene	1,1,1-Trichloroethane
	p-Dichlorobenzene	Trichloroethylene
	cis-1,2-Dichloroethylene	Xylenes
	trans-1,2-Dichloroethylene	

*For Further Discussion, See Section VI.A.

Figure 2
Derivation of MCLs: Contaminants
with Health-Based Levels
Less Than the PQL



Examples: Benzene
Carbon Tetrachloride
Chlordane
1,2-Dichloroethane
1,1-Dichloroethylene
Polychlorinated Biphenyls
Tetrachloroethylene
Vinyl Chloride

*The health-based levels may occur either below or above the method detection level for the chemicals listed depending on the contaminant, and the laboratory and analysis methods used.

**For Further Discussion, See Section VI.A.

Table 13
Health-based Levels, PQLs, U.S.EPA Proposed MCLS and Institute Recommended MCLs (ug/l)

Contaminant	Health-Based Levels	PQLs	U.S.EPA Proposed MCLs [1]	Institute Recommended MCLs
1) Benzene	0.15	1	5	1
2) Carbon Tetrachloride	0.39	2	5	2
3) Chlordane	0.013	0.5	NA[2]	0.5
4) Chlorobenzene	4.6	2	NA	4
5) o-Dichlorobenzene[3]	600	5	NA	600
m-Dichlorobenzene[3]	600	5	NA	600
p-Dichlorobenzene[3]	6.1	5	750[4]	6
6) 1,2-Dichloroethane	0.29	2	5	2
7) 1,1-Dichloroethylene	1.0	2	7	2
8) cis-1,2-Dichloroethylene[3]	10	2	NA	10
9) trans-1,2-Dichloroethylene[3]	10	2	NA	10
10) Ethylene Glycol	290	NA	NA	NR[5]
11) Formaldehyde	0.65	NA	NA	NR
12) n-Hexane	33	NA	NA	NR
13) Kerosene[6]	NA	NA	NA	NR
14) Methylene Chloride	2.5	2	NA	2
15) Methyl Ethyl Ketone	270	NA	NA	NR
16) Polychlorinated Biphenyls[3]	0.024	0.5	NA	0.5
17) Tetrachloroethylene	0.44	1	NA	1
18) Trichlorobenzenes[3]	8.6	5	NA	8
19) 1,1,1-Trichloroethane[7]	26	1	200	26
20) Trichloroethylene	1.2	1	5	1

21) Vinyl Chloride	0.084	5	1	5
22) Xylenes[3]	44	2	NA	44

[1] U.S. EPA, 1985c

[2] NA = Not Available

[3] See Section VI for discussion of MCL application for compounds with multiple isomers.

[4] Revision of U.S.EPA proposed MCL is expected for p-dichlorobenzene due to recently released and reviewed positive carcinogenicity data. These results indicate that this compound should be classified as a probable human carcinogen (National Drinking Water Advisory Council, 1986).

[5] NR = No Recommendation for Institute MCL at this time due to lack of U.S.EPA approved methodology and PQL data.

[6] See Section VII for recommendation to remove kerosene from the A-280 2a list.

[7] The major factor in the difference between the U.S.EPA proposed MCL of 200 ug/l versus the Institute recommended MCL of 26 ug/l is that the U.S.EPA (1984a) did not incorporate an additional uncertainty factor of 10 for estimation of a NOAEL from a LOAEL. The use of such an uncertainty factor is recommended by Dourson and Stara (1983) of the U.S.EPA.

VI. MAXIMUM CONTAMINANT LEVEL APPLICATION

A. Use of MCLs by NJDEP

The A-280 law states that the New Jersey Drinking Water Quality Institute will recommend maximum contaminant levels to the Commissioner of the Department of Environmental Protection for adoption into the rules and regulations for the N.J. Safe Drinking Water Act (Act). The definition of a maximum contaminant level, set forth in the Act, states that an MCL is the ..."maximum permissible level of a contaminant which is delivered to the free-flowing outlet of the ultimate user...". The exact criteria for setting the MCLs for the hazardous contaminants listed in the law was discussed in Section V. This document consolidates the work of the Institute and the three Subcommittees by establishing recommendations for MCLs and is being submitted to the Commissioner in accord with the A-280 amendments.

The A-280 law also states that the owner or operator of each water system, upon receipt of test results that confirm that an MCL has been violated, must bring the water into compliance with the standard within one year. In cases of immediate public health threat, the water supply may be required to comply with the standards more rapidly. A specified high value above each of the MCLs should be designated by NJDEP as that which would define the water as undrinkable because of acute adverse health effects. Low values, below the MCL and above the MDL, should also be reviewed because some MCLs were set above the health-based number. Details concerning the implementation of the drinking water program will be described in the regulations.

The MCLs that will be adopted by NJDEP should be used to insure that all PCWS in New Jersey do not contain the hazardous contaminants listed in the A-280 legislation at concentrations which exceed the criteria stated in the A-280 law. These MCLs will provide the Department with a basis for assessing the risk of levels of contaminants reported during semi-annual testing performed by the 630 PCWS in N.J. The MCLs will also be used as appropriate to assess water quality in non-community and non-public water supplies.

As an interim measure to direct Departmental response to the detection of contaminants in potable water, the Bureau of Safe Drinking Water (BSDW) has been using a document developed by OSR entitled "Drinking Water Guidance, Interim Action Levels and Recommendations for Responses for Selected Organics in Drinking Water" (NJDEP, 1986a) . This document was released in January 1986 and was developed from previously published U.S.EPA levels. As soon as the MCLs are adopted by NJDEP, drinking water quality in N.J. is to be assessed based on the MCLs in the regulations; the MCLs are to supersede any other guidance numbers available, including those published previously in the Drinking Water Guidance.

The MCLs developed as part of the A-280 program are not intended to be used for assessing contamination in other environmental media. The MCLs were developed based on specific stringent criteria in the law that use ingestion of drinking water each day for a lifetime as part of the risk assessment. Other NJDEP programs should take this limitation into account when reviewing the drinking water recommendations of this Institute.

B. Compound Specific MCL Considerations

Many of the 22 A-280 hazardous contaminants are listed in the law as single compounds. Other contaminants, however, are listed as multiple isomers of the same compound. Risk assessments were developed for all the isomers whenever sufficient information was available. The following policies should be considered by the NJDEP for those chemicals with multiple isomers:

1) The PCB health-based number was based on a risk assessment of one of the six PCB mixtures currently monitored. There was insufficient information available for calculating risk assessments for each mixture. The compliance test result data from each of these six mixtures of PCBs should be totaled, and this total compared to the MCL to determine if there is a violation of the MCL.

2) The 1,2,4-trichlorobenzene isomer was chosen for derivation of a health-based MCL for "trichlorobenzene(s)" because it is the only isomer used commercially and the only one with any toxicology data available. It is also being used more extensively than in the past as a substitute for PCBs in electrical transformers. The 1,2,4-isomer is the only isomer required to be reported in the GC and GC/MS methods according to the laboratory certification regulations. Therefore, the MCL for "trichlorobenzene(s)" will be measured by this isomer.

3) Only the trans-isomer of 1,2-dichloroethylene is presently reported to NJDEP. The cis-and trans-isomers of 1,2-dichloroethylene do not separate during GC analysis on the primary column and therefore, cannot be distinguished using either the 502.1 or 524.1 methods. Due to possible misidentification and the lack of toxicology data available to distinguish between the two isomers, these compounds should be regulated as total 1,2-dichloroethylenes (e.g. 10 ppb for the sum of both compounds). The 1,1-dichloroethylene isomer should still be treated separately.

4) Risk assessments for each of the three dichlorobenzene isomers were calculated separately because toxicology information was available for each isomer. The isomers should be reported as total dichlorobenzenes, however, since the isomers are difficult to separate. If the total dichlorobenzene(s) concentration exceeds the MCL for the isomer with the lowest health effect number, p-dichlorobenzene, a resample to quantify the separate isomers should be taken as soon as possible.

5) The xylene health-based number is based on the total xylene concentration because there is no information to justify separate risk assessments for the three isomers. The laboratory community, however, has been separating the three isomers according to the laboratory certification regulations. The NJDEP should calculate the total of the three isomers and compare the total to the MCL to determine the water quality of the drinking water supply.

VII. FUTURE INSTITUTE CONSIDERATIONS

The presentation of the MCLs to the Department concludes the main task of the Institute. There are now several other tasks to be performed for the 2a list contaminants for which MCLs were not recommended at this time. The Institute will also continue its efforts to generate a recommended 2b list.

A. 2a List Activities

1. Analytical Methodology Development

Several of the 2a list contaminants do not have standardized methodologies, and therefore, no attempt has been made to detect these contaminants in the waters of New Jersey under the A-280 program. Two contaminants that are currently not tested for are kerosene, which is recommended for deletion from the 2a list, and cis-1,2-dichloroethylene which can be detected by U.S.EPA methods 502.1 and 524.1 which will be used in the future. Four chemicals for which methodology development is needed are methyl ethyl ketone, ethylene glycol, n-hexane and formaldehyde. Preliminary methodology development was performed by Rutgers University for these four chemicals. Final methodology development and validation, to insure the methods are accurate and precise for environmental samples, will be performed under contract with OSR by Battelle Laboratories. A number of drinking water samples in New Jersey will also be analyzed for formaldehyde by Battelle. Analysis for this chemical will be performed in environmental samples because the method development has advanced further than for the other chemicals. The NJDEP intends to use these newly developed methods for the analysis of New Jersey water samples to see if MCLs need to be promulgated when the method validation process has been completed.

2. MCLs for Chemicals Without U.S.EPA Analytical Methodologies

Three key pieces of information, a health-based number, a PQL and available treatment technologies must be evaluated in order for an MCL to be set. Health-based numbers have been developed for all the A-280 contaminants, however, PQLs are not available for those contaminants with no standardized, validated analysis methodologies. MCLs can be set only after PQL information is complete, and after available treatment technologies are adequately evaluated for removal capabilities.

The Institute is not required to set MCLs until the presence of these contaminants is established in drinking water. The Institute may choose to develop MCLs before these contaminants are incorporated into the semi-annual testing by PCWS, so that appropriate action may be taken by NJDEP should these substances be detected in drinking water.

3. Removal of Kerosene From the 2a List

The contaminant mixture kerosene, listed on the 2a list, was evaluated in detail by the Lists and Levels Subcommittee for risk assessment. Kerosene is a mixture of aliphatic and aromatic hydrocarbon compounds with differing properties and water solubilities. There were no adequate toxicity studies available that could be used to develop a risk assessment for kerosene in drinking water. The toxicology of several components of kerosene, especially those that are water soluble, may be more appropriate for assessing the risk presented by kerosene contamination. Two of the most common water soluble compounds in kerosene are benzene, a 2a list contaminant, and naphthalene. The Institute finds that kerosene is an inappropriate contaminant for the 2a list, and recommends that kerosene not be regulated as such, since it cannot be evaluated according to the procedures set forth in the A-280 law. It is also recommended that naphthalene be considered for the 2b list.

B. 2b List Activities

One of the provisions of the amendments to the N.J. Safe Drinking Water Act gave the Institute the responsibility of choosing additional chemicals for regulation in drinking water. This list of additional chemicals, specifically metals, base/neutrals, acid extractables, and pesticides and related compounds is commonly called the "2b" list after the section of the legislation mandating this responsibility.

In order to narrow the field of chemicals to those most appropriate for regulation in drinking water, a 2b Contaminant Work Group, comprised of members of NJDEP and NJDOH was formed. The three main criteria used to screen chemicals for possible placement on the 2b list were: 1) toxicity, 2) occurrence in potable water, and 3) availability of reliable analytical methodology. To date, the 2b work group has done a preliminary assessment of phthalates, phenols, metals, and additional volatile organic chemicals. Some of the findings and recommendations for these groups of chemicals have been discussed by the Lists and Levels Subcommittee.

The Institute has requested that the four trihalomethane compounds currently regulated as primary drinking water contaminants be looked at first as part of this 2b process. Naphthalene will also be considered at the beginning of the process since this compound is to be regulated in place of kerosene as discussed above. The Lists and Levels Subcommittee will be working more on this activity in the future.

The legislation mandates that the maximum contaminant levels that will be developed for the 2b chemicals follow the same process as was set up for the 22 2a hazardous contaminants and was described in this document. The carcinogens are to be regulated

based on one in one million excess cancer incidence for a lifetime exposure; the noncarcinogen MCLs are to be based on adverse physiological effects. If new standardized test methodologies need to be developed, they will be developed and validated in the same manner as for four of the hazardous 2a contaminants. U.S.EPA approved test methodologies will be used whenever possible.

C. Periodic Review of Work

The Institute proposes a review of new toxicological data and new advances in analytical technology at least every three years. The Institute realizes that in the future, the classification of chemicals according to carcinogenicity may change based on new studies, or more sensitive endpoints may be found for certain chemicals. Such new developments may warrant the use of alternate toxicology data, new mathematical models, or new calculations to be used for MCL development. Substantial changes in the toxicology database for an individual chemical may require a recalculation of the MCL at the time the data becomes available. Also, new analytical techniques may be available to detect lower levels of contamination with more precision and accuracy than presently reflected by the PQLs. The Institute proposes that this body perform a reassessment every three years at a minimum to assure that the MCLs will reflect the best available information to effectively protect the health of the citizens of New Jersey.

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APPENDICES

APPENDIX A

Members of the New Jersey Drinking Water Quality Institute

Ex officio members

Richard T. Dewling, Ph.D., P.E., Commissioner of New Jersey Department of Environmental Protection (designated representative-Assistant Commissioner Donald A. Deieso, Ph.D.)

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Harold Florence, Ridgewood Water Department, Chairman of the Water Supply Advisory Council

George G. McCann, P.E., Director of the Division of Water Resources

Robert Tucker, Ph.D., Director of the Office of Science and Research (designated representative - Deputy Director Leslie McGeorge, M.S.P.H.)

Thomas Burke, Ph.D., M.P.H., Assistant Commissioner, Division of Occupational and Environmental Health

Appointed Members

By the Governor:

Richard Sullivan, New Jersey First, Inc., Chairman of the N.J. Drinking Water Quality Institute

Wendell Inhoffer, P.E., Passaic Valley Water Commission

Joseph Hunter, Ph.D., Cook College, Rutgers University

By the Speaker of the General Assembly:

Paul D. Schumann, Garden State Water Company

Judith S. Weis, Ph.D., Rutgers University

Rudolph LaRocca, LaRocca Science Laboratories*

By the President of the Senate:

Thomas Cawley, P.E., Elizabethtown Water Company

Theodore B. Shelton, Ph.D., Cook College, Rutgers University

Frank Livelli, Retired Executive Chemist**

*Resigned September 10, 1986. His position is currently vacant.

**Mr. Livelli was appointed to the Institute effective December 18, 1986. He replaced John Bogden, Ph.D., University of Medicine and Dentistry who had served from January 23, 1985 through the date of appointment of Mr. Livelli.

APPENDIX B

SUMMARIES OF HEALTH-BASED MAXIMUM CONTAMINANT LEVEL SUPPORT DOCUMENTS

Adopted by the Lists and Levels Subcommittee
to be transmitted to the
New Jersey Drinking Water Quality Institute
for Consideration in Maximum Contaminant Level Development

Copies of the Health-Based
Support Documents are
available upon request from
the New Jersey Department of Environmental Protection

INTRODUCTION

The basis for the health-based maximum contaminant level (MCL) for each of the A-280 contaminants is briefly summarized below. Detailed discussion of the risk assessment for each compound, along with relevant supporting information, is found in the Health-Based Maximum Contaminant Level Support Documents (NJDWQI, 1987; Appendix B, Section A-T). A discussion of the methodology, including carcinogenicity category (I, II, III) and the approach used in the risk assessments is found in "Health Effects Considerations for MCL Derivation" (NJDWQI, 1987, Chapter II).

BENZENE

Benzene is considered a human carcinogen and was therefore placed in Category I. It has been shown to cause cancer in numerous organs in rats and mice and leukemia in humans. The risk assessment was based on pooled epidemiologic data from occupational studies (Ott et al., 1978; Rinsky et al., 1981, and Wong, 1983). The endpoint considered was leukemia. A relative risk model for high to low dose extrapolation was used to derive a health-based MCL of 0.15 ug/L.

CARBON TETRACHLORIDE

Carbon tetrachloride is considered a probable human carcinogen and was therefore placed in Category I. This compound has been shown to cause liver cancer in rats, mice, and hamsters. The risk assessment was based on an oral exposure study in mice (NCI, 1976). The endpoint considered was combined male and female mouse hepatocellular carcinomas. The multistage-Weibull model was used to derive a health-based MCL of 0.39 ug/L.

CHLORDANE

Chlordane is considered a probable human carcinogen and was therefore placed in Category I. This insecticide has been shown to cause cancer in mice. The risk assessment was based on a study involving chronic oral exposure of mice (RIAST, 1983). The endpoint considered was the incidence of hepatocellular adenoma in male mice. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.013 ug/L.

CHLOROBENZENE

Chlorobenzene is considered a possible human carcinogen via ingestion, and was therefore placed in Category II. This compound has been shown to be associated with an increased occurrence of neoplastic nodules of the liver in highly dosed male rats. The risk assessment was based on a study involving subchronic oral exposure of dogs (Monsanto

Company, 1977). The endpoints considered were minimum histological changes in the liver, kidneys and hematopoietic tissues in dogs. Appropriate uncertainty factors were applied to the NOAEL of 27.3 mg/kg/day, including an additional safety factor for the possible carcinogenicity of chlorobenzene. The resulting health-based MCL of 4.5 ug/L was derived.

DICHLOROBENZENES

p-Dichlorobenzene is considered to be a probable human carcinogen and was therefore placed in Category I. This compound was found to cause cancer in both rats and mice. The risk assessment was based on a study involving chronic oral exposure of p-dichlorobenzene to rats and mice (NTP, 1986). The toxic endpoint was an increase in kidney adenocarcinomas in male rats. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.61 ug/L.

o-Dichlorobenzene is considered to be a non-carcinogen and was therefore placed in Category III. Toxicity to the liver and kidney are the predominant chronic effects of exposure to o-dichlorobenzene. The risk assessment was based on a study involving chronic oral exposure of o-dichlorobenzene to male rats (NTP, 1985). The endpoint considered was a dose related increase in kidney tubular regeneration. Appropriate uncertainty factors were applied to the LOAEL of 60 mg/kg/day, and a health-based MCL of 600 ug/L of drinking water was derived.

Comments are requested regarding the significance of a marginal dose related increase in the serum cholesterol levels of male and female rats in the NTP (1985) study.

1,2-DICHLOROETHANE

1,2-Dichloroethane is considered a probable human carcinogen and was therefore placed in Category I. This compound has been shown to cause cancer in various organs of rats and mice. The risk assessment was based on a study involving chronic oral exposure of rats and mice (NCI, 1978). The endpoint considered was the incidence of hemangiosarcomas in male rats. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.29 ug/L.

DICHLOROETHYLENES

1,1-Dichloroethylene was considered to be a possible human carcinogen and was therefore placed in Category II. 1,2-dichloroethylenes are not considered to be human carcinogens and were placed in Category III. 1,1-dichloroethylene has been shown to cause liver and kidney injury in experimental animals. Little is known regarding the chronic toxicity of cis- or trans- 1,2-dichloroethylenes, however available information indicates that they are less toxic than

1,1-dichloroethylene. The risk assessment for all dichloroethylenes was based on a chronic oral exposure of mice to 1,1-dichloroethylene (NCI/NTP, 1982). The toxic endpoint was an increase in liver necrosis in mice. Appropriate safety factors were applied to a LOAEL of 2 mg/kg/day, including an additional safety factor for the possible carcinogenicity of 1,1-dichloroethylene. The resulting health-based MCL for 1,1-dichloroethylene is 1 ug/L and for cis- or trans-1,2-dichloroethylenes, 10 ug/L.

ETHYLENE GLYCOL

Ethylene glycol is considered a non-carcinogen and was therefore placed in Category III. This compound causes kidney toxicity in both humans and animals. The risk assessment was based on a study involving chronic oral exposure of rats (Blood, 1965). The endpoint considered was kidney toxicity in male rats. Appropriate uncertainty factors were applied to the NOAEL of 42 mg/kg/day, and a health-based MCL of 290 ug/L was derived.

FORMALDEHYDE

Formaldehyde has been shown to cause nasal cancers in rodents and was therefore placed in Category I. Additionally, carcinoma in situ was observed after repeated exposure of the oral mucosa of rabbits (Muller et al., 1978). The risk assessment was based on a study involving chronic inhalation exposure of rats (CIIT, 1981). The endpoint considered was the incidence of nasal cell tumors in male and female rats. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.65 ug/L.

n-HEXANE

n-Hexane is considered a non-carcinogen and was therefore placed in Category III. Neuropathy was observed in both humans and animals exposed to n-hexane. The risk assessment was based on a study involving subchronic inhalation exposure of rats to n-hexane (Rebert and Sorenson, 1983). The endpoint considered was decreased neural response time. Appropriate uncertainty factors were applied to the LOAEL of 500 ppm, and a health-based MCL of 33 ug/L was derived.

KEROSENE

Kerosene cannot be classified as to human carcinogenicity. Due to lack of relevant information, no risk assessment for kerosene was performed and, therefore no health-based MCL is recommended. Instead, it was recommended that kerosene be regulated on the basis of two of its components, benzene and naphthalene.

METHYL ETHYL KETONE

Methyl ethyl ketone is considered a non-carcinogen and was therefore placed in Category III. Irritation and mild neurologic symptoms were reported in humans exposed to methyl ethyl ketone. The risk assessment is based on a study which described the effects of methyl ethyl ketone in an occupational setting (Smith and Mayers, 1944). The toxic endpoint considered was mild neuropathy. Appropriate uncertainty factors were applied to the LOAEL of 300 ppm, and a health-based MCL of 270 ug/L was derived.

METHYLENE CHLORIDE

Methylene chloride is considered a probable human carcinogen and was therefore placed in Category I. It has been shown to cause cancer in various organs in rats and mice. The risk assessment was based on a study involving oral exposure in mice (NCA, 1983). The endpoint considered was a combination of hepatocellular carcinoma and adenoma in male mice. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 2.5 ug/L.

POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) are considered to be probable human carcinogens and were therefore placed in Category I. These compounds were found to cause cancer in both rats and mice. The risk assessment was based on a study involving chronic oral exposure to Clophen 60 (a PCB mixture) to rats (Schaefer et al., 1984). The toxic endpoint was an increase in liver tumors in male rats. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.024 ug/L.

Comments are requested regarding whether neoplastic nodules, a possible precarcinogenic stage, should be combined with fully developed tumors for the purposes of risk assessment.

TETRACHLOROETHYLENE

Tetrachloroethylene is considered a probable human carcinogen and was therefore placed in Category I. It has been shown to cause cancer at various sites in rats and mice. The risk assessment was based on an oral exposure study in male mice (NCI, 1977). The endpoint considered was hepatocellular carcinoma. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 0.44 ug/L.

1,2,4-TRICHLOROBENZENE

1,2,4-Trichlorobenzene is considered a non-carcinogen and was therefore placed in Category III. This compound causes kidney and

respiratory toxicity in humans, and liver and reproductive toxicity in animals. The risk assessment was based on a study involving subchronic inhalation exposure of rats (Watanabe et al., 1977). The endpoint considered was liver porphyria in rats. Appropriate uncertainty factors were applied to the NOAEL of 3 ppm, and a health-based MCL of 8.6 ug/L was derived.

1,1,1-TRICHLOROETHANE

1,1,1-Trichloroethane is considered a non-carcinogen and was therefore placed in Category III. Repeated exposure of experimental animals to this compound has been associated with liver toxicity. The risk assessment was based on a subchronic study involving continuous inhalation exposure of mice (McNutt et al., 1975). The endpoint considered was hepatic toxicity. Pharmacokinetic modeling was used to derive the oral dose in humans equivalent to the dose received in the mice by continuous inhalation exposure. Appropriate uncertainty factors were applied to the dose received at the LOAEL of 250 ppm, and a health-based MCL of 26 ug/L was derived.

Comments are requested on the application of pharmacokinetic modeling for calculation of equivalent doses with differing routes of exposure.

Additionally, it should be noted that a carcinogenicity bioassay for 1,1,1-trichloroethane (NCI, 1983) involving oral exposure of rats and mice suggested an increased incidence of liver cancers in mice. Because of serious data discrepancies, the NTP is currently conducting an audit of this study. Based on NTP's conclusions when the audit is completed, the carcinogenicity status of 1,1,1-trichloroethane may change in the future.

TRICHLOROETHYLENE

Trichloroethylene is considered a probable human carcinogen and was therefore placed in Category I. This compound has been shown to cause liver cancer in mice. The risk assessment was based on a study involving oral exposure to mice (NTP, 1984). The endpoint considered was hepatocellular carcinoma and adenoma in male mice. The multistage model for high to low dose extrapolation was used to derive a health-based MCL of 1.2 ug/L.

VINYL CHLORIDE

Vinyl chloride is considered a human carcinogen and was therefore placed in Category I. It has been shown to induce liver cancer in rats, mice, hamsters, and humans. The risk assessment was based on an oral exposure study by Feron et al. (1981). The endpoint considered was hepatocellular carcinoma in female rats. The multistage model for high

to low dose extrapolation was used to derive a health-based MCL of 0.084 ug/L.

Comments are requested regarding whether neoplastic nodules, a possible precarcinogenic stage, should be combined with fully developed tumors for the purposes of risk assessment.

XYLENES

Xylenes are considered non-carcinogens and were therefore placed in Category III. These compounds cause central nervous system, lung and kidney toxicity in humans and animals. The risk assessment was based on a study involving inhalation exposure of female rats during gestation (Mirkova et al., 1983). The endpoints considered were embryonic and developmental toxicity. Appropriate uncertainty factors were applied to the NOAEL of 2.3 ppm, and a health-based MCL of 44 ug/L was derived.

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Appendix C
Derivation of Compound Specific PQLs

This section describes the derivation of the practical quantitation levels (PQLs) on a compound by compound basis. The sources of information, which include a) the NJDEP PQL study, b) Department of Environmental Sciences, Rutgers University (RUDES) method validation study, and c) the U.S.EPA Water Supply Performance Evaluation Study 17 have been described in Section III C. A general description of the data is provided below.

a) NJDEP PQL Study - Sample Results

Results are presented representing the analysis of the A-280 compounds at 5 concentrations levels. Four replicates were run at each concentration level. A total of 6 laboratories participated in the study. The number of laboratories reporting results for each method are:

U.S.EPA Method	Number of Laboratories
502.1	4
503.1	5
524.1	1
608 (Aroclor 1254)	3
608 (Chlordane)	2

The following descriptions and definitions were used to describe the data:

True Value - Known concentration of the sample

Mean - The average value reported for each sample at each concentration.

% STD Reps - The average % standard deviation of the four replicates in each laboratory. % STD Reps was used for evaluation of individual laboratory precision.

% Diff. Mean vs True - The average of all participating laboratories percent difference of the laboratory reported mean from the true value as calculated below:

$$\%\ \text{Diff. Mean vs True} = \frac{(\text{True Value} - (\text{Mean of 4 Reps}))}{\text{True Value}} \times 100$$

% Diff. Mean vs True was used for the evaluation of accuracy.

% STD Mean Represents the % standard deviation of the laboratory determined means at each concentration level. % STD Mean was used for the evaluation of interlaboratory precision.

The acceptance criteria for each value is:

% STD Reps < 20%
% Diff. Mean vs True < 40%
% STD Mean < 40%

b) NJDEP PQL Study - MDLs

The MDLs reported by the laboratories in the PQL study were determined using 40 CFR Part 136, Appendix B. Analytes were spiked into a reagent water matrix. The variables used to describe the data are:

Mean - Average of all MDLs reported
Min - Minimum or lowest MDL reported
Max - Maximum or highest MDL reported

Various factors are applied to the average MDL to get an estimate of the PQL. The factor of 3.3 comes from the American Chemical Society. The factors of 5 and 10 come from the U.S.EPA definition of the PQL. Using these factors, a range for the PQLs can be derived where the PQL should be between 3.3 and 10 times the MDL.

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs reported by RUDES were determined as specified in 40 CFR Part 136, Appendix B. MDLs were determined for U.S.EPA methods 524.1, 502.1, and 608. Only MDLs determined by methods 524.1 + 608 were used for the evaluation of the PQL because they were performed exactly as specified in the methods. Analytes were spiked into two finished drinking water matrices.

d) U.S.EPA - WS#17

Results are reported for U.S.EPA and State Laboratories performance in the Water Supply Performance Evaluation Study #17 (U.S.EPA - WS#17). The following descriptions and definitions were used to describe the data:

True Value - Known concentration of the sample.

Mean - Average of results reported from each laboratories.

# of Labs - Number of U.S.EPA and State Laboratories participating in the study.

# of Labs Outside +/- 20% and +/- 40% - The number of laboratories with results outside +/- 20% and +/- 40% of the true value.

No breakdown was provided by U.S.EPA with the results of WS#17 to specify whether GC or GC/MS methods were being performed. It is assumed that most of the laboratories were using the 600 series methodologies at the time of this study.

e) NJDEP Certified A-280 Laboratories - MDLs Reported during Second Periodic Round of A-280 Testing

MDLs were reported to the BSDW during the second periodic round of A-280 testing by 15 Certified Laboratories. The methods for determining these MDLs were not clearly defined. Some laboratories reported a constant value for each analyte indicating that values reported were estimates and not statistically determined.

1) Benzene

The PQL was determined to be 1 ppb for benzene. Data from Rutgers University, Dept. of Environmental Sciences (RUDES), U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 503.1 and 524.1, given below, show acceptable accuracy and individual laboratory precision down to a concentration of 0.52 ppb. Interlaboratory precision was outside the acceptable limit (46% STD Mean > 40% acceptance limit) at this concentration. At 1.29 ppb and above, the results indicate acceptable precision and accuracy. The PQL, as indicated by the results of the PQL study could be set above 0.52 ppb but below 1.29 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	5.15	6.33	14.92	27.20	23.71
2	1.29	1.41	9.08	23.94	28.09
3	0.52	0.66	14.92	38.52	46.39
4	0.10	0.16	37.72	66.61	31.94
5	0.02	0.05	25.55	203.33	100.00

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL should be set between 1.06 - 3.20 ppb.

	Mean	Min	Max
MDL (ug/l)	0.32	0.02	1.45
3.3 x MDL	1.06		
5 x MDL	1.61		
10 x MDL	3.20		

c) Dept. of Environmental Science, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 524.1, GC/MS, are given below. Results show a large variation in the data depending upon the matrix and it is not known whether this matrix problem would be consistently observed. These MDLs are within the range observed in the PQL study.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.80	0.07

d) U.S.EPA - WS#17

Results from U.S.EPA WS#17, given below, do not indicate any problems with the quantitation of benzene within +/- 40% at concentrations of 2.8 and 5.8 ppb. The data quality should also improve when all laboratories use the new 500 series methodology. This indicates that quantitation at 1 ppb may be achievable.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
2.78	2.90	37	11	4
5.80	6.21	37	12	5

e) Conclusions

Based on the results of the PQL study and the MDLs reported during the study, a PQL of 1 ppb was determined for benzene. MDLs from RUDES and data from U.S. EPA WS-17 support this conclusion.

2) Carbon Tetrachloride

The PQL was determined to be 1 ppb for carbon tetrachloride. Data from Dept. of Environmental Sciences, Rutgers University (RUDES), U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1 and 524.1, given below, show acceptable accuracy and precision at concentrations of 2.65 ppb and above. At 1.06 ppb, both precision and accuracy were outside acceptable limits. A problem with quantitation of carbon tetrachloride sometimes exists due to peak overlapping with 1,1,1-trichloroethane on the primary GC column. The PQL, as indicated by the results of the PQL study, could be set above 1.06 but below 2.65 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	10.6	9.93	8.99	15.11	23.24
2	2.65	1.89	5.47	28.59	23.24
3	1.06	0.58	36.76	45.07	49.17
4	0.21	0.12	28.60	46.02	51.32
5	0.04	0.01	35.07	73.96	139.97

b) NJDEP PQL Study - MDLs

Multipication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicates that the PQL could be set between 1.06 - 3.20 ppb.

	Mean	Min	Max
MDL (ug/l)	0.32	0.04	0.96
3.3 x MDL	1.06		
5 x MDL	1.62		
10 x MDL	3.20		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using methods 524.1, GC/MS, are given below. Results show approximate agreement between the MDLs reported by RUDES and the average MDL reported in the PQL study. A small variation is observed in the data depending upon the matrix, and it is not known whether a matrix problem would be consistently observed.

	Ground Water	Surface Water
MDL Method 524.1 (ug/l)	0.60	0.21

d) U.S.EPA - WS#17

Results from U.S.EPA WP#17, given below, do not indicate any problems with quantitation of carbon tetrachloride at 5.53 ppb (only 4 labs out of 38 were outside 40% of the true value). At 2.51 ppb, however, approximately 25% (9 out of 37) of the labs were outside 40% of the true value. This data would indicate a range of acceptable quantitation between 2.51 and 5.53 ppb.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
2.51	2.48	37	20	9
6.68	6.37	38	15	3

e) Conclusions

Results from the sample analysis in the PQL study indicated that the PQL can be set above 1.06 ppb but below 2.65 ppb. MDLs from both the PQL study and RUDES indicate that the PQL could be set between 1.06 to 3.20 ppb. U.S.EPA results in WS-#17 indicated that acceptable quantitation could be achieved around 2.51 ppb. Results should be improved with the use of the 500 series methods.

Based on these results the PQL was set at 2 ppb. This decision was made mainly on the results of samples analysis in the PQL study.

3) Chlorobenzene

The PQL was determined to be 2 ppb for chlorobenzene. Data from Dept. of Environmental Sciences, Rutgers University, U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1, 503.1 and 524.1, given below, show acceptable accuracy and individual laboratory precision down to a concentration of 1.58 ppb. Interlaboratory precision was outside the acceptable limit (47% STD Mean > 40% acceptance limit) at this concentration range. At 4.00 ppb and above, the results indicate acceptable precision and accuracy. The PQL, as indicated by the results of the PQL study could be set above 1.58 but below 4.00 ppb.

Sample #	True Value	Lab Mean	%STD Reps	%DIFF Mean vs True	%STD Mean
1	15.8	15.77	9.21	16.80	27.77
2	4.00	3.10	9.47	29.75	35.31
3	1.58	1.31	11.85	34.20	47.12
4	0.32	0.31	40.92	46.77	60.84
5	0.06	0.10	38.45	165.92	146.88

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set in the range 1.09 - 3.30 ppb.

	Mean	Min	Max
MDL (ug/l)	0.33	0.05	1.05
3.3 x MDL	1.09		
5 x MDL	1.65		
10 x MDL	3.30		

c) Dept. of Environmental Sciences, Rutgers, Univ. (RUDES) - MDLs

MDLs from RUDES using method 524.1, GC/MS, are given below. Results show a small variation in the data depending upon the matrix and it is not known whether this matrix problem would be consistently observed. Results are fairly consistent with those found in the PQL study.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.50	0.21

d) Conclusions

Based on the results of sample analysis in the PQL study, a PQL of 2 ppb was determined. MDLs from RUDES and the PQL study support this conclusion.

4) Chlordane

The PQL was determined to be 0.5 ppb for chlordane. Data from Dept. of Environmental Sciences, Rutgers University and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results
Sample analysis results from the PQL study using U.S.EPA method 608, given below, show acceptable accuracy and precision down to a concentration of 0.16 ppb. The PQL, as indicated by the results of the PQL study could be set above 0.06 but below 0.16 ppb. It should be noted that only 2

laboratories reported results for chlordane and the sample matrix was reagent water.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	1.18	1.23	3.07	8.46	8.13
2	0.59	0.63	2.97	5.17	0.80
3	0.16	0.19	2.71	23.29	21.05
4	0.06	0.09	7.61	50.42	22.22
5	0.03	0.05	2.75	66.67	20.00

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the four laboratories reporting MDLs for chlordane in the PQL study by appropriate factors, shown below, indicate that the PQL could be set betwen 0.142 - 0.425 ppb.

	Mean	Min	Max
MDL (ug/l)	0.043	0.014	0.077
3.3 x MDL	0.142		
5 x MDL	0.213		
10 x MDL	0.425		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 608, are given below. Results show a variation in the data depending upon the matrix. These MDLs are also higher than the average MDL reported by the laboratories participating in the PQL study and indicate that the matrix may affect quantitation.

	Surface Water	Groundwater
MDL Method 608 (ug/l)	0.141 (ug/l)	0.054 (ug/l)

d) Conclusions

Results from the PQL study sample analysis and MDLs indicate that the PQL could be set around 0.2 ppb. The results from Rutgers University indicate that the sample matrix may affect quantitation. Therefore, the factor of 3.3 times the surface water MDL from RUDES (.465) was used to determine a PQL of 0.5 ppb.

5) Dichlorobenzenes

The PQL was determined to be 5 ppb for each of the dichlorobenzene isomers due to their similar chemical nature. Data was available on each isomer from the PQL study and on the 1,4-dichlorobenzene from the U.S.EPA.

5.1) 1,2-Dichlorobenzene

a) NJDEP PQL Study - Sample Analysis

Sample analysis results from the PQL study using U.S.EPA methods 503.1 and 524.1, given below, show acceptable accuracy down to a concentration of 2.85 ppb. Individual laboratory precision was outside acceptance limits at 15.5 ppb (22% STD Reps > 20% acceptance limit) but was acceptable at 1.55 and 2.85 ppb. Interlaboratory precision was outside the acceptable limit (STD Mean > 40% acceptance limit) at all concentration levels. The results would indicate that acceptable accuracy could be achieved at 2.85 ppb and above, but with a lot of variation between laboratories. Results of the PQL study do not provide clear guidance to set a PQL for this compound.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	15.5	14.98	21.99	34.02	45.13
2	2.85	3.05	15.15	36.10	46.87
3	1.55	1.42	19.68	49.47	49.47
4	0.22	0.46	29.38	191.82	127.66
5	0.05	0.80	8.35	1813.92	191.12

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the six laboratories participating in the PQL study by an appropriate factor, shown below, indicate that the PQL should be set between 5.02 - 15.20 ppb.

	Mean	Min	Max
MDL (ug/l)	1.52	0.14	4.40
3.3 x MDL	5.02		
5 x MDL	7.60		
10 x MDL	15.20		

5.2) 1,3-Dichlorobenzene

a) NJDEP PQL Study - Sample Analysis

Sample analysis results from the PQL study using U.S. EPA methods 503.1 and 524. 1, given below, show acceptable accuracy and precision down to a concentration of 2.58 ppb. At the next lowest concentration, 0.52 ppb, precision and accuracy were not acceptable. The PQL, as indicated by the results of the PQL study could be set between 0.52 - 2.58 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	25.8	27.49	17.68	12.42	12.25
2	6.45	6.03	13.56	21.78	26.45
3	2.58	2.24	11.38	17.96	20.12
4	0.52	0.35	34.25	52.39	78.99
5	0.10	0.03	43.08	86.34	192.03

b) Multiplication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 2.74 - 8.33 ppb.

	Mean	Min	Max
MDL (ug/l)	0.83	0.04	3.20
3.3 x MDL	2.74		
5 x MDL	4.16		
10 x MDL	8.33		

5.3) 1,4-Dichlorobenzene

a) NJDEP PQL Study - Sample Analysis

Sample analysis results from the PQL study using U.S.EPA methods 503.1 and 524.1, given below, show acceptable accuracy down to a concentration of 1.36 ppb. Interlaboratory precision was outside the acceptable limit (46% STD Mean > 40% acceptance limit) at 3.4 ppb but was acceptable at 13.6 ppb or 1.36 ppb. At 13.6 ppb individual laboratory precision was outside acceptable limits (% STD Reps > 20% acceptance limit). The PQL, as indicated by acceptable accuracy could be set around 1.36 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	13.6	14.62	24.33	30.76	34.32
2	3.4	3.16	8.46	35.61	45.80
3	1.36	1.09	13.77	19.66	18.54
4	0.27	0.26	26.80	73.91	100.88
5	0.05	0.15	8.53	303.98	158.18

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 2.84 - 8.64 ppb.

	Mean	Min	Max
MDL (ug/l)	0.86	0.17	2.72
3.3 x MDL	2.84		
5 x MDL	4.32		
10 x MDL	8.64		

c) U.S.EPA - WS#17

Results from U.S.EPA - WS#17, given below, do not indicate any problems with the quantitation of 1,4-dichlorobenzene within +/- 40% at concentrations of 3.64 and 776 ppb. It should be noted that only the 1,4 isomer was used in WS#17 and therefore no problems were observed due to coelution of the isomers.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
3.64	3.55	31	13	4
776	739	32	14	2

5.4) Conclusions

Results for all three dichlorobenzene isomers indicate that acceptable accuracy (within +/- 40%) can be achieved between 1.5 and 3 ppb. Precision in both the individual laboratories and among laboratories is quite variable. This problem is probably due to poor resolution on the primary GC column and would indicate that the PQL should be above the low end of acceptable accuracy. Method detection limits reflected the problems observed with quantitation. The highest average MDL was 1.52 for 1,2-dichlorobenzene. Using a factor of 3.3 times this MDL yields a PQL of 5.02. The PQL was set at 5 ppb for the dichlorobenzenes.

6) 1,2-Dichloroethane

The PQL was determined to be 2 ppb for 1,2-dichloroethane. Data from Department of Environmental Sciences, Rutgers University and U.S.EPA were available for this compound.

a) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 524.1 are given below. The results are fairly consistent and do not indicate a matrix problem. Multiplication of the average MDL by the appropriate factors (3.3-10) indicate that the PQL can range from 2.56 - 7.76 ppb.

	Surface Water	Ground Water
MDL Method 524.1	0.83	0.72

b) U.S.EPA - WS#17

Results from U.S.EPA WS#17, given below, do not indicate that any problems exist with the quantitation of 1,2-dichloroethane at 5.38 ppb. Only 8 of the laboratories were outside +/- 40% of the true value. At 1.51 ppb, however, 24% of the laboratories were outside +/- 40% of the true value.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
1.51	1.77	33	12	8
5.38	5.39	37	4	3

c) Conclusions

With no information available from the PQL study, the PQL for 1,2-dichloroethane was determined from RUDES MDLs and U.S.EPA WS#17 data. The RUDES data indicated an average matrix MDL of 0.78. A factor of 3.3 times the average MDL would be 2.56 ppb. U.S. EPA data indicated that quantitation was difficult at 1.51 ppb. Results can be expected to improve with the use of the 500 series methods. The PQL was set at 2 ppb.

7) 1,1-Dichloroethylene

The PQL was determined to be 2 ppb for 1,1-dichloroethylene. Data from RUDES and the U.S.EPA were available for this compound.

a) RUDES - MDL

MDLs from RUDES using method 524.1, GC/MS, are given below. The results are consistent indicating no matrix effects. A factor of 3.3 times the average MDL would be 1.2 ppb, 5 times would be 1.78, and 10 times would be 3.55.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.37	0.34

b) U.S.EPA WS#17

Results from U.S.EPA WS#17, given below, indicated difficulty with the quantitation at both concentration levels tested. At 2.38 ppb, 31% of the laboratories were outside the +/- 40% acceptance limits. At 4.75 the number outside this limit dropped to 24% outside the acceptance limits.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
2.38	3.10	32	19	10
4.75	6.28	33	15	8

c) Conclusions

Since the PQL study did not include 1,1-dichloroethylene, the PQL of 2 ppb was based upon the RUDES and U.S.EPA data. The RUDES MDLs indicated the the PQL should be around 1.2 to 3.55 ppb. The results from U.S.EPA WS#17 indicated that quantitation of 1,1-dichloroethylene is difficult around 2 ppb. Quantitation is expected to improve with the use of the 500 series methods. The PQL was set at 2 ppb.

8) trans-1,2-Dichloroethylene

The PQL was determined to be 2 ppb for trans-1,2-dichloroethylene. Data was only available from Dept. of Environmental Sciences, Rutgers University (RUDES).

a) RUDES

MDLs from RUDES using method 524.1, GC/MS, are given below. Results show a variation in the data depending upon the matrix and it is not known whether this matrix problem would be consistently observed. The average MDL is 0.52 ppb and 3.3 times this value would be 1.72 ppb.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.86	0.18

Very little information is available for trans-1,2-dichloroethylene. Since its chemical nature is similiar to 1,1-dichloroethylene, a PQL of 2 ppb was used.

9) Methylene Chloride

The PQL was determined to be 2 ppb for methylene chloride. Data from Dept. of Environmental Sciences, Rutgers University and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1 and 524.1, given below, show acceptable accuracy and precision at concentrations of 0.91 ppb and above. At the next lowest concentration level, 0.18 ppb, precision and accuracy were outside acceptable limits. One problem associated with the quantitation of methylene chloride, but not evident in the PQL study is blank contamination. The PQL, as indicated by the results of the PQL study could be set above 0.18 but below 0.91 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	9.11	11.03	9.15	24.02	13.76
2	2.38	2.51	9.73	22.03	20.46
3	0.91	1.10	12.62	34.58	33.05
4	0.18	0.45	27.23	147.61	61.27
5	0.04	0.37	23.97	717.87	74.22

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the five laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 1.12 - 3.41 ppb.

	Mean	Min	Max
MDL (ug/l)	0.34	0.07	1.00
3.3 x MDL	1.12		
5 x MDL	1.70		
10 x MDL	3.41		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 524.1, GC/MS, are given below. Results show a small variation in the MDLs depending upon the matrix and it is not known whether this matrix problem would be consistently observed. Results are within the range observed in the PQL study.

	Surface Water	Groundwater
MDL Method 524.1 (ug/l)	0.45	0.81

d) Conclusions

Results from the sample analysis in the PQL study indicated that the PQL can be set between 0.18 ppb and 0.91 ppb. MDLs from the PQL study were between 1.12 - 3.41 ppb. MDLs from RUDES, using surface and groundwater matrices, indicate that the matrix may affect quantitation. Based on these results and the fact that methylene chloride is a known laboratory contaminant, the PQL was set at 2 ppb.

10) PCBs

The PQL was determined to be 0.5 ppb for PCBs. Data from Dept. of Environmental Sciences Rutgers University (RUDES), NJDEP Certified Laboratories, and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study given below, with 3 laboratories reporting results, show acceptable accuracy and precision at concentrations of 0.13 ppb and above. At the lowest concentration, 0.07 ppb, both individual laboratory precision and accuracy were outside acceptable limits. U.S.EPA Method 608 was used

for the analysis of the PCB mixture, Aroclor 1254. One limitation to the PQL study data was that the samples were prepared in reagent water and, therefore, matrix problems which are known to affect PCB quantitation, were not observed. The PQL, as indicated by the results of the PQL study could be set between 0.07 - 0.13 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	0.97	0.92	7.59	14.69	16.04
2	0.49	0.44	13.83	17.47	22.51
3	0.32	0.30	15.70	35.75	39.15
4	0.13	0.14	11.03	31.86	32.90
5	0.07	0.09	29.56	45.64	24.00

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the four laboratories reporting MDLs in the PQL study for Aroclor 1254, by the appropriate factors shown below, indicate that the PQL could be set between 0.525 - 1.59 ppb.

	Mean	Min	Max
MDL (ug/l)	0.159	0.060	0.252
3.3 x MDL	0.525		
5 x MDL	0.793		
10 x MDL	1.59		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 608 for the analysis of Aroclors 1254 and 1242 are given below. Results show the MDLs to be within the range of the PQL study MDLs. No matrix problems were apparent. The MDLs were slightly higher for Aroclor 1242 than 1254.

	Surface Water	Ground Water
MDL Aroclor 1254 (ug/l)	0.131	0.173
MDL Aroclor 1242 (ug/l)	0.189	0.185

d) NJDEP Certified A-280 Laboratories - MDLs Reported During Second Periodic Round of A-280 Testing

MDLs were reported by 15 A-280 certified laboratories for a series of PCB mixtures (Aroclors are mixtures of PCB isomers) during the second periodic round of A-280 testing. These laboratories were using U.S.EPA method 608, but their methods of determining the MDLs were not clearly defined. This lack of a specified method For MDL determination was obvious from a consistently reported MDL minimum of 0.05 ppb and a maximum of 5 ppb which indicates that the were not statistically determined estimates. The means, however varied due to some laboratories determining the MDLs for the individual Aroclors. Average MDLs do not show any major differences among the specific PCB mixtures.

	Mean (ug/l)	Minimum (ug/l)	Maximum (ug/l)
Aroclor 1016	0.84	0.05	5
Aroclor 1221	1.11	0.05	5
Aroclor 1232	0.92	0.06	5
Aroclor 1242	0.93	0.05	5
Aroclor 1248	1.04	0.05	5
Aroclor 1254	1.03	0.05	5
Aroclor 1260	0.96	0.05	5

e) Conclusions

Results from the sample analysis in the PQL study indicate the PQL for Aroclor 1254 could be set above 0.07 ppb but below 0.13 ppb. Two limitations to this data are that only three laboratories reported data, and there were no matrix interferences such as these known to affect PCB analysis. Multiplication of the MDLs from the PQL study by specified factors indicate that the PQLs could be set between 0.525 an 1.59 ppb. RUDES data was within the range of MDLs reported in the PQL study. Based on these results, the PQL was set at 0.5 ppb for Aroclor 1254. Data from the A-280 certified laboratories and RUDES did not show any major differences between the MDLs for the different Aroclors (PCB mixtures). Therefore, the PQL for PCBs (each individual Aroclor) is 0.5 ppb.

11) Tetrachloroethylene (PCE)

The PQL was determined to be 1 ppb for tetrachloroethylene or perchlorethylene (PCE). Data from Dept. of Environmental Sciences, Rutgers University (RUDES), U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1, 503.1, and 524.1, given below, show acceptable accuracy and precision at concentrations of 2.26 ppb and above. At the next lowest concentration, 0.45 ppb, both precision and accuracy were outside acceptable limits. The PQL, as indicated by the results of the PQL study could be set between 0.45 - 2.26.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	22.60	24.56	11.15	14.27	15.53
2	5.65	4.95	7.63	18.57	12.37
3	2.26	1.94	6.80	30.65	31.42
4	0.45	0.35	19.97	53.21	51.18
5	0.09	0.07	18.19	68.91	102.04

b) NJDEP PQL Study - MDLs

Multiplication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 0.63 and 1.88 ppb.

	Mean	Min	Min
MDL (ug/l)	0.19	0.02	0.59
3.3 x MDL	0.63		
5 x MDL	0.94		
10 x MDL	1.88		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 524.1, GC/MS, are given below. Results are within the range of MDLs reported in the PQL study and no matrix problems are indicated.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.34	0.20

d) U.S.EPA - WS#17

Results for U.S. EPA WP#17, given below do not indicate any problems with quantitation of PCE down to 2.18 ppb (only 2 labs out of 37 reported results outside +/- 40% of the true value). This would indicate that quantitation could be achieved below 2.18 ppb.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
2.18	2.64	34	10	2
8.74	8.06	38	4	1

e) Conclusions

Results from the sample analysis in the PQL study indicated that the PQL can be set above 0.45 ppb but below 2.26 ppb. MDLs from the PQL study indicate that the PQL could be set between 0.63 - 1.88 ppb. Data from RUDES is within the range of the MDLs reported in the PQL study. U.S.EPA results in WS#17 indicated that quantitation is easily achieved at 2.18 ppb. These results would be expected to improve with the use of the 500 series. Based on these results, the PQL for PCE was set at 1 ppb.

12) 1,2,4-Trichlorobenzene

There were no data available on 1,2,4-trichlorobenzene from the Department of Environmental Sciences, Rutgers University, U.S.EPA or the NJDEP PQL study. The PQL for 1,2,4-trichlorobenzene was, therefore, based on the dichlorobenzenes which are the most structurally similiar compounds to it, and set at 5 ppb.

13) 1,1,1-Trichloroethane

The PQL was determined to be 1 ppb for 1,1,1-trichloroethane. Data from Rutgers University, U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Analysis

Sample analysis results from the PQL study using U.S.EPA methods 502.1 and 524.1, given below, show acceptable accuracy down to a concentration of 0.15 ppb. Precision (individual and interlaboratory) was outside the acceptable limit at this concentration level and at 0.74 ppb range. At 1.85 ppb and above, the results indicate both acceptable precision and accuracy. The PQL, as indicated by the results of the PQL study could be set above 0.74 but below 1.85 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	7.39	6.47	9.61	33.32	57.02
2	1.85	1.58	7.62	22.84	24.94
3	0.74	0.48	30.64	34.46	46.36
4	0.15	0.17	53.98	23.79	36.28
5	0.03	0.05	8.54	151.87	99.85

b) NJDEP PQL Study - MDLs

Multipication of the average MDLs from the five laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 1.25 - 3.78 ppb.

	Mean	Min	Max
MDL (ug/l)	0.38	0.06	1.28
3.3 x MDL	1.25		
5 x MDL	1.89		
10 x MDL	3.78		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using method 524.1, GC/MS, is given below. Results show close agreement between the MDLs reported by RUDES, using method 524.1, and the average MDL reported in the PQL study. These results do not indicate any matrix problems.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	0.31	0.27

d) U.S.EPA - WS#17

Results for U.S.EPA WS#17, given below, indicate that the laboratories were having some difficulty with the quantitation of 1,1,1-trichloroethane at 2.64 ppb (19% of the laboratories results were outside +/- 40% of the true value).

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
2.51	2.48	37	20	9
5.53	5.39	38	15	4

e) Conclusions

Results from the sample analysis in the PQL study indicated that the PQL can be set above 0.74 ppb but below 1.85 ppb. MDLs from both the PQL study and RUDES indicate that the PQL could be set between 1.25 - 3.78 ppb. U.S.EPA results in WS#17 indicated that there was some difficulty in quantitation at 2.64 ppb. Results should be improved with the use of the 500 series methods. Based on these results the PQL was set at 1 ppb.

This decision was made mainly on the results of sample analysis in the PQL study.

14) Trichloroethylene

The PQL was determined to be 1 ppb for trichloroethylene. Data from Dept. of Environmental Sciences Rutgers University, U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1, 503.1, and 524.1, given below, show acceptable accuracy down to a concentration of 0.35 ppb. Precision (both individual and interlaboratory) was outside acceptable limits at this level. At 1.75 ppb both laboratory precision and accuracy were acceptable. The PQL, as indicated by the results of the PQL study could be set above 0.35 but below 1.75 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	17.5	18.45	9.27	9.27	18.04
2	4.38	3.70	4.58	19.27	16.07
3	1.75	1.42	7.252	27.26	34.47
4	0.35	0.27	21.29	29.21	40.56
5	0.07	0.04	31.90	64.42	110.29

b) NJDEP PQL Study - MDLs

Multipication of the average MDLs from the six laboratories participating in the PQL study by appropriate factors, shown below, indicated that the PQL could be set betwen 1.25 - 3.79 ppb.

	Mean	Min	Max
MDL (ug/l)	0.38	0.04	2.76
3.3 x MDL	1.25		
5 x MDL	1.89		
10 x MDL	3.79		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from Rutgers University using method 524.1, GC/MS, are given below. Results show a small variation in the data depending upon the matrix, and it is not known whether this matrix problem would be consistently observed. RUDES MDLs are within the range reported in the PQL study.

	Surface Water	Ground Water
MDLs Method 524.1 (ug/l)	0.60	0.28

d) U.S.EPA - WS#17

Results from U.S.EPA WS#17, given below do not indicate any problems with quantitation of trichloroethylene down to 1.74 ppb (only 1 lab out of 26 was outside acceptable accuracy limits). This would indicate a range of acceptable quantitation below 1.74 ppb.

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
1.74	1.70	36	10	1
5.53	5.39	38	7	2

e) Conclusions

Results from the sample analysis in the PQL study indicated that the PQL can be set above 0.35 ppb but below 1.75 ppb. MDLs from both the PQL study and RUDES indicate that the PQL could be set between 1.25 to 3.79 ppb. U.S. EPA results in WS#17 indicated that acceptable quantitation could be achieved down to 1.74 ppb. Results should be improved with the use of the 500 series methods. Based on these results, the PQL was set at 1 ppb. This decision was made based on the results of sample analyses in the PQL study.

15) Xylenes

The PQL was determined to be 2 ppb for each of the three xylene isomers. Data was only available from the Department of Environmental Sciences, Rutgers University (RUDES).

The MDLs reported by RUDES using method 524.1, GC/MS, are given below. MDLs show small variations in the results depending upon the matrix, and it is not known whether this problem would be consistently observed.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)		
1,3-xylene	0.35	0.20
1,2- and 1,4-xylene	0.75	0.22

Applying factors (3,3-10) to the average of the MDLs reported by RUDES indicated that the PQL could be set between 1.25 and 3.80 ppb. Multiplication of the highest MDL reported (0.75 ppb) by the smallest factor, 3.3, would yield 2.48 ppb. The PQL was, therefore, set at 2 ppb.

16) Vinyl Chloride

The PQL was determined to be 5 ppb for vinyl chloride. Data from Department of Environmental Sciences, Rutgers University, U.S.EPA and the PQL study were available for this compound.

a) NJDEP PQL Study - Sample Results

Sample analysis results from the PQL study using U.S.EPA methods 502.1 and 524.1, given below, show acceptable accuracy at a concentration of 5.08 ppb. At the two concentration levels above and below 5.08 ppb, accuracy was outside acceptable limits. Interlaboratory precision was outside the acceptance limits at each concentration level studied. Variations in interlaboratory precision and accuracy are due to the fact that vinyl chloride is so volatile and it is very difficult to prepare standards and samples.

Individual laboratory precision was just outside the acceptable level (23.32% > 20%) at 5.08 ppb. At 12.72 and 50.8 ppb, individual laboratory precision was acceptable. The PQL, as indicated by the results of the PQL study should be set around 5 ppb.

Sample #	True Value (ug/l)	Lab Mean (ug/l)	%STD Reps	%DIFF Mean vs True	%STD Mean
1	50.8	55.73	17.99	62.39	80.85
2	12.72	12.62	7.50	42.99	58.07
3	5.08	3.94	23.32	34.78	49.48
4	1.02	0.85	51.77	54.92	65.60
5	0.2	0.24	26.17	82.7	78.86

b) NJDEP PQL Study - MDLs

Multipication of the average MDLs from the five laboratories participating in the PQL study by appropriate factors, shown below, indicate that the PQL could be set between 2.18 - 6.60 ppb.

	Mean	Min	Max
MDL (ug/l)	0.66	0.04	2.24
3.3 x MDL	2.18		
5 x MDL	3.30		
10 x MDL	6.60		

c) Dept. of Environmental Sciences, Rutgers University (RUDES) - MDLs

MDLs from RUDES using Method 524.1, GC/MS, are given below. Results show small variations in the results depending upon the matrix, and it is not known whether this matrix problem would be consistently observed.

	Surface Water	Ground Water
MDL Method 524.1 (ug/l)	1.51	1.08

d) U.S.EPA - WS#17

Results for U.S.EPA WP#17, given below, indicate the difficulty with the quantitation of vinyl chloride. Results range from 46% of the labs outside acceptance limits at 1.51 ppb to 26% of the labs outside acceptable accuracy limits at 12.7 ppb. Accuracy and precision are expected to improve when using the 500 series methods

True Value (ug/l)	Mean (ug/l)	# of Labs	# of Labs Outside +/- 20%	# of Labs Outside +/- 40%
1.51	2.12	24	19	11
6.74	8.42	26	14	9
12.7	16.5	27	15	7

e) Conclusions

Results from the sample analyses in the PQL study indicated that the PQL can be set around 5 ppb. MDLS from both the PQL study and RUDES indicate that the PQL could be set between 2.18 and 6.60 ppb. U.S.EPA results in WS-17 indicated that quantitation of all tested concentration levels will be difficult. Results may be improved with the use of the 500 series methods.

Based on these results the PQL, was set at 5 ppb.

Appendix D
TECHNOLOGICAL FEASIBILITY AND COST SUPPORT DOCUMENT

Program Subcommittee

Drinking Water Quality Institute

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Bureau of Safe Drinking Water
New Jersey Department of
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Dated: March, 1987

TECHNOLOGICAL FEASIBILITY AND COST

A. Summary

Two technologies, packed aeration towers (air stripping) and granular activated carbon contactors (GAC contacting) can remove from drinking water the "A-280" chemicals currently monitored. Specifically, trichloroethylene, tetrachloroethylene, 1,1-dichloroethylene, carbon tetrachloride, vinyl chloride, cis- and trans-1,2-dichloroethylene, 1,1,1-trichloroethane, xylenes, benzene, chlorobenzene, dichlorobenzene(s), methylene chloride, 1,2-dichloroethane, trichlorobenzene(s), polychlorinated biphenyls (PCBs) and chlordane can be removed with air stripping and/or GAC contacting. There is insufficient data to draw a conclusion for methyl ethyl ketone, ethylene glycol, kerosene, formaldehyde and n-hexane.

Theoretical models of the air stripping process along with laboratory, bench scale and pilot studies accurately predict performance of full scale air stripping towers. When towers are engineered and operated to standards, removal efficiencies better than 99% have been achieved. These models are based in part on the behavior of ideal dilute solutions. Performance should approximate predictions as solutions become more dilute as they do when concentrations are less than 100 parts per billion.

On the other hand, theoretical models are not generally available to predict single or multi-contaminant removals by GAC contacting. Full scale systems have the best chance for success when based on pilot systems tested in the field. Complex mixtures of contaminants and naturally occurring organics make predictions more difficult as well as the nature of GAC and its ability to adsorb and desorb organics selectively.

In New Jersey, both air stripping and GAC contactors have been successfully designed, constructed and operated to achieve reductions of organics. Reductions have been achieved to the limits of analytical detectability, which may be less than one part per billion. Air strippers and GAC contactors in use in New Jersey vary widely in size. The smallest serves fewer than 100 people with a capacity of 200 gallons per minute (gpm). The largest, presently under construction, could serve over 50,000 people with a capacity of 3,680 gpm (5.2 million gallons per day (mgd)).

Statewide cost estimates indicate that a total of about fifty to seventy million dollars (1986$) would be needed by approximately one hundred and twenty public community water supplies to provide treatment for organics noted above. Estimated rate increases could range from about $0.05 to $0.96 per 1,000 gallons of treated water. These cost estimates are conceptual and are only for air stripping by a packed aeration tower. These estimated are based on data provided by suppliers and NJDEP.

Cost estimates must increase with site and system improvements, air emission controls, disposal of spent carbon and local zoning requirements.

The effected supplies typically rely on groundwater as their source of water. They are located in all areas of New Jersey. While treatment is feasible and practicable, costs of alternatives may determine if treatment is employed. It must be noted that noncommunity public water supplies and private individual well supplies are not included in the description of impacts.

In summary, treatment with air stripping and GAC contacting is both feasible and practicable for organic carcinogens and non-carcinogens for which MCLs are recommended. However, investigations should be continued to determine the feasibility and practicability of treatment for organics as they are recommended for regulation.

B. Feasibility of Treatment of Carcinogens

The nature of the organic compound determines the treatment technique. Some organics are readily volatilized and some are readily adsorbed. To evaluate the technological feasibility of treatment to achieve recommended maximum contaminant levels, available literature and actual field studies were utilized. Laboratory, bench scale, pilot and field studies for all of the volatiles except for xylenes, polychlorinated biphenyls (PCBs) and chlordane are summarized by Love et al. in a U.S.EPA publication entitled "Treatment of Volatile Organic Chemicals in Drinking Water" (March 1984). For xylenes, PCBs and chlordane, the following three reference sources were used: U.S.EPA's "Review of Treatability Data for Twenty-Five Synthetic Organic Chemicals;" U.S.EPA's "Carbon Adsorption Isotherms for Toxic Organic Chemicals" by Dobbs and Cohen; and Draft Reports by Abrams and Medlar for NJDEP's Special Water Treatment Study. Feasibility data were not summarized for the remaining chemicals: methyl ethyl ketone, ethylene glycol, kerosene, formaldehyde and n-hexane. The reported removal efficiency for specific treatment process are noted in Table 1. Air stripping and GAC contacting are preferred treatment techniques.

Table 1
Treatment Technologies For VOC Reduction

Air Stripping	Reported Removal Efficiency
Packed Aeration Towers	90-99.9%
Multiple Trav Aeration	40-90%
Diffused Aeration	70-92%
Spray Aeration	75-90%
Air Lift Pumping	40-97%
Cascade Aeration	40-80%
GAC Contacting	
Granular Activated Carbon Contactors (GAC)	>99%
Powered Activated Carbon Addition	50-90%
Synthetic Resin Contactors	>90%
Other Treatment Options	
Point of Use GAC	90->99%

Ref. U.S.EPA Briefing Materials, 1985.

Henry's Constants

Most of the A-280 organics under consideration are generally volatile. Many of these compounds are amenable to aeration. If present in ground water supplies, their concentration is usually less than one hundred parts per billion. If present in surface water supplies, their concentration is usually lower. Henry's Law for ideal dilute solutions is appropriate for calculating the amount of a compound that may transfer from the water to the air. Henry's Law in general describes the transfer process with a constant called Henry's Constant. The higher the Constant the greater the air concentration will be relative to the water concentration for a specific compound. These calculations are essential for the design of treatment processes. The calculations are simplified when the organics dissolved in the water are at low concentrations, do not react with other dissolved compounds and are allowed to reach equilibrium with clean air at normal temperatures and pressures. These conditions can be approximated in actual practice. Therefore, the performance of air strippers may be predicted. A simplified mathematical expression of the air-water equilibrium for a compound follows:

$Cg = H*Cl$

Cg = concentration in the air (gas) of compound A (ug/l)
Cl = concentration in the water (liquid) of compound A (ug/l)
H = Assumed Henry's Constant (partition coefficient atm-cm/cm)

Packed aeration towers provide treatment by bringing clean air into contact with contaminated water. The tower is filled with an inert packing media. Water cascades down and forms a thin film on the packing. A continuous flow of fresh air passing over the film of water helps vaporize the organics from the water into the air. The relative ease of stripping is portrayed on Table 2. For organics that are weakly air-stripped, such as 1,2-dichloroethane, a combination of air stripping and GAC contacting makes reduction feasible. Two organics, chlordane and PCBs have very low H values. It is not feasible to air strip either of these chemicals. These compounds are readily adsorbed onto carbon.

Carbon Isotherms

Similarly, most of the A-280 organics are adsorbable onto granular activated carbon (GAC). The GAC is typically kept in a cylindrical contactor through which contaminated water flows. GAC is specially treated carbon that has an enormous internal surface area on which organic molecules in the water can be adsorbed.

The balance or equilibrium between the adsorbed organics and those remaining in solution can be upset. Changes in water quality alter the equilibrium. Ideal conditions require that water temperature remain constant and that equilibrium be reached. Then the capacity of a particular organic to be adsorbed by a specific GAC may be measured. The mathematical relationship between the amount of organic compound in the water and the amount of organic compound adsorbed is described by a carbon adsorption isotherm.

The relative ease of adsorption by GAC contacting is portrayed on Table 3. Weakly adsorbed organics may require a combination of air stripping and carbon adsorption. Vinyl chloride which is not feasible to adsorb is readily air stripped.

Air Emissions

Packed aeration towers may emit unacceptable concentrations of volatile organic contaminants into the air. The present rules of the Bureau of Air Pollution Control require state of the art control if more than .1 pound per hour of TVOS is emitted. TVOS is an acronym for toxic volatile organic substances which are defined by the Bureau of Air Pollution Control. This may necessitate the use of vapor phase carbon to adsorb the organics being emitted. Costs for air stripping may double if vapor phase carbon treatment is required.

Breakthrough

GAC adsorbs organics selectively and may release subsequently what was previously adsorbed. GAC has a limited capacity to adsorb a specific organic. This may result in the organic breaking through the contactor and reentering the drinking water.

Table 2
Relative Ease of Removing Selected
Volatile Chemicals from Water by Air Stripping

	Air Strippability				
	READILY	MODERATE	WEAKLY	NOT	REF.
Benzene		X			3,9
Carbon Tetrachloride	X				1,9
Chlordane				X	6,9
Chlorobenzene	X				10,9
p-Dichlorobenzene			X		6,9
o-Dichlorobenzene		X			10,9
m-Dichlorobenzene		X			10,9
1,2-Dichloroethane			X		1,9
1,1-Dichloroethylene	X				6,9
Cis-1,2-Dichloroethylene		X			7,9
Trans-1,2-Dichloroethylene		X			1
Ethylene Glycol	----------NR----------				
Formaldehyde	----------NR----------				
Kerosene	----------NR----------				
Methyl Ethyl Ketone	----------NR----------				
Methylene Chloride			X		4,9
N-Hexane	----------NR----------				6
Polychlorinated Biphenyls				X	6,9,12
Tetrachloroethylene	X				5,9
1,1,1-Trichloroethane					4,9
1,2,4,-Trichloroebenzene					10,9
Trichloroethylene					2,9
Vinyl Chloride					1
Xylenes Ortho, Meta, Para					1,9

NR = Not Reported

Table 3
Relative Ease of Removing Selected
Volatile Chemicals from Water by GAC Contacting

ORGANIC CHEMICAL	Carbon Adsorbability			
	READILY	MODERATELY	WEAKLY	NOT
Benzene			X	
Carbon Tetrachloride			X	
Chlordane	X			
Chlorobenzene			X	
p-Dichlorobenzene		X		
o-Dichlorobenzene		X		
m-Dichlorobenzene		X		
1,2-Dichloroethane			X	
1,1-Dichloroethylene			X	
Cis-1,2-Dichloroethylene			X	
Trans-1,2-Dichloroethylene			X	
Ethylene Glycol	----------NR----------			
Formaldehyde	----------NR----------			
Kerosene	----------NR----------			
Methylene Chloride			X	
N-Hexane	----------NR----------			
Polychlorinated Biphenyls	X			
Tetrachloroethylene			X	
1,1,1-Trichloroethane			X	
1,2,4-Trichlorobenzene		X		
Trichloroethylene			X	
Vinyl Chloride				X
Xylenes Ortho, Meta, Para			X	

NR = Not Reported

To control this potential problem utilities will have to monitor and replace the carbon. The frequency of replacing the carbon will significantly affect costs.

Other Chemicals

There are some organics such as methyl ethyl ketone that may be neither strippable nor adsorbable. As such chemicals are considered for regulation in drinking water, appropriate treatment technologies will have to be investigated.

C. Impact

The latest compilation (February 1987) of laboratory results submitted by purveyors and taken by NJDEP for public community water supplies has been reviewed and compared to the recommended maximum contaminant levels that the N.J. Drinking Water Quality Institute has considered adopting, prior to the final vote of the Institute. This includes results from December 1984 to November 1986. The summary below indicates that about 120 purveyors have reported organics above what the Institute has considered recommending as MCLs. This amounts to about 20% of the 630 public community water suppliers. It must be noted that exceeding the recommended MCL was the only criteria used to determine if a purveyor was affected. Secondly, the capacity of the facilities needed to create the contaminated wellfield was estimated from historical information and the experience of Bureau of Safe Drinking Water (Division of Water Resources) staff. Lastly, the population that may be expected to share in the cost of improvements was estimated to be the entire service area and not just those served by the wells and treatment facility.

Estimated Impact on Public Community Water Supplies (PCWS)

	Service Area Population		
	Less than 5000	More than 5000 and less than 50,000	More than 50,000
Total Number of PCWS	57	53	9
Total Estimated PCWS Pop.	70,000	890,000	2,040,000

D. Practicability of Treatment for Noncarcinogens

The practicability of achieving the recommended MCLs was considered for the following noncarcinogens: chlorobenzene, trichlorobenzene, 1,1,1-trichloroethane, 1,1-dichloroethylene, cis- and trans-1,2-dichloroethylene and xylenes. Maximum contaminant levels are not recommended for the following noncarcinogens: ethylene glycol, kerosene, methyl ethyl ketone and n-hexane. In general, practicability was considered by estimating the size and cost of hypothetical treatment facilities, namely air strippers for various capacities and contaminant concentrations (Abrams and Medlar, 1986). Table 4 summarizes available data for a hypothetical one mgd air stripper with a hypothetical influent concentration of 100 ppb for each noncarcinogen. In summary, for noncarcinogens noted, available studies and limited field data indicate the practicability of air stripping, even for the not so strippable dichlorobenzenes and trichlorobenzene. A brief discussion of each of the noncarcinogens follows.

Table 4
Air Stripper Hypothetical Design
for Noncarcinogens
($1986)

Non-Carcinogens	Estimated Tower Height (ft.)	Estimated Tower Diameter (ft.)
Chlorobenzene	not calculated	
o-Dichlorobenzene	5	5
m-Dichlorobenzene	5	5
1,1-Dichloroethylene	14	5
Trans-1,2-Dichloroethylene	7	5
Cis-1,2-Dichloroethylene	7	5
Ethylene Glycol	No data available	
Methyl Ethyl Ketone	No data available	
n-Hexane	No data available	
1,1,1-Trichloroethane	10	5
Trichlorobenzene	No data available	
Xylenes	6	5

Ref: Abrams, 1986

1. Assume Plant Design Capacity is 1 MGD
2. Use Construction Cost Index, ENR CCI4229
3. Assume Effluent Concentration, Level I, Drinking Water Guidance (NJDEP, 1986)

Chlorobenzene - Pilot scale studies reported by Suffet, 1981 indicate the reduction of chlorobenzene with GAC and with resins. They also report what appears to be desorption. Aeration studies (Love, 1983) reported by U.S.EPA indicate that air stripping is feasible. U.S.EPA's reported value for the Henry's Constant is 0.19 units.

Trichlorobenzene, Ortho- and Meta- Dichlorobenzene - Pilot scale studies reported by Suffet, 1981 indicate that GAC can adsorb the trichlorobenzene completely. However, they also report an increase in concentration (desorption) after treatment by resins. Desorption is a concern with organics that are weakly adsorbed. Dobbs and Cohen, U.S.EPA 1980, have provided laboratory values for GAC adsorption from isotherm data.

U.S.EPA (Love, 1983) has conducted aeration studies and reported values for Henry's Constants that indicate the practicability of air stripping for trichlorobenzene and dichlorobenzenes. Because these organics are weakly strippable, both air stripping and GAC contacting may be considered practicable.

1,1,1-Trichloroethane - Pilot and field studies by Love, 1983 for air stripping and carbon adsorbing of this compound indicate the feasibility of treatment. Air stripping is practicable and avoids the problem of desorption.

1,1-Dichloroethylene - Theoretical, pilot scale and field studies reported by Love, 1983 indicate that this compound is readily stripped and adsorbed.

Cis- and trans-1,2 Dichloroethylene - Despite the difficulty of separating the isomers, pilot and field studies cited by U.S.EPA and reported by Love, 1983 indicate that the compounds are amenable to GAC adsorption and air stripping. Since the compound is weakly adsorbed and readily stripped, air stripping is practicable. Both isomers have the same Henry's Constants for all practical purposes.

Xylenes - The three isomers, ortho, meta and para-xylene, have been the subject of various field and pilot studies. U.S.EPA Review, 1984 has reported on carbon adsorption tests. Dobbs, 1980 has indicated that para-xylene is weakly adsorbed. Ortho-xylene was traced through a lime softening plant in Florida (Berkowitz, 1978). An industrial plant reportedly uses GAC to reduce xylene in its wastewater (Berkowitz, 1978). Nevertheless the value for the Henry's Constants would make air stripping more feasible.

E. Estimated Statewide Cost to Achieve Maximum Contaminant Levels

Cost estimates to provide treatment for A-280 chemicals typically found in New Jersey have been prepared. Chemicals classified as carcinogens such as trichloroethylene,

TABLE 5

Estimated Number of Public Community Water Supplies

Reporting A-280 Organics Exceeding Recommended MCLs

Estimated Number of Packed Aeration Towers Needed for Treatment

COUNTY	#SUPPLIES	0.037 MGD	.95 MGD
Atlantic	10	8	2
Bergen	13	2	20
Burlington	7	5	2
Camden	4	1	13
Cape May	5	3	2
Cumberland	3	0	6
Essex	9	0	22
Gloucester	6	2	5
Hudson	0	0	0
Hunterdon	4	3	1
Mercer	2	2	0
Middlesex	3	1	16
Monmouth	1	-	1
Morris	16	4	13
Ocean	13	11	2
Passaic	4	0	14
Salem	0	0	0
Somerset	4	4	0
Sussex	11	9	2
Union	2	2	10
Warren	1	1	0
Totals	118	58	131

tetrachloroethylene, carbon tetrachloride, methylene chloride, and 1,2-dichloroethane which have been detected in New Jersey's water supplies in low concentrations can be removed with packed aeration towers. Noncarcinogens such as 1,1,1-trichloroethane, trans-1,2-dichloroethylene and 1,1-dichloroethylene have also been detected and may also be removed by packed aeration towers. Table 5 indicates the number of supplies in each County that have reported carcinogens and noncarcinogens. The table gives an estimate of the number of Packed Aeration Towers needed by county and by plant capacity. Plant capacities were estimated to be 0.037 mgd, 0.95 mgd or multiples thereof depending on the estimated capacity of the wellfield. The total number of plants needed may exceed the number of supplies. This is because one supply may need several plants to treat different wells. Estimates noted below are based on costs for treatment facilities with only packed aeration towers. While an estimate has been provided, unique site conditions and distribution system improvements will increase cost estimates. In addition, stringent New Jersey air pollution regulations may significantly increase costs. Therefore, actual costs may be more than estimated costs. The Statewide estimate to provide treatment to meet recommended drinking water objectives is from 50 to 70 million dollars. This estimate is presented in Table 6.

Table 6

ESTIMATED COST OF A PACKED AERATION TOWER[1]
(1986$)

Estimated Plant Capacity	0.037 mgd	0.95 mgd
Estimated Capital Cost	$85,000	$325,000
Estimated Annual Operation And Maintenance Cost	1,700	21,600
Estimated Cost Per 1000 Gallons For Treatment Only	0.97	0.19

1. Costs are based on U.S.EPA Proposed Rules, 1985 and NJDEP studies (Abrams, 1986).

Estimated Total Statewide Costs

Estimated Number of Air Strippers Needed

Estimated Capacity - 0.037 mgd 60 - 90
Estimated Capacity - 0.95 mgd 130 - 190

Estimated Total Statewide Costs = 50 - 70 million dollars

Water Rates in New Jersey

The cost of water varies widely in New Jersey. Typical water rates for purveyors as of 1984 ranged from a low of 0.56 per 1000 gallon in Trenton to between 2 and 3 dollars per 1000 gallon for Jersey City, Toms River and several other utilities. Generally, smaller water utilities, especially those relying only on groundwater, will have lower charges because they may only have been required to provide chlorination.

Existing Facilities

Reported design and cost data to construct and operate existing water treatment plants designed to remove organics have been tabulated for plants in New Jersey. Not all of them have been designed to meet what the Institute has considered recommending as MCLs. Under certain operating conditions, however, all plants are capable of achieving the stringent levels, below analytical detectability.

Hidden Costs

The cost of obtaining local zoning and planning approvals has to be considered. On the other hand, the presence of a treatment facility will provide some assurance to those that rely on a contaminated source of supply. Treatment facilities designed to remove volatile organics often generate waste by-products such as spent granular activated carbon. The carbon manufacturer is typically responsible for removing spent carbon. Some purveyors, to avoid future liability from landfilling spent carbon, have paid for carbon regeneration.

F. Conclusion

It is technologically feasible and practicable to remove the A-280 volatile and readily adsorbable organics to recommended MCL's. Specifically, trichloroethylene, tetrachloroethylene, 1,1-dichloroethylene, carbon tetrachloride, vinyl chloride, cis and trans-1,2,-dichloroethylene, 1,1,1-trichloroethane, xylenes, benzene, chlorobenzene, dichlorobenzene(s), methylene chloride, 1,2-dichloroethane, trichlorobenzene(s), PCBs and chlordane can be removed with air stripping and/or granular activated carbon contacting. There is insufficient data to draw a conclusion for methyl ethyl ketone, ethylene glycol, kerosene, formaldehyde, and n-hexane.

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APPENDIX E

Dissenting Opinion by

One Institute

Member

DISSENTING OPINION

First of all, I would like to say that a lot of fine work by some very dedicated people went into this report. Nothing that I say below should be construed to minimize their efforts.

Also, please bear in mind that this report deals with only twenty-two chemicals. They are only a small fraction of the more than 700 chemicals already identified in U.S. drinking water supplies. There are many other extremely dangerous and harmful contaminants that have yet to be addressed.

LEGISLATIVE GOALS

With respect to the non-carcinogens, the directive was "... to develop maximum contaminant levels (MCL's) at which no adverse physiological effects would be expected to result from a lifetime of exposure."

With respect to the carcinogens (cancer-causers), the directive was "...the maximum contaminant levels for carcinogens...shall permit cancer in no more than one in one million persons ingesting that chemical for a lifetime."

I believe the goals for dealing with the non-carcinogens and the carcinogens are backwards. I realize that there is no safe level for carcinogens, but I certainly would have preferred a goal of no cancers in a lifetime from carcinogens in drinking water and one in one million physiological effects in a lifetime from non-carcinogens in drinking water.

I don't know where it got started, but the one in one million cancer risk seems to have become an "acceptable" risk. In my opinion, it is not an acceptable risk. I ask you, is it an acceptable risk when that one in one million is your wife, or husband, or

child, or mother, or father, or even yourself?

I believe our Legislators wrote the law this way because they were led to believe that this was the best that can be reasonably expected. When a basic premise is faulted, the entire structure built on that premise is severely weakened.

It must also be realized that the one in one million cancers goal is for each chemical that is a known carcinogen and is not the overall effect of all the carcinogens, or possible carcinogens, found in drinking water.

Therefore, since this first report deals with eleven (11) known carcinogens at this time, the overall cancer level suggested by these goals, for just these particular chemicals, could be almost eleven (11) in a million and still meet the requirements of the directive. The next question is, what about the many carcinogens to be addressed in the future? Of even greater concern is the fact that the one in one million risk is based upon a single carcinogen acting alone. There is no knowledge of, or consideration given to the many carcinogens acting in concert. There is also no knowledge of the likely synergistic effects, or the effects of "initiators" which can greatly increase the carcinogenicity of a chemical.

I believe that our Legislators would have been happy to accept a more stringent level of carcinogens as a goal if they were requested to do so. There is ample evidence that we must become far more diligent about removing carcinogens from our environment. The fact that "...the current lifetime cancer incidence in the U.S. is approximately one in three individuals (American Cancer Society, 1985)" is a compelling reason why we must change our views and stop trying to make the unacceptable acceptable.

It should be noted that chemical contamination of the drinking

water in Woburn, Massachusetts had its disasterous effects on those least able to defend themselves -- the children. The "one in one million for a lifetime" can have a different connotation when a child's life is snuffed out before even reaching a double digit age.

DETECTION

The Health-based Level of a contaminant is the maximum contamination level set forth in the goals. For carcinogens, it is one cancer in a million and for non-carcinogens it is no physiological effects in a lifetime.

It is true that many of the minimum detection levels available to us today are above the Health-based Levels. It must be remembered that the Health-based Levels are levels arrived at by using the best available information for that particular chemical acting alone to cause the maximum adverse health effect permitted under the law as presently written.

It is very unfortunate that we do not have reliable detection levels for many of these chemicals at concentrations beneath the Health-based contamination levels. In fact, in most instances, the confirmable minimum detection levels are considerably above the Health-based contamination levels.

Under these circumstances I strongly believe that when the Health-based contamination level is lower than the confirmable minimum detection level, the Health-based contamination level should become the maximum contamination level to be permitted in our drinking water. In this way, whenever a contaminant is detected and that level of detection is above the Health-based Level, it would trigger defensive actions with respect to the water supply. As far as I am concerned, the ultimate accuracy of that analytical determination is totally immaterial as long as the concentration of the

contaminant is "likely" to be at or above the Health-based Level.

After arriving at reasonably supportable Health-based Levels, instead of viewing them as the maximums to be allowed as directed by the statute, the levels were subjugated to existing analytical techniques. Furthermore, they did not use the minimum detection levels of these techniques but adopted levels at which the average laboratory could comfortably reproduce the analytical results. This was called the Practical Quantitation Level (PQL).

Having adopted this rationale, the Health-based Level in most cases was abandoned to the Practical Quantitation Level even if it meant that the recommended maximum contamination levels were no longer related to maximum health risk levels, but to the practicalities of analytical chemistry. This new rationale resulted in maximum contamination levels which were 7, 21, 38 and even 60 times higher than the Health-based Levels.

It is my contention that even though, in many instances, no analytical techniques exist which can detect these chemicals at or below their maximum Health-based Levels, the Maximum Contaminant Level (MCL) must be set at the Health-based Level so that if any confirmable detection occurs which is at or above the Health-based Levels, it would indicate that the water is unfit to drink and treatment should be initiated as soon as possible.

It should also be noted that the new minimum detection levels recently developed by Rutgers University, known as the 502.1 method, compares very favorably with Health-based Levels and, in some cases, have minimum detection levels beneath the Health-based Levels.

In consideration of all the above, I believe that to recommend Maximum Contaminant Levels (MCL's) which are higher than the Health-based Levels is unconscionable.

CONTAMINATION SOLUTIONS

It has been clearly established that the use of simple technologies (air stripping and activated carbon adsorption) will reduce the levels of these contaminants to levels beneath the minimum detection levels of all our present science.

However, we should never permit air stripping to be used alone, it must always be used in conjunction with a carbon adsorption system. To do otherwise would be the equivalent of moving the contaminants from the water we drink to the air we breathe. This must not be allowed to occur.

A cost analysis for using these technologies to remove both the carcinogens and the non-carcinogens from our water for the entire state would cost only approximately $70 million in capital investments and operating expenses of approximately $2 million per year. These figures are for the entire state's drinking water supplies that are presently contaminated with these chemicals.

The cost analysis suggests that the above figures could result in an additional expense (if it is borne by the users alone) of from approximately $28 to $144 per household per year. (The variation is due to several factors, the most important of which is the size of the population being served by a particular water supply.)

Not only do I sincerely believe that every household would be willing to pay these costs in order to be assured that the water they are drinking is free from detectable carcinogens and non-carcinogens, but I also believe that a good part of this money can be reclaimed from the polluters and that our Legislators could be persuaded to put a bond issue on the ballot so that the entire population would share the expense for the unfortunate few...because who knows when your drinking water may show contamination.

Please, let us not forget that the Health-based Contamination Levels are not levels at which exposure to that chemical is safe. There are no safe levels for carcinogens. Our Health-based Levels are the maximum levels of exposure to "limit" the additional cancers produced to one in one million for each of these chemicals.

Unfortunately, none of the above takes into account that we not only drink our drinking water, we also bathe in our drinking water. Skin absorption through bathing, which can be substantial, has not been included in this investigation.

If we want to change the American Cancer Society statistics that one in three of us will develop cancer, then we must stop accepting that one cancer in one million for each and every thing we do, or each and every thing we are exposed to, is an acceptable risk.

We must stop accepting the unacceptable!

In the law, there is the concept of the "prudent man". This concept states that if someone sets into motion a chain of events that causes death or injury to his fellow man, the law evaluates whether a prudent man could have foreseen the outcome of this actions.

If it is adjudicated that a prudent man could have foreseen such an outcome, then that person is held responsible for the outcome of his actions.

He cannot say in his defense that he killed only one in two hundred-fifty million and, therefore, that is an acceptable risk in our society. Is such a defense acceptable? Of course not!

To knowingly allow a chain of events to occur which will knowingly cause death and/or injury to others is, in effect, giving out licenses to kill with impunity.

Let us be prudent men. Let us not give licenses to anyone to kill or injure his fellow man under any banner.

I repeat...let us not accept the unacceptable!

Frank Livelli