PATTERNS OF TOXICS CONTAMINATION AND COMPARISON OF CONCENTRATIONS IN THE GROUND AND SURFACE WATERS OF NEW JERSEY

by

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with

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Part I

Summary

Surface Water Data

The data set of toxic substances in the surface waters of New Jersey is described and analysed. The surface water data set consists of 320 samples of fresh water collected throughout the state. While there are some duplicate samples and some time series sampling has started, the samples in the surface water data set are basically single grab samples.

The surface water data set consists of information on the concentrations of a large number of toxic substances and some standard water quality parameters. There are 27 light chlorinated hydrocarbons in the surface water data set. These are low molecular weight, relatively volatile organic compounds. There are also 20 heavy chlorinated hydrocarbons. These substances are primarily pesticides noted for their extreme persistence once released into the natural environment. Finally, there are 14 heavy metals and 4 polycyclic aromatic hydrocarbons in the surface water data set. There four categories of chemical substances total to 65 toxic substances in the surface water data set. There is also information on 17 standard water quality parameters to complete the chemical substances in the surface water data set. Among these 65 toxics are 21 substances which are presently classified as confirmed or suspected carcinogens.

Spearman's rank correlation, a non-parametric statistical procedure, was used to calculate the bivariate correlations between the toxic substances in the surface water data. The largest number of significant correlations and most of the largest correlation coefficients are found between substances within the same chemical category. The chemical substances with high positive correlation coefficients indicate those chemicals which are often found in the same water samples.

Factor analysis was used to identify the most important patterns of contamination in the surface water data. Each pattern of contamination identified consists of the set of chemical substances which are found to be present together and vary directly in surface water samples. The four most important patterns of contamination in the surface water data are a pesticide factor, a standard water quality parameters factor, a heavy metals factor, and a benzo(a)pyrene-mercury-iron factor. Several potential explanations for the presence and chemical composition of the patterns of contamination identified are discussed. These range from patterns of human chemical use, the stability of the chemical substances, and the potential of toxic substances for metabolic and chemical reactions.

An attempt was made to find associations between the characteristics of the areas surrounding the sample site locations with the patterns of contamination identified by factor analysis of the surface water data. If land use or some other characteristic could be identified with the patterns of contamination, the results could be of assistance in the effort to identify and control water pollution by toxic substances. Unfortunately missing data precluded positive findings.

Ground Water Data

The ground water data set consists of 692 samples collected throughout the state. While there are some duplicate samples and some time series sampling has started, the samples in the ground water data set are basically single grab samples.

The ground water data set consists of information on the concentrations of a large number of toxic substances and some standard water quality parameters. There are 27 light chlorinated hydrocarbons in the ground water data set. There are the same 27 low molecular weight, relatively volatile organic compound that are included in the surface water data set. There are 20 heavy chlorinated hydrocarbons in the ground water data set, again the same 20 heavy organics, primarily pesticides, that are included in the surface water data set. There are 9 heavy metals and 15 standard water quality parameters in the ground water data set. All of these heavy metals and standard water quality parameters are included among the larger list of substances within these categories in the surface water data set. Among these 56 toxic substances in the ground water data set, 20 substances are either confirmed or suspected carcinogens.

The bivariate correlations between the toxic substances in the ground water data set were calculated using Spearman's Rank Correlation. The largest number of significant correlations and most of the highest correlation coefficients are found between toxic substances within the same chemical category. This indicates that toxic substances within the light chlorinated hydrocarbons are found together in the same ground water samples more often than they are found in the same ground water sample with heavy chlorinated hydrocarbons, heavy metals, or standard water quality parameters.

Factor analysis was used to identify the most important patterns of contamination in the ground water data. Each pattern of contamination explains a major portion of the variation in the ground water data and consists of a set of substances which are present together and which vary in concentration directly in a segment of the ground water samples. Factor analysis identified six distinctive patterns of contamination in the ground water data. These patterns of contamination are a pesticide factor, a heavy metals factor, a standard water quality parameters factor, a nitrogen factor, a second heavy metals factor, and a cyanide-BHC-beta--fluoride factor.

An attempt was made to find associations between the characteristics of the wells and the areas surrounding the wells from which the samples were collected with the patterns of contamination identified by factor analysis of the ground water data. One of the most interesting findings of this analysis concerns the depth of the wells. The ground water samples most strongly associated with each of the 6 patterns of contamination were found to have been collected from wells with a great range of depths. Unfortunately much of the other descriptive information concerning the surroundings of the wells was missing and this seriously limited the effectiveness of this analysis.

Part II

A Comparison of Ground and Surface Water Quality

Water is essential to life and ground water sources are essential to the supply of water in the United States. It is estimated that 110 million Americans, over one half the national population, rely on underground sources for drinking water (Wilson, 1978). Approximately 22 percent of the domestic, agricultural, and industrial water use; 50 percent of the irrigation water and livestock use; and 77 percent of public water systems depend on ground water entirely or in part (Wilson, 1976).

The assumption is widely accepted that ground water supplies are relatively uncontaminated with toxic substances when compared to surface water supplies. This assumption is supported by both theory and some field results. Geohydrologic theory predicts that ground water is effectively protected from toxic substances contamination by the layer of soil which toxic contaminants must pass through before reaching ground water supplies and by the chemical, physical, and biological processes acting to capture and or degrade toxics both in the soil and within an aquifer. Although the literature contains no studies systematically comparing levels of toxics in ground water and surface water, a number of studies do reach conclusions about toxic substances contamination of ground water. The preponderance of this published literature (reviewed in this report) concludes that ground water supplies are relatively uncontaminated by toxic substances.

A variety of federal and state laws and policy proposals dealing with toxic substances in water supplies require less monitoring and less treatment of potable water from ground water sources than from surface water sources. The laws and policy proposals systematically provide less protection from the public health dangers of consuming toxic and carcinogenic substances to that portion of the population consuming water from ground water sources.

A systematic comparison of the concentration of toxic substances in the ground and surface waters of New Jersey was performed to determine if ground water is relatively less contaminated with toxics than surface water. The comparison is based on three analyses: 1) comparison of the maximum concentration of each toxic in ground water and in surface water; 2) comparison of the probability of detecting each toxic in ground water and in surface water; and 3) comparison of the nonparametric average concentration of each toxic substance in detectable ground water and surface water samples. These three analyses were performed on 52 toxic substances common to the ground and surface water data sets. The ground water data set consists of 692 grab samples collected throughout the state. The surface water data set consists of 320 grab samples collected throughout the state. Both data sets are thought to be representative samples of the respective water sources in New Jersey.

The toxic substances studied in this report are however, only a small sample of the toxics thought to be widely distributed in the ground and surface waters of New Jersey and the nation. The more than 300 organic toxics which have been identified in the drinking water literature are thought to be a small component of the total toxic contaminants present (Kraybill, 1977). For example, the 89 toxics identified in a study of New Orleans water represented only approximately 2 percent by weight of the total organics in the drinking water (Guinan et al., 1977). Until data on the presence of these other toxic and potentially carcinogenic substances in our ground and surface waters are available, we must assume that the results of the analyses on the sample of toxics we have data for would be valid for the presently undetected toxics suspected of being present.

The results of the systematic comparison of the concentrations of toxic substances in the ground and surface waters of New Jersey reveal that ground water is at least as contaminated with toxic substances as surface water. These results are summarized in Table S-1. The

TABLE S-1. SUMMARY OF COMPARISONS OF TOXICS CONCENTRATIONS IN THE GROUND AND SURFACE WATERS OF NEW JERSEY

	Percentage Toxics Maximum Concentration Found In Ground Water	Percentage Toxics With Probability Of Detection No Different Or Greater In Ground Water	Percentage Toxics With Average Detectable Concentration No Different Or Greater In Ground Water
All New Jersey Samples	73	60	90
All New Jersey Potable Water Samples	78	67	86
All New Jersey Nonpotable Water Samples	60	69	93
Southern New Jersey Samples	67	71	88
Northern New Jersey Samples	71	65	94

results of these analyses on all ground and surface water samples from New Jersey reveal the following: 1. the maximum concentration of 73 percent of the toxics was greater in samples from ground water than surface water; 2. the probability of detecting 60 percent of the toxics was not significantly different between ground and surface water or was greater in ground water; 3. the nonparametric average concentration was not significantly different in ground and surface water or was greater in ground water for 90 percent of the toxic substances in detectable samples.

The comparison of toxic substances in the ground and surface water of New Jersey was repeated for different subsets of the ground and surface water data. The comparison of toxics in only those samples of ground and surface water collected from sources used for potable water supply reveals that ground water is at least as contaminated as surface water for between 67 and 86 percent of the toxic substances included in this analysis. Comparing only those samples of ground and surface water from non-potable sources of water supply reveals that ground water is at least as contaminated as surface water for between 67 and 88 percent of the toxic substances. Comparing only samples from Southern New Jersey between 67 and 88 percent of the toxics are at least as contaminated in ground water as in surface water. In those samples from Northern New

Jersey between 65 and 94 percent of the toxics are at least as contaminated in ground water as in surface water.

The patterns of toxic substances contamination in the natural waters of New Jersey are found to be very similar in ground water and surface water. The four most important patterns of toxic substances which explain most of the variation in the data are a pesticide factor, a light chlorinated hydrocarbon factor, a heavy metals factor, and a BHC-related factor. The correlations between these factors in the ground and surface water data sets (using a method called RELATE) ranges from 0.92 to 0.99. This finding indicates that the ground waters of New Jersey are not only at least as contaminated with toxics as the surface waters, but that the patterns of toxics contamination are very similar.

These results lead to the conclusion that the potential threat to the public health of New Jersey caused by the exposure to toxic and carcinogenic substances in water is at least as great to that portion of the population consuming water from ground water sources as for the portion of the population consuming surface water. [While the precise etiology of cancer is unknown, many researchers believe that a single exposure to a high concentration of a carcinogen may trigger the processes which lead to cancer incidence.] Because of non-turbulent flow conditions, carcinogens and toxics in ground water are not

Reword this

diluted as they are in surface water. In the potable water samples analysed, the maximum concentrations of 78 percent of the toxics were recorded in samples from ground water.

The health data available indicates that toxicity varies greatly among the toxic substances included in this report. The following toxics are either confirmed or suspected carcinogens: vinyl chloride, benzo(a)pyrene, chloroform, carbon tetrachloride, trichloroethylene, polychlorinated biphenyls (at least certain of the archlors), dieldrin, chlordane, heptachlor, DDT (includes DDE and DDD), lindane, α BHC-alpha, β BHC-beta, aldrin, endrin, heptachlor epoxide, arsenic, beryllium, and selenium (National Research Council, 1977; Rohlich, 1978). Most of the other toxic substances included in this report have not had definitive tests for carcinogenicity.

SP

The long term impacts of exposure to toxic substances are potentially severe. Human beings have evolved without exposure to the synthetic organic chemicals which comprise the majority of the toxic substances included in these analyses. We lack adequate defense mechanisms, acclimation capabilities, and excretion pathways to deal with most of these toxics. There is an almost total lack of data regarding the potentially synergistic and antagonistic interactions of these agents with each other and with

much too strong & not entirely true

other environmental agents. The little we know about toxic substances synergisms is not promising. Toxic organics isolated from Missouri ground water exhibited strong synergistic effects and when combined at their naturally occurring ratio were frequently toxic to test fish (Grigoropoulis and Smith, 1971). Berg and Burbank (1974) have reported that many if not all metals are potentially cocarcinogens being capable of depressing the enzymic activities involved in the metabolism of organic carcinogens.

in what way ?

With the Safe Drinking Water Act and other actions the federal government has acknowledged the potential threat to the public health caused by the presence of toxic and carcinogenic substances in our water supplies. Unfortunately most government actions and proposals designed to protect the public health seem to have been based on the assumption that ground water is relatively uncontaminated with carcinogens and toxics when compared to surface water. In New Jersey this assumption is false. Clearly requirements for monitoring levels of toxics and for water treatment technology should treat water supplies from ground water at least as stringently as from surface water.

PART I.

PATTERNS OF TOXICS CONTAMINATION IN THE SURFACE AND GROUND WATERS OF NEW JERSEY

CHAPTER 1

PATTERNS OF TOXICS IN NEW JERSEY SURFACE WATER

Data Description: Surface Water

The surface water data analysed in this report were developed by the Department of Environmental Sciences, Cook College under contract to the New Jersey Department of Environmental Protection (DEP). The data include all of the samples collected under the 1977-1978 contract with the DEP 208 Planning Groups and part of the data collected under the 1978-1979 contract with the DEP Program on Environmental Cancer and Toxic Substances. Only data turned over to the state as of April 30, 1979 has been analysed for this report. This includes only Interim Report 1 of the second contract.

The surface water data constitutes a representative sample of the surface water of New Jersey insofar as samples from every county in the state are included in the data set. There are more samples from northern New Jersey than from the southern half of the state reflecting the more numerous lakes, larger rivers, and the much greater use of surface waters in the northern portion of New Jersey.

The sample sites for the first year's data were selected by 208 planning groups. The Northeast 208 planning group selected sample sites in Union, Hudson, Bergen, Passaic, Morris, Somerset, and Essex counties. The Monmouth 208 Planning group selected the sample sites in Monmouth County. Together these two groups selected 154 sample sites. The Program on Environmental Cancer and Toxic Substances selected the remaining 44 sample sites in the first year's data as either repeat samples or in the vicinity of samples already selected.

The sample sites for the second year's data were selected by the Program on Environmental Cancer and Toxic Substances in an attempt to obtain a representative sample of surface water bodies in the New Jersey counties not sampled in the first year's data.

The surface water data used in this report was received in three distinct sets which have been combined for this report. While the three subsets of data are largely comparable, several noteworthy differences exist.

A small number of samples collected under the first year's contract were collected from tidal waters. Sample sites included the Arthur Kill, Newark Bay, Kill van Kull, and the lower tidal reaches of the Hudson, Hackensack, and Passaic Rivers. In these cases the water sampled is sufficiently different from the fresh surface water of the state that they constitute a distinct population of potential samples. These samples were deleted from all analyses in this report. Only samples containing less than 1000 ppm of dissolved solids (Hem, 1973) were used. Twenty four samples of saline water were deleted.

There have been several changes in the chemical substance data. These changes are the result of decisions concerning which substances would be tested, as well as changes in the equipment and procedures used to detect and quantify these substances. Unfortunately this has the effect of causing large quantities of missing data to be present in the data set and often results in making considerable quantities of potentially useful and interesting information unuseable in statistical analyses.

There have been several changes in the chemical substances included in the analyses within the group of light chlorinated hydrocarbons. The following substances were not included in the analyses of the first year, but were added to the analyses under the second year's contract: Same fluoroform, dichlorobromomethane, dichloroethylene (gem), dibromomethane, and t-dichloroethylene. Trifluoromethane was included in the first year's data, but was not included in the data from the second year.

Changes have occurred in the analysis of dichlorobenzene. Under the first year's contract the data contains the substance dichlorobenzene. Under the second year's contract the data contains quantities of the o-, m- and p-isomers of dichlorobenzene. The o-dichlorobenzene, m-dichlorobenzene, and p-dichlorobenzene isomers are retained as variables on the data set, but a variable called total dichlorobenzene is created by combining the o- m- and p-isomers to make one measure of dichlorobenzene consistent throughout the data (Hunter, 1979).

Four light chlorinated hydrocarbons have at different times been reported as distinct substances and at other times as combinations of substances. In the first surface water data received by DEP, bromodichloromethane and 1,1,2-trichloroethylene were reported as one variable. In the second portion of data, still under the first year's contract, these substances were included as distinct variables. In the data received under the second year's contract, 1,1,2-trichloroethylene is a variable, but bromodichloromethane is not included. Detectable concentrations of both substances are included in the data, therefore, both substances are retained as variables on the data set. The information included in the combined variable: bromodichloromethane + 1,1,2-trichloroethylene, in the first 154 samples has not been used in this report. In the first year's data 1,2-dibromoethane and 1,1,2,2-tetrachloroethylene were reported as two distinct variables. In the second year's data they are combined as one variable. The information from the combined variable: 1,2-dibromoethane + 1,1,2,2-tetrachloroethylene, in the 142 samples from the second year's data is not included in this report.

Several metals were included in the first year's data but are not included in the second year's data. These metals include: silver, iron, mercury, manganese, and sodium.

Several standard water quality variables are included in the first year's data, but are not included in the second year's data. These include: dissolved oxygen, ammonia, organic nitrogen, nitrate, nitrite, phosphate, sulfate, alkalinity, chloride, fluoride, cyanide, LAS, dissolved solids, and fecal coliforms.

Several polycyclic aromatic hydrocarbons (PAH's) have been included in the surface water analyses. Some of the first year's data included as many as 14 PAH's, but this data was collected for only a small number of samples. The 4 PAH's which are included in the second year's data and presumably in future sampling are used in this report. These 4 PAH's are consistent for all the surface water data.

One broad parameter, total organic carbon (TOC) is included in the surface water data set. TOC is included in the second year's data, but not in the data from the first year.

The 82 variables included in the surface water data set used for this report are listed in Table 1. The light chlorinated hydrocarbons include 27 relatively volatile organic compounds. The heavy chlorinated hydrocarbons

TABLE 1. SURFACE WATER DATA

I. LIGHT CHLORINATED HYDROCARBONS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number Detectable	%	Median Conc.	Range of Detectable Concentrations	
						Min.	Max.
1. Fluoroform	PPB	142	3		0.0	<0.5	<0.5
2. Methyl Chloride	PPB	316	3		0.0	6.0	6.0
3. Methyl Bromide	PPB	316	0		0.0	0.0	0.0
4. Vinyl Chloride	PPB	317	4		0.0	1.0	5.9
5. Methylene Chloride	PPB	316	114		0.0	90.0	743.3
6. Chloroform	PPB	317	237	75	<0.8	<0.8	2461.8
7. 1,2-Dichloroethane	PPB	317	35		0.0	<1.6	304.9
8. 1,1,1-Trichloroethane	PPB	317	277	87	<2.0	<2.0	22.7
9. Carbon Tetrachloride	PPB	317	267	84	<0.1	<0.1	20.6
10. 1,1,2-Trichloroethylene	PPB	173	120	69	<0.3	<0.3	4.7
11. Dichlorobromomethane	PPB	142	79		<0.1	<0.1	2.0
12. 1,1,2-Trichloroethane	PPB	314	42		0.0	<1.0	4.4
13. Dibromochloromethane	PPB	317	81		0.0	<0.1	8.2
14. 1,2-Dibromoethane	PPB	316	90		0.0	<0.1	46.5
15. 1,1,2,2-Tetrachloroethylene	PPB	314	252	80	0.0	<0.1	46.5
16. Bromoform	PPB	313	88		0.0	<1.0	3.7
17. 1,1,2,2-Tetrachloroethane	PPB	316	56		0.0	<1.0	<1.0
18. Diiodomethane	PPB	316	9		0.0	<0.3	3.2
19. Total Dichlorobenzene	PPB	318	29		0.0	<2.2	30.7
20. m-Dichlorobenzene	PPB	172	12		0.0	<1.3	5.0
21. p-Dichlorobenzene	PPB	172	20		0.0	1.3	30.5
22. o-Dichlorobenzene	PPB	172	8		0.0	2.2	8.2
23. Trichlorobenzene	PPB	315	24		0.0	2.0	2.2
24. Dichloroethylene (gem)	PPB	97	62		0.0	7.8	489.1
25. Dibromomethane	PPB	97	35		0.0	<1.0	3.3
26. t-Dichloroethylene	PPB	97	75		10.0	10.0	1307.5
27. Bromodichloroethane	PPB	31	2		0.0	<1.0	4.7

TABLE 1. (Continued)

II. HEAVY CHLORINATED HYDROCARBONS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations		Median Conc.	Range of Detectable Concentrations	
						Min.	Max.
1. Arochlor 1016	PPB	319	5		0	<1.0	1.9
2. Arochlor 1242	PPB	319	10		0	<1.0	117.3
3. Arochlor 1248	PPB	319	32		0	<1.0	109.1
4. Arochlor 1254	PPB	319	57		0	<1.0	127.0
5. α-BHC-~~Alpha~~	PPB	311	82		0	<1.0	<1.0
6. Lindane	PPB	311	74		0	<1.0	<1.0
7. β-BHC-~~Beta~~	PPB	311	182	59	0	<1.0	3.1
8. Heptachlor	PPB	311	63		0	<1.0	5.9
9. Aldrin	PPB	311	30		0	<1.0	<1.0
10. Heptachlor Epoxide	PPB	311	114	37	0	<1.0	<1.0
11. Chlordane	PPB	310	148	18	0	<1.0	<1.0
12. o,p'-DDE	PPB	311	101	32	0	<1.0	<1.0
13. Dieldrin	PPB	311	118	38	0	<1.0	<1.0
14. Endrin	PPB	311	42		0	<1.0	<1.0
15. o,p'-DDT	PPB	311	45		0	<1.0	<1.0
16. p,p'-DDD	PPB	311	71		0	<1.0	<1.0
17. p,p'-DDT	PPB	311	51		0	<1.0	<1.0
18. Mirex	PPB	311	19		0	<1.0	<1.0
19. Methyoxychlor	PPB	311	0		0		
20. Toxaphene	PPB	310	2		0	<1.0	<1.0

TABLE 1. (Continued)

III. HEAVY METALS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations	Median Conc.	Range of Detectable Concentrations	
					Min.	Max.
1. Silver	PPB	153	153	0.5	<1.0	2.0
2. Arsenic	PPB	294	294	1.0	<1.0	392.0
3. Beryllium	PPB	294	294	1.0	<1.0	1.0
4. Cadmium	PPB	294	294	1.0	<1.0	6.0
5. Copper	PPB	294	294	2.0	<1.0	124.0
6. Chromium	PPB	294	293	1.0	<1.0	216.0
7. Iron	PPB	153	153	145.0	1.0	46,800.0
8. Mercury	PPB	153	153	0.1	<1.0	1.2
9. Manganese	PPB	153	153	20.0	5.0	1,150.0
10. Sodium	PPB	153	153	22,500.0	2,000.0	229,000.0
11. Nickel	PPB	294	294	2.5	2.0	36.0
12. Lead	PPB	294	294	2.0	<1.0	86.0
13. Selenium	PPB	293	293	1.0	<1.0	7.0
14. Zinc	PPB	292	292	2.5	2.5	420.0
IV. POLYCYCLIC AROMATIC HYDROCARBONS						
1. Benzo~~-x-~~(a)pyrene	PPB	241	28	0.0	<1.0	2,790.0
2. Perylene	PPB	231	6	0.0	<1.0	5.2
3. Chrysene	PPB	161	24	0.0	<1.0	9.9
4. Fluorenthene	PPB	270	57	0.0	<1.0	4.7

TABLE 1. (Continued)

V. STANDARD WATER QUALITY PARAMETERS

	Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations	Median Conc.	Range of Detectable Concentrations	
						Min.	Max.
1.	Dissolved Oxygen	PPM	175	174	8.0	1.8	16.4
2.	NH_3-N (Ammonia)	PPM	177	128	0.0	<1.0	21.5
3.	Organic Nitrogen	PPM	176	166	0.3	<1.0	8.6
4.	NO_3-N (Nitrate)	PPM	177	169	0.2	<1.0	2.8
5.	NO_2-N (Nitrite)	PPM	178	80	0.0	<1.0	15.6
6.	PO_4-Phosphate	PPM	177	120	0.0	<1.0	1.2
7.	SO_4-Sulfate	PPM	177	175	21.7	2.0	5,900.0
8.	Alkalinity	PPM	167	164	72.0	2.4	232.0
9.	Chloride	PPM	153	153	37.0	<1.0	230.0
10.	Fluoride	PPM	153	135	0.3	<1.0	2.2
11.	Cyanide	PPM	154	14	0.0	<1.0	<1.0
12.	Las-Detergent	PPM	153	79	0.0	<1.0	<1.0
13.	Dissolved Solids	PPM	154	154	250.0	1.4	804.0
14.	Fecal Coliforms	#/100 ML	150	133	0.0	<1.0	56,000.0
15.	Water Temperature	C^o	292	292	22.0	4.0	35.0
16.	pH	1-14	304	304	6.8	1.9	9.4
17.	Total Organic Carbon	PPB	141	141	425.0	300.0	68,500.0

include 20 relatively persistent organic compounds. The heavy metals include 14 metallic substances grouped for convenience under this heading. The polycyclic aromatic hydrocarbons include 4 related organic substances. The standard water quality parameters include 17 non-toxic substances or measurements used to determine water quality.

Table 1 reflects the changes made in the chemical substances included in the sample analyses during the two years the project has been in existence. The number of samples analysed for each substance varies widely. This is caused by variables being included or excluded from the analyses at different times, and some slight difference are caused by an occasional analysis being lost or otherwise missing. The number of samples in which the substance was detectable shows even greater variation.

The surface water data set is basically composed of single grab samples for each location. A limited number of repeat samples were taken each year, and during the second year of data collection some seasonal and monthly samples are being collected. These series of samples at the same locations collected over a period of time will become very important because they will reveal the average composition of toxics in the surface water of the locations sampled. There are presently insufficient time series data to attempt an analysis of average concentrations or trends.

Analysis of the Surface Water Data

The median value reported and the range of detectable concentrations give some indication of the severely right skewed frequency distributions of most of these substances. The standard water quality variables are approximately normal in their distributions, but all of the toxics are skewed. While all of the toxics are skewed in their frequency distributions, there is variation in the degree to which these substances are right skewed. Generally the heavy metals are less skewed and the chlorinated hydrocarbons are more severely skewed.

The distinctly non-normal frequency distributions of the toxic substances in the surface water data limit the statistical analyses which may be employed. The data does not support the underlying assumptions of the whole family of parametric procedures. The use of parametric procedures with this severely skewed data would be likely to produce entirely unreliable results.

This report is based on a variety of non-parametric statistical analyses. These procedures make no assumptions concerning the nature of the frequency distributions of the data being analysed. The disadvantage of these non-parametric procedures is their inherent conservatism. They are slightly less powerful than the equivalent parametric procedure and tend to underestimate any statistical associations present in the data.

Surface Water Correlation Analysis

One of the goals of this report is to investigate the intercorrelations among the chemical substances and water quality measurements included as variables in the surface water data. A non-parametric statistical procedure, Spearman's Rank Correlation, was used to calculate the bivariate correlations presented as Table 2.

Most of the highest correlations occur between substances within the same chemical category: light chlorinated hydrocarbons, heavy chlorinated hydrocarbons, heavy metals, polycyclic aromatic hydrocarbons and standard water quality parameters. While some high correlation coefficients are found between substances in different chemical categories, they are generally not as prevalent, nor as high. Only correlation coefficients significant at the 0.001 level are presented and discussed.

The highest correlation coefficients are found within the heavy metals. Beryllium has correlation coefficients of 0.96 with cadmium, 0.88 with selenium and 0.72 with silver. This tells us that samples containing one of these substances is very likely to contain the others, and that in those samples in which the concentration of one of these substances is high, the others are likely to be high. The magnitude of the correlation coefficients is surprisingly high given the trace levels of the substances and the non-parametric statistical correlation procedure. The high

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	1	2	3	4	5
1. Methylene Chloride		.31	.26		
2. Chloroform	.31			.32	.41
3. 1,2-Dichloroethane	.26				
4. 1,1,-Trichloroethane		.32			
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane		.22			
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene		.36		.40	.35
12. Bromoform	.21				
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene (gem)					
15. Dibromomethane					
16. t-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254	-.32				
19. α BHC-~~Alpha~~	.41				
20. Lindane					
21. β BHC-~~Beta~~	.53				.24
22. Heptachlor					
23. Heptachlor Epoxide	.33				
24. Chlordane	.38				
25. o,p'-DDE	.37				
26. Dieldrin	.34				
27. Endrin					
28. o,p'-DDT	.26				
29. p,p'-DDD	.30				
30. p,p'-DDT	.28				
31. Silver					
32. Arsenic	.36	.29			
33. Beryllium	.71	.38	.29		.30
34. Cadmium	.67	.40	.27		.31
35. Copper		.38			
36. Chromium	.36	.41		.26	
37. Iron				-.40	
38. Mercury				-.34	
39. Manganese					
40. Sodium		.38			
41. Nickel					
42. Lead	.28	.38		.30	
43. Selenium	.72	.30	.20		.29
44. Zinc					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	1	2	3	4	5
45. Total Organic Carbon					
46. Benzo(a)pyrene			.41		
47. Flrnthene ← ~~Fluoranthene~~ Fluoranthene	-.22				
48. Dissolved Oxygen					
49. NH_3-N (Ammonia)		.36			
50. Organic Nitrogen					
51. NO_3-N (Nitrate)		.34			
52. NO_2-N (Nitrite)		.42			
53. PO_4-Phosphate		.42			
54. SO_4-Sulfate		.28			
55. Alkalinity		.32	-.31	.37	
56. Chloride		.32			
57. Fluoride					
58. Las-Detergent					
59. Dissolved Solids		.29		.32	
60. Fecal Coliforms					
61. Water Temperature					
62. pH (pH)					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	6	7	8	9	10
1. Methylene Chloride					
2. Chloroform					
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane	.34				
5. Carbon Tetrachloride		.31			
6. 1,1,2-Trichloroethylene				.37	
7. Dichlorobromomethane				.40	
8. 1,1,2-Trichloroethane				.27	
9. Dibromochlormethane	.37	.40	.27		
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene	.31			.42	
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					.32
14. Dichloroethylene (gem)					
15. Dibromomethane			.46		
16. t-Dichloroethylene	.45				
17. Arochlor 1248					
18. Arochlor 1254					
19. α-BHC-~~Alpha~~					
20. Lindane					
21. β-BHC ~~Beta~~					
22. Heptachlor					
23. Heptachlor Epoxide					
24. Chlordane					
25. o,p'-DDE					
26. Dieldrin					
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver					
32. Arsenic					
33. Beryllium				-.27	
34. Cadmium	-.22			-.25	
35. Copper					
36. Chromium					
37. Iron	.46				
38. Mercury					
39. Manganese					
40. Sodium				.44	
41. Nickel					
42. Lead					
43. Selenium				-.25	
44. Zinc					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

SURFACE WATER CORRELATION MATRIX[1] (Continued)

	6	7	8	9	10
ganic Carbon					
-Pyrene					
ne					
d Oxygen					
mmonia)				.27	
Nitrogen					
itrate)					
itrite)					
phate				.31	
ate				.28	
ty				.41	
				.46	
rgent				.33	
d Solids				.41	
liforms					
nperature					

correlation coefficients significant at the 0.001
ncluded in this Table. Correlation coefficients
sing Spearman's Rank Correlation procedure.

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TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	11	12	13	14	15
1. Methylene Chloride		.21			
2. Chloroform	.36				
3. 1,2-Dichloroethane					.33
4. 1,1-Trichloroethane	.40				
5. Carbon Tetrachloride	.35				
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane	.31				
9. Dibromochlormethane	.42				
10. 1,2-Dibromoethane			.32		
11. 1,1,2,2-Tetrachloroethylene					
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene (gem)					
15. Dibromomethane					
16. t-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254					
19. α-BHC ~~-Alpha~~					
20. Lindane					
21. β-BHC ~~-Beta~~		.26			
22. Heptachlor					
23. Heptachlor Epoxide					
24. Chlordane		.27			
25. o,p'-DDE					
26. Dieldrin					
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver					
32. Arsenic					
33. Beryllium		.40			
34. Cadmium		.37			
35. Copper	.39				
36. Chromium	.33				
37. Iron					
38. Mercury					
39. Manganese			.71		
40. Sodium	.38		.43		
41. Nickel	.34				
42. Lead	.36		.32		
43. Selenium		.38			
44. Zinc					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	11	12	13	14	15
45. Total Organic Carbon					
46. Benzo-A-Pyrene					
47. Flrnthene ← sp		-.22			
48. Dissolved Oxygen			-.51		
49. NH_3-N (Ammonia)	.29				
50. Organic Nitrogen					
51. NO_3-N (Nitrate)	.28				
52. NO_2-N (Nitrite)					
53. PO_4-Phosphate	.36				
54. SO_4-Sulfate					
55. Alkalinity	.44				
56. Chloride	.41		.54		
57. Fluoride					
58. Las-Detergent	.33				
59. Dissolved Solids	.33				
60. Fecal Coliforms					
61. Water Temperature					
62. pH			-.24		

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	16	17	18	19	20
1. Methylene Chloride					
2. Chloroform					
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane	-.45				
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane					
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene					
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -(gem)					
15. Dibromomethane					
16. ~~t~~-Dichloroethylene					
17. Arochlor 1248					-.31
18. Arochlor 1254				-.38	-.41
19 α-BHC-~~Alpha~~			-.28		
20. Lindane					
21 β-BHC-~~Beta~~		-.31	-.41	.32	
22. Heptachlor					.25
23. Heptachlor Epoxide		-.24		.27	.21
24. Chlordane		-.24	-.36	.30	.35
25. o,p'-DDE			-.27	.26	.34
26. Dieldrin		-.23	-.32	.27	.38
27. Endrin					.37
28. o,p'-DDT					.25
29. p,p'-DDD			-.22	.24	.27
30. p,p'-DDT				.23	.25
31. Silver					
32. Arsenic			-.31		
33. Beryllium		-.30	-.47	.41	
34. Cadmium		-.29	-.41	.39	
35. Copper					
36. Chromium					
37. Iron			-.38		
38. Mercury			-.38		
39. Manganese					
40. Sodium					
41. Nickel					
42. Lead					
43. Selenium		-.30	-.37	.45	
44. Zinc					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	16	17	18	19	20
45. Total Organic Carbon					
46. Benzo(a)Pyrene				-.23	
47. Flrnthene					
48. Dissolved Oxygen					
49. NH_3-N (Ammonia)					
50. Organic Nitrogen					
51. NO_3-N (Nitrate)					
52. NO_2-N (Nitrite)					
53. PO_4-Phosphate					
54. SO_4-Sulfate					
55. Alkalinity			.26		
56. Chloride					
57. Fluoride					
58. Las-Detergent					
59. Dissolved Solids					
60. Fecal Coliforms					
61. Water Temperature			-.19		
62. pH					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

See previous charts for correct nomenclature

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	21	22	23	24	25
1. Methylene Chloride	.53	.33	.33	.38	.37
2. Chloroform					
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane					
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane					
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene					
12. Bromoform	.26			.27	
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248			-.24	-.24	
18. Arochlor 1254				-.36	-.27
19. BHC-Alpha	.32		-.27	.30	.26
20. Lindane		.25	.21	.35	.34
21. BHC-Beta			.35	.53	.39
22. Heptachlor				.22	.26
23. Heptachlor Epoxide	.35			.34	.40
24. Chlordane	.53	.22	.34		.53
25. o,p'-DDE	.39	.26	.40	.53	
26. Dieldrin	.42	.22	.40	.56	.61
27. Endrin			.22	.39	.45
28. o,p'-DDT	.31		.30	.38	.46
29. p,p'-DDD	.34		.31	.49	.52
30. p,p'-DDT	.33	.23	.28	.32	.51
31. Silver					
32. Arsenic	.36			.23	.22
33. Beryllium	.62		.29	.47	.39
34. Cadmium	.58		.26	.43	.37
35. Copper					
36. Chromium	.23		.25		
37. Iron	.49				
38. Mercury	.40				
39. Manganese					
40. Sodium					
41. Nickel					
42. Lead	.20				
43. Selenium	.62		.34	.53	.44
44. Zinc					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	21	22	23	24	25
45. Total Organic Carbon					
46. Benzo-A-Pyrene					-.26
47. Flrnthene					
48. Dissolved Oxygen					
49. NH3-N (Ammonia)					
50. Organic Nitrogen					
51. NO3-N (Nitrate)					
52. NO2-N (Nitrite)					
53. PO4-Phosphate					
54. SO4-Sulfate		.37			
55. Alkalinity					
56. Chloride					
57. Fluoride					
58. Las-Detergent					
59. Dissolved Solids					
60. Fecal Coliforms					
61. Water Temperature					
62. PH					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	26	27	28	29	30
1. Methylene Chloride	.34		.26	.30	.28
2. Chloroform					
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane					
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane					
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene					
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248	-.23				
18. Arochlor 1254	-.32				
19. BHC-Alpha	.27			.24	.23
20. Lindane	.38	.37	.25	.27	.25
21. BHC-Beta	.42		.31	.34	.33
22. Heptachlor	.22				.23
23. Heptachlor Epoxide	.40	.22	.30	.31	.28
24. Chlordane	.56	.39	.38	.49	.32
25. o,p'-DDE	.61	.45	.46	.52	.51
26. Dieldrin		.45	.48	.55	.42
27. Endrin	.45		.54	.41	.46
28. o,p'-DDT	.48	.54		.62	.69
29. p,p'-DDD	.55	.41	.62		.64
30. p,p'-DDT	.42	.46	.69	.64	
31. Silver					
32. Arsenic					
33. Beryllium	.39			.34	.30
34. Cadmium	.36			.32	.28
35. Copper					
36. Chromium					
37. Iron					
38. Mercury					
39. Manganese					
40. Sodium					
41. Nickel					
42. Lead					
43. Selenium	.44		.21	.38	.33
44. Zinc					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	26	27	28	29	30
45. Total Organic Carbon					
46. Benzo-A-Pyrene	-.30				
47. Flrnthene					
48. Dissolved Oxygen					
49. NH3-N (Ammonia)					
50. Organic Nitrogen					
51. NO3-N (Nitrate)					
52. NO2-N (Nitrite)					
53. PO4-Phosphate					
54. SO4-Sulfate					
55. Alkalinity					
56. Chloride					
57. Fluoride					
58. Las-Detergent					
59. Dissolved Solids					
60. Fecal Coliforms	.30				
61. Water Temperature					
62. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	31	32	33	34	35
1. Methylene Chloride		.36	.41	.67	.36
2. Chloroform			.38	.40	.38
3. 1,2-Dichloroethane			.29	.27	
4. 1,1-Trichloroethane					.25
5. Carbon Tetrachloride			.30	.31	
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane			-.27	-.25	
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene					.39
12. Bromoform			.40	.37	
13. 1,1,2,2-Tetrachloroethane				-.22	
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248			-.30	-.29	
18. Arochlor 1254		-.31	-.47	-.41	
19. BHC-Alpha			.41	.39	
20. Lindane					
21. BHC-Beta		.36	.62	.58	
22. Heptachlor					
23. Heptachlor Epoxide			.29	.26	
24. Chlordane		.23	.47	.43	
25. o,p'-DDE		.24	.39	.37	
26. Dieldrin			.39	.36	
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD			.34	.32	
30. p,p'-DDT			.30	.28	
31. Silver			.72	.64	
32. Arsenic			.47	.46	.34
33. Beryllium	.72	.47		.96	.29
34. Cadmium	.64	.46	.96		.33
35. Copper		.34	.29	.32	
36. Chromium		.43	.40	.42	.40
37. Iron					
38. Mercury	.32		.39	.31	
39. Manganese					.34
40. Sodium					.39
41. Nickel					
42. Lead		.40	.34	.36	.54
43. Selenium		.39	.88	.84	.23
44. Zinc					.40

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	31	32	33	34	35
45. Total Organic Carbon					
46. Benzo-A-Pyrene	.60				
47. Flrnthene			-.33	-.31	
48. Dissolved Oxygen					
49. NH3-N (Ammonia)					
50. Organic Nitrogen					
51. NO3-N (Nitrate)					
52. NO2-N (Nitrite)			.37	.29	.39
53. PO4-Phosphate					.31
54. SO4-Sulfate		.31			
55. Alkalinity					.35
56. Chloride					.34
57. Fluoride	.52		.56	.51	
58. Las-Detergent					
59. Dissolved Solids			-.42	-.34	
60. Fecal Coliforms					
61. Water Temperature	.37				
62. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	36	37	38	39	40
1. Methylene Chloride	.36				
2. Chloroform	.41				.38
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane	.26	-.40	-.34		
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane					.44
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene	.33				.38
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254		-.39	-.38		
19. BHC-Alpha					
20. Lindane					
21. BHC-Beta	.23	.49	.40		
22. Heptachlor					
23. Heptachlor Epoxide	.25				
24. Chlordane		.28			
25. o,p'-DDE					
26. Dieldrin					
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver			.32		
32. Arsenic	.43				
33. Beryllium	.40		.39		
34. Cadmium	.42				
35. Copper	.40			.34	.39
36. Chromium				.37	.53
37. Iron			.43		
38. Mercury		.43			
39. Manganese	.37	.27			.43
40. Sodium	.53			.43	
41. Nickel	.27				
42. Lead	.54			.48	.46
43. Selenium	.36				
44. Zinc	.40	.30			.28

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	36	37	38	39	40
45. Total Organic Carbon					
46. Benzo-A-Pyrene			.36		
47. Flrnthene					
48. Dissolved Oxygen		-.44	-.34		
49. NH3-N (Ammonia)	.43	.47		.34	.53
50. Organic Nitrogen					
51. NO3-N (Nitrate)	.45				.50
52. NO2-N (Nitrite)	.47			.41	.54
53. PO4-Phosphate	.42			.41	.53
54. SO4-Sulfate	.42	.27			.44
55. Alkalinity	.52			.31	.64
56. Chloride	.51			.33	.76
57. Fluoride					
58. Las-Detergent	.35			.30	.42
59. Dissolved Solids	.41				.58
60. Fecal Coliforms					
61. Water Temperature		.27	.48		
62. PH		-.40			

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	41	42	43	44	45
1. Methylene Chloride		.28	.72		
2. Chloroform		.38	.30		
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane		.30			
5. Carbon Tetrachloride			.29		
6. 1,1,2-Trichloroethylene		.32			
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane			-.25		
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene	.34	.36			
12. Bromoform			.38		
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248			-.30		
18. Arochlor 1254			-.37		
19. BHC-Alpha			.45		
20. Lindane					
21. BHC-Beta			.62		
22. Heptachlor					
23. Heptachlor Epoxide			.34		
24. Chlordane			.53		
25. o,p'-DDE			.44		
26. Dieldrin			.44		
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD			.38		
30. p,p'-DDT			.33		
31. Silver					
32. Arsenic		.40	.39	.23	
33. Beryllium		.34	.88		
34. Cadmium		.36	.84		
35. Copper		.54		.40	
36. Chromium	.27	.54	.36	.40	
37. Iron				.30	
38. Mercury					
39. Manganese		.48			
40. Sodium		.46		.28	
41. Nickel				.31	
42. Lead	.22		.29	.48	
43. Selenium		.29			
44. Zinc	.31	.48			

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	41	42	43	44	45
45. Total Organic Carbon					
46. Benzo-A-Pyrene			-.28		
47. Flrnthene			-.30		
48. Dissolved Oxygen					
49. NH3-N (Ammonia)		.36		.30	
50. Organic Nitrogen		.41			
51. NO3-N (Nitrate)		.39			
52. NO2-N (Nitrite)		.44			
53. PO4-Phosphate		.34			
54. SO4-Sulfate		.27			
55. Alkalinity		.42			
56. Chloride		.44			
57. Fluoride					
58. Las-Detergent		.50			
59. Dissolved Solids		.35			
60. Fecal Coliforms					
61. Water Temperature					
62. PH					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	46	47	48	49	50
1. Methylene Chloride					
2. Chloroform				.36	
3. 1,2-Dichloroethane	.41				
4. 1,1-Trichloroethane					
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane					
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene			.33	.29	
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254					
19. BHC-Alpha					
20. Lindane					
21. BHC-Beta					
22. Heptachlor					
23. Heptachlor Epoxide					
24. Chlordane					
25. o,p'-DDE	-.26				
26. Dieldrin	-.30				
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver	.60				
32. Arsenic					
33. Beryllium		-.33	-.42		
34. Cadmium		-.31			
35. Copper					
36. Chromium				.43	
37. Iron			-.44	.47	
38. Mercury	.36				
39. Manganese				.34	
40. Sodium				.53	
41. Nickel					
42. Lead				.36	.41
43. Selenium					
44. Zinc				.30	

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	46	47	48	49	50
45. Total Organic Carbon					
46. Benzo-A-Pyrene					
47. Flrnthene					
48. Dissolved Oxygen				-.51	
49. NH3-N (Ammonia)			-.51		
50. Organic Nitrogen					
51. NO3-N (Nitrate)				.51	
52. NO2-N (Nitrite)	.40		-.25	.52	
53. PO4-Phosphate				.55	
54. SO4-Sulfate			-.34	.35	
55. Alkalinity	-.43			.38	
56. Chloride				.52	
57. Fluoride	.63				
58. Las-Detergent				.29	
59. Dissolved Solids	-.46			.42	
60. Fecal Coliforms					
61. Water Temperature			-.45		
62. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	51	52	53	54	55
1. Methylene Chloride					
2. Chloroform	.34	.42	.42		.32
3. 1,2-Dichloroethane					-.31
4. 1,1-Trichloroethane					.37
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane			.31		.41
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene			.36		.44
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254					
19. BHC-Alpha					
20. Lindane					
21. BHC-Beta					
22. Heptachlor				.37	
23. Heptachlor Epoxide					
24. Chlordane					
25. o,p'-DDE					
26. Dieldrin					
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver					
32. Arsenic				.31	
33. Beryllium		.37			
34. Cadmium					
35. Copper		.39	.31		.35
36. Chromium	.45	.47	.42	.42	.52
37. Iron					
38. Mercury					
39. Manganese		.41	.41		.31
40. Sodium	.50	.54	.53	.44	.64
41. Nickel					
42. Lead	.39	.44	.34	.27	.42
43. Selenium					
44. Zinc					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	51	52	53	54	55
45. Total Organic Carbon					
46. Benzo-A-Pyrene		.40			-.53
47. Flrnthene					
48. Dissolved Oxygen		-.25		-.34	
49. NH3-N (Ammonia)	.51	.52	.55	.35	.38
50. Organic Nitrogen					
51. NO3-N (Nitrate)		.45	.55	.37	.27
52. NO2-N (Nitrite)	.45		.56	.37	.30
53. PO4-Phosphate	.55	.56		.29	.30
54. SO4-Sulfate	.37	.37	.29		
55. Alkalinity	.27	.30	.30		
56. Chloride	.61	.50	.57	.41	.65
57. Fluoride	-.37				-.44
58. Las-Detergent	.41		.34		.31
59. Dissolved Solids	.53		.43	.51	.63
60. Fecal Coliforms				.27	
61. Water Temperature				.31	
62. PH					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	56	57	58	59	60
1. Methylene Chloride					
2. Chloroform	.32				
3. 1,2-Dichloroethane					
4. 1,1-Trichloroethane	.26			.32	
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dichlorobromomethane					
8. 1,1,2-Trichloroethane					
9. Dibromochlormethane	.46		.33	.41	
10. 1,2-Dibromoethane					
11. 1,1,2,2-Tetrachloroethylene	.41		.33		
12. Bromoform					
13. 1,1,2,2-Tetrachloroethane					
14. Dichloroethylene -Gem					
15. Dibromomethane					
16. T-Dichloroethylene					
17. Arochlor 1248					
18. Arochlor 1254					
19. BHC-Alpha					
20. Lindane					
21. BHC-Beta					
22. Heptachlor					
23. Heptachlor Epoxide					
24. Chlordane					
25. o,p'-DDE					
26. Dieldrin					
27. Endrin					
28. o,p'-DDT					
29. p,p'-DDD					
30. p,p'-DDT					
31. Silver		.52			
32. Arsenic					
33. Beryllium		.56			
34. Cadmium		.51		-.34	
35. Copper	.34				
36. Chromium	.51		.35	.41	
37. Iron					
38. Mercury				-.34	
39. Manganese	.33		.30		
40. Sodium	.76		.42	.58	
41. Nickel					
42. Lead	.44		.50	.35	
43. Selenium					
44. Zinc					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	56	57	58	59	60
45. Total Organic Carbon					
46. Benzo-A-Pyrene		.63		-.46	
47. Flrnthene					
48. Dissolved Oxygen					
49. NH3-N (Ammonia)	.52		.29	.42	
50. Organic Nitrogen					
51. NO3-N (Nitrate)	.61	-.37	.41	.53	
52. NO2-N (Nitrite)	.50				
53. PO4-Phosphate	.57		.34	.43	
54. SO4-Sulfate	.41		.51		.27
55. Alkalinity	.65	-.44	.31	.63	
56. Chloride		-.31	.34	.62	
57. Fluoride	-.31		-.28	-.48	
58. Las-Detergent	.34	-.28		.45	
59. Dissolved Solids	.62	-.48	.45		.30
60. Fecal Coliforms				.30	
61. Water Temperature			-.28		
62. PH					

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1]

	61	62
1. Methylene Chloride		
2. Chloroform		
3. 1,2-Dichloroethane		
4. 1,1-Trichloroethane		
5. Carbon Tetrachloride		
6. 1,1,2-Trichloroethylene		
7. Dichlorobromomethane		
8. 1,1,2-Trichloroethane		
9. Dibromochlormethane		
10. 1,2-Dibromoethane		
11. 1,1,2,2-Tetrachloroethylene		
12. Bromoform		
13. 1,1,2,2-Tetrachloroethane		-.24
14. Dichloroethylene -Gem		
15. Dibromomethane		
16. T-Dichloroethylene		
17. Arochlor 1248		
18. Arochlor 1254		
19. BHC-Alpha		
20. Lindane		
21. BHC-Beta		
22. Heptachlor		
23. Heptachlor Epoxide		
24. Chlordane		
25. o,p'-DDE		
26. Dieldrin		
27. Endrin		
28. o,p'-DDT		
29. p,p'-DDD		
30. p,p'-DDT		
31. Silver	.37	
32. Arsenic		
33. Beryllium		
34. Cadmium		
35. Copper		
36. Chromium		
37. Iron		-.38
38. Mercury	.48	
39. Manganese		
40. Sodium		
41. Nickel		
42. Lead		
43. Selenium		
44. Zinc		

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 2 : SURFACE WATER CORRELATION MATRIX[1] (Continued)

	61	62
45. Total Organic Carbon		
46. Benzo-A-Pyrene		
47. Flrnthene		
48. Dissolved Oxygen	-.45	
49. NH3-N (Ammonia)		
50. Organic Nitrogen		
51. NO3-N (Nitrate)		
52. NO2-N (Nitrite)		
53. PO4-Phosphate		
54. SO4-Sulfate	.31	
55. Alkalinity		
56. Chloride		
57. Fluoride		
58. Las-Detergent	-.28	
59. Dissolved Solids		
60. Fecal Coliforms		
61. Water Temperature		
62. PH		

[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

correlation coefficients result to some extent from the analytic techniques used to quantify these substances which for all four of these heavy metals were overwhelmingly reported at either the minimum reportable concentrations of 1.0 ppb or 2.0 ppb.

The small number of concentrations greater than the minimum reportable value have a great effect on the correlation coefficients.

Consistently high correlation coefficients are found between many of the standard water quality parameters. Sodium, for instance, has correlation coefficients of 0.76 with chloride, 0.64 with alkalinity, 0.58 with dissolved solids, 0.54 with nitrite, 0.53 with ammonia, 0.53 with phosphate, and 0.50 with nitrate. The expected inverse relationship, -0.45, was found between water temperature and dissolved oxygen.

Within the heavy chlorinated hydrocarbons there are many high correlations. The metabolites of DDT show the expected high correlations. P,p^1-DDD has correlation coefficients of 0.64 with p,p^1-DDT, 0.62 with o,p^1-DDT, 0.55 with dieldrin, and 0.52 with o,p^1-DDE.

The light chlorinated hydrocarbons have many significant intercorrelations, but none of the correlation coefficients between light chlorinated hydrocarbons are as high as 0.50. These more volatile and less persistent organic chemicals have many intercorrelations at the 0.40 level.

The correlations between dissimilar chemical substances are not as prevalent, but are perhaps even more interesting than those between chemically similar substances. Many of the correlations are among the highest in the surface water data. Most of the relationships suggested by these correlations are not intuitively clear and may suggest future areas of research. Methylene chloride has correlation coefficients of 0.72 with selenium, 0.71 with beryllium, 0.67 with cadmium, and 0.53 with Beta BHC~~-Beta~~. 1,1,2-trichloroethylene has correlation coefficients of 0.71 with manganese, 0.54 with chloride, and -0.51 with dissolved oxygen. Benzo(a)pyrene has correlation coefficients of 0.63 with fluoride and 0.60 with silver. In addition to having a correlation of 0.54 with 1,1,2-trichloroethylene, chloride also has a correlation coefficient of 0.51 with chromium.

The correlation matrix in Table 2 has only 62 of the 82 variables in the surface water data. The 20 variables which are not included have several very high and statistically significant correlation coefficients, but were dropped from the analysis because of the small number of detectable concentrations of each of these substances. When only a small number of concentrations were detected, one or two high concentrations in the same sample in which another substance was found in a high concentration results in a high correlation coefficient. The correlation which results from such a circumstance may indicate a chemical relationship between the substance, an anthropogenic pattern of use, or purely a chance occurrence. As a conservative step, all substances with less than ten percent of the total samples (i.e., 32, detectable concentrations) were dropped from the correlation matrix. This step is intended to decrease the possibility that a purely chance occurrence could unduly influence the statistical analyses.

The substances not included in the correlation matrix include: fluoroform, methyl chloride, methyl bromide, vinyl chloride, diiodomethane, total dichlorobenzene, m-dichlorobenzene, p-dichlorobenzene, o-dichlorobenzene, trichlorobenzene, arochlor 1016, arochlor 1242, bromodichloroethane, aldrin, mirex, methyoxychlor, toxaphene, perylene, chrysene, and cyanide.

Although correlations involving variables with so few detectable concentrations may be unreliable, some of the high correlation coefficients are reported. Viewed in light of the small number of positive samples, these correlations may stimulate hypotheses to be investigated in future research. Methyl chloride has correlation coefficients of 0.82 with iron and 0.55 with vinyl chloride. Vinyl chloride has correlation coefficients of 0.74 with benzo(a)pyrene, 0.65 with iron, and 0.50 with cyanide in addition to its high correlation with methyl chloride. P-dichlorobenzene has correlation coefficients of 0.99 with bromodichloromethane, 0.95 with total dichlorobenzene, 0.80 with phosphate, and 0.50 with BHC-Alpha. Aldrin has correlation coefficients of 0.84 with bromodichloromethane, and 0.75 with fluoride. Crysene has correlation coefficients of o.97 with mercury and 0.69 with fluor~~e~~anthene.

Summary of Correlation Analysis

Spearman's rank correlation, a non-parametric statistical procedure, was used to calculate the bivariate correlations of the variables in the surface water data. The correlation coefficients are presented in Table 2. The largest number of significant correlations and most of the largest correlation coefficients are found between substances within the same chemical category. The chemical categories are: light chlorinated hydrocarbons, heavy chlorinated hydrocarbons, heavy metals, polycyclic aromatic hydrocarbons, and a broad group of chemical substances and measurements designated standard water quality parameters. The largest correlations are found within the heavy metals where beryllium, cadmium, selenium, and silver are found to be highly correlated. Other high correlations are found between many of the standard water quality parameters and between the pesticides.

There are some high correlations between chemical substances in different chemical categories. While there are not as many as those within categories, some of these suggest interesting questions as to why certain dissimilar chemical substances are often found in comparable relative concentrations in many samples.

To decrease the possibility of pure chance dominating the statistical analysis, 20 chemical substances were dropped from the correlation analysis. These substances all had less than 32 detectable concentrations (ten percent of the 320 samples). Some of the high correlations involving these substances have been mentioned.

Factor Analysis of Surface Water Data

Factor analysis is a multivariate statistical technique which identifies statistically independent structural patterns exhibited by a set of intercorrelated variables (Rummel, 1979). It is intended to identify distinctive combinations of chemical substances which tend to be found in the same water samples. The bivariate correlation analysis has identified many of the pairs of substances which tend to be found together. Factor analysis identifies independent patterns of contamination and indicates how strongly or weakly each of the chemical substances or water quality measurements in the data is associated with each of the patterns of contamination identified.

The 62 chemical substances and water quality measurements included in the correlation analysis were included in the factor analysis of the surface water data. These 62 substances and measurements are only a small sample of the potential number of substances which could be identified in water samples. Shakelford and Keith (1977) report that 1,259 different chemical compounds have been identified in water samples. The Environmental Defense Fund and Boyle (1979) estimate that only 10% of the organic chemicals contaminating drinking water in the United States have been identified. Since not all of the variation in the surface water samples can be assumed to be explained by the surface water data set, the conservative procedure of using the square of the multiple correlation coefficient (R^2) of each variable with every other variable was used to estimate the communalities. These estimated communalities replace the unities along the principal diagonal of the correlation matrix used in the factor analysis procedure. This conservative approach should assure that any unique variance which is not accounted for by the variables in the data set will not be included in the resulting factors.

The large quantities of missing data in the surface water data set present a number of problems in interpreting the results of factor analysis. When factor analysis is performed on a data set with missing data values, the actual variance of the data is increased by a quantity of "imaginary variance" (Rummel, 1970). The effect of this imaginary variance is to inflate the total variance which the factors identified have been calculated to explain.

The imaginary variance caused by missing data results in communalities which are inflated.

Presentation of Results of Factor Analysis

The results of factor analysing the surface water data set indicate many patterns of variation. Using an eigenvalue cutoff of one, 18 factors are identified. This is a very large number of factors indicating that many different patterns of contamination exist in the 320 surface water samples. Most of the factors identified do not have any of the chemical substances strongly identified with them. While some combination of the 62 variables identify the factors, none of them are strongly associated with the factors. When none of the variables are strongly associated with a factor, that factor can not be interpreted.

The first 4 of the 18 factors identified in the surface water data explain virtually all of the variation in the data and each can be interpreted since all four of the factors have several chemical substances strongly associated with the pattern of contamination identified by that factor. Mathematically forcing only four factors to be calculated, and using a varimax rotation to maximize the independent clusters of chemical substances which explain the variation in the data, produces the rotated factor matrix presented in Table 3 . The unrotated solution maximized the explanatory power of the first factor. The rotated solution more clearly delineates the four distinc-

TABLE 3: ROTATED FACTOR MATRIX TOXIC SUBSTANCES AND STANDARD WATER QUALITY PARAMETERS IN NEW JERSEY SURFACE WATER.[4]

Variables	I Pesticide	II Stnd WQ (SO4-CL-DS)	III Heavy Metals	IV Iron-Mer Bnzo-A-Pyrene	Communality h^2
1. methylene chloride	.45		.56		.51
2. chloroform		.49	.46		.46
3. 1,1,2-trichloroethylene		.44			.23
4. dibromochloromethane		.44			.30
5. 1,1,1-trichloroethane				-.46	.36
6. 1,1,2,2-tetrachloroethylene		.51			.38
7. BHC -	.46				.29
8. BHC - B	.58				.53
9. lindane	.44				.22
10. dieldrin	.76				.60
11. p,p^1-DDT	.62				.40
12. heptachlor epoxide	.49				.27
13. o,p^1-DDE	.70				.51
14. o,p^1-DDT	.63				.40
15. p,p^1-DDD	.67				.47
16. endrin	.54				.30
17. chlordane	.69				.51
18. manganese		.53			.29
19. beryllium			.93		1.11
20. cadmium			.92		1.03
21. copper		.49	.42		.43
22. chromium		.65			.62

TABLE 3 : ROTATED FACTOR MATRIX TOXIC SUBSTANCES AND STANDARD WATER QUALITY PARAMETERS IN NEW JERSEY SURFACE WATER. (Continued)

Variables	I Pesticide	II Stnd WQ (SO4-CL-DS)	III Heavy Metals	IV Iron-Mer Bnzo-A-Pyrene	Communality h^2
23. sodium		.82			.68
24. lead		.64			.56
25. selenium	.53		.72		.80
26. zinc		.41			.22
27. iron	.42			.59	.68
28. silver			.57	.47	.63
29. mercury				.65	.46
30. water temperature				.43	.20
31. benzo-a-pyrene	-.43			.70	.70
32. dissolved oxygen				-.42	.34
33. ammonia		.72			.60
34. nitrate		.64			.41
35. nitrite		.63			.55
36. phosphate		.66			.44
37. sulfate		.52			.39
38. alkalinity		.62		-.44	.58
39. chloride		.81			.71
40. LAS		.48			.29
41. dissolved solids		.68			.68
42. fluoride				.43	.42
Eigenvalues	8.42	7.30	4.12	3.07	
Percent total variation	37.00	32.10	18.10	13.50	

TABLE 3: ROTATED FACTOR MATRIX TOXIC SUBSTANCES AND STANDARD WATER QUALITY PARAMETERS IN NEW JERSEY SURFACE WATER. (Continued)

[1] Varimax Rotation. The Squared multiple correlation coefficients were used as communality estimates. N = 320.

[2] Only factor loadings greater than 0.40 are presented.

tive patterns of contamination in the surface water data.

Factor 1 is a *pesticide factor*. The pattern of contamination identified by Factor 1 explains 37 percent of the variation in the surface water data. All 11 pesticides included in the analysis are significantly associated with Factor 1. The chemical substances with the highest factor loadings in Factor 1 are pesticides: dieldrin 0.76; o,p^{1}-DDE 0.70; chlordane 0.69; p,p^{1}-DDD 0.67; p,p^{1}-DDT 0.63; and p,p^{1}-DDT 0.62. These heavy chlorinated hydrocarbons are noted for there extreme persistence in the environment. Despite the fact that several of these pesticides having been banned, since 1972, their persistence explains their presence in the surface waters of New Jersey in the period 1978-1979. Factor 1 tells us that where one of these pesticides is present in a New Jersey surface water sample, all eleven are likely to be found. The factor loadings indicate the relative probabilities that each of the pesticides will be found in a surface water sample known to contain pesticides.

The persistence of heavy chlorinated hydrocarbons and anthropocentric patterns of use of these pesticides are probably the major reasons for the pattern of surface water contamination identified by Factor 1. In areas where pesticides are used or have been used in the past, the long term effectiveness, the economics, and the regulatory situation have usually caused a variety of pesticides to be used. Once these heavy chlorinated hydrocarbons have been introduced to the land surface and the aquatic environment, their stable chemical nature insures extreme persistence. Other contributing causes include metabolic and chemical reactions (Walker, 1975) and contamination of products (Edwards, 1977).

In addition to the pesticides, 4 other chemical substances are found to be associated with Factor 1. The metals selenium and iron and the light chlorinated hydrocarbon methylene chloride are identified as likely to be found in the same surface water samples as the pesticides. Benzo{a}pyrene, a polycyclic aromatic hydrocarbon has a negative factor loading of -0.43 with Factor 1. The negative factor loading indicates that in those surface water samples in which the pesticides are likely to be found, benzo{a}pyrene is not likely to be found, and when benzo{a}pyrene is found in a water sample, the pesticides are unlikely to be found.

Logical explanations for the four non-pesticides associated with Factor 1 are not readily available. Factor analysis tells us that in a significant number of surface water samples in which the pesticide pattern was found, selenium, iron, and methylene chloride were also found and were found in greater concentrations when the pesticide concentrations were greater. The reverse is found to be true of benzo{a}pyrene. It is interesting to note that methylene chloride is one of the chemicals combined to manufacture DDT and other pesticides.

← That is Probably irrelevant

Factor 2 is a standard water quality factor with many of the standard water quality parameters strongly associated with this factor. Factor 2 is dominated by sodium, chloride, ammonia, and dissolved solids with factor loadings of 0.82, 0.81, 0.72, and 0.68, respectively. With these substances and measurements most strongly associated with Factor 2, the pattern of contamination identified is that common to the downstream reaches of the larger rivers of the state. While the samples most strongly associated with Factor 2 did not exceed the criteria to be deleted as saline, many of them may be brackish water high in sodium, chloride, and dissolved solids. Factor 2 identifies a very important pattern of contamination in New Jersey surface water, explaining 32.1 percent of the variation in the data.

Several chemical substances which are not standard water quality parameters are significantly associated with Factor 2. In addition to the alkali metal, sodium, several other metals are associated with Factor 2. These include: chromium, lead, manganese, copper and zinc. These metals are not uncommon in the lower reaches of the New Jersey's rivers where they enter the rivers from urban runoff and industrial activity (Wilber and Hunter, 1975). Several light chlorinated hydrocarbons are also associated with Factor 2. These are 1,1,2,2-tetrachloroethylene, chloroform, 1,1,2-trichloroethylene, and dibromochloromethane.

These chemicals are commonly used solvents, raw ingredients and by-products in many industrial operations.

Factor 3 is a heavy metals factor which explains 18.1 percent of the variation in the surface water data. Factor 3 has 5 metals and 2 light chlorinated hydrocarbons significantly associated, but is dominated by beryllium, cadmium, and selenium with factor loadings of 0.93, 0.92, and 0.72 respectively. The very high intercorrelations between these three substances has been discussed in the section on correlation analysis. Because these three substances were reported at the minimum reportable concentration in almost all surface water samples, Factor 3 is most strongly associated with those few samples in which beryllium, cadmium, and selenium were found in higher concentrations. The other substances associated with Factor 3 were also found in higher concentrations in those few samples.

In addition to beryllium, cadmium, and selenium, four other chemical substances are significantly associated with Factor 3. Two metals, silver with a factor loading of 0.57 and copper with a factor loading of 0.42 help explain the pattern of contamination dominated by heavy metals. Two light chlorinated hydrocarbons, methylene chloride with a factor loading of 0.56 and chloroform with a factor loading of 0.46 are also associated with Factor 3.

Factor 4 is a very interesting pattern of contamination which explains 13.5 percent of the variation in the surface water data. The unique set of substances associated with Factor 4 make this factor interesting and difficult to understand. Benzo(a)pyrene with a factor loading of 0.70, mercury with a factor loading of 0.65, and iron with a factor loading of 0.59 dominate Factor 4. Other substances which are identified with this pattern of contamination and which vary in concentration or measurement directly with benzo(a)pyrene, mercury, and iron include silver, fluoride, and water temperature. The substances which vary inversely with benzo(a)pyrene, mercury, and iron include 1,1,1-trichloroethane, alkalinity, and dissolved oxygen. Using these standard water quality measurements to help interpret this pattern of contamination, the toxics associated with Factor 4 with the exception of 1,1,1-trichloroethane are likely to be found in those surface waters which are relatively warm, acidic, and low in dissolved oxygen. Recent research in New Jersey and Philadelphia reports that benzo(a)pyrene and other polynuclear aromatic hydrocarbons are found in urban runoff and speculates that one of the major sources is used crankcase oil (Mackenzie, Moira and Hunter, 1979; Whipple and Hunter, 1979).

Summary of Surface Water Data Factor Analysis

Factor analysis identified 18 independent patterns of variation in the surface water data, but the first 4 factors explain most of the variation in the data and have sufficient chemical substances strongly associated with them to permit interpretation. The four most important patterns of contamination in the surface water data are a pesticide factor, a standard water quality parameters factor, a heavy metals factor, and a benzo{a}pyrene-mercury-iron factor.

Associations of Surface Water Sample Sites With Patterns of Contamination

An attempt was made to associate the characteristics of the sample sites with the patterns of contamination identified by factor analysis. If some set of characteristics such as land use or location could be found to be associated with one of the four distinct patterns of contamination, then we might have some clues to assist the research effort in discovering the causes of the toxics pollution identified in the surface water data. Factor scores were calculated for each sample measuring the association of that sample with each of the factors and were used to find which samples were most strongly associated with the patterns of contamination.

Problems of missing data seriously hinder site characteristics with patterns of contamination. Each of the four patterns of contamination identified in the surface water data is dominated by a small number of chemical substances. When a sample has missing data for some of those chemical substances which are most important in determining a pattern of contamination, the resulting factor score may be biased by overemphasis on the substances for which data are available.

The factor scores of the upper decile of samples (about 30) that most strongly identify with each factor were reviewed on the assumption that those samples would most strongly manifest causal clues. Unfortunately some of these samples have problems of missing data. Therefore, the following results must be looked at with this serious weakness in mind.

The descriptive information for each sample location also suffers from missing data and inconsistently collected data. As Table 4 indicates many potentially interesting items of information are missing. Many additional descriptive characteristics have not been included in Table because so little data were available. The land use data suffer from inconsistency. The people collecting the water samples were asked to describe the land use in the immediate vicinity of the sample site. The results indicate wide variation in the categories of land use assigned by different sampling teams. Efforts have been made to standardize the categories based on additional information, but the land use data remain suspect.

One piece of descriptive data which has no missing observations is that concerning whether the water is potable or nonpotable. A sample has been classified pota-

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER

Factor 1 - Pesticide Factor

Sample ID	County	Municipality	Source
CAM 104	Camden	Cherry Hill	Cooper River
CAM 109	Camden	Lindenwold	Cooper River
MON 5	Monmouth		Newman Springs
MON 8	Monmouth		
MON 28	Monmouth		
MON 2-11	Monmouth		
MON 104	Monmouth	Neptune City	Jumping Brook
OC 102	Ocean	Jackan Twp.	
OC 105	Ocean	Lacey Twp.	Forked River
PAS 101	Passaic	West Milford	Pequannack R.
PAS 103	Passaic		Passaic R.
SOM 102	Somerset	Hillsborough Twp.	Holland Brook
SOM 109	Somerset	Frankling Twp.	D & R Canal
SOM 110	Somerset	Rocky Hill Twp.	Beden Brook
SOM 108	Somerset	South Bound Br.	Raritan R.
BER 105	Passaic	Little Falls	Passaic R.
BER 107	Bergen	Mahwah	Ramapo R.
BUR 105	Burlington	Mansfield Twp.	Crafts Creek
BUR 110	Burlington	Burlington City	Delaware R.
HUNT 111	Hunterdon	Readington Twp.	Rockaway Creek
HUNT 112	Hunterdon	West Amwell	Moore Creek
MER 101	Mercer	Plainsboro Twp.	Plainsboro Pond
MER 102	Mercer	Princeton Twp.	Devils Creek
MER 108	Mercer	Trenton	Assunpink Creek
MER 109	Mercer	Hamilton Twp.	Crosswicks Creek
MER 110	Mercer	Princeton	D & R Canal
MER 112	Mercer	Princeton	Stoney Brook
MER 113	Mercer	Trenton	Assunpink Creek
MER 114	Mercer	Hamilton Twp.	Crosswicks Creek
SUS 103	Sussex	Sussex Boro	Wallkill R.
UN 102	Union	Rahwah City	Robbinson Branch
WAR 102	Warren	Oxford Twp.	Pequest R.
WAR 110	Warren	White Twp.	Buckhorn Creek

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER

Factor 1 - Pesticide Factor

Comments	Potable/ Nonpotable	Land Use
Water Murky	Nonpotable	Forest
	Nonporable	Urban Residential
Reddish Pool Below Pipe	Potable	Suburban Commercial
Downstream from Industry	Potable	Open Space
Murky Water	Nonpotable	Urban Residential
Near Golf Course	Nonpotable	Urban Residential
	Nonpotable	Forest
	Nonpotable	Urban Commercial
	Nonpotable	Urban Commercial
	Potable	Suburban Residential
Oil Slicks	Nonpotable	Industrial
Cows Use Brook	Potable	Farm
	Potable	Suburban Residential
	Potable	Industrial
Oil Slick	Nonpotable	Industrial
Oil Slicks, Foam	Potable	Urban Commercial
Murky, Bad Odor	Potable	Urban Commercial
	Potable	Urban Residential
	Potable	Industrial
	Potable	Farm
	Potable	Farm
Ducks & Gease on Pond	Potable	Urban Residential
	Potable	Farm
Trash in Stream	Potable	
Oil Slicks	Potable	Forest
Oil Slicks	Potable	Forest
	Potable	Suburban Commercial
Refuse in Water	Potable	
Dye Industry	Potable	Industrial
	Potable	Suburban Residential
	Potable	Forest
	Potable	Suburban Residential
	Potable	Suburban Residential

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 2 - Standard Water Quality Parameters

Sample ID	County	Municipality	Source
BER 5	Bergen		
BER 7	Bergen		
BER 9	Bergen	Hohokus	
BER 15	Bergen		Saddle River County Park
BER 23	Bergen		
ESS 13	Essex		
ESS 14	Essex		(Near Rt. 21)
ESS 1	Essex		
ESS 9	Essex		(South Orange Ave.)
ESS 11	Essex		
ESS 12	Essex		
ESS 18	Essex		Above Orange Resevoir
MON 23	Monmouth		
MON 24	Monmouth		(Rt. 33)
MON 25	Monmouth		
MON 28	Monmouth		
MON 34	Monmouth		
MON 104	Monmouth	Neptune City	Jumping Brook
MON 2-10	Monmouth		Big Brook
MON 2-11	Monmouth		
MON 2-14	Monmouth		
MON 2-24	Monmouth		Big Brook
MOR 14	Morris		Lake Parsippany
OC 105	Ocean	Lacey Twp.	Forked River
PAS 3	Passaic		(Rt. 507)
PAS 7	Passaic		
PAS 25	Passaic	Cedar Grove	Peckman River
PAS 26	Passaic		
PAS 32	Passaic	Hawthorne	Passaic River
SOM 108	Somerset	South Bound Brook	Raritan River
SUS 103	Sussex	Sussex Boro	Wallkill River (Rt. 565)

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 2 - Standard Water Quality Parameters

Comments	Potable/ Nonpotable	Land Use
	Nonpotable	Industrial
Fish in River	Nonpotable	Urban Commercial
	Nonpotable	Open Space
Runoff from Road	Nonpotable	Open Space
Pipe Upstream, Decaying Debris	Nonpotable	Urban Residential
Debris Floating, Oil on Surface	Nonpotable	Urban Commercial
	Nonpotable	Urban Residential
Pond Feeds Into River	Potable	Urban Residential
Parking Area on Left	Potable	Open Space
Near Abandoned Shopping Center	Potable	Industrial
Woods and Vegetation on Banks	Potable	Open Space
Oil Slick, Opaque Green Color	Potable	Urban Commercial
Sludge Farm Upstream	Nonpotable	Industrial
	Nonpotable	Industrial
Near Discharge Pipe	Nonpotable	Industrial
Murky Water	Nonpotable	Urban Residential
Farm Area	Nonpotable	Farm
	Nonpotable	Forest
Very Polluted	Potable	Industrial
Near Golf Course	Nonpotable	Urban Residential
Bacterial Growth	Nonpotable	Open Space
Old Pipe Dumped	Potable	Suburban Residential
	Potable	Suburban Residential
	Nonpotable	Urban Commercial
	Nonpotable	Urban Residential
Parking Lot, Discharge Pipes	Potable	Urban Commercial
Treatment Plants Upstream	Nonpotable	Urban Commercial
	Nonpotable	Industrial
	Nonpotable	Urban Commercial
Oil Slick	Nonpotable	Industrial
	Potable	Suburban Residential

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 3 - Heavy Metals

Sample ID	County	Municipality	Source
BER 20	Bergen		(Glen & Passaic Rds.)
BER 21	Bergen		Woodcliff Lake
BER 24	Bergen		
BER 28	Bergen	Englewood	
CAM 105	Camden	Camden	Cooper River
CUM 101	Cumberland	Millville	Maurice River
CUM 104	Cumberland	Mauricetown	Maurice River
ESS 5	Essex		
HUNT 114	Hunterdon	Lambertville	Swan Creek Resevoir
HUD 3	Hudson		Weequahic Lake
MON 15	Monmouth		Consolidated Water Co.
MON 21	Monmouth		Tap at Water Plant
MON 103	Monmouth	Neptune City	Shark River
MON 2-11	Monmouth		
MON 2-12	Monmouth		
MON 2-14	Monmouth		
MOR 14	Morris		Lake Parsippany
MOR 21	Morris		(Rt. 46)
MOR 25	Morris		(Rt. 23)
MOR 26	Morris		Taylortown Resevoir
PAS 14	Passaic		
PAS 16	Passaic		
PAS 29	Passaic		Passaic R. (Rossiter Ave.)
PAS 101	Passaic	West Milford	Pequannock R.
SA 101	Salem	Pittsgrove	Maurice R. (Norma Almond Br.)
SOM 111	Somerset	Hillsborough	
SUS 102	Sussex	Franklin	Wallkill R. (Rt. 631)
SUS 103	Sussex	Sussex Boro	Wallkill R. (Rt. 565)
UNI 9	Union		
UNI 10	Union	Elizabeth	Elizabeth R.
WAR 106	Warren	Franklin	Musconetcong R.
WAR 107	Warren	Mount Olive	

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 3 - Heavy Metals

Comments	Potable/ Nonpotable	Land Use
	Potable	Urban Residential
Residential	Potable	Suburban Residential
	Potable	
	Nonpotable	Urban Residential
Old Tires & Other Debris in Water	Nonpotable	Industrial
White Scum on Surface	Nonpotable	Forest
	Nonpotable	Urban Residential
	Nonpotable	Suburban Residential
Water Aerated at Intake	Potable	Forest
Dense Algae, Eutrophic	Nonpotable	Industrial
Treated Water	Potable	Suburban Residential
Potable Water	Potable	
	Nonpotable	Forest
Near Golf Course	Nonpotable	Urban Residential
Near Canoe Rental	Nonpotable	Open Space
Bacterial Growth, Red and Orange	Nonpotable	Open Space
Petroleum Substance on Water	Potable	Urban Commercial
Channelled Stream	Potable	Open Space
	Potable	Forest
Oil Slick	Potable	Suburban Residential
	Potable	Urban Residential
	Nonpotable	Urban Commercial
	Potable	Suburban Residential
White Foam on Water	Nonpotable	Forest
	Potable	Farm
Suds on Water	Potable	Forest
	Potable	Suburban Residential
	Nonpotable	Urban Residential
	Nonpotable	Urban Commercial
Hwy. Crew Spraying Trees	Potable	
	Potable	Forest
	Potable	Suburban Residential

TABLE 4: ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 4 - Monmouth County Factor

Sample ID	County	Municipality	Source
BER 20	Bergen		(Glen Rd.)
ESS 17	Essex		
HUD 3	Hudson		Weequahic Lake
MON 15	Monmouth		Consolidated Water Co.
MON 21	Monmouth		Water Co.
MON 23	Monmouth		(Near Freehold)
MON 26	Monmouth		
MON 2-10	Monmouth		Big Brook
MON 2-10R	Monmouth		Big Brook
MON 2-12	Monmouth		(Near Canoe Rental)
MON 2-13	Monmouth		From Origin in Marsh
MON 2-14	Monmouth		
MON 2-15	Monmouth		Ramanesseen Brook
MON 2-16	Monmouth		Ramanesseen Brook
MON 2-17	Monmouth		(Shank Rd.)
MON 2-18	Monmouth		Willow Brook
MON 2-19	Monmouth		Willow Brook
MON 2-20	Monmouth		Willow Brook
MON 2-21	Monmouth		Big Brook
MON 2-22	Monmouth		
MON 2-23	Monmouth		Big Brook
MON 2-25	Monmouth		
MON 2-29	Monmouth		Mahoras Brook
MON 2-30	Monmouth		
MON 2-31	Monmouth		
MON 102	Monmouth	Tinton Falls	Pine Brook
MON 104	Monmouth	Neptune City	Jumping Brook
MOR 14	Morris		Lake Parsippany
MOR 16	Morris		Greenpond Lake
PAS 11	Passaic		
PAS 14	Passaic		
PAS 16	Passaic		
UNI 4	Union		Robinson Brank Above Res.
UNI 9	Union		

TABLE 4 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN SURFACE WATER (Continued)

Factor 4 - Monmouth County Factor

Comments	Potable/ Nonpotable	Land Use
	Potable	Urban Residential
	Nonpotable	
Dense Algae, Eutrophic	Nonpotable	Industrial
Treated Water	Potable	Suburban Residential
Potable Water	Potable	
Sludge Farm Nearby	Nonpotable	Industrial
Area Smells	Nonpotable	
Very Polluted	Potable	Industrial
Black Oil on Bottom	Potable	Industrial
	Nonpotable	Open Space
	Nonpotable	Industrial
Baterial Growth, Red and Orange	Nonpotable	Open Space
	Potable	Farm
Garbage Dumped in Stream	Potable	Suburban Residential
	Potable	Suburban Residential
	Potable	Suburban Residential
	Potable	Open Space
Undeveloped Area	Potable	Open Space
Bottles and Cans Dumped	Potable	Urban Commercial
	Potable	Open Space
	Potable	Farm
	Potable	Suburban Residential
	Nonpotable	
	Nonpotable	
	Nonpotable	Urban Residential
	Nonpotable	Urban Residential
	Nonpotable	Forest
	Potable	Suburban Residential
	Potable	Suburban Residential
	Potable	Open Space
Oil Slick	Potable	Suburban Residential
	Potable	Urban Residential
	Potable	Urban Residential
Below Dam Spillway	Nonpotable	Urban Residential

ble if the sample location is upstream of any potable water supply intake facility. The determination were made by Dr. Robert Tucker and Barker Hamill of DEP and the author. The intake facility used in the classification may be in a neighboring state. Those samples classified nonpotable were determined to be downstream of all potable supply intake facilities.

It must be reemphasized that the patterns of toxics contamination identified by means of factor analysis do not identify risks to the health of those people consuming the water. The factors identified are mathematical patterns in the data. The toxicity and or health effects of consuming these substances is not addressed in this report but can be found in Drinking Water and Health (National Research Council, 1977). The concentrations of toxic substances which are calculated to form a pattern of contamination are in most cases very small. The fact that a source of potable water supply is found to be highly associated with one of the patterns of contamination does not by itself indicate a public health danger.

Factor 1

The characteristics of the surface water sample sites associated with Factor 1, the pesticide factor, are presented in Table 4 . The sample sites indicate that the pesticide pattern of contamination is widespread throughout the state. About two-thirds of the samples were collected in Central New Jersey from Monmouth County to Hunterdon County. The 33 samples were collected in twelve different counties with Mercer County having the largest number of samples.

The land use of the areas surrounding the sample sites represent a wide range of uses, but the developed land uses do predominate. Of course, the pollutants measured in the samples collected may have entered the surface water far upstream of the sample site. The comments indicate that many of the sample sites exhibit evidence of some form of pollution, such as oil slicks, odors, refuse, etc.

It is interesting that many of these obvious signs of pollution are found in streams upstream from potable water supply intakes. The pesticide factor is associated with 24 potable and 9 nonpotable waters.

Factor 2

The surface water samples most strongly associated with Factor 2, the standard water quality parameters factor, are from largely developed areas. The counties of Bergen, Essex, Passaic and Monmouth account for 28 of the 31 samples most strongly associated with Factor 2. The land uses of the areas surrounding the sample sites indicate the built-up nature of these areas. Many of the comments describe conditions which would be expected to lead to low water quality as measured by the standard water quality parameters associated with Factor 2. These include runoff, debris, oil slicks, bacterial growths, discharge pipes, etc. Of the 31 samples most strongly associated with Factor 2, 10 were from potable waters and 21 from nonpotable waters.

Factor 3

The characteristics of the surface water samples most strongly associated with Factor 3, the heavy metals factor, are presented in Table 4 . The samples were collected in 14 different counties located throughout the state. While many of these samples were collected in the highly developed areas one would expect, about half the samples are from potable waters in rural or lighty developed counties. The land uses surrounding the sample sites also indicate that while many are industrial and or urban, 7 sample sites were characterized as forest, 2 open space, and 1 as farm. The comments do indicate some local pollution may be present, but do not give indications of sources of pollution which are often associated with heavy metals pollution such as runoff or industrial activities.

Factor 4

The surface water samples associated with Factor 4 are presented in Table 4 . Factor 4 is identified by a very distinctive pattern of contamination which is dominated by benzo{a}pyrene, mercury, and iron with several other substances and water quality measurements (see Table 4). This factor was very difficult to interpret until the factor scores were studied. Factor 4 is a Monmouth County factor. Of the 34 samples most highly associated with Factor 4, 24 were collected in Monmouth County. If we look only at those 16 samples which had factor scores of 2 or greater, 13 are from Monmouth County. The pattern of contamination identified by Factor 4 is evidently a distinctive combination of pollutants which are present in the surface waters of Monmouth County.

The Monmouth County factor is most strongly associated with 3 streams which drain into the Swimming River Resevoir. They are Big Brook, Ramenessen Brook, and Willow Brook. All three streams are classified as potable and their drainage basins are lightly developed but do contain some industrial facilities. The samples from other counties which are among those most strongly associated with Factor 4 are from urban-undustrial areas of Bergen, Essex, Hudson, Passaic, and Union Counties, with the exception of two samples from lakes in Morris County. Given the common sources of benzo{a}pyrene and mercury, it is possible that industrial activity is the cause of the distinctive pattern of contamination identified by the Monmouth County factor along with high concentrations of iron which are found in the soils and water of Monmouth County and many other areas of New Jersey. Unfortunately, missing data values for some of the most important chemical substances associated with Factor 4 hinder the interpretation.

Summary of Associations of Surface Water Sample Sites with Patterns of Contamination

The characteristics of the surface water sample sites mostly strongly associated with the patterns of contamination identified by factor analysis are presented in Table 4. It was hoped that some of the characteristics or comments might provide research hypotheses concerning the causes of toxics pollution of the surface water of New Jersey.

Missing data is so pervasive in the surface water data set that relatively little additional information could be gleened from the analysis of associations of sample site characteristics with patterns of contamination. The missing data for the concentrations of toxics in the water samples greatly diminishes the reliability of the factor scores which indicate the degree of association of the samples with the patterns of contamination. The missing data in the descriptive characteristics of the sample sites effectively masks whatever relationships or clues may be present.

The only interesting finding to come from the analysis of associations of sample site characteristics with patterns of contamination is the identification of the Monmouth County pattern of contamination. The spatial concentration of those samples most strongly associated with Factor 4 of the surface water factor analysis led to the naming of this pattern of contamination the Monmouth County factor.

CHAPTER 2

PATTERNS OF TOXICS IN NEW JERSEY GROUND WATER

Data Description: Ground Water

The ground water data analysed in this report were developed by the Department of Environmental Sciences, Cook College under contract to the New Jersey Department of Environmental Protection. The data include all of the samples collected under the 1977-1978 contract and *Interim* Report #1 from the 1978-1979 contract.

The ground water samples were collected from wells in every county in New Jersey, but are concentrated in certain areas of the state. The first 408 ground water samples were a representative sample of the state's ground water, when judged from the perspective that about the same number of samples were collected in each county. The subsequent samples were collected to gain additional information about high levels of toxics in a small number of the wells already sampled or in their vicinity.

The initial 408 samples were taken from 408 different sites (Page and Greenberg, 1978). In the second year's contract, some wells have been selected for monthly or seasonal sampling. There are a maximum of 5 samples from

15 different sample locations. These data are at present insufficient for any rigorous analysis of temporal variation.

Several subsets of ground water data were combined for this report. While these subsets of data are largely comparable in terms of the chemical substances included in the sample analyses, there have been some noteworthy changes. Some chemical substances have been dropped from the analyses, others have been added. Merging these subsets of ground water data results in missing data.

Most of the changes have been within the light chlorinated hydrocarbons. Trifluoromethane was included in the first 408 samples, but was dropped from all subsequent analyses. Fluoroform, dichlorobromomethane, dichloroethylene (gem), dibromomethane, t-dichloroethylene, arochlor 1016, arochlor 1242, and arochlor 1248 have all been added to the analyses under the second year's contract.

Changes have occurred in the analysis of dichlorobenzene. In the first subset of data, dichlorobenzene was the variable reported. Subsequently, the o- m- and p-isomers have been reported. The o-, m- and p-isomers have been retained in the merged data along with a composite total dichlorobenzene to make the ground water data comparable to the surface water data.

Four other light chlorinated hydrocarbons which have been changed during the course of data collection were treated to make them commensurate with the surface water data. Concentrations of bromodichloromethane and 1,1,2-trichloroethylene were originally reported as one variable, later as two separate variables, and in the last data received only 1,1,2-trichloroethylene was reported. Both substances are retained as variables, but the information is lost from those samples from which they were combined. In the first ground water data set, 1,2-dibromoethane and 1,1,2,2-tetrachloroethylene were each variables. In the most recent data, these two substances are combined as one variable. The information from the 143 samples with these two substances combined is not included in this analysis.

Standard water quality parameters were reported from the first 245 ground water samples, but have not been reported for any subsequent samples. Total Organic carbon (TOC) is included in sample results from the second year's contract but had not previously been reported. The variables included in the ground water data set used for this report are listed in Table 5 . The 71 chemical substances or water quality measurements are divided into four general categories. There are 27 light chlorinated hydrocarbons, 20 heavy chlorinated hydrocarbons, 9 heavy metals, and 15 standard water quality parameters.

The number of samples collected for each variable listed in Table 5 highlights the problems of missing data. While 692 ground water samples are included in the data

TABLE 5 : GROUND WATER DATA

I. LIGHT CHLORINATED HYDROCARBONS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations	Median Conc.	Range of Detectable Concentrations	
					Min.	Max.
1. Fluoroform	PPB	130	15	0.0	<0.5	159.2
2. Methyl Chloride	PPB	628	3	0.0	<6.0	220.6
3. Methyl Bromide	PPB	628	2	0.0	<1.0	6.0
4. Vinyl Chloride	PPB	627	2	0.0	1.0	2.5
5. Methylene Chloride	PPB	624	88	0.0	90.0	1,900.0
6. Chloroform	PPB	640	439	0.3	<0.8	691.2
7. 1,2-Dichloroethane	PPB	634	57	0.0	<1.6	2,300.0
8. 1,1,1-Trichloroethane	PPB	638	535	2.0	<2.0	607.8
9. Carbon Tetrachloride	PPB	639	431	<0.1	<0.1	150.2
10. 1,1,2-Trichloroethylene	PPB	250	175	<0.3	<0.3	635.0
11. Dichlorobromoethane	PPB	142	60	0.0	<0.1	604.5
12. 1,1,2-Trichloroethane	PPB	637	55	0.0	<1.0	31.1
13. Dibromochloromethane	PPB	640	104	0.0	<0.1	2.4
14. 1,2-Dibromoethane	PPB	640	107	0.0	<0.1	196.7
15. 1,1,2,2-Tetrachloroethylene	PPB	638	348	<0.1	<0.1	299.6
16. Bromoform	PPB	640	124	0.0	<1.0	34.3
17. 1,1,2,2-Tetrachloroethane	PPB	640	57	0.0	<0.3	2.7
18. Diiodomethane	PPB	639	66	0.0	<0.3	2.0
19. Total Dichlorobenzene	PPB	674	22	0.0	<2.2	102.3
20. m-Dichlorobenzene	PPB	249	6	0.0	<1.3	25.4
21. p-Dichlorobenzene	PPB	249	12	0.0	<1.3	78.5
22. o-Dichlorobenzene	PPB	249	9	0.0	<2.2	5.2
23. 1,3,5-Trichlorobenzene	PPB	637	24	0.0	<2.0	33.7
24. Dichloroethylene (gem)	PPB	64	34	10.0	1.1	1,280.2
25. Dibromomethane	PPB	64	23	0.0	<0.1	44.9
26. t-Dichloroethylene	PPB	64	51	10.0	<0.1	549.3
27. Bromodichloroethane	PPB	108	18	0.0	<0.1	1.6

TABLE 5 : (Continued)

II. HEAVY CHLORINATED HYDROCARBONS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concen-trations	Median Conc.	Range of Detectable Concen-trations Min.	Max.
1. Ar^{o}chlor 1016	PPB	248	0			
2. Ar^{o}chlor 1242	PPB	248	7	0	<0.1	3.4
3. Ar^{o}chlor 1248	PPB	248	3	0	<0.1	0.2
4. Ar^{o}chlor 1254	PPB	638	11	0	<0.1	0.4
5. BHC-Alpha α-BHC	PPB	653	96	0	<0.1	0.8
6. Lindane	PPB	653	166	0	<0.1	0.9
7. BHC-Beta β-BHC	PPB	563	245	0	<0.1	118.4
8. Heptachlor	PPB	653	172	0	<0.1	1.0
9. Aldrin	PPB	653	156	0	<0.1	1.2
10. Heptachlor Epoxide	PPB	653	155	0	<0.1	0.6
11. Chlordane	PPB	653	185	0	<0.1	0.3
12. o,p'-DDE	PPB	653	116	0	<0.1	0.9
13. Dieldrin	PPB	653	89	0	<0.1	0.9
14. Endrin	PPB	653	75	0	<0.1	0.6
15. o,p'-DDT	PPB	653	70	0	<0.1	3.7
16. p,p'-DDD	PPB	653	72	0	<0.1	1.8
17. p,p'-DDT	PPB	651	60	0	<0.1	5.0
18. Mirex	PPB	653	39	0	<0.1	0.4
19. Methyoxychlor	PPB	653	0			
20. Toxaphene	PPB	652	1	0		<0.1

error
in
data

TABLE 5 : (Continued)

III. HEAVY METALS

Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations	Median Conc.	Range of Detectable Concentrations Min.	Max.
1. Arsenic	PPB	642	639	1.0	<1.0	1,160
2. Beryllium	PPB	642	642	<0.5	<0.5	84
3. Cadmium	PPB	638	638	<0.5	<0.5	405
4. Copper	PPB	638	635	4.0	<0.5	1,381
5. Chromium	PPB	638	638	2.0	<0.5	179
6. Nickel	PPB	637	637	2.5	<0.5	600
7. Lead	PPB	636	633	1.0	<0.5	329
8. Selenium	PPB	637	637	2.0	<1.0	8
9. Zinc	PPB	638	638	15.0	<2.5	36,500

TABLE 5 : (Continued)

IV. STANDARD WATER QUALITY PARAMETERS

	Chemical Substance	Unit of Measure	Number of Samples Collected	Number of Detectable Concentrations	Median Conc.	Detectable Concentrations	
						Min.	Max.
1.	NH_3-N (Ammonia)	PPM	343	343	<0.1	<0.1	9,048.0
2.	Organic Nitrogen	PPM	341	332	<0.1	<0.1	320.0
3.	NO_3-N (Nitrate)	PPM	342	330	0.4	<0.1	2.9
4.	NO_2-N (Nitrite)	PPM	384	209	<0.1	<0.2	4,515.0
5.	PO_4 Phosphate	PPM	347	306	<0.1	<0.1	200.0
6.	SO_4 Sulfate	PPM	347	341	30.0	<0.1	3,750.0
7.	Alkalinity	PPM	345	327	96.0	2.0	446.0
8.	Chloride	PPM	345	345	17.0	1.8	4,400.0
9.	Fluoride	PPM	348	348	0.2	<0.1	5.4
10.	Cyanide	PPM	344	344	<0.1	<0.1	2.5
11.	Las-Detergent	PPM	348	330	0.0	<0.1	2.1
12.	Dissolved Solids	PPM	343	342	134.0	2.2	3,240.0
13.	Fecal Coliforms	#/100 ML	349	10	0.0	<1.0	8.0
14.	Water Temperature	C°	623	623	13.0	5.0	25.0
15.	pH	1-14	607	607	7.2	4.0	9.9

set, no variable has more than 674 sample concentrations and many have far fewer. This is caused by analytic results from many samples not being available for different chemical substances. The largest quantities of missing data are caused by changes in the chemical substances included in the chemical analyses. Missing data is also caused by analytic results being lost or not performed on certain samples. Whatever the cause, missing data presents serious obstacles to any statistical analysis. Some information is lost due to chemical substance combinations. Even more disturbing is inflated or imaginary variance caused by missing data. These problems will be reviewed during the discussion of statistical procedures.

Analysis of the Ground Water Data

Table 5 indicates that the toxics data are severely right skewed, particularly the light and heavy chlorinated hydrocarbons. Most of the samples analysed were found at non-detectable concentrations; yet a few samples contain concentrations three or four orders of magnitude larger. Analysis of the frequency distributions of the heavy metals reveals that they are also right skewed even though they are detectable in virtually all samples. The standard water quality parameters are approximately normal. These are the same patterns as were found in the surface water data.

The distinctly non-normal frequency distributions of the toxics data from the ground water of New Jersey require the use of non-parametric statistical procedures. As with the surface water data, the underlying assumptions of the more powerful parametric statistical procedures are severely violated by the data. The non-parametric statistical procedures used in this report are appropriate for the data but tend to be less powerful than the equivalent parametric procedures.

Ground Water Correlation Analysis

Initially, Spearman's Rank Correlation procedure, a non-parametric procedure, was used to calculate the bivariate correlations between the water quality variables. Those correlation coefficients significant at the 0.001 level are presented in Table 6 .

As was found in the surface water data, most of the highest correlations occur between substances within the same chemical category. Those categories are: light chlorinated hydrocarbons, heavy chlorinated hydrocarbons, heavy metals, and standard water quality parameters. There are many highly significant correlation coefficients between substances in different chemical categories, but they are generally not as prevalent, nor as high as those between substances within the same chemical category.

The highest correlation coefficients are found within the heavy metals. Beryllium has Spearmen correlation

TABLE 6: GROUND WATER CORRELATION MATRIX[1]

	1	2	3	4	5
1. Vinyl Chloride					
2. Methylene Chloride			.19		.24
3. Chloroform		.19		.22	.39
4. 1,1,1-Trichloroethane			.22		
5. Carbon Tetrachloride		.24	.37		
6. 1,1,2-Trichloroethylene			.29	.34	.26
7. Dibromochloromethane			.22		
8. 1,2-Dibromoethane			.15		
9. 1,1,2,2-Tetrachloroethylene			.46	.40	.31
10. Bromoform		.25	.34		.19
11. αBHC-~~Alpha~~					
12. Lindane		-.20		-.20	
13. βBHC-~~Beta~~		.20	.26		
14. Heptachlor		-.16			
15. Aldrin		-.15		-.15	
16. Heptachlor Epoxide					
17. Chlordane					
18. o,p'-DDE				-.16	
19. Dieldrin					
20. Endrin					
21. o,p'-DDT				-.16	
22. p,p'-DDD					
23. Arsenic			.27	.21	
24. Beryllium		.33	.47		.21
25. Cadmium		.30	.45		.18
26. Copper					
27. Chromium				.14	.27
28. Nickel		-.21	-.14	-.17	
29. Lead					
30. Selenium		.21	.36		.15
31. Zinc					
32. TOC					
33. NH_3-N (Ammonia)					
34. Organic-N					
35. NO_3-N (Nitrate)					
36. NO_2-N (Nitrite)					
37. PO_4-Phosphate					
38. SO_4-Sulfate			.23		
39. Alkalinity					
40. Chloride					
41. Fluoride					
42. Cyanide				.19	
43. LAS					
44. Dissolved Solids					
45. Water Temperature					
46. pH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	6	7	8	9	10
1. Vinyl Chloride					
2. Methylene Chloride					.25
3. Chloroform	.29	.22	.15	.46	.34
4. 1,1,1-Trichloroethane	.34			.40	
5. Carbon Tetrachloride	.26			.31	.19
6. 1,1,2-Trichloroethylene				.52	
7. Dibromochloromethane			.17		.24
8. 1,2-Dibromoethane		.17			
9. 1,1,2,2-Tetrachloroethylene	.52				.25
10. Bromoform		.24		.25	
11. BHC-Alpha					
12. Lindane					
13. BHC-Beta				.18	.19
14. Heptachlor					
15. Aldrin					
16. Heptachlor Epoxide					
17. Chlordane					
18. o,p'-DDE					
19. Dieldrin					
20. Endrin					
21. o,p'-DDT					
22. p,p'-DDD					
23. Arsenic				.27	.17
24. Beryllium				.26	.36
25. Cadmium				.25	.33
26. Copper					
27. Chromium				.28	
28. Nickel					
29. Lead					
30. Selenium				.17	.28
31. Zinc					
32. TOC					
33. NH3-N (Ammonia)					
34. Organic-N					
35. NO3-N (Nitrate)				.20	
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate				.25	
39. Alkalinity	.27				
40. Chloride					
41. Fluoride				.21	
42. Cyanide					
43. LAS			.21		
44. Dissolved Solids	.36				
45. Water Temperature					
46. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation Coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	11	12	13	14	15
1. Vinyl Chloride					
2. Methylene Chloride		-.20	.20	-.16	-.15
3. Chloroform			.26		
4. 1,1,1-Trichloroethane		-.20			-.15
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene			.18		
10. Bromoform			.19		
11. BHC-Alpha		.50	.22	.27	.33
12. Lindane	.50		.30	.49	.52
13. BHC-Beta	.22	.30			.17
14. Heptachlor	.27	.49			.55
15. Aldrin	.33	.52	.17	.55	
16. Heptachlor Epoxide	.27	.35	.29	.34	.48
17. Chlordane	.29	.32	.35	.25	.34
18. o,p'-DDE	.28	.35		.34	.43
19. Dieldrin	.29	.28	.25	.23	.40
20. Endrin	.31	.31	.14	.30	.39
21. o,p'-DDT	.30	.35	.15	.30	.41
22. p,p'-DDD	.28	.31	.18	.25	.39
23. Arsenic	-.17	-.22		-.16	-.24
24. Beryllium	-.25	-.40	.22	-.20	-.30
25. Cadmium	.20	-.33	.21	-.18	-.25
26. Copper		-.16			
27. Chromium					
28. Nickel			-.19		
29. Lead	-.16	-.24			-.20
30. Selenium		-.17	.23		
31. Zinc					
32. TOC					
33. NH3-N (Ammonia)					
34. Organic-N					
35. NO3-N (Nitrate)					
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate					
39. Alkalinity					-.24
40. Chloride					
41. Fluoride	-.27	-.35	-.26		-.30
42. Cyanide		-.27			-.20
43. LAS					
44. Dissolved Solids					
45. Water Temperature		.28	.21	.19	.23
46. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	16	17	18	19	20
1. Vinyl Chloride					
2. Methylene Chloride					
3. Chloroform					
4. 1,1,1-Trichloroethane			-.16		
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene					
10. Bromoform					
11. BHC-Alpha	.27	.29	.28	.29	.31
12. Lindane	.35	.32	.35	.28	.31
13. BHC-Beta	.29	.35		.25	.14
14. Heptachlor	.34	.25	.34	.23	.30
15. Aldrin	.48	.34	.43	.40	.39
16. Heptachlor Epoxide		.42	.42	.44	.36
17. Chlordane	.42		.43	.43	.43
18. .42	.42	.43		.48	.53
19. Dieldrin	.44	.43	.48		.57
20. Endrin	.36	.43	.53	.57	
21. o,p'-DDT	.36	.42	.49	.51	.64
22. p,p'-DDD	.37	.40	.54	.55	.67
23. Arsenic					
24. Beryllium	-.18				
25. Cadmium	-.17				
26. Copper					
27. Chromium	-.14	-.14			
28. Nickel					
29. Lead	-.14				
30. Selenium					
31. Zinc					
32. TOC					
33. NH3-N (Ammonia)					
34. Organic-N					
35. NO3-N (Nitrate)					
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate					
39. Alkalinity	-.24				-.19
40. Chloride					
41. Fluoride	-.25	-.25		-.23	
42. Cyanide					
43. LAS					
44. Dissolved Solids					
45. Water Temperature	.14		.22	.14	
46. PH					

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	21	22	23	24	25
1. Vinvl Chloride					
2. Methylene Chloride				.33	.30
3. Chloroform			.27	.47	.45
4. 1,1,1-Trichloroethane	-.16		.21	.16	
5. Carbon Tetrachloride				.21	.18
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene			.27	.26	.25
10. Bromoform			.17	.36	.33
11. BHC-Alpha	.30	.28	-.17	-.25	-.20
12. Lindane	.35	.31	-.22	-.40	-.33
13. BHC-Beta	.15	.18		.22	.21
14. Heptachlor	.30	.25	-.16	-.20	-.18
15. Aldrin	.41	.39	-.24	-.30	-.25
16. Heptachlor Epoxide	.36	.37		-.18	-.17
17. Chlordane	.42	.40			
18. o,p'-DDE	.49	.54			
19. Dieldrin	.51	.55			
20. Endrin	.64	.67			
21. o,p'-DDT		.69	-.15	-.15	-.14
22. p,p'-DDD	.69				
23. Arsenic				.49	.48
24. Beryllium	-.15		.49		.89
25. Cadmium	-.14		.48	.89	
26. Copper				.17	.21
27. Chromium		-.14	.14		
28. Nickel					
29. Lead			.17	.34	.38
30. Selenium			.29	.65	.61
31. Zinc					.15
32. TOC					
33. NH3-N (Ammonia)					
34. Organic-N					
35. NO3-N (Nitrate)					
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate		-.19			
39. Alkalinity	-.23	-.22			
40. Chloride					
41. Fluoride	-.21	-.19	.47	.61	.54
42. Cyanide			.30	.55	.43
43. LAS					
44. Dissolved Solids				-.45	-.38
45. Water Temperature	.17	.14			
46. PH			.14		

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	26	27	28	29	30
1. Vinyl Chloride					
2. Methylene Chloride			-.21		.21
3. Chloroform			-.14		.36
4. 1,1,1-Trichloroethane		.14	-.17		
5. Carbon Tetrachloride		.27			.15
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene		.28			.17
10. Bromoform					.28
11. BHC-Alpha				-.16	
12. Lindane	-.16			-.24	-.17
13. BHC-Beta			-.19		.23
14. Heptachlor					
15. Aldrin				-.20	
16. Heptachlor Epoxide		-.14		-.14	
17. Chlordane		-.14			
18. o,p'-DDE					
19. Dieldrin					
20. Endrin					
21. o,p'-DDT					
22. p,p'-DDD		-.14			
23. Arsenic				.17	.29
24. Beryllium	.17			.34	.65
25. Cadmium	.21			.38	.61
26. Copper				.59	
27. Chromium					
28. Nickel					
29. Lead	.59				.15
30. Selenium				.15	
31. Zinc	.41		.16	.39	
32. TOC					
33. NH3-N (Ammonia)			.21		
34. Organic-N		-.19			
35. NO3-N (Nitrate)		.20			
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate		.25	-.26		
39. Alkalinity		.22			
40. Chloride					
41. Fluoride				.21	.33
42. Cyanide			.21		.33
43. LAS					
44. Dissolved Solids		.23	-.28	-.24	-.30
45. Water Temperature		-.14			
46. PH	-.23		-.17		

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	31	32	33	34	35
1. Vinyl Chloride					
2. Methylene Chloride					
3. Chloroform					
4. 1,1,1-Trichloroethane					.17
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene					.20
10. Bromoform					
11. BHC-Alpha					
12. Lindane				.16	
13. BHC-Beta					
14. Heptachlor					
15. Aldrin					
16. Heptachlor Epoxide					
17. Chlordane					
18. o,p'-DDE					
19. Dieldrin					
20. Endrin					
21. o,p'-DDT					
22. p,p'-DDD					
23. Arsenic		.18			
24. Beryllium					
25. Cadmium	.15				
26. Copper	.41				
27. Chromium				-.19	.20
28. Nickel	.16		.21		
29. Lead	.39				
30. Selenium					
31. Zinc					
32. TOC					
33. NH3-N (Ammonia)				.31	-.21
34. Organic-N			.31		-.40
35. NO3-N (Nitrate)			-.21	-.40	
36. NO2-N (Nitrite)			.20	.26	-.26
37. PO4-Phosphate					
38. SO4-Sulfate					.23
39. Alkalinity					
40. Chloride					.34
41. Fluoride	.20				
42. Cyanide			.21		
43. LAS			.22		
44. Dissolved Solids					
45. Water Temperature					
46. PH	-.14	.28			

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	36	37	38	39	40
1. Vinyl Chloride					
2. Methylene Chloride					
3. Chloroform			.23		
4. 1,1,1-Trichloroethane			.18		
5. Carbon Tetrachloride					
6. 1,1,2-Trichloroethylene					
7. Dibromochloromethane					
8. 1,2-Dibromoethane					
9. 1,1,2,2-Tetrachloroethylene			.25		
10. Bromoform					
11. BHC-Alpha					
12. Lindane					
13. BHC-Beta					-.20
14. Heptachlor			-.17	-.16	
15. Aldrin				-.23	
16. Heptachlor Epoxide				-.24	
17. Chlordane					
18. o,p'-DDE					
19. Dieldrin					
20. Endrin				-.19	
21. o,p'-DDT				-.23	
22. p,p'-DDD			-.19	-.22	
23. Arsenic					
24. Beryllium					
25. Cadmium					
26. Copper					
27. Chromium			.25	.22	
28. Nickel			-.26		
29. Lead					
30. Selenium					
31. Zinc					
32. TOC					
33. NH3-N (Ammonia	.20				
34. Organic-N	.26				
35. NO3-N (Nitrate)	.26		.23		.34
36. NO2-N (Nitrite)					
37. PO4-Phosphate					
38. SO4-Sulfate				.31	.29
39. Alkalinity			.31		.29
40. Chloride			.29	.29	
41. Fluoride	.20				
42. Cyanide					
43. LAS					
44. Dissolved Solids			.50	.54	.43
45. Water Temperature					
46. PH				.39	

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	41	42	43	44
1. Vinyl Chloride				
2. Methylene Chloride				
3. Chloroform				
4. 1,1,-Trichloroethane		.19		
5. Carbon Tetrachloride				
6. 1,1,2-Trichloroethylene				.36
7. Dibromochloromethane				
8. 1,2-Dibromoethane			.21	
9. 1,1,2,2-Tetrachloroethylene	.21			
10. Bromoform				
11. BHC-Alpha	-.27			
12. Lindane	-.35	-.27		
13. BHC-Beta	-.26			
14. Heptachlor	-.16			
15. Aldrin	-.30	-.20		
16. Heptachlor Epoxide	-.25			
17. Chlordane	-.25			
18. o,p'DDE				
19. Dieldrin	-.23			
20. Endrin				
21. o,p'-DDT	-.21			
22. p,p'-DDD	-.19			
23. Arsenic	.27	.30		
24. Beryllium	.61	.55		-.45
25. Cadmium	.54	.53		-.38
26. Copper				
27. Chromium				.23
28. Nickel		.21		-.28
29. Lead	.21			-.24
30. Selenium	.33	.33		-.30
31. Zinc	.20			
32. TOC				
33. NH3-N (Ammonia)		.21	.22	
34. Organic-N				
35. NO3-N (Nitrate)				
36. NO2-N (Nitrite)	-.20			
37. PO4-Phosphate				
38. SO4-Sulfate				.50
39. Alkalinity				.54
40. Chloride				.43
41. Fluoride		.39		-.25
42. Cyanide	.39			-.23
43. LAS				
44. Dissolved Solids	-.25	-.23		
45. Water Temperature	-.31	-.28		
46. PH				

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

TABLE 6 : GROUND WATER CORRELATION MATRIX[1]

	45	46
1. Vinyl Chloride		
2. Methylene Chloride		
3. Chloroform		
4. 1,1,1-Trichloroethane		
5. Carbon Tetrachloride		
6. 1,1,2-Trichloroethylene		
7. Dibromochloromethane		
8. 1,2-Dibromoethane		
9. 1,1,2,2-Tetrachloroethylene		
10. Bromoform		
11. BHC-Alpha	.16	
12. Lindane	.28	
13. BHC-Beta	.21	
14. Heptachlor	.19	
15. Aldrin	.23	
16. Heptachlor Epoxide	.14	
17. Chlordane		
18. o,p-DDE	.22	
19. Dieldrin	.14	
20. Endrin		
21. o,p'-DDT	.17	
22. p,p'-DDD	.14	
23. Arsenic		
24. Beryllium		
25. Cadmium		
26. Copper		-.23
27. Chromium	-.14	
28. Nickel		-.17
29. Lead		
30. Selenium		
31. Zinc		-.14
32. TOC		
33. NH3-N (Ammonia)		
34. Organic-N		
35. NO3-N (Nitrate)		
36. NO2-N (Nitrite)		
37. PO4-Phosphate		
38. SO4-Sulfate		
39. Alkalinity		.39
40. Chloride		
41. Fluoride	-.31	
42. Cyanide	-.28	
43. LAS		
44. Dissolved Solids		
45. Water Temperature		
46. PH		

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[1] Only those correlation coefficients significant at the 0.001 level are included in this Table. Correlation coefficients calculated using Spearman's Rank Correlation procedure.

coefficients of 0.89 with cadmium and 0.65 with selenium. Cadmium has a correlation coefficient of 0.61 with selenium in addition to 0.89 with beryllium. Copper has a correlation coefficient of 0.59 with lead. The very high correlation coefficient between beryllium, cadmium, and selenium are influenced by the analytic techniques used to quantify these substances in the ground water samples. As was found in the surface water data, the overwhelming majority of sample concentrations for all three metals were reported at either the minimum reportable concentration of less than 1.0 ppb for beryllium and cadmium and less than 2.0 ppb for selenium. A small number of samples can have a very great impact on the correlation coefficient if those samples contain some of the small number of high concentrations for these three metals. In the ground water data that appears to have happened.

Many of the highest correlation coefficients are between the heavy chlorinated hydrocarbons. This finding is not surprising. Most of these substances are used as pesticides and are extremely persistent in the environment. Some of them are breakdown products of others within the category. Some are likely to have been used in the same areas either concomittantly or sequentially. Contamination of products with chemically similar substances has also been found to be common with pesticides. These potential explanations have been discussed in greater detail (Page and Greenberg, 1978).

The correlation matrix from the 692 samples of ground water data is similar to the correlation matrix of the first 408 samples (Page and Greenberg, 1978). This is to be expected since these 408 sample results are included in the 692 samples analysed in this report. While the correlation coefficients are nearly the same for most substances, some of the heavy metals have much higher correlation coefficients in the 692 sample results. For example, in the first 408 samples the correlation coefficient of beryllium with cadmium was 0.40, whereas in the total 692 samples of ground water the correlation coefficient is 0.89. In the first 408 samples the correlation of beryllium with selenium was very low and not significant at the 0.10 level, while in the total 692 samples the correlation coefficient is 0.65 and is significant at the 0.0001 level.

The cause of the large increase in the correlation coefficients between beryllium, cadmium, and selenium is caused by the lack of variation in the concentrations of these three substances in the ground water samples collected after the first 408 sample results. Every ground water sample analysed since the first 408 has been reported as containing less than 1.0 ppb of beryllium. After the first 408 samples, 246 of the 251 detectable concentrations of cadmium have been reported at less than 1.0 ppb. After the first 408 samples, 245 of the 251 detectable concentrations of selenium have been reported as less than 2.0 ppb. These large numbers of samples all containing the minimum reportable concentrations of beryllium, cadmium, and selenium has caused the correlation coefficients between these substances to increase substantially. In short, the correlations of these three substances are high because of consistency not because of parallel patterns.

The patterns of correlations found in the correlation matrix of 692 ground water samples (Table 6) are very similar to the patterns of correlations found in the correlation matrix of 320 surface water samples (Table 2). This is not surprising. Ground water and surface water are both interconnected components of the hydrologic cycle. Many of the same chemical and physical processes occur in both surface and ground water.

The greatest difference between the correlation matrices of ground and surface water samples is in the standard water quality parameters. The same parameters are intercorrelated, but the correlation coefficients in the ground water data are generally smaller than those between the same substances in the surface water data. The highest correlation coefficient among the standard water quality parameters in the ground water data involves dissolved solids with alkalinity, 0.54. The surface water data the correlation coefficient for the same substances is 0.63 and is exceeded by 0.65 between alkalinity and chloride.

In general, all of the correlations among the standard water quality parameters are higher in the surface water data than in the ground water samples.

Several chemical substances included in the ground water data are not included in the correlation matrix. Those substances which had fewer detectable concentrations than ten percent of the total ground water samples collected (69) were deleted from the correlation calculations to decrease the possibility of purely chance occurrences unduly influencing the statistical analyses. This is the same criteria used to delete substances from the surface water data. The following substances were deleted: fluoROform, methyl chloride, methyl bromide, 1,2-dichloroethane, dichlorobromomethane, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, diiodomethane, total dichlorobenzene, p-dichlorobenzene, o-dichlorobenzene, m-dichlorobenzene, trichlorobenzene, arochlor 1016, arochlor 1242, arochlor 1248, arochlor 1254, dichloroethylene (gem), dibromomethane, t-dichloroethylene, bromodichloromethane, p,p^1-DDT, mirex, methyoxychlor, toxaphene, and fecal coliform. With these 26 variables deleted, the ground water data set is left with 46 variables.

Summary of Ground Water Correlation Analysis

The bivariate correlations of the chemical substances in the ground water data set were calculated using Spearman's Rank Correlation procedure. The resulting correlation matrix (Table 6) was found to closely resemble the correlation matrix of chemical substances calculated for the first 408 ground water samples (Page and Greenberg, 1978). The greatest difference in these two correlation matrices was identified to be in the heavy metals and the cause was investigated. The similarity with the surface water bivariate correlation matrix (Table) was also noted and the minor difference examined.

Factor Analysis of Ground Water Data

Factor analysis was performed on the ground water data set of 692 samples in an attempt to identify chemical clusters of contamination. The same 46 chemical substances and water quality measurements analysed by correlation analysis were included as the variables in the factor analysis. These substances were selected on the basis of having at least 10 percent of the total number of samples in the data set detectable.

The factor analysis was performed conservatively. The correlation matrix produced by Spearman's Rank Correlation, a non-parametric statistical procedure was used in the factor analysis. This tends to underestimate the degree of correlation between variables but eliminates bias in the analysis due to the distinctly non-normal distributions of the toxic chemicals. The square of the multiple correlation coefficients (R^2) of each variable with every other variable were used to estimate the communalities. The use of R^2 to estimate the communalities prevents factor analysis from attributing to the chemical substances in the analysis the power to explain all the variation in the data. Since many unsampled variables may contribute to the variation in the data, this is a realistic step. An eigenvalue cutoff of unity was used to identify only the most important patterns of contamination within the ground water data set.

Problems are caused by missing data values in the ground water data set. Missing data causes extra or imaginary variance to be present in the results of factor analysis. This problem is present in interpreting the factor analysis results of the 408 ground water samples (Page and Greenberg, 1978) and the 320 surface water samples. The factors are computed to explain more variation in the data than actually exists because of the missing data values.

Some of the most common methods of dealing with missing data were not used in this analysis. The most common practice in statistically analysing a set of data with missing data is to eliminate those observations which do not have all data elements. In the ground water data set this approach was not used because only 3 samples have data for each variable! Another common approach is to use the mean or other measure of central tendency of a variable in the data set to fill in missing data for that variable. Because of the extremely skewed distributions of toxic substances in water the mean was out of the question. The use of the mode to replace missing values was evaluated in the analysis of the first 408 ground water samples (Page and Greenberg, 1978). It was found to produce results comparable to those produced by forcing the correlation matrix into the factor analysis as if there were no missing data. This last approach was used in this analysis.

Results of Ground Water Factor Analysis

Factor analysis of the ground water data extracted six independent patterns of contamination. This is comparable to the factor analysis of the first 408 ground water samples, which identified 5 factors using an eigenvalue cutoff of unity, but is in great contrast to the 18 factors calculated for the surface water data. Although there were insufficient chemical substances identified with most of the surface water factors to enable clear interpretation of the factors, the results of the factor analysis indicate that toxic substances in the surface waters of New Jersey are present in a much larger number of combinations or patterns of contamination than in the ground waters. (See Table 7).

Factor 1 is a pesticide factor. All twelve of the heavy chlorinated hydrocarbons in the ground water data

TABLE 7: FACTOR ANALYSIS OF 692 NEW JERSEY GROUND WATER SAMPLES

Variable	F1	F2	F3	F4	F5	F6	Communalities h^2
Vinyl chloride							.02
Methylene chloride							.22
Chloroform		.59					.45
1,1,1-trichloroethane							.21
Carbon tetrachloride							.16
1,1,2-trichloroethylene			.67				.65
Dibromochloroethane							.12
1,2-dibromoethane							.05
1,1,2,2-tetrachloroethylene		.41	.49				.46
Bromoform		.44					.23
BHC-Alpha	.47						.26
Lindane	.57						.46
BHC-Beta						-.48	.47
Heptachlor	.50						.28
Aldrin	.65						.48
Heptachlor epoxide	.59						.37
Chlordane	.59						.41
o,p^1-DDE	.68						.47
Dieldrin	.68						.48
Endrin	.74						.57
o,p^1-DDT	.72						.54
p,p^1-DDD	.72						.56
Arsenic		.50					.34
Beryllium		.93					.99
Cadmium		.85					.83
Copper					.75		.57
Chromium							.19
Nickel						.41	.26
[illegible]					.68		.53
[illegible]		.67					.49
[illegible]					.49		.25

TABLE 7: FACTOR ANALYSIS OF 692 NEW JERSEY GROUND WATER SAMPLES (Continued)

Variable	F1	F2	F3	F4	F5	F6	Communalities h^2
TOC							.02
NH3-N (Ammonia)				.56			.38
Organic Nitrogen				.57			.36
NO3-N (Nitrate)				-.51			.34
NO2-N (Nitrite)							.27
PO4 (Phosphate							.09
SO4 (Sulfate)			.51				.36
Alkalinity			.49				.35
Chloride			.40				.19
Fluoride						.45	.53
Cyanide						.52	.47
LAS (Detergent)							.17
Dissolved Solids			.76			-.41	.85
Water Temperature							.13
PH							.11
Eigenvalues	6.00	3.81	2.98	1.55	1.53	1.11	
Percent Variation	35.4	22.4	17.6	9.1	9.0	6.5	

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[1] Varimax rotation. The squared multiple correlation coefficients were used as communality estimates, and only eigenvalues greater than 1.0 were extracted. N = 692.

[2] Only factor loadings greater than 0.40 are presented.

set which are commonly used as pesticides are significantly associated with Factor 1. Factor 1 explains the greatest percentage of variation, 35.4 percent, in the ground water data.

The pesticide factor explains the greatest percentage of variation in the factor analysis of both the first 408 ground water samples and the full 692 ground water samples. In the first 408 ground water samples the pesticides were even more important in explaining variation (Page and Greenberg, 1978), with Factor 1 explaining 48.7 percent of the variation in the data as compared to 35.4 percent in the factor analysis of all 692 ground water samples.

A second difference between the 408 and 692 sample analyses was that the first 408 sample results yielded two pesticide factors in the varimax rotated solution. Factor 1 was a DDT-related pesticide factor and Factor 4 was a BHC-related pesticide factor. Factor 4 in the factor analysis of the first 408 samples explained 9.9 percent of the variation. In the factor analysis of all 692 ground water samples all the pesticides are associated with Factor 1.

Factor 2 is a heavy metals factor, although several light chlorinated hydrocarbons are also associated with this factor. Factor 2 is dominated by beryllium, cadmium, and selenium with factor loadings of 0.93, 0.85, and 0.67, respectively. These are extremely high factor loadings given our conservative approach. The explanation for these high values has been discussed in the section on correlation analysis where the high correlations among these three substances were explained in terms of the large number of samples which were reported at the minimum reportable concentration.

Several other substances are associated with Factor 2, although not as strongly as beryllium, cadmium, and selenium. Arsenic, which is categorized as a metal although it and selenium are in fact non-metals, has a factor loading of 0.50. Three light chlorinated hydrocarbons are also associated with factor 2. Chloroform, 1,1,2,2-tetrachloroethylene, and bromoform have factor loadings of 0.59, 0.41, and 0.44. Factor 2 explains 22.4 percent of the variation in the data from the 692 samples of ground water.

There are several significant differences in Factor 2 in the factor analyses of the first 408 and the full 692 ground water samples. One of the differences is due to the finding of beryllium, cadmium, and selenium at the minimum reportable concentration in almost all ground water samples collected after the first 408 samples. Beryllium and cadmium were associated with the heavy metals factor in the analysis of the first 408 samples, but with much lower factor loadings. Selenium was not strongly associated with any of the factors in the analysis of the first 408 ground water samples.

The second major difference in Factor 2 between the factor analyses of the first 408 and the full 692 ground water samples concerns the light chlorinated hydrocarbons. In the analysis of the first 408 samples, Factor 2 was a light chlorinated hydrocarbon factor and Factor 3 was a heavy metals factor. Much of this difference is probably due to chemical analysis procedures rather than to different patterns of contamination being identified in the ground water samples collected after the first 408. Chloroform, and 1,1,2,2-tetrachloroethylene are associated with Factor 2 in both analyses. The discussion, under the heading data weaknesses, of bromodichloromethane with 1,1,2-trichloroethylene and 1,2-dibromoethane with 1,1,2,2-tetrachloroethylene explains why considerable information was lost to the data set. This lost information is probably a large cause of the differences in light chlorinated hydrocarbons in the two factor analyses.

Factor 3 is a *standard water quality parameters* factor. Factor 3 is dominated by dissolved solids with sulfate, alkalinity, and chloride also identifying this pattern of contamination. Ground water samples exhibiting this pattern of contamination also have relatively high concentrations of 1,1,2-trichloroethylene and 1,1,2,2-tetrachloroethylene, although missing data values for both of these light chlorinated hydrocarbons may inflate their contribution. Factor 3 explains 17.6 percent of the variation in the data from the 692 samples of ground water.

The standard water quality parameters form more factors, with a greater number of variables associated with them, and explain a greater percentage of the variation in the full 692 ground water samples than in the first 408 samples data. Factor 3 in the 692 sample analysis explains the same percentage of the total variation, 17.6, as the two standard water quality parameter factors identified in the analysis of the data from the first 408 samples.

Factor 4 is a *nitrogen* factor. It explains 9.1 percent of the total variation in the data set. Organic nitrogen and ammonia have factor loadings of 0.57 and 0.56. Nitrite nitrogen (NO_2-N) is just below the level reported with a factor loading of 0.39. Nitrate-nitrogen (NO_3-N) has a factor loading of -0.51 which indicates it is found in low concentrations or not at all in those samples in which the other forms of nitrogen are found in high concentrations. This is an interesting pattern of contamination. The negative correlation coefficients were also found in the analysis of the data from the first 408 ground water samples. This is a finding the author has not seen reported in the literature perhaps because in routine analysis of ground water samples nitrate nitrogen is usually the only form of nitrogen that is looked for (Hem, 1970). The nitrate form of nitrogen, because of its oxidized form, is most easily leached into ground water.

Where the soil is polluted with large amounts of nitrogen it is likely that both nitrate and nitrite nitrogen would reach the ground water.

Factor 5 is a second heavy metals factor. It explains 9.0 percent of the total variation in the data set and is dominated by copper, lead, and zinc with factor loadings of 0.75, 0.68, and 0.49. Factor 5 resembles Factor 3 from the 408 sample analysis. In an analysis of landfills in the Los Angeles area, copper and zinc along with chromium were found to be the greatest threats to ground and surface water (Eichenberger, et al., 1978).

Factor 6 is interesting but hard to interpret. It explains only 6.5 percent of the total variation in the data set, and while 5 variables are associated with it, none have high factor loadings. Factor 6 has variables from 3 of the 4 general categories of substances in the data set. The pattern of contamination identified by Factor 6 is established by those ground water samples in which concentrations of cyanide, fluoride, and nickel are relatively high when concentrations of β BHC~~-Beta~~ and dissolved solids are relatively low and probably non-detectable. Other substances in the data set contribute to this pattern of contamination to a lesser extent, but in terms of the whole data set this is a minor pattern of contamination.

Summary of Ground Water Factor Analysis

Factor analysis was performed on 46 chemical substances and water quality measurements collected for 692 ground water samples. The 46 chemical substances and water quality measurements were selected because they had detectable concentrations in at least ten percent of the samples in the data set.

The factor analysis was performed using conservative procedures. Spearman's Rank Correlation, a non-parametric procedure produced the correlation matrix. The square of the multiple correlation coefficient for each variable with every other variable was used to estimate the communalities. An eigenvalue cutoff of unity was used to determine the number of factors to be interpreted.

The factor analysis of the ground water data set identified 6 factors. Factor 1 is a pesticide factor which explains 35.3 percent of the total variation in the ground water data. Factor 2 is a heavy metals factor which explains 22.4 percent of the variation in the data. Factor 3 is a standard water quality parameters factor which explains 17.6 percent of the variation in the data. Factor 4 is a nitrogen factor which explains 9.1 percent of the variation in the data. Factor 5 is a second heavy metals factor which explains 9.0 percent of the variation in the data. Factor 6 is a cyanide-βBHC-~~beta~~-fluoride factor which is difficult to interpret and explains only

6.5 percent of the variation in the ground water data set.

Comparisons were made between the results of the factor analysis of all 692 ground water samples and the results of an earlier factor analysis of the first 408 ground water samples. The patterns of ground water contamination in the two analyses were found to be very similar. The greatest differences were found to be the decreased importance of the pesticide factor and the increased importance of the standard water quality parameter and the nitrogen factor in the analysis of all 692 samples from the earlier analysis. Problems of missing data and especially changes in the light chlorinated hydrocarbons included in the chemical analyses of the samples make comparisons of the light chlorinated hydrocarbons between the factor analysis results impossible.

Associations of Ground Water Sample Site Characteristics With Patterns of Contamination

An attempt was made to associate the characteristics of the ground water sample sites with the patterns of contamination identified by factor analysis. This analysis repeats for the ground water data the analysis performed on the surface water data. Factor scores were used to select those samples most strongly associated with the patterns of contamination identified by the factor analysis of the ground water data. The characteristics of the wells from which the samples were collected and the areas around those wells were then examined in an attempt to discover any common characteristics among those samples most strongly associated with the different patterns of contamination.

Like the surface water data, missing information in the ground water data set is a very serious problem. Missing concentrations for chemical substances tend to cause bias in the factor scores which were used to select those ground water samples most strongly associated with the patterns of contamination. Missing characteristics of the wells from which the ground water samples were collected and the areas surrounding the wells make identification of any associations among those characteristics extremely difficult.

Factor 1

The characteristics of the ground water samples most strongly associated with Factor 1, the pesticide factor, are presented in Table 8 . The 24 ground water samples most strongly associated with the pesticide factor were collected in 10 different counties in all parts of New Jersey. Monmouth and Salem counties with 6 samples each are the counties most strongly associated with the ground water pesticide factor. The land uses of the areas immediately surrounding the ground water sample sites are somewhat surprising. Only 3 of the samples had surrounding land uses characterized as farms while 2 were com-

TABLE 8: ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER

Factor 1 - Pesticide Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
CAM 12JY	Camden	Camden	179	Car Lot	Potable	Industrial
CAM 12	Camden	Camden		21st St.	Potable	Industrial
CU 3	Cumberland		154		Potable	Sub. resid.[1]
CU 5	Cumberland	Lusberg	284	Near Delaware R.	Potable	
CU 6	Cumberland	Upper Dearfield Twp			Potable	
HUD 1A	Hudson		307			Sub. resid.
MER 19	Mercer	Hamilton	40	Near building	Cooling	Industrial
MON 1	Monmouth	Atl. Highlands	660		Potable	Industrial
MON 3	Monmouth	Atl. Highlands	280		Potable	Urb. Comm.[1]
MON 2	Monmouth	Atl. Highlands	600		Potable	Urb. Comm.
MON 5	Monmouth	Hondel	104		Potable	
MON 6	Monmouth	Eatontown	150		Cooling	Industrial
MON 13	Monmouth	Keesport	361		Potable	Industrial
MOR 105	Morris		83		Potable	
PAS 2	Passaic	Clifton	389		Process	Industrial
RH 20	Hunterdon	Oldwick			Potable	Sub. resid.
RH 5	Morris	Mendham	225		Potable	Sub. resid.
RH 6	Morris	Mendham			Potable	
SA 3	Salem	Auburn	205	Behind fire house	Potable	Farm
SA 4B	Salem		154	Near Cabins	Potable	
SA 5	Salem	Pennsgrove	54		Potable	Farm
SA 6	Salem	Woodstown	713		Potable	Farm
SA 10	Salem	Oldmans	124		Process	Industrial
SA 13A	Salem	Upper Penns	122	At Plant	Cooling	Industrial

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[1] Abbreviations used in the Table: Sub. resid. = Suburban residential; Urb. comm. = Urban commercial.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 2 - Urban-Industrial Heavy Metals Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
BER 13	Bergen	Hackensack				Urb. Comm.[1]
CAM 12JE	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 12SP	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 12	Camden	Camden	179	(21st St.)	Potable	Industrial
CAM 12AU	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 113	Camden	Pennsauken	220	Grassy field	Potable	Sub. resid.[1]
CU 11	Cumberland	Vineland	35	(Mill Rd.)	Potable	Industrial
CU 12	Cumberland		17	(Rt. 47)	Potable	Industrial
CU 6	Cumberland	Upper Dearfield			Potable	
ESS 18	Essex	Newark	350	Fairmont Chemical	Process	Industrial
NEESS 16	Essex	Millburne	462		Potable	
MER 19	Mercer	Hamilton	40	Near building	Cooling	Industrial
MON 22	Monmouth	Freehold	13		Monitoring	Industrial
MOR 105	Morris		83	Forest	Potable	Sub. resid.
RH 18	Hunterdon	Lebanon	260		Potable	Urb. resid.
RH 20	Hunterdon	Oldwick			Potable	Sub. resid.
RS 11	Somerset	Montgomery			Potable	
RS 13AU	Somerset	Rocky Hill			Potable	Commercial
RS 13OB	Somerset	Rocky Hill			Potable	Commercial
SA 21	Salem	Oldmans	17		Monitoring	Industrial
SA 21B	Salem	Upper Penns Neck	17		Monitoring	Industrial
UN 12	Union	Elizabeth	25		Monitoring	Industrial
W 7	Warren		495	Panther Valley	Potable	Sub. resid.
W 12A	Warren	Phillipsburg			Monitoring	Industrial
W 19	Warren	Oxford			Potable	Industrial

[1] Abbreviations used in the Table: Sub. resid. = Suburban residential; Urb. comm. = Urban commercial.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 3 - Standard Water Quality Parameters

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
BER 5	Bergen	Park Ridge	42	(Sulak Ave.)	Potable	
BER 6	Bergen	Rochelle Park			Potable	Sub. resid.[1]
BER 11	Bergen	Teeterboro	425			Industrial
BER 13	Bergen	Hackensack			Potable	Urb. comm.[1]
CAM 12AU	Camden	Camden			Potable	
CU 21	Cumberland		295	Near sludge beds	Potable	Urb. resid.[1]
HUD 1A	Hudson		307			Sub. resid.
HUD 1B	Hudson		165	(Raydol Ave.)	Cooling	Industrial
HUD 2	Hudson		300	Inside building	Cooling	Industrial
MON 37	Monmouth		472		Potable	Open Space
MOR 2	Morris	Morristown	85		Potable	Industrial
MOR 15	Morris		332	(Rt. 46)	Potable	Urb. comm.
NEESS 3	Essex	South Orange	685		Process	Industrial
NEESS 8	Essex	Belleville	300	Inside building	Cooling	Industrial
NEESS 9	Essex					
ESS 18	Essex	Newark	350	Fairmont Chemical	Cooling	Industrial
PAS 7	Passaic		300		Other	Urb. comm.
RH 14	Hunterdon		144			
RH 17	Hunterdon	Raritan Twp.	122	Past Med. Center (Rt.31)	Potable	Industrial
RH 18	Hunterdon		150	(Rt. 31)	Potable	
RS 10	Somerset		80		Potable	Farm
RS 11	Somerset	Montgomery			Potable	
RS 12	Somerset	Montgomery			Potable	Open Space
RS 13AU	Somerset	Rocky Hill	200	Commercial	Potable	Commercial
RS 13OB	Somerset	Rocky Hill	200	Small Field	Potable	Sub. comm.[1]

[1] Abbreviations used in the Table: Sub. resid. = Suburban residential; Urb. comm. = Urban commercial; Urb. resid. = Urban residential; Sub. comm. = Suburban commercial.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 3 - Standard Water Quality Parameters

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
SA 6	Salem	Woodstown	710		Potable	Urb. resid.[1]
SA 31	Salem	Peensville	39		Potable	Urb. resid.
UN 7	Union		400	Yard at Main Gate	Potable	Urb. comm.[1]
UN 9	Union	Hillside			Cooling	Industrial
W 3	Warren	Brainards	180		Potable	Farm
W 4	Warren	Phillipsburg	86		Potable	Industrial
W 6	Warren	Washington	345		Potable	Urb. resid.
W 7	Warren		495	Panther Valley	Potable	Sub. resid.[1]
W 8	Warren	Stewartsville	250		Potable	Farm
W 12A	Warren	Phillipsburg			Monitoring	Industrial
W 16	Warren	Hackettstown	100	Sludge field	Monitoring	Industrial
W 18	Warren	Washington	285		Potable	Industrial

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[1] Abbreviations used in the Table: Sub. resid. = Suburban residential; Urb. comm. = Urban commercial; Urb. resid. = Urban residential.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 4 - Nitrogen Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
BER 13	Bergen	Hackensack			Potable	Urb. comm.[1]
BER 51	Bergen		47	Grassy Area	Potable	
CAM 12JE	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 12SP	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 13	Camden	Camden	230		Potable	Sub. resid.[1]
CU 9	Cumberland	Millville	150		Potable	Industrial
CU 12	Cumberland	Maurice R. Twn	17	(Rt. 47)	Monitoring	Industrial
NEESS 3	Essex		685	(Grove St.)	Cooling	Industrial
MER 12JY	Mercer	Trenton	110		Potable	
MID 11	Middlesex		600		Potable	Industrial
MON 20	Monmouth	Freehold	702		Potable	Industrial
MON 24	Monmouth	Freehold		Campsite	Potable	Farm
MON 37	Monmouth	Homestead	472	Next to Swimming pool	Potable	Open Space
MON 39	Monmouth	Fort Monmouth	97		Other	
MON 59	Monmouth	Holmdel	104		Potable	Industrial
MOR 2	Morris	Morristown	85		Potable	Industrial
MOR 14	Morris	Dover	70	Grassy Area	Potable	
RH 14	Hunterdon		144			
RH 19	Hunterdon					
RH 12	Somerset	Montgomery			Potable	Open Space
RS 11	Somerset	Montgomery			Potable	
RS 8	Somerset	Manville	195	Grassy and Trees	Potable	Sub. resid.
RS 13JE	Somerset	Rocky Hill	200	Small Field	Potable	Sub. comm.[1]
RS 13JY	Somerset	Rocky Hill	200	Small Field	Potable	Sub. comm.
RS 13AU	Somerset	Rocky Hill	200	Commercial	Potable	Sub. comm.

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[1] Abbreviations used in the Table: Urb. comm. = Urban commercial; Sub. resid. = Suburban residential; Sub. comm. = Suburban commercial.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 4 - Nitrogen Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
RS 13SP	Somerset	Rocky Hill	200	Small Field	Potable	Sub. comm.[1]
RS 13OB	Somerset	Rocky Hill	200	Small Field	Potable	Sub. comm.
SA 2	Salem	Elmer			Potable	Farm
SA 13B	Salem	Upper Penns Neck	356	Near Plant	Potable	Industrial
SA 16	Salem	Elmer	65		Potable	Farm
SA 20	Salem	Quinton	105		Potable	
SA 21	Salem	Oldmans			Monitoring	Industrial
SA 30A	Salem	Elmer			Potable	
SUS 11JY	Sussex				Potable	Sub. comm.
SUS 11CB	Sussex				Potable	Sub. comm.
SUS 21	Sussex		200	Park Vegeration	Potable	Sub. resid.[1]

[1] Abbreviations used in the Table: Sub. comm. = Suburban commercial; Sub. resid. = Suburban residential.

TABLE 8: ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 5 - Suburban and Rural Heavy Metals (Lead, Zinc, Copper)

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
ATL 4	Atlantic	Buens	180		Potable	Open Space
ATL 8	Atlantic		507		Potable	Sub. resid.[1]
ATL 9	Atlantic		95		Potable	Sub. resid.
CU 6	Cumberland	Upper Dearfield	186		Cooling	Industrial
CU 17	Cumberland		102		Potable	
MER 2	Mercer	Trenton	85			Industrial
MER 14	Mercer				Potable	Open Space
MER 101	Mercer	Lawrenceville	85		Potable	Urb. comm.[1]
MON 16	Monmouth	Middletownship	126	Parking Lot, Oil Storage	Process	Industrial
MON 27	Monmouth	Colts Neck			Potable	Open Space
MON 54	Monmouth		35		Monitoring	Industrial
MOR 2	Morris	Morristown Twp.	85		Potable	Industrial
MOR 4	Morris	Hanover Twp.	400			Industrial
MOR 14	Morris	Dover	70	Grassy Lawn	Potable	
RH 6	Hunterdon			Observatory	Potable	
RH 14	Hunterdon		144			
RH 16	Hunterdon				Potable	Urb. comm.
RH 17	Hunterdon	Raritan Twp.	122		Potable	Industrial
RH 19	Hunterdon				Potable	Sub. resid.
RS 10	Somerset	Flagtown	160		Potable	Sub. resid.
SA 3	Salem		205		Potable	Farm
SA 5	Salem	Pennsgrove	54		Potable	Farm
SA 10	Salem	Oldmans	124		Process	Industrial
SA 16	Salem	Elmer	65		Potable	Farm
SA 20	Salem	Quinton	105		Potable	

[1] Abbreviations used in the Table: Sub. resid. = Suburban residential; Urb. comm. = Urban commercial.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 5 - Suburban and Rural Heavy Metals (Lead, Zinc, Copper)

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
SA 21A	Salem	Oldmans	19		Potable	
SA 30	Salem	Elmer			Potable	
W 2	Warren	Blairstown	200	Blair Academy	Potable	Urb. comm.[1]
W 7	Warren		495	Panther Valley	Potable	Sub. resid.[1]

[1] Abbreviations used in the Table: Sub resid. = Suburban residential; Urb. comm. = Urban commercial.

TABLE 8: ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER

Factor 6 - Urban-Industrial Cyanide, β BHC-~~Beta~~, Fluoride Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
BER 11	Bergen	Teeterboro	425			Industrial
BER 13	Bergen	Hackensack			Potable	Urb. comm.[1]
BER 114	Bergen	Fairlawn	75		Potable	Sub. resid.[1]
CAM 12	Camden	Camden			Potable	Industrial
CAM 12JE	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 12JY	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 12SP	Camden	Camden	179	Metals Plant	Potable	Industrial
CAM 113	Camden	Pennsauken	220	Grassy Field	Potable	Sub. resid.
CAM 104	Camden		116	Outside School	Potable	Urb. resid.[1]
CAP 12	Cape May		262		Potable	Sub. resid.
CU 6	Cumberland				Potable	
ESS 18	Essex	Newark	350	Fairmont Chemical	Cooling	Industrial
NESS 16	Essex	Millburne	462		Potable	
MER 19	Mercer	Hamilton	40		Cooling	Industrial
MID 17	Middlesex	Westfield	523		Potable	Industrial
MON 14	Monmouth	Union Beach	290		Potable	Industrial
MON 20	Monmouth	Freehold	702		Potable	
MON 22	Monmouth	Freehold	13		Monitoring	Industrial
OCE 8B	Ocean		177		Potable	Sub. resid.
RH 18	Hunterdon	Lebanon	2601		Potable	Urb. resid.
RH 19	Hunterdon				Potable	Industrial
RS 13JE	Somerset	Rocky Hill	200	Commercial	Potable	Sub. comm.[1]
RS 13RU	Somerset	Rocky Hill	200	Commercial	Potable	Sub. comm.
RS 13OB	Somerset	Rocky Hill	200	Commercial	Potable	Sub. comm.
SA 1	Salem	Salem City	160		Potable	Sub. resid.

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[1] Abbreviations used in the Table: Urb. comm. = Urban commercial; Sub. resid. = Suburban residential; Urb. resid. = Urban residential; Sub. comm. = Suburban comm.

TABLE 8 : ASSOCIATIONS OF SAMPLE SITE CHARACTERISTICS WITH PATTERNS OF CONTAMINATION IN GROUND WATER (Continued)

Factor 6 - Urban-Industrial Cyanide, BHC-Beta, Fluoride Factor

Sample ID	County	Municipality	Depth In Feet	Comments	Use of Water	Land Use
SA 3	Salem	Oldmans	205		Potable	Farm
SA 5	Salem	Pennsgrove	54		Potable	Farm
SA 21B	Salem	Oldmans	17		Monitoring	Industrial
SA 21	Salem	Oldmans	40		Monitoring	Industrial
SA 15	Salem	Oldmans	19		Monitoring	Industrial
UN 103	Union	Rahway	200		Potable	Urb. resid.[1]

[1] Abbreviations used in the Table: Urb. resid. = Urban residential.

mercial, 4 suburban residential, 8 industrial, and 5 missing data. The water is used overwhelmingly as potable water. The wells ranged in depth from 54 to 713 feet deep.

Factor 2

The characteristics of the ground water samples most strongly associated with Factor 2, the heavy metals factor, are presented in Table 8 . The 25 ground water samples most strongly associated with the heavy metals factor were collected in 12 counties in all parts of New Jersey. The distinctive characteristics of the wells are established by two sets of wells: 5 wells which are shallow monitoring wells probably monitoring landfill leachate, and 4 wells identified by comments as metals or chemical plants. The 9 ground water samples from these wells are most strongly associated with the heavy metals factor.

Three of the wells had more than one sample associated with Factor 2. Cam 12, a well used by a metals plant in Camden City was identified as having high concentrations of heavy metals during the first year's data collection. The well was selected for monthly sampling during the second year of data collection. Three of the five monthly samples from the second year of data collection included in the ground water data set are among the 30 samples most strongly associated with Factor 2. Two of the five monthly samples from RS13 are among the 30 samples most strongly associated with Factor 2. Samples Sa21 and Sa 21B are from the same well. Overall, Factor 2 is an urban-industrial, heavy metals factor.

Factor 3

The characteristics of the ground water samples most strongly associated with Factor 3, the standard water quality parameters factor, are presented in Table 8 . The wells from which samples were most strongly associated with the standard water quality factor show great diversity and no distinctive patterns. The wells are located in 13 counties throughout the state. The wells range in depth from 42 to 710 feet. The land uses surrounding the wells include almost every land use, although the more heavily developed land uses do predominate.

Factor 4

The charateristics of the ground water samples most strongly associated with Factor 4, the nitrogen factor, are presented in Table 8 . The samples were collected in 12 different counties throughout the state, but seem to have a greater proportion of the newer suburban counties than of the inner cities or older suburban counties. The land use data support the suburban interpretation but also indicate that many of the samples were collected in industrial areas. The depths of the wells ranged from 17 to 685 feet, and most are used as sources of potable supply. The comments mention grassy, fields or parks. One point of interest is that all five monthly samples from well RS13 were among those most strongly associated with the nitrogen factor.

Factor 5

The characteristics of the ground water samples most strongly associated with Factor 5, the second heavy metals factor, are presented in Table 8 . The second heavy metals factor is dominated by relatively high concentrations of lead, zinc and copper (see Table 7). The samples most strongly associated with this factor were collected in 9 counties in the southern and western portions of New Jersey. Salem County with 7 samples and Hunterdon County with 5 samples are the counties most strongly associated with Factor 5. This factor appears to be a combination of areas with naturally high concentrations of lead, zinc and copper in the soil and rock formations and also some industrial activity. The land use data indicate industrial activity in the vicinity of several wells in these predominantly rural or suburban counties.

Factor 6

The characteristics of the ground water samples most strongly associated with Factor 6, the cyanide, βBHC~~-Beta~~, fluoride factor, are presented in Table 8. Factor 6 identifies a distinct but relatively minor pattern of contamination in the ground water of New Jersey. The samples most strongly identified with Factor 6 were collected in 14 counties from all portions of the state. The municipality and land use data indicate that Factor 6 is strongly identified with industrial areas and often those industrial areas within urban areas. Both Cam 12 and RS13 have three monthly samples among those samples most strongly associated with Factor 6.

Summary of Associations of Ground Water Sample Site Characteristics with Patterns of Contamination

The characteristics of the wells and surrounding areas most strongly associated with the patterns of contamination identified by factor analysis are presented in Table 8 . The goal of the analysis was to discover if any of the descriptive characteristics or comments made by the sampling teams might provide research hypotheses concerning the causes of toxics pollution of the ground waters of New Jersey.

Missing data is so pervasive in the ground water data set that relatively little additional information could be gleened from the analysis of associations of sample site charateristics with patterns of contamination. This is the same finding that was reached in the analysis of toxics substances in the surface waters of New Jersey.

One of the most interesting findings of this analysis concerns the depth of the wells from which samples were collected that are most strongly associated with the patterns of contamination. For each of the 6 patterns of contamination the samples most strongly associated were found to come from wells of a great range of depths. There has been research results and speculation published (EPA, 1975) which indicates that at least for some toxics pollution of ground water would be expected in shallow aquifers if at all.

The other interesting finding was the two heavy metals factors--one concentrated in and around urban-industrial sites, the second in less developed places.

PART II.

COMPARISON OF TOXICS IN GROUND AND SURFACE WATER

CHAPTER 3

REVIEW OF THEORY AND PREVIOUS RESEARCH

Introduction to a Comparison of Toxics In the Ground and Surface Waters of New Jersey

In the United States we sometimes loose sight of the interconnectedness of the natural environment in attempting to control the release of waste products. Separate programs are developed to deal with solid waste disposal, air pollution or water pollution. Yet, all of these problems are intregally connected.

Everything that man releases into the biosphere can ultimately contaminate our water supplies. When toxic substances are find their way into our water supplies in sufficient quantities they should be removed before that water can be potable.

Study of the hydrologic cycle shows us that all forms of water in the natural environment move continously between the oceans, the rivers, lakes, and estuaries, through the soil and ground, and the atmosphere. Despite the interconnectedness of the hydrologic cycle the United States has overwhelmingly emphasized the protection and cleaning of surface waters. Since the passage of the 1972 amendments to the Federal Water Pollution Control Act (U.S. Congress, 1972), and despite the fact that at least half of the U.S. population depends on ground waters billions of federal, state, local, and corporate dollars have been spent to enhance the quality of the nation's surface waters. State and local governments have followed the federal government in assigning control of ground water contamination a low priority when compared the priority assigned to control of surface water contamination (Environmental Protection Agency, 1974).

The physical and chemical filtering of water percolating through soil and flowing through an aquifer are very effective at removing the bacteria which can cause serious water borne diseases. For this reason ground water has been the favored potable water supply in much of the world and is often distributed without any pretreatment or chlorination (Sontheimer, 1978). Because of the natural protection from chemical and biological contamination, anthropogenic sources of ground water contamination have been considered improbable (Miller _et al_., 1974; Vander Leeden _et al_., 1975).

Field research has found a variety of toxic substances in the nations water supply from both surface water and ground water sources. These substances are usually detected at low concentrations (see next section for a review of the data). The health effects of long term ingestion are presently unknown but are considered potentially serious (National Research Council, 1977).

Using the data on toxic substances in the ground water and surface water of New Jersey this report compares the levels of toxics in ground water and surface water supplies in New Jersey in order to determine their relative contamination.

Research on Toxics Pollution of Surface Water

Advances in gas or high pressure liquid chromatographs and mass spectometers have enabled researchers to quantify many toxic substances at the level of nanograms per litre (ng/l) = ppb). These technological advances have stimulated research into trace contaminants in water. Durum, Hem and Heidel (1971) found concentrations of heavy metals to be widespread in this nation's surface waters. Metals were found everywhere from urban centers to undeveloped backcountry. Shakelford and Keith (1976) reported that 1259 organic compounds have been identified in water. Most of these substances were found in surface water sources. It has been estimated that only about 10 percent of the organic chemicals actually present have been identified (EDF and Boyle, 1978).

Associations of Toxics in Surface Waters With Cancer

Much of the recent interest in research into trace levels of contaminants in water has been caused by inferred associations with cancer mortality. Several substances found in surface water sources are confirmed human carcinogens and many others are suspected carcinogens (Dostal, et al., 1965; Friloux, 1971; Hites and Biemann, 1972; Svec, et al., 1973; Harris, 1974; Moskowitz, 1977). The potential impacts of the synergistic and antogonistic effects of the myriad mixtures of chemicals commonly found in water is essentially unknown.

Several studies have found associations between the presence of Carcinogens ~~toxic substances~~ in surface water supplies and cancer mortality rates. Many of these studies have tested and found ground water sources are not ~~to be not~~ significantly associated with cancer mortality rates. Stocks (1947) in a study in London, England found areas served by ground water supplies to have lower cancer mortality rates than those areas served potable water from the Thames, Lea and New Rivers. Studies by Diehl and Tromp (1953) and Tromp (1955) report that municipalities receiving potable water from rivers in the Netherlands had higher cancer mortality rates than those receiving their water from ground water sources. Berg and Burbank (1972) found several significant correlations between river drainage basins with high concentrations of heavy metals and cancer mortality rates for specific body sites. Page, et al., (1976) investigated the impact of the use of Mississippi River water known to contain many toxic~~s~~ Chemicals as a potable water source. The authors estimated that a switch from Mississippi River water to presumably clean ground water sources would eventually reduce total cancer mortality rates in the area studied by approximately 18 percent. Kuzma, et al. (1977) used ground water as a presumably clean control for their study in Ohio. They also report significant correlations of surface water supplies known to be contaminated with toxics and cancer mortality rates for specific body sites. In his study of cancer mortality in New Jersey, Greenberg (1977) found cancer mortality rates for several body sites including those in the gastro-intestinal tract to be positively associated with the use of surface water supplies, but found no association with the use of ground water.

When other factors common to the urban industrial corridor were added, the importance of surface water was greatly reduced. These studies must be evaluated in light of water quality data limitations, the ecological fallacy, and the many methodological difficulties in adequately controlling for the many potentially confounding personal, local ambient environment, and occupational factors.

Trihalomethanes in Surface and Ground Waters

A great deal of research has been directed to finished potable water and especially to the presence of trihalomethanes which are produced during chlorination (Rook, 1974; Belar, et al., 1974; Dowty, et al., 1975). The presence of trihalomethanes in drinking water has been associated with several specific body site cancers (Cantor, et al., 1978). Finished water from ground water sources have been found to have lower quantities of low molecular weight halogenated hydrocarbons than those from surface water sources (Bellar, et al., 1974; Symons, et al., 1975). The generally low turbidity and low presence of organic material in ground water is cited as the explanation of low trihalomethane concentrations after chlorination (National Research Council, 1978).

The National Organics Reconnaissance Survey (NORS) of 80 cities in 1975 examined finished water from both surface and ground water sources. NORS found that total trihalomethane concentrations were greatest in surface water sources, but exceptions existed. For instance the highest concentration of chloroform detected, 311 ug/l, was found in Miami which has a ground water source (EPA, 1975). The report notes that the organics found in ground water from Miami were surprising in light of the traditional assumption of ground water being low in contaminants. The report speculates that the high concentrations of trihalomethanes in ground water may only be representative of areas with high ground water tables and shallow wells (EPA, 1975).

Research Indicating Ground Waters Are Not Polluted With Toxics

There has not been a great deal of research on the presence of toxic substances in ground water because geohydrologic theory predicts ground water will be less contaminated than surface water. Ground water contamination is not usually direct. In most cases the pollutant must pass through a layer of soil. Attenuation of contaminants flowing in the unsaturated zone is generally greater than below the water table because there is more potential for aerobic degradation, adsorption, complexing and ion exchange of organics, inorganics, and microbes. Even after a contaminant has reached the water table, many physical-chemical processes may operate to purify fluid wastes. These include: dilution, buffering of pH, precipitation by reaction of water with indigenous waters or solids, precipitation due to hydrolysis, removal due to oxidation or reduction, mechanical filtration, volatilization and loss as a gas, biological assimilation or degradation, radioactive decay, membrane filtration, and sorption (Runnells, 1977).

There is a body of research which indicates that these processes are effective at removing toxic substances before they reach ground water supplies. Terrierae et al. (1966) found that less than 0.1% of DDT applied to orchards reached ground water. Thompson et al. (1970) found less than 2% of dieldrin was leached through soil after one year of precipitation. Reese and Beck (1972) found that after 20 years forest soils in Mississippi retained 34 to 50% of the DDT originally found. Based on the organochlorine insecticides which have been most extensively studied many have concluded that leaching of pesticides from soils into ground water does not appear important (Lichtenstein, _et al_., 1962; Park and McClone, 1966; Sparr, _et al_., 1966; Hindin, May and Dunstan, 1966; Eye, 1968; Harris, 1969; Edwards, 1970; Edwards, _et al_., 1970; Eto, _et al_., 1967; Fuhriman and Barton, 1971; and Kaufman, 1974). Richard , _et al_. (1974) in a study in Iowa found that well systems adjacent to the alluvial plain of a river in which pesticides were found showed little or no biocide contamination.

In summary, both theory and previous research indicate that most toxics, especially synthetic organic toxics, are unlikely to be found in our ground water supplies. Toxics in water percolating through soil, and even after reaching ground water, are exposed to many mechanisms which are potentially effective at eliminating or reducing the concentrations of toxics in ground water. Previous research is briefly reviewed which indicates toxics are not found in ground water supplies.

Indications That Ground Waters May Be Polluted With Toxics

If the soil is polluted by toxic substances to such a degree that its adsorptive retention power is exceeded, the most diverse materials can be released to the water and can be detected in the ground water (Leithe, 1973). Unfortunately this has happened in a number of instances, many like that in N.J. (U.S. EPA, 1974). These instances of ground water contamination by toxic substances may have resulted from the inadvertant release of toxics from poorly sealed landfill sites or surface impoundments, leakage from petroleum storage and distribution facilities, improper application of agricultural chemicals, or spills caused by industrial or transportation accidents.

The potential for toxic substances contamination of the nation's ground water is substantial. It is estimated that 1.7 trillion gallons of contaminated fluids are being disposed of into the ground each year (Pojasek, 1977). The proportion of that staggering quantity containing toxic substances is unknown. Concentrating on industrial effluent which may be more likely to contain toxics, EPA used standard leakage coefficients and volumes of waste waters discharged to estimate that more than 100 billion gallons per year of industrial effluent enters the U.S. ground water system. (EPA, 1974) EPA estimates that 80 percent of the toxic waste in the nation is either placed in drums and stored, poured out in the woods or on roadways or dumped in inadequate landfills (N.Y. Times, 1979). EPA surveys indicate that over 9 percent of all hazardous industrial wastes are disposed of on the land (EPA, 1974).

The great emphasis on controlling surface water pollution, especially the impetus of zero discharge, and the mandated end of ocean dumping are greatly increasing the disposal of waste products including toxics on the land. It is now national policy that land treatment of waste water is the preferred method of treatment (Costle, 1977). These policies are apparently formed under the assumption that our ground water resources are protected from contamination by toxics.

Landfills

EPA estimates that 240 million tons of industrial wastes end up in land disposal sites each year because it is the cheapest waste management option (EPA, 1977). Eckhardt C. Beck, an EPA regional director, has estimated that 15 percent of the annual U.S. production of 34.5 million metric tons of industrial waste was hazardous (EPA, 1977). The situation in New Jersey is especially dangerous. The 15,000 New Jersey manufacturers generate 1.2 billion gallons of chemical waste every year (N.Y. Times, 1979). EPA has estimated that more than 10 percent of the nine million tons of industrial waste generated in New Jersey each year is toxic and that about 100 New Jersey garbage dumps contain potentially dangerous amounts of toxic wastes (N.Y. Times, 1979).

Very few land disposal sites are sufficiently secure that waste products are not able to leach into ground water supplies. Leaching is the process of dissolving or otherwise placing solids, liquids, or gases in solution by the action of water moving through the parent material. Leaching of toxic chemicals from a land disposal site can occur due to horizontal flow of ground water or as a result of vertical leaching by percolating water from rainfall or runoff (Robertson, et al., 1974). In the study of a typical landfill which did not receive appreciable wastes from industrial operators, over 40 undesireable organic compounds were found in wells surrounding the landfill (Robertson, et al., 1974). The authors concluded that the source of the organic compounds was the breakdown of manufactured products discarded in the landfill. The slow degradation of manufactured products may release toxic substances into our ground water supplies for many years even long after the landfills have been closed and forgotten.

Surface Impoundments

Surface impoundments, also called pits, ponds, basins and lagoons among other names, may constitute an even greater threat to our ground water supplies than landfills. Annual waste production in the U.S. includes 1 700 billion gallons pumped to some form of surface impoundment (Russell, 1978).

Surface impoundments are successful because they leak. An evaporation pit is successful in a humid region only if enough leakage takes place through the bottom and sides to create storage space for continued waste discharges (Braids, et al., 1977). An EPA survey of surface impoundments reports that the large majority are unlined with any substance which might keep the waste products from percolating into ground water supplies (EPA, 1978).

Little is known about the numbers of surface impoundments and the volumes of wastes pumped into them. Most impoundments are on industrial property and until recently have received no government regulation. A preliminary survey by the EPA estimates that the minimum number of impoundment sites in the nation is 132,700 and that each site on the average contains 2 or 3 surface impoundments (EPA, 1978). Industrial waste sites are estimated to operate 75 percent of the impoundment sites. Fifteen percent are agricultural and 10 percent municipal, institutional or private/commercial. Using a survey of secondary sources EPA estimates that there are 277 impoundment sites in New Jersey again with 2 or 3 surface impoundments per site (EPA, 1978). The New Jersey impoundment sites are broken down as follows: 9 municipal, 20 private/commercial, 5 institutional, 230 industrial, 13 agricultural. No estimates of the volumes of wastes nor the percentage of toxic wastes pumped to impoundments are available.

Movement of Polluted Ground Water

Generally, the contaminated water seeping into an aquifer forms a discrete body or plume of contamination elongated in the direction of ground water movement (EPA, 1978). Unlike surface waters, contaminated ground waters are not subject to rapid dilution because of laminar non-turbulent flow conditions and perhaps to differences in specific gravity, temperature and viscosity between the contaminated water and the native ground water (Walker, 1973; Pettyjohn, 1977). As a result toxics in ground water can move great distances, hidden from view and little changed in toxicity by the processes of attenuation for decades and even centuries (EPA, 1977). This behavior of toxic pollutants in ground water makes the protection of ground water sources of potable supply by means of routine monitoring much more difficult than it is for surface water supplies.

Even where toxics have apparently been immobilized in the ground, potential dangers exist. Toxic substances which are sorbed relatively strongly on aquifer solids could ultimately pose a pollution threat if they were resistent to biochemical and abiotic degradation in the ground water environment. It is possible such substances could move as zones by slow "chromatographic" migration and eventually pollute wells (Robertson, _et al._, 1974).

Research Reporting Toxics Pollution of Ground Water

While relatively little research has been completed on toxics contamination of ground water, some research has reported the presence of toxics in both shallow and deep aquifers. Borneff and Kunte (1963) found carcinogens in deep soil deposits in Germany. Robinson, et al. (1967) recovered significant quantities of organic materials from Illinois well waters and concluded that concentrations of organics in some well waters are as high as in many surface waters. Grigoropoulis and Smith (1968) found organic contaminants in a natural spring and from wells 1150 feet deep and 1745 feet deep in Missouri. They found that the concentrations were comparable to those in unpolluted Missouri surface water. Walker (1969) reported hydrocarbon pollution of several Illinois aquifers. The pollution was traced to breaks in transmission lines and leaking fuel oil tanks. Although the leak was quickly repaired in one of the situations one well 500 feet from the break had a gasoline taste during the next 4 years during periods of heavy rainfall. Borneff (1974) reports that in many parts of Europe ground water has normal background concentrations of the toxics fluoranthene, benzofluoranthene, benzopyrene, benzoperylene, and indenopyrene. He concludes that the concentrations of these substances in ground water are generally less than those in surface waters. Achari, Sandhu, and Warren (1975) have reported pesticides contaminating ground water in an agricultural area of South Carolina.

In a study of the first 408 ground water samples in New Jersey analysed for toxics, Page and Greenberg (1978) described patterns of toxics contamination in ground water throughout the state.

Statutory Treatment of Toxics

Recent federal laws and regulatory proposals treat the problem of toxic substances contaminating surface water supplies differently from their treatment of toxics contaminating ground water supplies. With passage of the Safe Drinking Water Act (U.S. Congress, 1974) the federal government has for the first time taken the lead role in protecting the nations health from water related dangers. In the recent and technologically complex issue of toxics contamination, the federal EPA is uncontestedly in the forefront in research and regulatory activity. A review of EPA policy and proposals indicates the agency is operating under the assumption that the nations ground water supplies are not threatened by toxics contamination comparable to the toxics contamination threatening surface water.

EPA's proposed strategy to protect the public health from toxics contamination of drinking water is to require potable water purveyors to install new filtering equipment to remove toxics. This proposal has been intensely debated largely on the issues of cost and effectiveness. The EPA proposals is that potable water purveyors serving more than 75,000 people and using surface water sources install and operate granular activated carbon filtration systems (Federal Register, 1978). The issue of why potable water purveyors using ground water sources should not be required to use the granular activated carbon filtration system to remove toxics has not been serious questioned in the literature.

The Safe Drinking Water Act establishes maximum contaminant levels for a small number of organic toxics and monitoring requirements which are different for surface water sources of drinking water than for ground water sources of drinking water (U.S. Congress, 1974). These requirements do not even apply to ground water sources of potable water unless the water supply system has been designated by the state as subject to the requirement. If a ground water system has been so designated by the state, it would also be required to monitor for the six organic toxics within two years and thereafter monitor every three years which is the same schedule as surface water purveyors must follow. At this time no ground water system has been designated by New Jersey as subject to this requirement (Hamill, 1979), although a few systems are required to monitor different toxics. All surface water purveyors are required to monitor for inorganic toxics yearly. All ground water purveyors are required to monitor for inorganic toxics every three years.

Summary of Previous Research on Toxics in Ground and Surface Water

Improved technical capability has enabled scientists to detect many toxics in our water supplies. At high concentrations these toxics pose an immediate danger to public health. The danger of long term exposure to low concentrations of toxics in drinking water is at present largely unknown (National Research Council, 1977). The best available information indicates that the exposure to any quantity of a carcinogen increases the probability of developing cancer and therefore the long term result of toxics and carcinogens in our drinking water supplies may be an elevated cancer mortality rate. Several statistical studies were reviewed which found significant associations of water supplies with toxics and elevated cancer mortality rates. All of these studies focused on surface water supplies.

One of the few studies which investigated toxics contamination of water from both surface and ground water sources was the National Organics Reconnaissance Survey (NORS). This was a survey of treated water from 80 U.S. cities which was primarily interested in trihalomethanes. Finished water from ground water sources was found to have lower concentrations of trihaloxmethanes than those from surface water sources. Other research indicating that toxics contamination of ground water is not a problem is also reviewed.

Recapitulating, this section presented evidence of toxics pollution of ground waters. Included were discussions of toxics reaching ground water from landfills and surface impoundments in the nationa and in New Jersey along with a brief review of our knowledge of what happens to toxics once they reach ground water supplies.

Recent federal laws and regulatory proposals dealing with toxics substances in our water supplies were briefly reviewed. This legislation places EPA in the role of being responsible for setting national standards to ensure the nations health from water related dangers. The aspects of these laws and regulatory proposals which treat toxics in surface water differently from toxics in ground water were emphasized.

CHAPTER 4

COMPARISONS OF TOXICS IN THE GROUND WATERS AND SURFACE WATERS OF NEW JERSEY

A comparison was made of the concentrations of toxics and the patterns of toxics contamination in the ground and surface waters of New Jersey. Geohydrologic theory and previous research indicate that with isolated exceptions ground waters should not be as contaminated with toxics as surface waters. The large toxic substances data sets for both ground water and surface water in New Jersey were used to test this hypothesis.

Selection of Data

First, we had to choose which data sets to compare. The first 408 ground water samples were thought to constitute a representative sample of toxics in the ground waters of New Jersey. It was thought that the 284 ground waters samples collected after the first 408 might be biased because they were selected to investigate ground water in the vicinity of wells known to have relatively high toxics concentrations.

It was decided to compare the concentrations of toxics in the first 408 ground water samples with the concentrations of toxics in the last 284 ground water samples which together constitute the full 692 ground water samples available for this analysis. If the 284 sample data set was found to have significantly greater concentrations of toxics than the first 408 samples set then it would be concluded that it was biased by the sample site selection procedure and only the original 408 ground water samples would be used for the comparison with the concentrations of toxics in surface water. If the comparison revealed no compelling evidence of upward bias in the concentrations of toxics in the last 284 samples, then the full 692 ground water samples would be used for the comparison.

The Mann-Whitney U test was used to determine if concentrations of each toxic substance were significantly greater in the first 408 ground water samples or the last 284 ground water samples. The Mann-Whitney U-test is a nonparametric statistical procedure which does not require the assumption of normally distributed variables (Hollander and Wolfe, 1973). Since the toxics in the N.J. ground water data have highly right skewed distributions, a nonparametric procedure was required. The Mann-Whitney U test is a nonparametric equivalent of the parametric difference of means test. It is in effect determining if the average rank of the concentration of toxics in one set of data is greater than the other. As a nonparametric procedure it uses the mean rank instead of the arithmetic mean which is normally associated with the term "average." The Mann-

TABLE 9. DESCRIPTIVE INFORMATION ON THE TOXIC SUBSTANCES IN THE FIRST 408 AND LAST 284 GROUND WATER SAMPLES[1]

First 408 Ground Water Samples

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
methylene chloride	390	23	0	0	0	959.7
chloroform	390	226	0	0.8	1.9	388.9
1,2-dichloroethane	390	16	0	0	0	1,968.9
1,1,1-trichloroethane	390	314	0	1.0	14.9	441.8
carbon tetrachloride	390	256	0	<0.1	0.5	263.9
1,1,2-trichloroethane	390	44	0	0	0.1	4,726.7
dibromochloromethane	390	61	0	0	<0.1	2.4
1,2-dibromoethane	390	30	0	0	<0.1	87.9
1,1,2,2-tetrachloroethylene	390	160	0	0	0.6	90.6
bromoform	390	32	0	0	0	34.3
1,1,2,2-tetrachloroethane	390	47	0	0	0	1.4
diiodomethane	390	58	0	0	0	1.2
trichlorobenzene	390	19	0	0	0	337.7
BHC-Alpha	405	87	0	0	<0.1	0.3
lindane	405	160	0	0	<0.1	0.9
BHC-Beta	315	120	0	0	<0.1	2.4
heptachlor	405	43	0	0	<0.1	1.0
aldrin	405	131	0	0	<0.1	1.2
heptachlor epoxide	405	125	0	0	<0.1	0.6
chlordane	405	113	0	0	<0.1	0.3
o,p^1-DDE	405	83	0	0	<0.1	0.9
dieldrin	405	67	0	0	<0.1	0.9
endrin	405	56	0	0	<0.1	0.6
o,p^1-DDT	405	58	0	0	<0.1	3.7
p,p^1-DDD	405	57	0	0	<0.1	1.8
p,p^1-DDT	403	49	0	0	<0.1	5.0

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[1] Concentrations in parts per billion.

TABLE 9. DESCRIPTIVE INFORMATION ON THE TOXIC SUBSTANCES IN THE FIRST 408 AND LAST 284 GROUND WATER SAMPLES (Continued)

First 408 Ground Water Samples

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
mirex	405	32	0	0	0	0.4
arsenic	387	384	1.0	1.0	2.0	1,160.0
beryllium	387	387	1.0	1.0	1.0	84.0
cadmium	387	387	1.0	1.0	1.0	450.0
copper	387	384	2.0	3.8	40.0	1,381.0
chromium	387	387	1.0	1.9	6.0	179.0
nickel	386	386	5.0	5.0	14.0	600.0
lead	385	383	1.0	1.0	6.0	329.0
selenium	386	386	2.0	2.0	2.0	8.0
zinc	387	387	5.0	15.0	160.0	28,360.0

TABLE 9. DESCRIPTIVE INFORMATION ON THE TOXIC SUBSTANCES IN THE FIRST 408 AND LAST 284 GROUND WATER SAMPLES (Continued)

Last 284 Ground Water Samples

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
methylene chloride	238	69	0	0	90.0	1,900.0
chloroform	250	212	0.8	0.8	2.6	691.2
1,2-dichloroethane	250	47	0	0	2.0	2,300.0
1,1,1-trichloroethane	249	227	2.0	2.0	2.8	607.8
carbon tetrachloride	250	176	0.1	0.1	0.5	9.1
1,1,2-trichloroethane	250	14	0	0	0	7.1
dibromochloromethane	250	43	0	0	0.1	1.5
1,2-dibromoethane	108	3	0	0	0	0.5
1,1,2,2-tetrachloroethylene	107	76	0	<0.1	1.4	83.0
bromoform	250	92	0	0	1.0	3.6
1,1,2,2-tetrachloroethane	250	20	0	0	0	2.7
diiodomethane	249	8	0	0	0	2.0
trichlorobenzene	249	7	0	0	0	5.1
BHC-Alpha	248	9	0	0	0	0.8
lindane	248	6	0	0	0	<0.1
BHC-Beta	248	125	0	0	0.1	118.4
heptachlor	248	29	0	0	<0.1	0.6
aldrin	248	15	0	0	0	0.2
heptachlor epoxide	248	30	0	0	<0.1	0.1
chlordane	248	73	0	0	<0.1	0.3
o,p^{1}-DDE	248	33	0	0	<0.1	<0.1
dieldrin	248	22	0	0	0	0.1
endrin	248	19	0	0	0	<0.1
o,p^{1}-DDT	248	12	0	0	0	0.1
p,p^{1}-DDD	248	15	0	0	0	0.2
p,p^{1}-DDT	248	11	0	0	0	<0.1

TABLE 9. DESCRIPTIVE INFORMATION ON THE TOXIC SUBSTANCES IN THE FIRST 408 AND LAST 284 GROUND WATER SAMPLES (Continued)

Last 284 Ground Water Samples

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
mirex	248	7	0	0	0	<0.1
arsenic	255	255	1.0	1.0	4.0	18.0
beryllium	255	255	1.0	1.0	1.0	1.0
cadmium	251	251	1.0	1.0	1.0	8.0
copper	251	251	1.0	6.0	42.0	1,349.0
chromium	251	251	1.0	1.0	4.0	65.0
nickel	251	251	5.0	5.0	7.0	31.0
lead	251	250	1.0	2.0	10.0	97.0
selenium	251	251	2.0	2.0	2.0	5.0
zinc	251	251	5.0	15.0	169.0	36,500.0

Whitney U test is able to test unequal sample sizes without bias.

Information on the toxic substances in the first 408 ground water samples and the last 284 ground water samples is presented in Table 9. The 36 toxics which have detectable concentrations in both data sets are included in Table 9 and are the variables in the Mann-Whitney U test. The mode and median show very little variation from one data set to the other. The 90th percentile concentration shows some variation, while the highest concentration shows considerable variation. It is interesting that the highest concentration is found in the first 408 ground water samples for 26 of the 36 toxics. If the last 284 samples were biased upward by the selection procedure, this result would not be expected.

The results of the Mann-Whitney U test comparing toxics in the first 408 with the last 284 ground water samples is presented in Table 10. The null hypothesis tested is that there is no statistically significant difference between the levels of concentrations of each toxic in the two data sets. The alternative hypothesis is that for a given toxic the average level of concentrations is greater in one data set than in the other.

The results indicate that of the 36 toxics for which a comparison can be made, more have greater concentrations in the first 408 ground water samples than in the last 284

TABLE 10. MANN-WHITNEY U TEST OF FIRST 408 VS LAST 284 GROUND WATER SAMPLES

	Greater at Significance Level		
	0.05	0.01	2-Tailed Probability
methylene chloride	Last	Last	<0.0001
chloroform	Laste	Last	<0.0001
1,2-dichloroethane	Last	Last	<0.0001
1,1,1-trichloroethane	First	First	0.004
carbon tetrachloride	No dif.	No dif.	0.11
1,1,2-trichloroethane	First	No dif.	0.03
dibromochloromethane	No dif.	No dif.	0.47
1,2-dibromoethane	No dif.	No dif.	0.07
1,1,2,2-tetrachloroethylene	Last	Last	<0.0001
bromoform	Last	Last	<0.0001
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.70
diiodomethane	First	First	<0.0001
trichlorobenzene	No dif.	No dif.	0.29
BHC-Alpha	First	First	<0.0001
lindane	First	First	<0.0001
BHC-Beta	Last	Last	<0.0001
heptachlor	First	First	<0.0001
aldrin	First	First	<0.0001
heptachlor epoxide	First	First	<0.0001
chlordane	No dif.	No dif.	0.46
o,p^{1}-DDE	First	No dif.	0.03
dieldrin	First	First	0.005
endrin	First	No dif.	0.012
o,p^{1}-DDT	First	First	0.0001
p,p^{1}-DDD	First	First	0.001
p,p^{1}-DDT	First	First	0.0007
mirex	First	First	0.0008
arsenic	Last	Last	0.009
beryllium	First	No dif.	0.04
cadmium	No dif.	No dif.	0.24
copper	Last	Last	0.0004
chromium	First	First	0.0006
nickel	First	First	0.001
lead	Last	Last	0.0001
selenium	First	First	0.0007
zinc	No dif.	No dif.	0.60

ground water samples. At the 0.05 level of significance, 19 toxics have greater average concentrations in the first 408 samples, 8 toxics have no significant differences, and 9 toxics have greater concentrations in the last 284 ground water samples. At the 0.01 level of significance, 15 toxics were greater in the first set, 12 showed no difference, and 9 were greater in the last 284 samples.

Furthermore, the results indicate that for the light chlorinated hydrocarbons and the heavy metals the results are approximately evenly divided between the concentrations being greater in the first 408 or last 284 samples. It is among the heavy chlorinated hydrocarbons that the concentrations are found to be greater in the first 408 samples for most of these pesticides.

After comparing the concentrations of toxics in the first 408 samples and the last 284 samples it is concluded that the last 284 ground water samples do not exhibit an upward bias in the levels of concentrations. For most of the toxics the highest concentrations were found in the first 408 samples. The average concentration was usually higher in the first 408 ground water samples. Since the last 284 ground water samples cannot be excluded because of bias, the ground water data set used for the comparison with the surface water data set will be composed of 692 ground water samples which is the sum of the first 408 and the last 284 samples.

Comparison of Toxics Concentrations in all New Jersey Ground and Surface Water Samples

Only 52 toxics for which detectable concentrations were found in both the ground water and surface water samples are included in the comparative analysis. These toxics include light chlorinated hydrocarbons, heavy chlorinated hydrocarbons and heavy metals. The ground water data set includes 692 samples and the surface water data set includes 320 samples. The 52 toxic substances for which the analysis will be performed and descriptive statistics on these toxics in both the ground water and surface water are presented in Table 11.

The number of samples collected and the number of samples detected exhibit great variation among the toxic substances and between the ground water and the surface water data sets. The explanation of the variation in the number of samples is provided in Chapter 1. For most of the toxic substances a greater number of samples were taken in ground water than in surface water.

The mode and median concentrations provide some indication of the severely right skewed frequency distributions of almost all of these toxic substances in both the ground water and the surface water data sets. The mode and median are measures of central tendency which for almost every toxic are either zero because it was non-detectable or the minimum reportable concentration. The measures of central tendency reveal a very substantial uniformity between ground water and surface water data sets

TABLE 11. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE 692 GROUND WATER AND 320 SURFACE WATER SAMPLES FROM NEW JERSEY[1]

Ground Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	130	15	0	0	0	0.5
methyl chloride	628	3	0	0	0	220.6
vinyl chloride	627	2	0	0	0	2.5
methylene chloride	624	88	0	0	90.0	1,900.0
chloroform	640	439	0	0.8	2.2	691.2
1,2-dichloroethane	634	57	0	0	0	2,300.0
1,1,1-trichloroethane	638	535	2.0	2.0	10.1	607.8
carbon tetrachloride	639	431	0	0.1	0.5	105.2
1,1,2-trichloroethylene	250	175	0.3	0.3	2.9	635.0
dichlorobromoethane	142	60	0	0	0.2	604.5
1,1,2-trichloroethane	637	55	0	0	0	31.1
dibromochloromethane	640	104	0	0	0.1	2.4
1,2-dibromoethane	498	33	0	0	0	87.9
1,1,2,2-tetrachloroethylene	498	237	0	0	1.3	90.6
bromoform	640	124	0	0	1.0	34.3
1,1,2,2-tetrachloroethane	640	57	0	0	0	2.7
diiodomethane	639	66	0	0	0	2.0
total dichlorobenzene	674	22	0	0	0	102.3
m-dichlorobenzene	249	6	0	0	0	25.4
p-dichlorobenzene	249	12	0	0	0	78.5
o-dichlorobenzene	249	9	0	0	0	5.2
trichlorobenzene	637	24	0	0	0	33.7
archlor 1242	248	7	0	0	0	3.4
archlor 1248	248	3	0	0	0	0.2
archlor 1254	638	11	0	0	0	0.4
dichloroethylene (gem)	64	34	0	10.0	169.9	1,280.2

[1] Concentrations in parts per billion.

TABLE 11. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE 692 GROUND WATER AND 320 SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Ground Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	64	23	0	0	0.1	44.9
t-dichloroethylene	64	51	10.0	10.0	73.2	549.3
bromodichloroethane	108	18	0	0	0.1	1.6
BHC-Alpha	653	96	0	0	<0.1	0.8
lindane	653	166	0	0	<0.1	0.9
BHC-Betal	563	245	0	0	<0.1	118.4
heptachlor	653	172	0	0	<0.1	1.0
aldrin	653	156	0	0	<0.1	1.2
heptachor epoxide	653	155	0	0	<0.1	0.6
chlordane	653	185	0	0	<0.1	0.3
o,p^{1}-DDE	653	116	0	0	<0.1	0.9
dieldrin	653	89	0	0	<0.1	0.9
endrin	653	75	0	0	<0.1	0.6
o,p^{1}-DDT	653	70	0	0	<0.1	3.7
p,p^{1}-DDD	653	72	0	0	<0.1	1.8
p,p^{1}-DDT	651	60	0	0	0.0	5.0
mirex	653	39	0	0	0.0	0.4
arsenic	642	639	1.0	1.0	3.0	1,160.0
beryllium	642	642	1.0	1.0	1.0	84.0
cadmium	638	638	1.0	1.0	1.0	405.0
copper	638	635	1.0	4.0	41.0	1,381.0
chromium	638	638	1.0	2.0	6.0	179.0
nickel	637	637	5.0	5.0	12.0	600.0
lead	636	633	1.0	1.0	8.0	329.0
selenium	637	637	2.0	2.0	2.0	8.0
zinc	638	638	5.0	15.0	172.0	36,500.0

TABLE 11. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE 692 GROUND WATER AND 320 SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Surface Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	142	3	0	0	0	0.5
methyl chloride	316	3	0	0	0	6.0
vinyl chloride	317	4	0	0	0	5.9
methylene chloride	316	114	0	0	90.0	743.3
chloroform	317	237	0.8	0.8	2.9	2,461.8
1,2-dichloroethane	317	35	0	0	<1.6	304.9
1,1,1-trichloroethane	317	277	2.0	2.0	4.1	22.7
carbon tetrachloride	317	267	0.1	0.1	0.4	20.6
1,1,2-trichloroethylene	173	120	0.3	0.3	0.7	4.7
dichlorobromoethane	142	79	0.1	0.1	0.1	2.0
1,1,2-trichloroethane	314	42	0	0	0.5	4.4
dibromochloromethane	317	81	0	0	0.1	8.2
1,2-dibromoethane	175	11	0	0	0	0.2
1,1,2,2-tetrachloroethylene	174	154	0	0.1	1.2	4.5
bromoform	313	88	0	0	1.0	3.7
1,1,2,2-tetrachloroethane	316	56	0	0	0.2	0.6
diiodomethane	316	9	0	0	0	3.2
total dichlorobenzene	318	29	0	0	0	30.7
m-dichlorobenzene	172	12	0	0	0	5.0
p-dichlorobenzene	172	20	0	0	1.3	30.5
o-dichlorobenzene	172	8	0	0	0	8.2
trichlorobenzene	315	24	0	0	0	2.2
archlor 1242	319	10	0	0	0	117.3
archlor 1248	319	32	0	0	0	109.1
archlor 1254	319	57	0	0	0.2	127.0
dichloroethylene (gem)	97	62	0	10.0	60.7	489.1

TABLE 11. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE 692 GROUND WATER AND 320 SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Surface Water

	Sampled	Detected	Mode	Median	Percentile	Highest
dibromomethane	97	35	0	0	0.1	3.3
t-dichloroethylene	97	75	10.0	10.0	526.0	1,307.5
bromodichloroethane	31	2	0	0	0	4.7
BHC-Alpha	311	82	0	0	<0.1	<0.1
lindane	311	74	0	0	<0.1	0.8
BHC-Betal	311	182	0	<0.1	0.2	3.1
heptachlor	311	63	0	0	<0.1	5.9
aldrin	311	30	0	0	0	0.6
heptachor epoxide	311	114	0	0	<0.1	0.5
chlordane	310	148	0	0	<0.1	0.8
o,p^{1}-DDE	311	101	0	0	<0.1	<0.1
dieldrin	311	118	0	0	<0.1	<0.1
endrin	311	42	0	0	<0.1	0.1
o,p^{1}-DDT	311	45	0	0	<0.1	<0.1
p,p^{1}-DDD	311	71	0	0	<0.1	<0.1
p,p^{1}-DDT	311	51	0	0	<0.1	<0.1
mirex	311	19	0	0	0	<0.1
arsenic	294	294	1.0	1.0	3.0	392.0
beryllium	294	294	1.0	1.0	1.0	1.0
cadmium	294	294	1.0	1.0	1.0	6.0
copper	294	294	1.0	3.0	8.0	124.0
chromium	294	293	1.0	2.0	4.0	216.0
nickel	294	294	5.0	5.0	9.0	36.0
lead	294	294	1.0	1.0	17.0	86.0
selenium	293	293	2.0	2.0	2.0	7.0
zinc	292	292	5.0	13.0	46.0	420.0

for the toxic substances included in this analysis.

The 90th percentile concentration and the highest concentration provide another indication of the skewness of the data and suggest important variation between concentration of toxics in ground water and surface water. Twelve toxics (23 percent) had greater 90th percentile concentrations in ground water and 10 toxics (19 percent) had greater 90th percentile concentrations in surface water.

The highest concentrations show even greater variation between ground and surface waters. For 38 of the toxics (73 percent) the highest concentration was found in ground water and for 13 toxics (25 percent) the highest concentration was found in surface water. In addition, for 31 percent of the toxics, the highest concentration was at least an order of magnitude greater in ground water than in surface water. For 6 percent (3) of the substances, the highest concentration was at least two orders of magnitude greater in ground water than in surface water. For only three toxics(6 percent) was the highest concentration an order of magnitude greater in surface water than in ground water and for two toxics (4 percent) the difference was 2 orders of magnitude. The 3 toxics with concentrations an order or more of magnitude greater in surface water are the archlors which are forms of polychlorinated biphenyls (PCB's). The finding that the highest concentrations of most of the toxics in the analysis were in ground water samples indicates that toxics contamination of ground water may be a seriously underestimated problem in New Jersey.

Probabilities of Detection of Toxics in Ground and Surface Water

In order to provide more precise data comparing toxics contamination of ground and surface water in New Jersey the probabilities of detecting toxics were calculated. The probability of detecting each toxic in New Jersey ground and surface water is presented in Table 12. These a posteriori probabilities are based on the limits of detection used in the analysis of the ground water and surface water samples collected in New Jersey (Department of Environmental Science, 1978A and B). With the rapid increase in the technological capability to detect trace levels of toxics in water, these probabilities will be expected to change as the ability to quantify toxics at ever lower concentrations is increased (Donaldson, 1977). The chi square test was used to test if the probability of detecting each toxic in ground water was different from the probability of detecting each toxic in surface water at the 0.05 significance level.

There is substantial variation in the probabilities of detection among the 52 toxic substances and between ground and surface water. Among the light chlorinated hydrocarbons

TABLE 12. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY GROUND WATER AND SURFACE WATER

	Probability Detectable In Ground W.	Probability Detectable In Surface W.	Significantly Different at 0.05 Level
fluoroform	.12	.02	Yes
methyl chloride	<.01	.01	No
vinyl chloride	<.01	.01	No
methylene chloride	.14	.36	Yes
chloroform	.69	.75	No
1,2-dichloroethane	.09	.11	No
1,1,1-trichloroethane	.84	.87	No
carbon tetrachloride	.67	.84	Yes
1,1,2-trichloroethylene	.70	.69	No
dichlorobromoethane	.42	.56	No
1,1,2-trichloroethane	.09	.13	Yes
dibromochloromethane	.16	.26	Yes
1,2-dibromoethane	.07	.06	No
1,1,2,2-tetrachloroethylene	.48	.89	Yes
bromoform	.19	.28	Yes
1,1,2,2-tetrachloroethane	.09	.18	Yes
diiodomethane	.10	.03	Yes
total dichlorobenzene	.03	.09	Yes
m-dichlorobenzene	.02	.07	Yes
p-dichlorobenzene	.05	.12	Yes
o-dichlorobenzene	.04	.05	No
trichlorobenzene	.04	.08	Yes
archlor 1242	.03	.03	No
archlor 1248	.01	.10	Yes
archlor 1254	.02	.15	Yes
dichloroethylene (gem)	.53	.64	No

TABLE 12. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY GROUND WATER AND SURFACE WATER (Continued)

	Probability Detectable In Ground W.	Probability Detectable In Surface W.	Significantly Different at 0.05 Level
dibromomethane	.36	.36	No
t-dichloroethylene	.80	.77	No
bromodichloroethane	.17	.06	No
BHC-Alpha	.15	.26	Yes
lindane	.25	.24	No
BHC-Betal	.44	.59	Yes
heptachlor	.26	.20	Yes
aldrin	.24	.10	Yes
heptachor epoxide	.24	.37	Yes
chlordane	.28	.48	Yes
o,p^{1}-DDE	.18	.32	Yes
dieldrin	.14	.38	Yes
endrin	.11	.14	No
o,p^{1}-DDT	.11	.14	No
p,p^{1}-DDD	.11	.23	Yes
p,p^{1}-DDT	.09	.16	Yes
mirex	.06	.06	No
arsenic	.99	1.00	No
beryllium	1.00	1.00	All Detectable
cadmium	1.00	1.00	All Detectable
copper	.99	1.00	No
chromium	1.00	1.00	No
nickel	1.00	1.00	All Detectable
lead	.99	.99	No
selenium	1.00	1.00	All Detectable
zinc	1.00	1.00	All Detectable

the probabilities of detection range from less than 0.01 for methyl chloride and vinyl chloride in ground water to 0.89 for 1,1,2,2-tetrachloroethylene in surface water. Among the heavy chlorinated hydrocarbons the probabilities range from 0.06 for mirex in both ground and surface water to 0.59 for BHC-beta in surface water. For both groups of organic toxics the variation is much greater between toxics than between the same toxic in ground and surface water. All of the heavy metals were detectable in almost all samples of both ground and surface water.

The results of the chi square tests indicate that for most toxics there is no significant difference in the probability of detection between ground water and surface water samples, but that 40 percent of the toxics are more likely to be detected in surface water. For 27 of the toxics (52 percent) there is no significant difference in the probability of detection in ground water or surface water. All of the heavy metals and some of both the light and heavy chlorinated hydrocarbons fall in this category. Four toxics (8 percent) are more likely to be detected in ground water. This category includes 2 light and 2 heavy chlorinated hydrocarbons. Twenty-one toxics (40 percent) have a significantly greater probability of being detected in surface water samples.

The conclusion reached from the analysis of probabilities of detection of toxic substances is that the majority of toxics studied are at least as likely to be detected in ground water in New Jersey as in surface water. There is no significance difference in the probability of detection for 27 toxics, and 4 toxics are more probably detected in ground water. The 31 toxics at least as likely to be detected in ground water as surface water are 60 percent of the toxics studied.

Comparison of Detectable Toxics in Ground and Surface Water

To complete the comparison of toxics in the ground and surface waters of New Jersey a comparison was performed of only the detectable concentrations in order to determine if ground waters are more contaminated than surface waters or vice versa when any contamination occurs. The analysis uses the Mann-Whitney U test to determine if the average concentration of each toxic in those ground water samples known to be contaminated with that toxic are less than, not significantly different from, or greater than the average concentration in those polluted surface water samples.

The results of comparing only samples with detectable concentrations reveals that there is no significant difference in the average concentration for the majority of toxics, but that the average concentration is greater in ground water than surface water for more than twice as many toxics. The results of the Mann-Whitney U test of detectable ground water samples versus detectable surface

TABLE 13. MANN-WHITNEY U TEST DETECTABLE GROUND WATER SAMPLES VS DETECTABLE SURFACE WATER SAMPLES

	Greater at Significance Level		
	0.05	0.01	2-Tailed Probability
fluoroform	No dif.	No dif.	0.41
methyl chloride	No dif.	No dif.	0.12
vinyl chloride	No dif.	No dif.	0.35
methylene chloride	No dif.	No dif.	0.77
chloroform	SUF	No dif.	0.03
1,2-dichloroethane	SUF	No dif.	0.01
1,1,1-trichloroethane	GRN	GRN	0.003
carbon tetrachloride	GRN	No dif.	0.04
1,1,2-trichloroethylene	GRN	GRN	0.003
dichlorobromoethane	GRN	GRN	0.001
1,1,2-trichloroethane	No dif.	No dif.	0.89
dibromochloromethane	No dif.	No dif.	0.16
1,2-dibromoethane	No dif.	No dif.	0.35
1,1,2,2-tetrachloroethylene	No dif.	No dif.	0.22
bromoform	No dif.	No dif.	0.92
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.61
diiodomethane	No dif.	No dif.	0.06
total dichlorobenzene	No dif.	No dif.	0.13
m-dichlorobenzene	No dif.	No dif.	0.12
p-dichlorobenzene	GRN	No dif.	0.013
o-dichlorobenzene	No dif.	No dif.	0.60
trichlorobenzene	GRN	GRN	<0.0001
archlor 1242	No dif.	No dif.	0.17
archlor 1248	SUF	No dif.	0.01
archlor 1254	No dif.	No dif.	0.26
dichloroethylene (gem)	GRN	No dif.	0.014

Table 13. MANN-WHITNEY U TEST DETECTABLE GROUND WATER SAMPLES VS DETECTABLE SURFACE WATER SAMPLES (Continued)

	Greater at Significance Level		
	0.05	0.01	2-Tailed Probability
dibromomethane	No dif.	No dif.	0.19
t-dichloroethylene	SUF	SUF	0.003
bromodichloroethane	No dif.	No dif.	0.31
BHC-Alpha	GRN	GRN	0.005
lindane	No dif.	No dif.	0.14
BHC-Betal	SUF	SUF	<0.0001
heptachlor	SUF	SUF	<0.0001
aldrin	No dif.	No dif.	0.87
heptachor epoxide	No dif.	No dif.	0.06
chlordane	No dif.	No dif.	0.46
o,p^{1}-DDE	GRN	GRN	0.0001
dieldrin	GRN	GRN	0.0003
endrin	GRN	GRN	0.004
o,p^{1}-DDT	GRN	GRN	0.0001
p,p^{1}-DDD	GRN	GRN	<0.0001
p,p^{1}-DDT	GRN	GRN	<0.0001
mirex	No dif.	No dif.	0.78
arsenic	SUF	SUF	<0.0001
beryllium	No dif.	No dif.	0.10
cadmium	No dif.	No dif.	0.07
copper	GRN	GRN	<0.0001
chromium	No dif.	No dif.	0.45
nickel	GRN	No dif.	0.049
lead	SUF	SUF	<0.0001
selenium	GRN	GRN	<0.0001
zinc	GRN	GRN	0.003

water samples is presented as Table 13. Depending on the level of significance, between 26 and 33 toxics (50-63 percent) have no significant difference between the average detectable concentrations in ground and surface water. Between 14-18 toxics (27-35 percent) have greater average detectable concentration in ground water than in surface water. Between 5-8 toxics (10-15 percent) have greater average rank detectable concentrations in surface water than in ground water. At the 0.01 significance level there is no difference in the average concentration for 33 toxics and a greater average concentration in ground water samples for 14 toxics. The total 47 toxics is 90 percent= of the toxic substances included in this analysis. Recapitulating, the overwhelming majority of toxics exhibit a typical detectable concentration at least as great in ground water as in surface water in New Jersey.

Summary of Comparisons of Toxics in Ground and Surface Water

Analysis of the concentrations of toxic substances in the ground waters and surface waters of New Jersey reveals that the levels of toxics in ground waters are at least as contaminated as those in surface waters for between 60 percent and 90 percent of the toxics studied depending on the method of comparison. Comparing only the highest concentration of each toxic, 73 percent of the toxics are more contaminated in ground water. Comparing the probabilities of detection, 60 percent of the toxics have no significant difference or have a greater probability of detection in ground water. Comparing only those samples with detectable concentrations, 90 percent of the toxics are not significantly different or are more contaminated in ground water than in surface water.

Because of the complexity of the tables presented during the comparison of toxics concentrations in ground and surface water, a selected summary of Tables 11-13 is presented as Table 14. Section A of Table 14 reviews comparative information on the 4 toxics with significantly greater probability of detection in New Jersey ground water. Section B reviews the comparative results for the 21 toxics with significantly greater probability of detection in New Jersey surface water. Of these 21 toxics, 17 (81 percent) have the highest concentration detected in ground water, while only 2 (10 percent) have the highest average detectable concentration in surface water compared to 8 (38 percent) in ground water and 11 (52 percent) with no significant difference.

Those toxics without significantly greater probability of detection in either New Jersey ground or surface water are reviewed in Section C of Table 14. Of these 27 toxics, 20 (74 percent) had the highest concentration in ground water. The average detectable concentration exhibited no difference between ground and surface water for 11 toxics

TABLE 14. SUMMARY OF COMPARISONS OF ALL GROUND AND SURFACE WATER DATA IN NEW JERSEY

A. Toxics with Significantly Greater Probability of Detection in Ground Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in[1]
1. fluoroform	Both	No dif.
2. diiodomethane	SUF	No dif.
3. heptachlor	SUF	SUF
4. aldrin	GRN	No dif.

B. Toxics with Significantly Greater Probability of Detection in Surface Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in[1]
1. methylene chloride	GRN	No dif.
2. carbon tetrachloride	GRN	GRN
3. 1,1,2 trichloroethane	GRN	No dif.
4. dibromochloromethane	SUF	No dif.
5. 1,1,2,2-tetrachloroethylene	GRN	No dif.
6. bromoform	GRN	No dif.
7. 1,1,2,2-tetrachloroethane	GRN	No dif.
8. total dichlorobenzene	GRN	No dif.
9. m-dichlorobenzene	GRN	No dif.
10. p-dichlorobenzene	GRN	GRN
11. trichlorobenzene	GRN	GRN
12. archlor 1248	SUF	SUF
13. archlor 1254	SUF	No dif.
14. BHC-Alpha	GRN	GRN
15. BHC-Beta	GRN	SUF
16. heptachlor epoxide	GRN	No dif.
17. chlordane	SUF	No dif.
18. o,p^1-DDE	GRN	GRN
19. dieldrin	GRN	GRN
20. p,p^1-DDD	GRN	GRN
21. p,p^1-DDT	GRN	GRN

[1] At 0.05 significance level with Mann-Whitney U test.

TABLE 14. SUMMARY OF COMPARISONS OF ALL GROUND AND SURFACE WATER DATA IN NEW JERSEY (Continued)

C. Toxics without Significantly Greater Probability of Detection in New Jersey Ground or Surface Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in
1. methyl chloride	GRN	No dif.
2. vinyl chloride	SUF	No dif.
3. chloroform	SUF	SUF
4. 1,2-dichloroethane	GRN	SUF
5. 1,1,1-trichloroethane	GRN	GRN
6. 1,1,2-trichloroethylene	GRN	GRN
7. dichlorobromomethane	GRN	GRN
8. 1,2-dibromoethane	GRN	No dif.
9. o-dichlorobenzene	SUF	No dif.
10. archlor 1242	SUF	No dif.
11. dichloroethylene (Gem)	GRN	GRN
12. dibromomethane	GRN	No dif.
13. T-dichloroethylene	SUF	SUF
14. bromodichloroethane	SUF	No dif.
15. lindane	GRN	No dif.
16. endrin	GRN	GRN
17. o,p^1-DDT	GRN	GRN
18. mirex	GRN	No dif.
19. arsenic	GRN	SUF
20. beryllium	GRN	No dif.
21. cadmium	GRN	No dif.
22. copper	GRN	GRN
23. chromium	SUF	No dif.
24. nickel	GRN	GRN
25. lead	GRN	SUF
26. selenium	GRN	GRN
27. zinc	GRN	GRN

(41 percent) was greater in ground water for 10 toxic (37 percent) and was greater in surface water in 5 of the toxic substances (19 percent). All of the heavy metals are included in the category of toxics without significantly greater probability of detection in either ground or surface water. The other toxics included in this category are from both light and heavy chlorinated hydrocarbons.

CHAPTER 5

COMPARISON OF TOXICS IN POTABLE GROUND AND SURFACE WATER

Introduction

A comparison of toxics concentrations limited to ground and surface waters used to supply drinking water is important. Some of the ground water samples included in the 692 sample ground water data set are known to monitor heavily polluted ground water in the vicinity of landfills. Some of the surface water samples in the 320 sample surface water data set were collected from the downstream reaches of rivers in heavily industrialized areas with known pollution problems from point sources and runoff. Some of these samples from both ground and surface waters may be so polluted as to be unrepresentative of the ground and surface waters of New Jersey. A comparison of only potable water sources will focus attention on water sources linked most directly with potential adverse health effects.

Limiting the comparison of toxics concentrations to potable waters is an indirect means of controlling for important causal factors in the distribution of toxic substances in water supplies. The distinction of nonpotable sources and potable sources of water supply is, in New

Jersey, a reasonably good surrogate for the distinction between areas of high population density and heavy industrial activity, and those areas characterized by lower population density and lower levels of industrial activity. This distinction is especially appropriate in New Jersey for surface water where the nonpotable, downstream reaches of the state's major rivers drain the urban-industrial corridor of the state.

Data Description

The initial step was to define a potable sample. A ground water sample was called potable if the water was used for drinking water. A surface water sample was characterized potable if it was collected upstream from or at a potable supply intake facility. The 52 toxic substances with descriptive statistics for both the potable ground water and potable surface water data sets are presented in Table 15. Since mirex had no detectable surface water concentrations, it was dropped from this analysis.

The number of valid sample results available for comparison varies by toxic and between the ground and surface water data sets. For most of the toxics there are more potable ground water samples than potable surface water samples. The number of potable ground sample results available for comparison ranges from 58 samples for

TABLE 15. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE POTABLE GROUND WATER SAMPLES AND POTABLE SURFACE WATER SAMPLES FROM NEW JERSEY[1]

Potable Ground Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	120	14	0	0	0.5	159.2
methyl chloride	509	3	0	0	0	220.6
vinyl chloride	508	2	0	0	0	2.5
methylene chloride	505	85	0	0	90.0	1,900.0
chloroform	521	356	0.8	0.8	2.0	691.2
1,2-dichloroethane	515	45	0	0	0	36.5
1,1,1-trichloroethane	519	434	0	2.0	9.3	607.8
carbon tetrachloride	520	348	0	0.1	0.5	150.2
1,1,2-trichloroethylene	223	150	0.3	0.3	2.7	635.0
dichlorobromoethane	132	54	0	0	0.2	604.5
1,1,2-trichloroethane	518	39	0	0	0	31.1
dibromochloromethane	521	77	0	0	<0.1	2.4
1,2-dibromoethane	389	22	0	0	0	48.8
1,1,2,2-tetrachloroethylene	388	170	0	0	1.1	90.6
bromoform	521	111	0	0	1.0	6.4
1,1,2,2-tetrachloroethane	521	43	0	0	0	2.7
diiodomethane	520	44	0	0	0	2.0
total dichlorobenzene	546	18	0	0	0	102.3
m-dichlorobenzene	222	4	0	0	0	19.1
p-dichlorobenzene	222	10	0	0	0	78.5
o-dichlorobenzene	222	7	0	0	0	4.7
trichlorobenzene	518	22	0	0	0	33.7
archlor 1242	220	7	0	0	0	3.4
archlor 1248	220	3	0	0	0	0.2
archlor 1254	518	8	0	0	0	0.4
dichloroethylene (gem)	58	30	0	1.1	138.7	1,280.2

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[1] Concentrations in parts per billion.

TABLE 15. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE POTABLE GROUND WATER SAMPLES AND POTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Potable Ground Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	58	20	0	0	0.1	44.9
t-dichloroethylene	58	45	10.0	10.0	73.2	549.3
bromodichloroethane	91	15	0	0	0.1	1.0
BHC-Alpha	530	73	0	0	<0.1	0.8
lindane	530	123	0	0	<0.1	0.9
BHC-Beta	464	198	0	0	<0.1	118.4
heptachlor	530	132	0	0	<0.1	0.6
aldrin	530	122	0	0	<0.1	0.4
heptachor epoxide	530	124	0	0	<0.1	0.6
chlordane	530	154	0	0	<0.1	0.3
o,p^{1}-DDE	530	93	0	0	<0.1	1.0
dieldrin	530	71	0	0	<0.1	0.9
endrin	530	59	0	0	<0.1	0.6
o,p^{1}-DDT	471	59	0	0	<0.1	3.7
p,p^{1}-DDD	530	57	0	0	<0.1	1.8
p,p^{1}-DDT	529	50	0	0	<0.1	5.0
mirex	530	25	0	0	0	0.4
arsenic	525	522	1.0	1.0	3.0	1,160.0
beryllium	525	525	1.0	1.0	1.0	3.0
cadmium	521	521	1.0	1.0	1.0	65.0
copper	521	519	1.0	5.0	41.0	1,381.0
chromium	521	521	1.0	1.0	5.0	85.0
nickel	520	520	5.0	5.0	11.0	96.0
lead	520	517	1.0	1.0	7.0	97.0
selenium	521	521	2.0	2.0	2.0	8.0
zinc	521	521	5.0	14.0	160.0	36,500.0

TABLE 15. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE POTABLE GROUND WATER SAMPLES AND POTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Potable Surface Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	83	3	0	0	0	0.5
methyl chloride	193	3	0	0	0	6.0
vinyl chloride	195	4	0	0	0	5.9
methylene chloride	193	66	0	0	90.0	304.5
chloroform	195	139	0.8	0.8	2.2	2,461.8
1,2-dichloroethane	195	22	0	0	1.6	304.9
1,1,1-trichloroethane	195	166	2.0	2.0	4.1	22.7
carbon tetrachloride	195	165	0.1	0.1	0.5	20.6
1,1,2-trichloroethylene	106	60	0	0.3	0.6	4.7
dichlorobromoethane	83	53	0.1	0.1	0.1	2.0
1,1,2-trichloroethane	192	25	0	0	1.0	4.4
dibromochloromethane	195	45	0	0	0.1	8.2
1,2-dibromoethane	112	6	0	0	0	0.1
1,1,2,2-tetrachloroethylene	111	95	0.3	0.3	0.6	4.5
bromoform	194	51	0	0	1.0	3.7
1,1,2,2-tetrachloroethane	195	30	0	0	0.1	0.6
diiodomethane	195	3	0	0	0	1.6
total dichlorobenzene	196	13	0	0	0	3.7
m-dichlorobenzene	106	6	0	0	0	1.3
p-dichlorobenzene	106	9	0	0	0	1.8
o-dichlorobenzene	106	2	0	0	0	2.2
trichlorobenzene	194	11	0	0	0	2.0
archlor 1242	196	7	0	0	0	117.3
archlor 1248	196	16	0	0	0	64.4
archlor 1254	196	33	0	0	0.2	127.0
dichloroethylene (gem)	58	41	10.0	10.0	114.9	489.1

TABLE 15. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE POTABLE GROUND WATER SAMPLES AND POTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Potable Surface Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	58	18	0	0	0.1	3.3
t-dichloroethylene	58	44	10.0	10.0	728.0	1,307.5
bromodichloroethane	23	1	0	0	0	4.7
BHC-Alpha	192	52	0	0	<0.1	<0.1
lindane	192	44	0	0	<0.1	0.8
BHC-Beta	192	109	0	<0.1	0.2	1.3
heptachlor	192	48	0	0	0.1	5.7
aldrin	192	22	0	0	<0.1	0.6
heptachor epoxide	192	73	0	0	<0.1	0.5
chlordane	191	94	0	0	<0.1	0.5
o,p^{1}-DDE	192	67	0	0	<0.1	<0.1
dieldrin	192	79	0	0	<0.1	<0.1
endrin	192	25	0	0	<0.1	<0.1
o,p^{1}-DDT	192	29	0	0	<0.1	<0.1
p,p^{1}-DDD	192	43	0	0	<0.1	<0.1
p,p^{1}-DDT	192	34	0	0	<0.1	<0.1
mirex	192	0	0	0	0	0
arsenic	176	155	1.0	1.0	3.0	44.0
beryllium	176	176	1.0	1.0	1.0	1.0
cadmium	176	176	1.0	1.0	1.0	2.0
copper	176	176	1.0	3.0	9.0	124.0
chromium	176	176	1.0	1.0	4.0	9.0
nickel	176	176	5.0	5.0	8.0	25.0
lead	176	176	1.0	3.0	15.0	86.0
selenium	175	175	2.0	2.0	2.0	7.0
zinc	174	174	5.0	10.0	34.0	274.0

dichloroethylene (gem), dibromomethane, and T-dichloroethylene to 546 samples for total dichlorobenzene. The number of potable surface water samples available for comparison ranges from 23 samples of bromodichloroethane to 196 samples of total dichlorobenzene and archlors 1242, 1248, and 1254.

The mode, median, and 90th percentile concentrations provide some indication of the severely right skewed frequency distributions of the toxic substances in both data sets. It is interesting to note that all three of these descriptive statistics show very little change from the corresponding statistic from the data sets containing all ground water and all surface water data. This observation leads to the conclusion that the selection of only potable ground and surface water samples has not altered the basic shape of the frequency distributions of the 52 toxics included in this analysis.

The highest concentrations in the potable ground and potable surface water data sets reveal the same relationship of toxics contamination found in the analysis of all ground and surface water samples. Having eliminated the ground and surface water samples collected from nonpotable sources of water supply, it was anticipated that there might be a change in the relationship of highest concentrations between potable ground water and potable surface water samples. As in the analysis of all ground and surface water samples, the great majority of highest toxics concentrations were detected in ground water samples. The highest concentration was detected in ground water samples in 40 of the 52 toxics (79 percent) while being detected in surface water samples in 12 toxics (23 percent). For 21 toxics (40 percent) the highest concentration in ground water was at least an order of magnitude greater than in the surface water data. For 5 toxics (10 percent) the highest concentration in ground water was at least two orders of magnitude greater in the ground water data. As in the analysis of all ground and surface water data, only for the 3 archlors were the highest concentrations in surface water one or more orders of magnitude greater than in the ground water data set.

Probabilities of Detection of Toxics in Potable Ground and Surface Water

A second comparison of toxic substances in potable ground and surface water in New Jersey involves the likelihood of toxics being present at detectable levels in potable water. These a posteriori probabilities are limited by the analytic methods used in the analysis of the water samples. The probability of detecting each toxic in potable ground water samples and potable surface water samples is presented in Table 16. The chi square test was used to test if the probability of detecting each toxic in potable ground water was different from the probability of

TABLE 16. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY POTABLE GROUND AND SURFACE WATER

	Probability Detectable In Ground W.	Probability Detectable In Surface W.	Significantly Different at 0.05 Level
fluoroform	.12	.04	No
methyl chloride	.01	.02	No
vinyl chloride	<.01	.02	No
methylene chloride	.17	.34	Yes
chloroform	.68	.71	No
1,2-dichloroethane	.09	.11	No
1,1,1-trichloroethane	.84	.85	No
carbon tetrachloride	.67	.85	Yes
1,1,2-trichloroethylene	.67	.57	No
dichlorobromoethane	.41	.64	Yes
1,1,2-trichloroethane	.08	.13	Yes
dibromochloromethane	.15	.23	Yes
1,2-dibromoethane	.06	.05	No
1,1,2,2-tetrachloroethylene	.44	.86	Yes
bromoform	.21	.26	No
1,1,2,2-tetrachloroethane	.08	.15	Yes
diiodomethane	.08	.02	Yes
total dichlorobenzene	.03	.07	No
m-dichlorobenzene	.02	.06	No
p-dichlorobenzene	.05	.08	No
o-dichlorobenzene	.03	.02	No
trichlorobenzene	.04	.06	No
archlor 1242	.03	.04	No
archlor 1248	.01	.08	Yes
archlor 1254	.02	.17	Yes
dichloroethylene (gem)	.52	.71	No

TABLE 16. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY POTABLE GROUND AND SURFACE WATER

	Probability Detectable In Ground W.	Probability Detectable In Surface W.	Significantly Different at 0.05 Level
dibromomethane	.34	.31	No
t-dichloroethylene	.78	.76	No
bromodichloroethane	.16	.04	No
BHC-Alpha	.14	.27	Yes
lindane	.23	.23	No
BHC-Betal	.43	.57	Yes
heptachlor	.25	.25	No
aldrin	.23	.11	Yes
heptachor epoxide	.23	.38	Yes
chlordane	.29	.49	Yes
o,p^{1}-DDE	.18	.35	Yes
dieldrin	.13	.41	Yes
endrin	.11	.13	No
o,p^{1}-DDT	.13	.15	No
p,p^{1}-DDD	.11	.22	Yes
p,p^{1}-DDT	.09	.18	Yes
mirex			
arsenic	.99	.88	No
beryllium	1.00	1.00	All Detectable
cadmium	1.00	1.00	All Detectable
copper	.99	1.00	No
chromium	1.00	1.00	All Detectable
nickel	1.00	1.00	All Detectable
lead	.99	1.00	No
selenium	1.00	1.00	All Detectable
zinc	1.00	1.00	All Detectable

detecting each toxic in potable surface water at the 0.05 significance level.

There is considerable variation in the probabilities of detection among the 52 toxic substances and between potable ground water samples and potable surface water samples. Among the light chlorinated hydrocarbons the probabilities of detection range from less than 0.01 for vinyl chloride in potable ground water to 0.86 for 1,1,2,2-tetrachloroethylene in potable surface water. Among the heavy chlorinated hydrocarbons the probabilities of detection range from 0.09 for p,p^1-DDT in potable ground water to 0.57 for BHC-Beta in potable surface water. With the exception of arsenic in potable surface water, all the heavy metals were detectable in virtually all samples of both ground and surface water.

The results of the chi square test indicate that for the majority of toxics there is no significant difference in the probability of detection between potable ground water samples and potable surface water samples. For 32 of the toxics (63 percent) there is no significant difference in the probability of detection between the potable ground and surface water samples. All of the heavy metals and some of both the light and heavy chlorinated hydrocarbons fall in this category.

Most of the toxic substances which have significantly greater probabilities of detection in ground or surface water, have a greater probability of detection in potable surface water samples than in potable ground water samples. Seventeen toxic substances out of the 51 toxics (excluding mirex) (33 percent) have a significantly greater probability of detection in potable surface water. Only 2 toxics (4 percent) have a significantly greater probability of detection in potable ground water samples.

Summarizing, two-thirds of the toxics studied are at least as likely to be detected in ground water in New Jersey as in surface water. There is no significant difference in the probability of detection for 32 toxics, and 2 toxics are more likely to be detected in ground water. The 34 toxics at least as likely to be detected in potable ground water as in potable surface water are 67 percent of the toxics included in the analysis.

Comparison of Detectable Toxics in Potable Ground Water and Potable Surface Water

Next, a comparison was made of toxics concentrations for only those samples with detectable concentrations. The analysis uses the Mann-Whitney U test to determine if the average rank of concentration of each toxic in those potable ground water samples known to be contaminated is less than, not significantly different from, or greater than the average concentration in those potable surface water samples which have detectable concentrations of the toxic.

The results indicate that there are no significant differences in the average concentrations of about half the toxics studied (Table 17). There was no difference in the average concentration of toxics between potable ground and surface water samples for 24 toxics (47 percent) at the 0.05 significance level, and 30 toxics (59 percent) at the 0.01 significance level. For those toxics in which the average concentration is greater in the potable ground or surface water samples, approximately twice as many toxics had the average concentration greater in potable ground water samples. At the 0.05 significance level 18 toxics (35 percent) had greater average concentrations in potable ground water samples. At the 0.01 significance level 14 toxics (27 percent) had greater average concentrations in potable ground water samples. The average concentration of toxics was found to be greater in potable surface water samples for 9 toxics (18 percent) at the 0.05 significance level, and 6 toxics (12 percent) at the 0.01 significance level.

In conclusion, with respect to potable water the overwhelming majority of toxics have an average concentration at least as great in ground water in New Jersey as in surface water. At the 0.01 significance level there is no difference in the average concentration for 30 toxics and a greater average concentration in potable ground water

TABLE 17. MANN-WHITNEY U TEST OF DETECTABLE POTABLE GROUND VS POTABLE SURFACE SAMPLES

	Greater at Significance Level		
	0.05	0.01	2-Tailed Probability
fluoroform	No dif.	No dif.	0.50
methyl chloride	No dif.	No dif.	0.12
vinyl chloride	No dif.	No dif.	0.35
methylene chloride	No dif.	No dif.	0.92
chloroform	No dif.	No dif.	0.20
1,2-dichloroethane	SUF	SUF	0.001
1,1,1-trichloroethane	GRN	No dif.	0.025
carbon tetrachloride	GRN	No dif.	0.04
1,1,2-trichloroethylene	GRN	No dif.	0.02
dichlorobromoethane	GRN	GRN	0.003
1,1,2-trichloroethane	No dif.	No dif.	0.29
dibromochloromethane	No dif.	No dif.	0.71
1,2-dibromoethane	No dif.	No dif.	0.09
1,1,2,2-tetrachloroethylene	No dif.	No dif.	0.14
bromoform	No dif.	No dif.	0.43
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.18
diiodomethane	No dif.	No dif.	0.62
total dichlorobenzene	GRN	No dif.	0.03
m-dichlorobenzene	No dif.	No dif.	0.07
p-dichlorobenzene	GRN	GRN	0.001
o-dichlorobenzene	No dif.	No dif.	0.36
trichlorobenzene	GRN	GRN	0.001
archlor 1242	No dif.	No dif.	0.12
archlor 1248	SUF	No dif.	0.02
archlor 1254	No dif.	No dif.	0.66
dichloroethylene (gem)	No dif.	No dif.	0.06

TABLE 17. MANN-WHITNEY U TEST OF DETECTABLE POTABLE GROUND VS POTABLE SURFACE SAMPLES (Continued)

	Greater at Significance Level		
	0.05	0.01	2-Tailed Probability
dibromomethane	No dif.	No dif.	0.26
t-dichloroethylene	SUF	SUF	0.005
bromodichloroethane	SUF	No dif.	0.03
BHC-Alpha	GRN	GRN	0.009
lindane	SUF	SUF	0.006
BHC-Beta	SUF	SUF	<0.0001
heptachlor	SUF	SUF	<0.0001
aldrin	No dif.	No dif.	0.38
heptachor epoxide	No dif.	No dif.	0.18
chlordane	No dif.	No dif.	0.39
o,p^{1}-DDE	GRN	GRN	0.0009
dieldrin	GRN	GRN	0.006
endrin	GRN	GRN	0.005
o,p^{1}-DDT	GRN	GRN	0.002
p,p^{1}-DDD	GRN	GRN	0.001
p,p^{1}-DDT	GRN	GRN	0.0002
mirex			
arsenic	SUF	SUF	0.007
beryllium	No dif.	No dif.	0.41
cadmium	No dif.	No dif.	0.14
copper	GRN	GRN	<0.0001
chromium	No dif.	No dif.	0.11
nickel	GRN	GRN	0.006
lead	SUF	SUF	<0.0001
selenium	GRN	GRN	0.004
zinc	GRN	GRN	0.0002

samples for 14 toxics. The total (44 toxics) is 86 percent of the toxic substances included in this analysis.

Summary of Comparisons of Toxics in Potable Ground and Surface Water

Analysis of the concentrations of toxic substances in the potable ground waters and potable surface waters of New Jersey reveals that the levels of toxics in potable ground waters are at least as contaminated as those in potable surface waters for between 67 percent and 86 percent of the toxics studied depending on the method of comparison. Comparing only the highest concentration of each toxic, 78 percent of the toxics are more contaminated in ground water. Comparing the probabilities of detection, 67 percent of the toxics have no significant difference or have a greater probability of detection in ground water. Comparing only those samples with detectable concentrations, 86 percent of the toxics are not significantly different or are more contaminated in potable ground water than in potable surface water.

Because of the complexity of the tables presented during the comparison of toxics in potable ground and potable surface water, a selected summary of Tables 15-17 is presented as Table 18. Section A presents information on the 2 toxics which have a significantly greater probability of detection in potable ground water than in potable surface water samples. Section B provides

TABLE 18. SUMMARY OF COMPARISONS OF TOXICS IN POTABLE GROUND AND POTABLE SURFACE WATER DATA IN NEW JERSEY

A. Toxics with Significantly Greater Probability of Being Detected in Potable Ground Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in [1]
1. diiodomethane	GRN	No dif.
2. aldrin	SUF	No dif.

B. Toxics with Significantly Greater Probability of Being Detected in Potable Surface Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in
1. methylene chloride	GRN	No dif.
2. carbon tetrachloride	GRN	GRN
3. dichlorobromomethane	GRN	GRN
4. 1,1,2-trichloroethane	GRN	No dif.
5. dibromochloromethane	SUF	No dif.
6. 1,1,2,2-tetrachloroethylene	GRN	No dif.
7. 1,1,2,2-tetrachloroethane	GRN	No dif.
8. archlor 1248	SUF	SUF
9. archlor 1254	SUF	No dif.
10. BHC-Alpha	GRN	GRN
11. BHC-Beta	GRN	SUF
12. heptachlor epoxide	GRN	No dif.
13. chlordane	SUF	No dif.
14. o,p^1-DDE	GRN	GRN
15. dieldrin	GRN	GRN
16. p,p^1-DDD	GRN	GRN
17. p,p^1-DDT	GRN	GRN

[1] Significant at the 0.05 level using Mann-Whitney U Test.

TABLE 18. SUMMARY OF COMPARISONS OF TOXICS IN POTABLE GROUND AND POTABLE SURFACE WATER DATA IN NEW JERSEY

C. Toxics Without Significantly Greater Probability of Detection in Ground Water or Surface Water

Toxic Substance	Highest Conc. Found in	Average Detectable Conc. Higher in
1. fluoroform	GRN	No dif.
2. methyl chloride	GRN	No dif.
3. vinyl chloride	SUF	No dif.
4. chloroform	SUF	No dif.
5. 1,2-dichloroethane	SUF	SUF
6. 1,1,1-trichloroethane	GRN	GRN
7. 1,1,2-trichloroethylene	GRN	GRN
8. 1,2-dibromoethane	GRN	No dif.
9. bromoform	GRN	No dif.
10. total dichlorobenzene	GRN	GRN
11. m-dichlorobenzene	GRN	No dif.
12. p-dichlorobenzene	GRN	GRN
13. o-dichlorobenzene	GRN	No dif.
14. trichlorobenzene	GRN	GRN
15. archlor 1242	SUF	No dif.
16. dichloroethylene (Gem)	GRN	No dif.
17. dibromomethane	GRN	No dif.
18. t-dichloroethylene	SUF	SUF
19. bromodichloroethane	SUF	SUF
20. lindane	GRN	SUF
21. heptachlor	SUF	SUF
22. endrin	GRN	GRN
23. o,p^1-DDT	GRN	GRN
24. arsenic	GRN	SUF
25. beryllium	GRN	No dif.
26. cadmium	GRN	No dif.
27. copper	GRN	GRN
28. chromium	GRN	No dif.
29. nickel	GRN	GRN
30. lead	GRN	SUF
31. selenium	GRN	GRN
32. zinc	GRN	GRN

information on those toxics with a greater probability of detection in potable surface water. Even among these substances, 76 percent had their highest concentration detected in potable ground water samples.

Those toxics without significantly greater probability of detection in either potable ground water or potable surface water are reviewed in Section C of Table C12. These substances represent 63 percent of the toxics included in this analysis. The highest concentration was found in potable ground water samples for 78 percent of these toxics. When the average rank of concentrations of each toxic were compared in only those samples for which measurable concentrations were found, there was no significant difference for 44 percent of the toxics, the average rank of detectable concentration was greater in potable ground water samples for 34 percent of the toxics, and was greater in potable surface water samples for 22 percent of the 32 toxics.

CHAPTER 6

COMPARISON OF TOXICS IN THE NONPOTABLE GROUND AND SURFACE WATERS OF NEW JERSEY

Introduction

A comparison of toxics concentrations of just those ground and surface water samples collected from nonpotable sources of supply focuses the analysis on those water supplies most likely to be contaminated with toxic substances. Some of the samples included in this analysis are from wells monitoring landfill leachate. Other samples are from surface waters near industrial outfalls. Most of these samples are collected in the urban-industrial corridor of New Jersey. Water from these sources is not generally consumed, but toxics in these sources flow into the estuaries and off-shore waters of New Jersey where they may enter the food web and be significantly biomagnified before being consumed by humans. Many popular food fish are resistant to certain toxics and may tolerate residues sufficient to kill predators several hundred times their own weight (Rosato and Ferguson, 1968). Research has indicated that fathead minnows exposed during their entire life to concentrations of PCB's of less than one part per billion have concentrated the PCB's as much as 200 to 240,000 times in the whole body of the minnow (Mount, 1973). Having made comparisons of toxics in all waters and only potable waters, we now turn to a comparison of toxics in the nonpotable fresh water supplies of New Jersey.

Data Description

A nonpotable sample is one which is collected from water not normally used for human consumption. Uses of ground water characterized as nonpotable include industrial process and cooling, agricultural uses, and monitoring purposes. Nonpotable surface water includes all surface water samples collected downstream from the most downstream potable supply intake facility. The 52 toxic substances with descriptive statistics for both nonpotable ground water and nonpotable surface water data sets are presented in Table 19.

The number of valid sample results available for comparison varies by toxic and between the ground and surface water data sets. For 10 of the 52 toxic substances there are no detectable concentrations in either the ground water, surface water, or both data sets. For this reason, comparisons of the following 10 toxics could not be performed: fluoroform, methyl chloride, vinyl chloride, dichlorobromomethane, p-dichlorobenzene, archlor 1242, archlor 1248, dichloroethylene (gem), dibromomethane and t-dichloroethylene. For the remaining 42 toxics the number

TABLE 19. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE NONPOTABLE GROUND WATER SAMPLES AND NONPOTABLE SURFACE WATER SAMPLES FROM NEW JERSEY

Nonpotable Ground Water

	# Sampled	# Detectable	Mode	Median	90th Percentile	Highest
fluoroform	1	0	0	0	0	0
methyl chloride	96	0	0	0	0	0
vinyl chloride	96	0	0	0	0	0
methylene chloride	96	1	0	0	0	5.5
chloroform	96	66		0.2	4.7	388.9
1,2-dichloroethane	96	7	0	0	0	2,300.0
1,1,1-trichloroethane	96	81	0	1.7	16.5	441.8
carbon tetrachloride	96	68	0	0.1	0.5	4.3
1,1,2-trichloroethylene	14	14	0.3	0.3	19.9	134.2
dichlorobromoethane	1	0	0	0	0	0
1,1,2-trichloroethane	96	14	0	0	0.2	1.3
dibromochloromethane	96	18	0	0	0.1	0.2
1,2-dibromoethane	95	10	0	0	1.6	87.9
1,1,2,2-tetrachloroethylene	95	57	0	<0.1	5.8	57.5
bromoform	96	10	0	0	1.0	34.3
1,1,2,2-tetrachloroethane	96	9	0	0	0	1.4
diiodomethane	96	20	0	0	0.1	0.9
total dichlorobenzene	103	2	0	0	0	3.4
m-dichlorobenzene	14	1	0	0	0	1.2
p-dichlorobenzene	14	0	0	0	0	0
o-dichlorobenzene	14	1	0	0	0	2.2
trichlorobenzene	96	1	0	0	0	2.0
archlor 1242	14	0	0	0	0	0
archlor 1248	14	0	0	0	0	0
archlor 1254	96	2	0	0	0	0.4
dichloroethylene (gem)	0	0	0	0	0	0

TABLE 19. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE NONPOTABLE GROUND WATER SAMPLES AND NONPOTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Nonpotable Ground Water

	# Sampled	# Detectable	Mode	Median	90th Percentile	Highest
dibromomethane	0	0	0	0	0	0
t-dichloroethylene	0	0	0	0	0	0
bromodichloroethane	13	3	0	0	0.3	1.6
BHC-Alpha	98	21	0	0	<0.1	0.3
lindane	98	41	0	0	<0.1	<0.1
BHC-Betal	74	36	0	0	<0.1	0.5
heptachlor	98	33	0	0	<0.1	1.0
aldrin	98	29	0	0	<0.1	1.2
heptachor epoxide	98	25	0	0	<0.1	0.2
chlordane	98	23	0	0	<0.1	<0.1
o,p^{1}-DDE	98	15	0	0	<0.1	0.5
dieldrin	98	14	0	0	<0.1	0.1
endrin	98	11	0	0	<0.1	0.2
o,p^{1}-DDT	98	8	0	0	0	0.5
p,p^{1}-DDD	98	10	0	0	<0.1	0.3
p,p^{1}-DDT	97	5	0	0	0	0.9
mirex	98	12	0	0	<0.1	<0.1
arsenic	95	95	1.0	1.0	6.0	232.0
beryllium	95	95	1.0	1.0	1.0	84.0
cadmium	95	95	1.0	1.0	1.0	405.0
copper	95	95	2.0	4.0	40.0	690.0
chromium	95	95	1.0	3.0	16.0	179.0
nickel	95	95	5.0	5.0	16.0	600.0
lead	95	95	1.0	1.0	20.0	329.0
selenium	94	94	2.0	2.0	2.0	5.0
zinc	95	95	5.0	17.0	384.0	3,345.0

TABLE 19. DESCRIPTIVE INFORM TION ON THE TOXICS IN THE NONPOTABLE GROUND WATER SAMPLES AND NONPOTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Nonpotable Surface Water

	# Sampled	# Detectable	Mode	Median	90th Percentile	Highest
fluoroform	59	0	0	0	0	0
methyl chloride	123	0	0	0	0	0
vinyl chloride	122	0	0	0	0	0
methylene chloride	123	48	0	0	90	743.3
chloroform	122	98	0.8	0.8	3.5	1,965.0
1,2-dichloroethane	122	13	0	0	1.6	35.1
1,1,1-trichloroethane	122	111	2.0	2.0	4.1	17.6
carbon tetrachloride	122	102	0.1	0.1	0.3	8.0
1,1,2-trichloroethylene	67	50	0.3	0.3	0.7	2.2
dichlorobromoethane	59	26	0	0	0.1	0.3
1,1,2-trichloroethane	122	17	0	0	1.0	2.9
dibromochloromethane	122	36	0	0	0.1	2.3
1,2-dibromoethane	63	5	0	0	0	0.2
1,1,2,2-tetrachloroethylene	63	59	0.3	0.3	1.6	4.4
bromoform	119	37	0	0	1.0	1.9
1,1,2,2-tetrachloroethane	121	26	0	0	0.3	0.5
diiodomethane	121	6	0	0	0	3.2
total dichlorobenzene	122	16	0	0	1.3	30.7
m-dichlorobenzene	66	6	0	0	0	5.1
p-dichlorobenzene	66	11	0	0	1.3	30.5
o-dichlorobenzene	66	6	0	0	0	8.2
trichlorobenzene	121	13	0	0	2.0	2.2
archlor 1242	123	3	0	0	0	2.4
archlor 1248	123	26	0	0	0.5	109.1
archlor 1254	123	24	0	0	0.2	106.0
dichloroethylene (gem)	39	21	0	10.0	38.9	68.5

TABLE 19. DESCRIPTIVE INFORMATION ON THE TOXICS IN THE NONPOTABLE GROUND WATER SAMPLES AND NONPOTABLE SURFACE WATER SAMPLES FROM NEW JERSEY (Continued)

Nonpotable Surface Water

	# Sampled	# Detectable	Mode	Median	90th Percentile	Highest
dibromomethane	39	17	0	0	0.1	0.7
t-dichloroethylene	39	31	10.0	10.0	286.6	1,208.6
bromodichloroethane	8	1	0	0	0.1	0.1
BHC-Alpha	119	30	0	0	<0.1	<0.1
lindane	119	30	0	0	<0.1	0.2
BHC-Betal	119	73	0	<0.1	0.2	3.1
heptachlor	119	15	0	0	<0.1	5.9
aldrin	119	8	0	0	0	<0.1
heptachor epoxide	119	41	0	0	<0.1	0.2
chlordane	119	54	0	0	<0.1	0.8
o,p^1-DDE	119	34	0	0	<0.1	<0.1
dieldrin	119	39	0	0	<0.1	<0.1
endrin	119	17	0	0	<0.1	0.1
o,p^1-DDT	119	16	0	0	<0.1	<0.1
p,p^1-DDD	119	28	0	0	<0.1	<0.1
p,p^1-DDT	119	17	0	0	<0.1	<0.1
mirex	119	8	0	0	0	<0.1
arsenic	118	118	1.0	2.0	6.0	392.0
beryllium	118	118	1.0	1.0	1.0	1.0
cadmium	118	118	1.0	1.0	1.0	6.0
copper	118	118	1.0	2.0	8.0	76.0
chromium	118	117	1.0	2.0	6.0	216.0
nickel	118	118	5.0	5.0	9.0	36.0
lead	118	118	1.0	6.0	26.0	75.0
selenium	118	118	2.0	2.0	2.0	2.0
zinc	118	118	5.0	16.0	49.0	420.0

of samples varies in ground water from 13 to 103 and in surface water from 8 to 123. In general, there are more samples of nonpotable surface water for any toxic than there are samples of nonpotable ground water.

The mode, median, and 90th percentile concentrations provide some indication of the severely right skewed frequency distributions of the toxic substances in both the ground and surface water data sets. The toxics in nonpotable water samples have skewed distributions comparable to those in all water samples and potable water samples. The greatest difference in the toxics from nonpotable samples is found in the light chlorinated hydrocarbons where the mode, median and 90th percentile concentrations are often greater in the surface water samples than in the ground water data. Even with the greater mode, median and 90th percentile concentrations among the toxics from nonpotable water samples, the basic shape of the severely right skewed frequency distributions of these toxics remains.

The highest concentration for the majority of toxic substances was detected in the nonpotable ground water samples. For 23 toxics (55 percent) the highest concentration was in the nonpotable ground water data, for 2 toxics (5 percent) the highest concentration was not significantly different, and for 17 toxics (40 percent) the highest concentration was found in the nonpotable surface water data. The highest concentration in 11 toxics was one or more orders of magnitude greater, and for one toxic two orders of magnitude greater, in the nonpotable ground water data than in the nonpotable surface water data. The highest concentration in three toxics was one or more orders of magnitude greater, and for two toxics it was two orders of magnitude greater in the nonpotable surface water data than in the nonpotable ground water data. The finding that for the majority of toxics the highest concentration was found in ground water corresponds to the results of the analysis of highest concentrations in all ground and surface water samples and only potable samples. However, the proportion of toxics for which the highest concentration was found in surface water increased from 25 percent for all samples, 23 percent for only potable samples, to 40 percent for only nonpotable water samples.

Probabilities of Detection of Toxics in Nonpotable Ground and Nonpotable Surface Water

The second comparison of toxic substances in nonpotable ground and surface water in New Jersey involves the likelihood of toxics being present within the limits of our ability to detect them in the nonpotable waters of the state. The probability of detecting each toxic substance in nonpotable water samples from both ground and surface water is presented in Table 20. The chi square

TABLE 20. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY NONPOTABLE GROUND AND SURFACE WATER

	Ground	Surface	Significant Difference At 0.05 Level
fluoroform			
methyl chloride			
vinyl chloride			
methylene chloride	.01	.39	Yes
chloroform	.69	.80	No
1,2-dichloroethane	.07	.11	No
1,1,1-trichloroethane	.84	.91	No
carbon tetrachloride	.71	.84	Yes
1,1,2-trichloroethylene	1.00	.75	No
dichlorobromoethane		.44	
1,1,2-trichloroethane	.15	.14	No
dibromochloromethane	.19	.30	No
1,2-dibromoethane	.11	.08	No
1,1,2,2-tetrachloroethylene	.60	.94	Yes
bromoform	.10	.31	Yes
1,1,2,2-tetrachloroethane	.09	.21	Yes
diiodomethane	.21	.05	Yes
total dichlorobenzene	.02	.13	Yes
m-dichlorobenzene	.07	.09	No
p-dichlorobenzene		.17	
o-dichlorobenzene	.07	.09	No
trichlorobenzene	.01	.11	Yes
archlor 1242		.02	
archlor 1248		.21	
archlor 1254	.02	.20	Yes
dichloroethylene (gem)		.54	

TABLE 20. PROBABILITIES OF DETECTING TOXICS IN NEW JERSEY NONPOTABLE GROUND AND SURFACE WATER (Continued)

	Ground	Surface	Significant Difference At 0.05 Level
dibromomethane		.44	
t-dichloroethylene		.79	
bromodichloroethane	.23	.13	No
BHC-Alpha	.21	.25	No
lindane	.42	.25	Yes
BHC-Betal	.49	.61	No
heptachlor	.34	.13	Yes
aldrin	.30	.07	Yes
heptachor epoxide	.26	.34	No
chlordane	.23	.45	Yes
o,p^1-DDE	.15	.29	Yes
dieldrin	.14	.33	Yes
endrin	.11	.14	No
o,p^1-DDT	.08	.14	No
p,p^1-DDD	.10	.24	Yes
p,p^1-DDT	.05	.14	Yes
mirex	.12	.07	No
arsenic	1.00	1.00	All Detectable
beryllium	1.00	1.00	All Detectable
cadmium	1.00	1.00	All Detectable
copper	1.00	1.00	All Detectable
chromium	1.00	.99	No
nickel	1.00	1.00	All Detectable
lead	1.00	1.00	All Detectable
selenium	1.00	1.00	All Detectable
zinc	1.00	1.00	All Detectable

test was used to test if the probability of detecting each toxic in nonpotable ground water was different from the probability of detecting each toxic in nonpotable surface water at the 0.05 significance level.

There is considerable variation in the probabilities of detection among the 42 toxic substances and between nonpotable ground water data and nonpotable surface water data. These probabilities are presented in Table 20. Some of these probabilities were calculated from small numbers of samples and should be considered questionable estimates of the true probabilities. For instance 1,1,2-trichloroethylene was detected in all 14 nonpotable ground water samples which were analysed for this substance. The probability of detection of 1,1,2-trichloroethylene in nonpotable ground water should not be considered with the same degree of confidence as the heavy metals which had the same probability, but were based on either 95 or 118 samples.

The results of the chi square test indicate that for the majority of toxics there is no significant difference in the probability of detection between nonpotable ground water samples and nonpotable surface water samples. For 25 of the toxics (59 percent) there is no significant difference in the probability of detection in nonpotable water samples from ground and surface water. All of the heavy metals and some of both the light and heavy chlorinated hydrocarbons fall in this category.

Most of the toxic substances which have significantly greater probabilities of detection in ground or surface water, have a greater probability of detection in nonpotable surface water samples than in nonpotable ground water samples. Thirteen toxic substances out of the 42 toxics included in this analysis (31 percent) have a significantly greater probability of detection in nonpotable surface water. Only 4 toxics (10 percent) have a significantly greater probability of detection in nonpotable ground water samples.

The analysis of probabilities of detection indicates that about two-thirds of the toxic substances are at least as likely to be detected in nonpotable ground water as in nonpotable surface water. These toxics include the 25 with no significant difference and the 4 with a significantly greater probability of detection in nonpotable ground water for a total of 29 toxics (69 percent). This result is consistent with the results of the earlier analyses. Toxics were at least as likely to be detected in ground water as in surface water samples in 60 percent of all ground and surface water samples, 67 percent of only potable samples, and 69 percent of only nonpotable samples.

Comparison of Detectable Toxics in Nonpotable Ground Water and Nonpotable Surface Water

The third comparison was for those samples with detectable concentrations. The analysis uses the Mann-Whitney U test to determine if the average concentration of each toxic in those nonpotable ground water samples with detectable levels of the toxic substance being tested, is less than, not significantly different from or greater than the average rank of concentration in those nonpotable surface water samples with detectable levels of the toxic.

The results indicate that there are no significant differences in the average rank of concentrations between nonpotable water samples from ground and surface water for 28 toxics (67 percent) at the 0.05 significance level and 36 toxics (86 percent) at the 0.01 significance level (Table 21). Among those toxics with greater average rank of detectable concentrations in one of the data sets, the number of toxics is approximately equal among those greater in nonpotable ground water and those greater in nonpotable surface water. At the 0.05 significance level 9 toxics (21 percent) had greater average concentrations in nonpotable ground water samples. At the 0.01 significance level 3 toxics (7 percent) had greater average concentrations in nonpotable ground water samples. The average concentration of toxics was found to be greater in nonpotable surface water samples for 5 toxics (12 percent) at the 0.05 significance level and 3 toxics (7 percent) at the 0.01 significance level.

TABLE 21. MANN-WHITNEY U TEST OF DETECTABLE NONPOTABLE GROUND AND SURFACE WATER SAMPLES

	Greater at Significance Level 0.05	0.01	2-Tailed Prob.
fluoroform			
methyl chloride			
vinyl chloride			
methylene chloride	No dif.	No dif.	0.74
chloroform	No dif.	No dif.	0.59
1,2-dichloroethane	No dif.	No dif.	0.55
1,1,1-trichloroethane	GRN	No dif.	0.012
carbon tetrachloride	No dif.	No dif.	0.85
1,1,2-trichloroethylene	No dif.	No dif.	0.09
dichlorobromoethane			
1,1,2-trichloroethane	No dif.	No dif.	0.07
dibromochloromethane	SUF	No dif.	0.02
1,2-dibromoethane	No dif.	No dif.	0.80
1,1,2,2-tetrachloroethylene	No dif.	No dif.	0.68
bromoform	No dif.	No dif.	0.30
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.06
diiodomethane	SUF	No dif.	0.04
total dichlorobenzene	No dif.	No dif.	0.20
m-dichlorobenzene	No dif.	No dif.	0.53
p-dichlorobenzene			
o-dichlorobenzene	No dif.	No dif.	0.53
trichlorobenzene	No dif.	No dif.	0.78
archlor 1242			
archlor 1248			
archlor 1254	No dif.	No dif.	0.85
dichloroethylene (gem)			

TABLE 21. MANN-WHITNEY U TEST OF DETECTABLE NONPOTABLE GROUND AND SURFACE WATER SAMPLES (Continued)

	Greater at Significance Level 0.05	0.01	2-Tailed Prob.
dibromomethane			
t-dichloroethylene			
bromodichloroethane	No dif.	No dif.	0.35
BHC-Alpha	No dif.	No dif.	0.11
lindane	No dif.	No dif.	0.25
BHC-Beta	SUF	SUF	<0.0001
heptachlor	SUF	SUF	0.002
aldrin	No dif.	No dif.	0.10
heptachor epoxide	No dif.	No dif.	0.13
chlordane	No dif.	No dif.	0.84
o,p^1-DDE	No dif.	No dif.	0.30
dieldrin	GRN	No dif.	0.045
endrin	No dif.	No dif.	0.45
o,p^1-DDT	GRN	No dif.	0.041
p,p^1-DDD	GRN	GRN	0.003
p,p^1-DDT	GRN	GRN	0.0004
mirex	No dif.	No dif.	0.80
arsenic	No dif.	No dif.	0.053
beryllium	No dif.	No dif.	0.052
cadmium	GRN	No dif.	0.042
copper	GRN	No dif.	0.016
chromium	GRN	No dif.	0.045
nickel	No dif.	No dif.	0.53
lead	SUF	SUF	<0.0001
selenium	GRN	GRN	0.001
zinc	No dif.	No dif.	0.31

Examining only those samples of nonpotable ground and nonpotable surface water which have detectable concentrations of a given toxic, the average concentration is at least as great in nonpotable ground water samples as in nonpotable surface water samples for the overwhelming majority of the toxics studied. At the 0.01 significance level 36 toxics had no significant difference and 3 toxics were greater in ground water. These total to 39 toxics out of the 42 toxics (93 percent) included in this analysis.

Summary of Comparisons of Toxics Concentrations in the Nonpotable Ground and Surface Waters of New Jersey

Analysis of the concentrations of toxic substances in the nonpotable ground and surface waters of New Jersey reveals that the levels of toxics in nonpotable ground water are not significantly different or are more contaminated than nonpotable surface water for between 60 percent and 93 percent of the toxics studied depending on the method of comparison. Looking only at the highest concentration of each toxic, 60 percent of the toxics are more contaminated in nonpotable ground water. Comparing the probabilities of detection, 69 percent of the toxics have no significant difference or have a greater probability of detection in nonpotable ground water. Comparing only those samples with detectable concentrations, 93 percent of the toxics are not significantly different or are more contaminated in nonpotable ground water than in nonpotable surface water.

Because of the complexity of the tables presented during the comparison of toxics in nonpotable ground water and nonpotable surface water, a selected summary of Tables 19-21 is presented as Table 22. Section A presents information on the 4 toxics which have a significantly greater probability of detection in nonpotable ground water than in nonpotable surface water samples. Section B provides information on those toxics with a greater probability of detection in nonpotable surface water. Even among these substances, 54 percent had their highest concentration detected in nonpotable ground water samples. When samples with nondetectable concentrations were eliminated from the analysis, 77 percent of these 13 toxics showed no significant difference and 33 percent had their average concentration greater in the nonpotable ground water samples.

Those toxics without significantly greater probability of detection in either nonpotable ground water or nonpotable surface water are reviewed in Section C of Table 22. These substances represent 60 percent of the toxics included in this analysis. The highest concentration was found in nonpotable ground water samples for 60 percent, and in nonpotable surface water samples for 32 percent of these toxics. When the average concentrations of each

TABLE 22. SUMMARY OF COMPARISONS OF TOXICS IN NONPOTABLE GROUND AND NONPOTABLE SURFACE WATER IN NEW JERSEY

A. Toxics with Significantly Greater Probability of Detection in Nonpotable Ground Water

Toxic Substance	Highest Conc. Found In	Average Detectable Conc. Higher In[1]
1. diiodomethane	SUF	SUF
2. lindane	SUF	No dif.
3. heptachlor	SUF	SUF
4. aldrin	GRN	No dif.

B. Toxics with Significantly Greater Probability of Detection in Nonpotable Surface Water

Toxic Substance	Highest Conc. Found In	Average Detectable Conc. Higher In
1. methylene chloride	SUF	No dif.
2. carbon tetrachloride	SUF	No dif.
3. 1,1,2,2-tetrachloroethylene	GRN	No dif.
4. bromoform	GRN	No dif.
5. 1,1,2,2-tetrachloroethane	GRN	No dif.
6. total dichlorobenzene	SUF	No dif.
7. trichlorobenzene	SUF	No dif.
8. archlor 1254	SUF	No dif.
9. chlordane	SUF	No dif.
10. o,p^1-DDE	GRN	No dif.
11. dieldrin	GRN	GRN
12. p,p^1-DDD	GRN	GRN
13. p,p^1-DDT	GRN	GRN

[1] Mann-Whitney U test at 0.05 significance level

TABLE 22. SUMMARY OF COMPARISONS OF TOXICS IN NONPOTABLE GROUND AND NONPOTABLE SURFACE WATER IN NEW JERSEY (Continued)

C. Toxics Without Significantly Greater Probability of Detection in Nonpotable Ground or Surface Water

Toxic Substance	Highest Conc. Found In	Average Detectable Conc. Highest In[1]
1. chloroform	SUF	No dif.
2. 1,2-dichloroethane	GRN	No dif.
3. 1,1,1-trichloroethane	GRN	GRN
4. 1,1,2-trichloroethylene	GRN	No dif.
5. 1,1,2-trichloroethyne	SUF	No dif.
6. dibromochloromethane	SUF	SUF
7. 1,2-dibromoethane	GRN	No dif.
8. m-dichlorobenzene	SUF	No dif.
9. o-divhlorobenzene	SUF	No dif.
10. bromodichloroethane	GRN	No dif.
11. BHC-Alpha	GRN	No dif.
12. BHC-Beta	SUF	SUF
13. heptachlor epoxide	BOTH	No dif.
14. endrin	GRN	No dif.
15. o,p^1-DDT	GRN	GRN
16. mirex	BOTH	No dif.
17. arsenic	SUF	No dif.
18. beryllium	GRN	No dif.
19. cadmium	GRN	GRN
20. copper	GRN	GRN
21. chromium	SUF	GRN
22. nickel	GRN	No dif.
23. lead	GRN	SUF
24. selenium	GRN	GRN
25. zinc	GRN	No dif.

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[1] Mann-Whitney U test at 0.05 significance level

toxic were compared in only those samples in which measurable concentrations were found, the average concentration was not significantly different or was greater in nonpotable ground water for 88 percent of these toxic substances.

CHAPTER 7

COMPARISON OF TOXICS CONTAMINATION IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY

Introduction

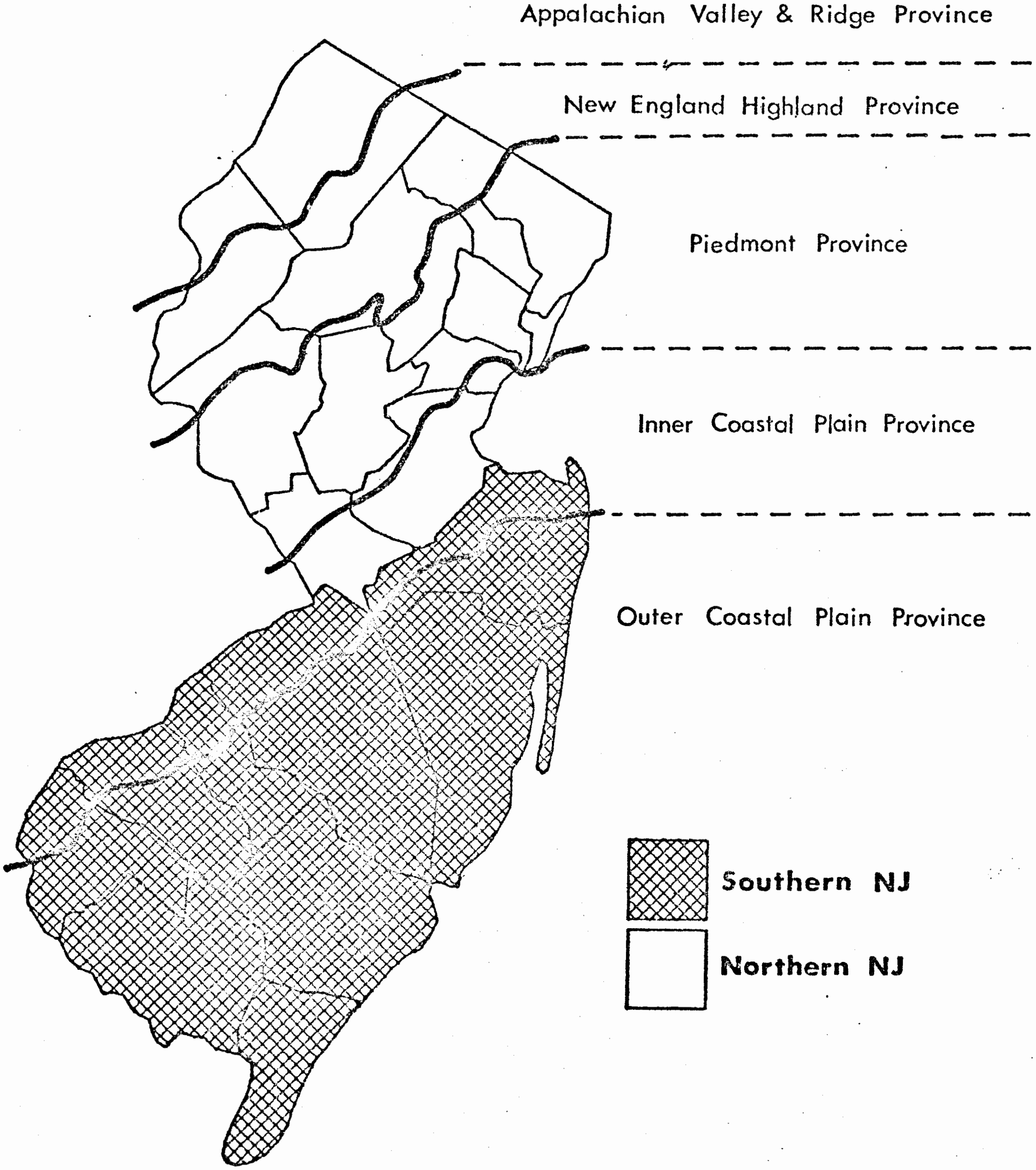
Assuming that anthropogenic development patterns were the same, differences in the rocks, soils, and topography among the physiographic provinces of New Jersey may lead to different levels and patterns of toxics contamination. The five physiographic provinces of New Jersey are in order from northwest to southeast the Appalachian Valley and Ridge Province, the New England Highlands Province, the Piedmont Province, the Inner Coastal Plain Province, and the Outer Coastal Plain Province.

Presently, the locations of the sample sites from which the 1012 ground and surface water samples in New Jersey were collected are not precise enough to permit division into the five physiographic provinces. The information is being collected.

A rough approximation of Northern New Jersey from Southern New Jersey does divide the state on the basis of the most distinctive physiographic characteristics in the state (see Figure 1). Southern New Jersey approximates the Inner Coastal Plain Province and Outer Coastal Plain

FIGURE !.

NORTHERN AND SOUTHERN NEW JERSEY REGIONS



Province. These two physiographic provinces have much in common and are distinctively different from the three physiographic provinces in Northern New Jersey.

The coastal plain, located in Southern New Jersey, occupies three-fifths of the land area of New Jersey and is the home of approximately one fourth the state's population (Widmer, 1964). The area included in Southern New Jersey in this analysis (Figure A) approximates the coastal plain reasonably well. County boundary lines were used to divide Southern from Northern New Jersey. Parts of Mercer, Middlesex, and Union Counties are actually included in the Coastal Plain but are included with the rest of the non-coastal plain portion of the state in Northern New Jersey for this analysis.

The Coastal Plain of New Jersey is an appropriate physiographic region to study contamination of ground water. There are several very important aquifers which underlay most of the coastal plain. The entire Coastal Plain rests on Precambrian rock which slopes to the ocean at a rate of 80 to 100 feet per mile. On top of this bedrock are from 14 to 24 formations of unconsolidated clays, sands, marls and gravels deposited as sediments during the Cretaceous period 140-170 million years ago (Widmer, 1964). While there is considerable spatial variation within these formations, several of these formations such as the Raritan, Cohansey, Magothy and Kirkwood are very important aquifers throughout most of Southern New Jersey.

In summary, Southern New Jersey offers an excellent physiographic region, the Coastal Plain, in which to isolate a comparison of toxics contamination of ground and surface water. It is a large area with great diversity of human activity, but with a very limited range of soil characteristics and many uniformities in the ground water aquifers.

Data Description

The number of valid sample results available for comparison varies by toxic and between the ground and surface water data sets. The number of samples varies in the ground water data from 29 to 318 and in the surface water data from 22 to 129. Information on the toxics in the ground and surface waters of Southern New Jersey is presented in Table 23.

The mode, median, and 90th percentile concentrations provide some indication of the severely right skewed frequency distributions of the toxic substances in both the ground and surface water data sets. The skewed distributions of toxics in the waters of the Southern New Jersey Coastal Plain are comparable to those found in the ground and surface water data from the entire state.

The highest concentration for the majority of toxic substances was detected in the ground water data from Southern New Jersey. For 35 toxics (67 percent) the highest concentration was in the ground water data, and for

TABLE 23. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY[1]

	Ground Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	62	7	0	0	0.5	159.2
methyl chloride	287	1	0	0	0	163.8
vinyl chloride	287	1	0	0	0	2.5
methylene chloride	287	33	0	0	90	1,900.0
chloroform	291	214	0.8	0.8	1.0	552.8
1,2-dichloroethane	288	20	0	0	0	120.4
1,1,1-trichloroethane	291	249	2.0	2.0	10.3	78.9
carbon tetrachloride	290	219	0.1	0.1	0.5	150.2
1,1,2-trichloroethylene	94	66	0.3	0.3	0.7	313.4
dichlorobromoethane	66	22	0	0	0.1	604.5
1,1,2-trichloroethane	291	10	0	0	0	5.9
dibromochloromethane	291	29	0	0	0	0.2
1,2-dibromoethane	225	9	0	0	0	0.6
1,1,2,2-tetrachloroethylene	225	86	0	0	0.9	57.5
bromoform	291	53	0	0	1.0	6.4
1,1,2,2-tetrachloroethane	291	14	0	0	0	1.2
diiodomethane	291	32	0	0	0.3	2.0
total dichlorobenzene	318	12	0	0	0	20.1
m-dichlorobenzene	94	2	0	0	0	1.3
p-dichlorobenzene	94	6	0	0	0	8.6
o-dichlorobenzene	94	5	0	0	0	3.1
trichlorobenzene	289	10	0	0	0	5.4
archlor 1242	95	0	0	0	0	0
archlor 1248	95	2	0	0	0	0.2
archlor 1254	292	5	0	0	0	0.2
dichloroethylene (gem)	29	14	0	0	96.2	1,280.2

[1] All concentrations in parts per billion (ppb).

TABLE 23. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY[1] (Continued)

	Ground Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	29	10	0	0	0.1	33.5
t-dichloroethylene	29	23	10.0	10.0	90.7	549.3
bromodichloroethane	28	2	0	0	0	1.0
BHC-Alpha	293	54	0	0	<0.1	0.8
lindane	293	84	0	0	<0.1	0.9
BHC-Beta	212	76	0	0	<0.1	5.4
heptachlor	293	94	0	0	<0.1	0.6
aldrin	293	81	0	0	<0.1	0.4
heptachor epoxide	293	81	0	0	<0.1	0.6
chlordane	293	96	0	0	<0.1	0.3
o,p^1-DDE	293	69	0	0	<0.1	1.0
dieldrin	293	49	0	0	<0.1	0.9
endrin	293	40	0	0	<0.1	0.6
o,p^1-DDT	293	46	0	0	<0.1	3.7
p,p^1-DDD	293	49	0	0	<0.1	1.8
p,p^1-DDT	291	38	0	0	<0.1	5.0
mirex	293	23	0	0	0	0.4
arsenic	279	278	1.0	1.0	2.0	1,160.0
beryllium	279	279	1.0	1.0	1.0	84.0
cadmium	274	274	1.0	1.0	1.0	405.0
copper	274	271	1.0	5.0	47.0	690.0
chromium	274	274	1.0	1.0	4.0	179.0
nickel	273	273	2.5	5.0	19.0	600.0
lead	274	272	1.0	1.0	8.0	329.0
selenium	274	274	2.0	2.0	2.0	8.0
zinc	274	274	5.0	15.0	179.0	3,345.0

TABLE 23. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY[1] (Continued)

	Surface Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	66	2	0	0	0	0.5
methyl chloride	127	2	0	0	0	6.0
vinyl chloride	128	2	0	0	0	5.9
methylene chloride	127	55	0	0	90	743.3
chloroform	128	85	0.8	0.8	2.8	1,965.0
1,2-dichloroethane	128	25	0	0	13.0	304.9
1,1,1-trichloroethane	128	100	2.0	2.0	2.0	13.2
carbon tetrachloride	128	102	0.1	0.1	0.5	6.6
1,1,2-trichloroethylene	88	54	0.3	0.3	0.6	1.4
dichlorobromoethane	66	26	0	0	0.1	0.1
1,1,2-trichloroethane	128	19	0	0	1.0	4.4
dibromochloromethane	128	18	0	0	0.1	8.2
1,2-dibromoethane	62	3	0	0	0	0.2
1,1,2,2-tetrachloroethylene	61	51	0.3	0.3	0.5	4.4
bromoform	125	37	0	0	1.0	1.9
1,1,2,2-tetrachloroethane	127	29	0	0	0.2	0.5
diiodomethane	127	6	0	0	0	3.2
total dichlorobenzene	129	16	0	0	1.3	30.7
m-dichlorobenzene	87	6	0	0	0	5.1
p-dichlorobenzene	87	11	0	0	1.3	30.5
o-dichlorobenzene	87	5	0	0	0	8.2
trichlorobenzene	127	12	0	0	0	2.2
archlor 1242	129	2	0	0	0	0.3
archlor 1248	129	5	0	0	0	4.9
archlor 1254	129	4	0	0	0	0.4
dichloroethylene (gem)	40	18	0	0	36.2	68.5

TABLE 23. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY[1] (Continued)

	Surface Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	40	18	0	0	0.1	0.7
t-dichloroethylene	40	29	10.0	10.0	244.5	1,208.6
bromodichloroethane	22	1	0	0	0	4.7
BHC-Alpha	127	42	0	0	<0.1	<0.1
lindane	127	48	0	0	<0.1	0.8
BHC-Beta	127	98	0	<0.1	0.2	3.1
heptachlor	127	31	0	0	<0.1	5.9
aldrin	127	13	0	0	<0.1	0.6
heptachor epoxide	127	59	0	0	<0.1	0.5
chlordane	126	73	0	<0.1	<0.1	0.8
o,p^1-DDE	127	45	0	0	<0.1	<0.1
dieldrin	127	60	0	0	<0.1	<0.1
endrin	127	21	0	0	<0.1	<0.1
o,p^1-DDT	127	22	0	0	<0.1	<0.1
p,p^1-DDD	127	37	0	0	<0.1	<0.1
p,p^1-DDT	127	24	0	0	<0.1	<0.1
mirex	127	9	0	0	0	<0.1
arsenic	111	111	1.0	1.0	6.0	392.0
beryllium	111	111	1.0	1.0	1.0	1.0
cadmium	111	111	1.0	1.0	1.0	1.0
copper	111	111	1.0	2.0	6.0	76.0
chromium	111	111	1.0	2.0	4.0	12.0
nickel	111	111	2.5	2.5	9.0	36.0
lead	111	111	1.0	4.0	16.0	75.0
selenium	111	111	2.0	2.0	2.0	2.0
zinc	111	111	5.0	16.0	46.0	134.0

17 toxics (33 percent) the highest concentration was found in the surface water of Southern New Jersey. The highest concentration in 16 toxics was one or more orders of magnitude greater, for 6 toxics two or more orders of magnitude, and for one toxic three orders of magnitude greater in the ground water data than in the surface water data. For 2 toxics the highest concentration is one order of magnitude greater in surface water than in ground water from Southern New Jersey.

Probabilities of Detection of Toxics in the Ground and Surface Waters of Southern New Jersey

The second comparison of toxic substances in the ground and surface waters of Southern New Jersey involves the likelihood of toxics being present in water samples. The probability of a toxic being detected is limited by our technological ability, but is the same for both ground and surface water samples. The probability of detecting each toxic substance in the samples from ground and surface water from Southern New Jersey is presented in Table 24. The chi square test was used to determine if the probability of detecting each toxic in ground water was different from the probability of detecting each toxic in surface water at the 0.05 significance level.

There is considerable variation in the probabilities of detection among the 52 toxic substances and between the ground and surface water data. Since there were no

TABLE 24. PROBABILITIES OF DETECTION OF TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY

	Ground	Surface	Significant Difference At 0.05 Level
fluoroform	0.11	0.03	No
methyl chloride	<0.01	0.02	No
vinyl chloride	<0.01	0.02	No
methylene chloride	0.11	0.43	Yes
chloroform	0.74	0.66	No
1,2-dichloroethane	0.07	0.20	Yes
1,1,1-trichloroethane	0.86	0.80	No
carbon tetrachloride	0.76	0.80	No
1,1,2-trichloroethylene	0.70	0.61	No
dichlorobromoethane	0.33	0.39	No
1,1,2-trichloroethane	0.03	0.15	Yes
dibromochloromethane	0.10	0.14	No
1,2-dibromoethane	0.04	0.05	No
1,1,2,2-tetrachloroethylene	0.38	0.84	Yes
bromoform	0.18	0.30	Yes
1,1,2,2-tetrachloroethane	0.05	0.23	Yes
diiodomethane	0.11	0.05	No
total dichlorobenzene	0.04	0.12	Yes
m-dichlorobenzene	0.02	0.07	No
p-dichlorobenzene	0.06	0.13	No
o-dichlorobenzene	0.05	0.06	No
trichlorobenzene	0.03	0.09	Yes
archlor 1242	0	0.02	
archlor 1248	0.02	0.04	No
archlor 1254	0.02	0.03	No
dichloroethylene (gem)	0.48	0.45	No

TABLE 24. PROBABILITIES OF DETECTION OF TOXICS IN THE GROUND AND SURFACE WATERS OF SOUTHERN NEW JERSEY (Continued)

	Ground	Surface	Significant Difference At 0.05 Level
dibromomethane	0.34	0.45	No
t-dichloroethylene	0.79	0.73	No
bromodichloroethane	0.07	0.05	No
BHC-Alpha	0.18	0.33	Yes
lindane	0.29	0.38	No
BHC-Beta	0.36	0.77	Yes
heptachlor	0.32	0.24	No
aldrin	0.28	0.10	Yes
heptachor epoxide	0.28	0.46	Yes
chlordane	0.33	0.57	Yes
o,p^{1}-DDE	0.24	0.35	Yes
dieldrin	0.17	0.47	Yes
endrin	0.14	0.17	No
o,p^{1}-DDT	0.16	0.17	No
p,p^{1}-DDD	0.17	0.29	Yes
p,p^{1}-DDT	0.13	0.19	No
mirex	0.08	0.07	No
arsenic	0.99	1.00	No
beryllium	1.00	1.00	No
cadmium	1.00	1.00	No
copper	0.99	1.00	No
chromium	1.00	1.00	No
nickel	1.00	1.00	No
lead	0.99	1.00	No
selenium	1.00	1.00	No
zinc	1.00	1.00	No

detectable concentrations of archlor 1242 in the ground water data, the comparison of probabilities in the ground and surface water will be based on 51 toxic substances.

The results of the chi square test indicate that for the majority of toxics there is no significant difference in the probabilities of detection between ground water samples and surface water samples from Southern New Jersey. For 35 toxics (69 percent) there is no significant difference in the probability of detection in samples from ground and surface water. All of the heavy metals and some of both the light and heavy chlorinated hydrocarbons fall in this category.

Most of the toxic substances which have significantly greater probabilities of detection in ground or surface water have a greater probability of detection in surface water samples than in ground water samples from Southern New Jersey. Fifteen toxic substances out of the 51 toxics included in this analysis (29 percent) have a significantly greater probability of detection in surface water samples. Only one toxic, aldrin, has a significantly greater probability of detection in ground water in Southern New Jersey.

The analysis of probabilities of detection indicates that more than two-thirds of the toxic substances are at least as likely to be detected in ground water as in surface water in Southern New Jersey. These toxics include the 35 toxics with no significant difference and the one toxic with a significantly greater probability of detection in ground water for a total of 36 toxics (71 percent). This result compares to the 60 percent of toxics which were at least as likely to be detected in ground water over the entire state.

Comparison of Detectable Toxics in the Ground And Surface Waters of Southern New Jersey

The third comparison is for those samples with detectable concentrations of toxics. This analysis uses the Mann-Whitney U test to determine if the average rank of concentration of each toxic in those ground water samples with detectable levels of the toxic substance being tested is less than, not significantly different from, or greater than the average rank of concentration in those surface water samples with detectable levels of the toxic.

The results indicate that there are no significant differences in the average rank of concentrations between samples from ground and surface water for 27 toxics (53 percent) at the 0.05 significance level and 36 toxics (70 percent) at the 0.01 significance level (Table 25). Among those toxics with greater average rank of detectable concentrations in one of the data sets, the number of toxics is greater in ground water than in surface water from Southern New Jersey. At the 0.05 significance level, 14 toxics (27 percent) had greater average concentrations

TABLE 25. MANN-WHITNEY U TEST OF DETECTABLE CONCENTRATIONS IN SOUTHERN NEW JERSEY

	Greater At Significance Level		
	0.05	0.01	2-Tailed Probability
fluoroform	No dif.	No dif.	0.56
methyl chloride	No dif.	No dif.	0.16
vinyl chloride	No dif.	No dif.	0.16
methylene chloride	No dif.	No dif.	0.22
chloroform	SUF	SUF	0.0008
1,2-dichloroethane	SUF	SUF	0.004
1,1,1-trichloroethane	GRN	GRN	<0.0001
carbon tetrachloride	No dif.	No dif.	0.90
1,1,2-trichloroethylene	No dif.	No dif.	0.85
dichlorobromoethane	GRN	No dif.	0.03
1,1,2-trichloroethane	No dif.	No dif.	0.17
dibromochloromethane	No dif.	No dif.	0.24
1,2-dibromoethane	No dif.	No dif.	0.19
1,1,2,2-tetrachloroethylene	No dif.	No dif.	0.07
bromoform	No dif.	No dif.	0.49
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.42
diiodomethane	No dif.	No dif.	0.09
total dichlorobenzene	No dif.	No dif.	0.84
m-dichlorobenzene	No dif.	No dif.	1.00
p-dichlorobenzene	No dif.	No dif.	0.59
o-dichlorobenzene	No dif.	No dif.	0.41
trichlorobenzene	GRN	No dif.	0.04
archlor 1242			
archlor 1248	No dif.	No dif.	0.12
archlor 1254	SUF	No dif.	0.02
dichloroethylene (gem)	No dif.	No dif.	0.14

TABLE 25. MANN-WHITNEY U TEST OF DETECTABLE CONCENTRATIONS IN SOUTHERN NEW JERSEY (Continued)

	Greater At Significance Level		
	0.05	0.01	2-Tailed Probability
dibromomethane	No dif.	No dif.	0.43
t-dichloroethylene	SUF	No dif.	0.03
bromodichloroethane	No dif.	No dif.	0.22
BHC-Alpha	GND	No dif.	0.02
lindane	No dif.	No dif.	0.21
BHC-Beta	SUF	No dif.	0.02
heptachlor	SUF	SUF	<0.0001
aldrin	No dif.	No dif.	0.68
heptachor epoxide	SUF	SUF	0.005
chlordane	No dif.	No dif.	0.35
o,p^1-DDE	No dif.	No dif.	0.40
dieldrin	GRN	No dif.	0.015
endrin	GRN	GRN	0.01
o,p^1-DDT	GRN	GRN	0.004
p,p^1-DDD	GRN	GRN	0.001
p,p^1-DDT	GRN	GRN	0.0002
mirex	No dif.	No dif.	0.31
arsenic	SUF	SUF	<0.0001
beryllium	No dif.	No dif.	0.15
cadmium	GRN	No dif.	0.02
copper	GRN	GRN	<0.0001
chromium	SUF	No dif.	0.03
nickel	GRN	GRN	0.001
lead	SUF	SUF	<0.0001
selenium	GRN	GRN	0.0008
zinc	GRN	GRN	0.57

in ground water samples. At the 0.01 significance level 9 toxics (18 percent) had greater average concentrations in ground water samples. The average concentration of toxics was found to be greater in surface water samples for 10 toxics (20 percent) at the 0.05 significance level and 6 toxics (12 percent) at the 0.01 significance level.

Examining only those samples of ground and surface water from Southern New Jersey which have detectable concentrations of a given toxic, the average concentration is at least as great in ground water samples as in surface water samples for the overwhelming majority of the toxics studied. At the 0.01 significance level 36 toxics had no significant difference and 9 toxics were greater in ground water. These total to 45 toxics (88 percent) of the 51 toxics included in the analysis.

Summary of Comparisons of Toxics Concentrations in the Ground and Surface Waters of Southern New Jersey

Analysis of the concentrations of toxic substances in the ground and surface waters of Southern New Jersey reveals that the levels of toxics in ground water are not significantly different or are more contaminated than in surface water for between 67 percent and 88 percent of the toxics studied depending on the method of comparison. Looking only at the highest concentration of each toxic, 67 percent of the toxics are more contaminated in ground water. Comparing the probabilities of detection, 71 percent of the toxics have no significant difference or have a greater probability of detection in ground water. Comparing only those samples with detectable concentrations, 88 percent of the toxics are not significantly different or are more contaminated in ground water than in surface water in Southern New Jersey.

Because of the complexity of the tables presented during the comparison of toxics in ground and surface water in Southern New Jersey, a selected summary of Tables 23-25 is presented as Table 27. Section A presents information on the single toxic, aldrin, which has a significantly greater probability of detection in ground water than in surface water. Section B provides information on those toxics with a greater probability of detection in surface water. Even among these substances, 80 percent had their highest concentration detected in ground water samples. When samples with nondetectable concentrations were eliminated from the analysis, 53 percent of these 15 toxics showed no significant difference and 27 percent had their average concentration greater in the ground water samples from Southern New Jersey.

Those toxics without significantly greater probability of detection in either ground or surface water from Southern New Jersey are reviewed in Section C of Table 27. These substances represent 69 percent of the toxics included in this analysis. The highest concentration was

TABLE 27. SUMMARY OF COMPARISONS OF TOXICS IN THE GROUND AND SURFACE WATER OF SOUTHERN NEW JERSEY

A. Toxics with Significantly Greater Probability of Detection in Ground Water

Toxic Substance	Highest Conc. Found In	Average Detectable Concentration Highest In[1]
aldrin	Surface	No dif.

B. Toxics with Significantly Greater Probability of Detection in Surface Water

Toxic Substance	Highest Conc. Found In	Average Detectable Concentration Highest In[1]
methylene chloride	Ground	No dif.
1,2-dichloroethane	Surface	Surface
1,1,2-trichloroethane	Ground	No dif.
1,1,2,2-tetrachloroethylene	Ground	No dif.
bromoform	Ground	No dif.
1,1,2,2-tetrachloroethane	Ground	No dif.
total dichlorobenzene	Surface	No dif.
trichlorobenzene	Ground	Ground
BHC-alpha	Ground	Ground
BHC-beta	Ground	Surface
heptachlor epoxide	Ground	Surface
chlordane	Surface	No dif.
o,p[1]-DDE	Ground	No dif.
dieldrin	Ground	Ground
p,p[1]-DDD	Ground	Ground

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[1] Mann-Whitney U test at 0.05 significance level.

TABLE 27. SUMMARY OF COMPARISONS OF TOXICS IN THE GROUND AND SURFACE WATER OF SOUTHERN NEW JERSEY (Continued)

C. Toxics Without Significantly Greater Probability of Detection in Ground or Surface Water from Southern New Jersey

Toxic Substance	Highest Conc. Found In	Average Detectable Concentration Highest In[1]
fluoroform	Ground	No dif.
methyl chloride	Ground	No dif.
vinyl chloride	Surface	No dif.
chloroform	Surface	Surface
1,1,1-trichloroethane	Ground	Ground
carbon tetrachloride	Ground	No dif.
1,1,2-trichloroethylene	Ground	No dif.
dichlorobromomethane	Ground	Ground
dibromochloromethane	Surface	No dif.
1,2-dibromoethane	Ground	No dif.
diiodomethane	Surface	No dif.
m-dichlorobenzene	Surface	No dif.
p-dichlorobenzene	Surface	No dif.
o-dichlorobenzene	Surface	No dif.
archlor 1248	Surface	No dif.
archlor 1254	Surface	Surface
dichloroethylene (gem)	Ground	No dif.
dibromomethane	Ground	No dif.
t-dichloroethylene	Surface	Surface
bromodichloroethane	Surface	No dif.
lindane	Ground	No dif.
heptachlor	Surface	Surface
endrin	Ground	Ground
o,p[1]-DDT	Ground	Ground
p,p[1]-DDT	Ground	Ground
mirex	Ground	No dif.
arsenic	Ground	Surface
beryllium	Ground	No dif.
cadmium	Ground	Ground
copper	Ground	Ground
chromium	Ground	Surface
nickel	Ground	Ground
lead	Ground	Surface
selenium	Ground	Ground
zinc	Ground	Ground

found in ground water samples for 66 percent and in surface water samples for 34 percent of these 35 toxics. When the average concentrations of each toxic were compared in the ground and surface water data in only those samples in which measurable concentrations were found, the average concentration was not significantly different or was greater in ground water samples from Southern New Jersey in 80 percent of these toxic substances.

Analyses were performed on subsets of the data on toxic substances in the ground and surface water of Southern New Jersey. One series of analyses were performed on only those samples of ground and surface water from Southern New Jersey which were from potable water sources. Another series of analyses were performed on only those samples of ground and surface water from Southern New Jersey which were from nonpotable water sources. For both of these subsets of data the series of analyses included analyses of the maximum concentrations, the probabilities of detection, and the average rank of detectable concentrations.

The analyses of the potable and nonpotable subsets of the data on toxic substances in the ground and surface water of Southern New Jersey revealed little additional information. The results were not very different from the analysis of all ground and surface water samples from Southern New Jersey. The results were also comparable to the analyses of potable and nonpotable ground and surface water samples from the entire state. For these reasons, the results of these analyses are not included in this report.

CHAPTER 8

COMPARISON OF TOXICS CONTAMINATION IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY

Introduction

Northern New Jersey for this analysis includes three of the five physiographic provinces of New Jersey (Figure 1). The physiographic provinces include the Appalachian Valley and Ridge Province, the New England Highlands Province and the Piedmont Province. The area included within Northern New Jersey includes great variety of land forms and of human activity. This area includes the Precambrian metamorphic rock of the Highlands which were formed about 600 million years ago, the Paleozoic rocks of the Ridge and Valley Province formed from 600 to 350 million years ago, to the triassic rocks and red shale lowlands of the Piedmont Province formed 200 million years ago. The Piedmont Province of New Jersey is the most heavily developed area of the state with approximately two-thirds of the population and most of the industrial activity (Widmer, 1964).

Northern New Jersey is such a great contrast to Southern New Jersey that it is an interesting geographic region in which to compare the concentrations of toxics in ground and surface water. Despite some spatial variation, Southern New Jersey is a relatively homogeneous, flat, plain of unconsolidated sandy sediments when compared to the consolidated rocks, hills and valleys of Northern New Jersey which have been further altered by glaciation. If the comparison of toxics contamination in the ground and surface waters of Northern New Jersey yields results comparable to those from the analysis of samples from Southern New Jersey, we can be reasonably confident that any conclusions concerning the relatively levels of toxics contamination of ground and surface waters is not due to a few isolated problems, but is a potentially wide ranging problem.

Data Description

The number of valid sample results available for comparison varies by toxic and between ground and surface water data sets. The number of samples varies in the ground water data from 35 to 364 and in the surface water data from 9 to 189. Information on the toxic substances in the ground and surface waters of Northern New Jersey is presented in Table 28.

The mode, median, and 90th percentile concentrations provide some indication of the severely right skewed frequency distributions of the toxic substances in both the ground and surface water data sets. The skewed distributions of toxics in the waters of Northern New

TABLE 28. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY[1]

	Ground Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	68	8	0	0	0.5	2.5
methyl chloride	341	2	0	0	0	220.6
vinyl chloride	340	1	0	0	0	1.0
methylene chloride	337	55	0	0	90.0	1,200.0
chloroform	349	225	0.8	0.8	3.2	691.2
1,2-dichloroethane	346	37	0	0	1.6	2,300.0
1,1,1-trichloroethane	347	286	2.0	2.0	10.0	607.8
carbon tetrachloride	349	212	0	0.1	0.6	6.8
1,1,2-trichloroethylene	156	109	0.3	0.3	8.0	635.0
dichlorobromoethane	76	38	0	0	0.2	43.0
1,1,2-trichloroethane	346	45	0	0	1.0	31.1
dibromochloromethane	349	75	0	0	0.1	2.4
1,2-dibromoethane	273	24	0	0	0	87.9
1,1,2,2-tetrachloroethylene	272	150	0	0.3	4.2	90.6
bromoform	349	71	0	0	1.0	34.3
1,1,2,2-tetrachloroethane	349	43	0	0	0.1	2.7
diiodomethane	348	34	0	0	0	1.2
total dichlorobenzene	356	10	0	0	0	102.3
m-dichlorobenzene	155	4	0	0	0	25.4
p-dichlorobenzene	155	6	0	0	0	78.5
o-dichlorobenzene	155	4	0	0	0	5.2
trichlorobenzene	348	14	0	0	0	33.7
archlor 1242	153	7	0	0	0	3.4
archlor 1248	153	1	0	0	0	<0.1
archlor 1254	346	6	0	0	0	0.4
dichloroethylene (gem)	35	20	0	10.0	240.7	992.3

[1] All concentrations in parts per billion (ppb)

TABLE 28. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY[1] (Continued)

Ground Water

	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	35	13	0	0	0.1	44.9
t-dichloroethylene	35	28	10.0	10.0	73.2	276.0
bromodichloroethane	80	16	0	0	0.1	1.6
BHC-Alpha	360	42	0	0	<0.1	<0.1
lindane	360	82	0	0	<0.1	0.1
BHC-Betal	351	169	0	0	<0.1	118.4
heptachlor	360	78	0	0	<0.1	1.0
aldrin	360	75	0	0	<0.1	1.2
heptachor epoxide	360	76	0	0	<0.1	0.5
chlordane	360	90	0	0	<0.1	0.3
o,p^{1}-DDE	360	47	0	0	<0.1	0.1
dieldrin	360	40	0	0	<0.1	0.2
endrin	360	35	0	0	0	0.2
o,p^{1}-DDT	360	24	0	0	0	0.2
p,p^{1}-DDD	360	23	0	0	0	0.2
p,p^{1}-DDT	360	22	0	0	0	0.5
mirex	360	16	0	0	0	0.1
arsenic	363	361	1.0	1.0	5.0	18.0
beryllium	363	363	1.0	1.0	1.0	2.0
cadmium	364	364	1.0	1.0	1.0	42.0
copper	364	364	1.0	4.0	37.0	1,381.0
chromium	364	364	1.0	2.0	6.0	90.0
nickel	364	364	2.5	2.5	8.0	25.0
lead	362	361	1.0	1.0	7.0	97.0
selenium	363	363	2.0	2.0	2.0	6.0
zinc	364	364	5.0	14.0	170.0	36,500.0

TABLE 28. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY[1] (Continued)

	Surface Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
fluoroform	76	1	0	0	0	0.5
methyl chloride	189	1	0	0	0	6.0
vinyl chloride	189	2	0	0	0	1.3
methylene chloride	189	59	0	0	90.0	304.5
chloroform	189	152	0.8	0.8	3.4	2,461.8
1,2-dichloroethane	189	10	0	0	0	67.6
1,1,1-trichloroethane	189	177	2.0	2.0	5.0	22.7
carbon tetrachloride	189	165	0.1	0.1	0.4	20.6
1,1,2-trichloroethylene	85	56	0.3	0.3	1.1	4.7
dichlorobromoethane	76	53	0.1	0.1	0.1	2.0
1,1,2-trichloroethane	186	23	0	0	1.0	2.9
dibromochloromethane	189	63	0	0	0.2	2.7
1,2-dibromoethane	113	8	0	0	0	0.1
1,1,2,2-tetrachloroethylene	113	103	0.3	0.3	1.4	4.5
bromoform	188	51	0	0	1.0	3.7
1,1,2,2-tetrachloroethane	189	27	0	0	0.1	0.6
diiodomethane	189	3	0	0	0	2.2
total dichlorobenzene	189	13	0	0	0	4.8
m-dichlorobenzene	85	6	0	0	0	1.3
p-dichlorobenzene	85	9	0	0	1.3	1.8
o-dichlorobenzene	85	3	0	0	0	3.3
trichlorobenzene	188	12	0	0	0	2.0
archlor 1242	190	8	0	0	0	117.3
archlor 1248	190	37	0	0	0.5	109.1
archlor 1254	190	63	0	0	0.2	127.0
dichloroethylene (gem)	57	44	10.0	10.0	114.9	489.1

TABLE 28. DESCRIPTIVE INFORMATION ON TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY[1] (Continued)

	Surface Water					
	# Sampled	# Detected	Mode	Median	90th Percentile	Highest
dibromomethane	57	17	0	0	0.1	3.3
t-dichloroethylene	57	46	10.0	10.0	728.0	1,307.5
bromodichloroethane	9	1	0	0	0.1	0.1
BHC-Alpha	184	40	0	0	<0.1	<0.1
lindane	184	26	0	0	<0.1	<0.1
BHC-Betal	184	84	0	0	0.2	1.3
heptachlor	184	32	0	0	<0.1	1.5
aldrin	184	17	0	0	0	<0.1
heptachor epoxide	184	55	0	0	<0.1	0.2
chlordane	184	75	0	0	<0.1	0.5
o,p^{1}-DDE	184	56	0	0	<0.1	<0.1
dieldrin	184	58	0	0	<0.1	<0.1
endrin	184	21	0	0	<0.1	0.1
o,p^{1}-DDT	184	23	0	0	<0.1	<0.1
p,p^{1}-DDD	184	34	0	0	<0.1	<0.1
p,p^{1}-DDT	184	27	0	0	<0.1	<0.1
mirex	184	10	0	0	<0.1	<0.1
arsenic	183	183	1.0	1.0	3.0	44.0
beryllium	183	183	1.0	1.0	1.0	1.0
cadmium	183	183	1.0	1.0	1.0	6.0
copper	183	183	1.0	3.0	9.0	124.0
chromium	183	182	1.0	1.0	4.0	216.0
nickel	183	183	2.5	2.5	8.0	24.0
lead	183	183	1.0	4.0	18.0	86.0
selenium	182	182	2.0	2.0	2.0	7.0
zinc	181	181	5.0	10.0	43.0	420.0

Jersey are comparable to those found in the ground and surface water data from Southern New Jersey and from the entire state.

The highest concentration for the majority of toxic substances was detected in the ground water data from Northern New Jersey. For 37 toxics (71 percent) the highest concentration was in the ground water data, and for 14 toxics (27 percent) the highest concentration was found in the surface water of Northern New Jersey. One toxic, BHC-alpha, had the same maximum concentration in both ground and surface water. The highest concentration in 24 toxics was one or more orders of magnitude greater and for 3 toxics two or more orders of magnitude greater in the ground water data than in the surface water data. For the three archlors, which are polychlorinated biphenyls, the maximum concentrations were one or more orders of magnitude greater in the surface water than in the ground water data.

Probabilities of Detection of Toxics in the Ground and Surface Waters of Northern New Jersey

The second comparison of toxic substances in the ground and surface waters of Northern New Jersey involves the likelihood of toxics being present in water samples. The probability of a toxic being detected is limited by our technological ability, but since these limits are the same for both the ground and surface water data, the comparison is reasonable. The probability of detecting each toxic substance in the samples from ground and surface water from Northern New Jersey is presented in Table 29. The chi square test was used to determine if the probability of detecting each toxic in ground water was different from the probability of detecting each toxic in surface water at the 0.05 significance level.

There is considerable variation in the probabilities of detection among the 52 toxic substances and between the ground and surface water data. The greatest variation is within the light chlorinated hydrocarbons where the probabilities of detection range from less than 0.01 to 0.94. Within the heavy chlorinated hydrocarbons the probabilities of detection range from 0.04 to 0.48. Every heavy metal was detected in almost every water sample from both ground and surface sources.

The results of the chi square test indicate that for the majority of toxics there is no significant difference in the probabilities of detection between ground water samples and surface water samples from Northern New Jersey. For 30 toxics (58 percent) there is no significant difference in the probability of detection in samples from ground and surface water.

Most of the toxic substances which have significantly greater probabilities of detection in ground or surface

TABLE 29. PROBABILITIES OF DETECTION OF TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY

	Ground	Surface	Significant Difference At 0.05 Level
fluoroform	0.12	0.01	Yes
methyl chloride	0.01	<0.01	No
vinyl chloride	<0.01	0.01	No
methylene chloride	0.16	0.31	Yes
chloroform	0.64	0.80	Yes
1,2-dichloroethane	0.11	0.05	No
1,1,1-trichloroethane	0.82	0.94	Yes
carbon tetrachloride	0.61	0.87	Yes
1,1,2-trichloroethylene	0.70	0.66	No
dichlorobromoethane	0.50	0.70	Yes
1,1,2-trichloroethane	0.13	0.12	No
dibromochloromethane	0.21	0.33	Yes
1,2-dibromoethane	0.09	0.07	No
1,1,2,2-tetrachloroethylene	0.55	0.91	Yes
bromoform	0.20	0.27	No
1,1,2,2-tetrachloroethane	0.12	0.14	No
diiodomethane	0.10	0.02	Yes
total dichlorobenzene	0.03	0.07	Yes
m-dichlorobenzene	0.03	0.07	No
p-dichlorobenzene	0.04	0.11	No
o-dichlorobenzene	0.03	0.04	No
trichlorobenzene	0.04	0.06	No
archlor 1242	0.05	<0.01	No
archlor 1248	0.01	0.19	Yes
archlor 1254	0.02	0.33	Yes
dichloroethylene (gem)	0.57	0.77	No

TABLE 29. PROBABILITIES OF DETECTION OF TOXICS IN THE GROUND AND SURFACE WATERS OF NORTHERN NEW JERSEY (Continued)

	Ground	Surface	Significant Difference At 0.05 Level
dibromomethane	0.37	0.30	No
t-dichloroethylene	0.80	0.81	No
bromodichloroethane	0.20	0.11	No
BHC-Alpha	0.12	0.22	Yes
lindane	0.23	0.14	Yes
BHC-Beta	0.48	0.46	No
heptachlor	0.22	0.17	No
aldrin	0.21	0.09	Yes
heptachor epoxide	0.21	0.30	Yes
chlordane	0.25	0.41	Yes
o,p^{1}-DDE	0.13	0.30	Yes
dieldrin	0.11	0.32	Yes
endrin	0.10	0.11	No
o,p^{1}-DDT	0.07	0.13	Yes
p,p^{1}-DDD	0.06	0.18	Yes
p,p^{1}-DDT	0.06	0.15	Yes
mirex	0.04	0.05	No
arsenic	0.99	1.00	No
beryllium	1.00	1.00	No
cadmium	1.00	1.00	No
copper	1.00	1.00	No
chromium	1.00	0.99	No
nickel	1.00	1.00	No
lead	0.99	1.00	No
selenium	1.00	1.00	No
zinc	1.00	1.00	No

water, have a greater probability of detection in surface water samples than in ground water samples from Northern New Jersey. Eighteen toxic substances out of the 52 toxics included in this analysis (35 percent) have a significantly greater probability of detection in surface water samples. Only 4 toxics (8 percent) have a significantly greater probability of detection in ground water.

The analysis of probabilities of detection indicates that about two-thirds of the toxic substances are at least as likely to be detected in ground water as in surface water in Northern New Jersey. These toxics include the 30 toxics with no significant difference and the four toxics with a significantly greater probability of detection in ground water for a total of 34 toxics (65 percent). This compares to the 60 percent of toxics which were at least as likely to be detected in ground water from the entire state, and the 71 percent from Southern New Jersey.

Comparison of Detectable Toxics in the Ground and Surface Waters of Northern New Jersey

The third comparison is for those samples with detectable concentrations of toxics. The analysis uses the Mann-Whitney U test to determine if the average concentration of each toxic in those ground water samples with detectable levels of the toxic substance being considered is less than, not significantly different from, or greater than the average rank of concentration in those surface water samples with detectable levels of the toxic.

The results indicate that there are no significant differences in the average rank of concentrations between samples from ground and surface water for about two-thirds of the toxic substances. There is no difference between concentrations in ground and surface water samples for 35 toxics (67 percent) at the 0.05 significance level and 39 toxics (75 percent) at the 0.01 significance level (Table 30).

Among those toxics with greater average rank of detectable concentrations in one of the data sets, the number of toxics is greater in ground water than in surface water from Northern New Jersey. At the 0.05 significance level 13 toxics (25 percent) had greater average concentrations in ground water samples. At the 0.01 significance level 10 toxics (19 percent) had greater average concentrations of toxics in ground water samples. The average concentration of toxics was found to be greater in surface water samples for 4 toxics (8 percent) at the 0.05 significance level and 3 toxics (6 percent) at the 0.01 significance level.

Examining only those samples of ground and surface water from Northern New Jersey which have detectable concentrations of a given toxic, the average concentration is at least as great in ground water samples as in surface water samples for the overwhelming majority of the toxic

TABLE 30. MANN-WHITNEY U TEST OF DETECTABLE CONCENTRATIONS OF TOXICS IN NORTHERN NEW JERSEY WATERS

	Greater Concentrations At Significance Level		2-Tailed Probability
	0.05	0.01	
fluoroform	No dif.	No dif.	0.72
methyl chloride	No dif.	No dif.	0.48
vinyl chloride	No dif.	No dif.	0.22
methylene chloride	No dif.	No dif.	0.58
chloroform	No dif.	No dif.	0.96
1,2-dichloroethane	No dif.	No dif.	0.88
1,1,1-trichloroethane	No dif.	No dif.	0.45
carbon tetrachloride	GRN	GRN	0.003
1,1,2-trichloroethylene	GRN	GRN	0.006
dichlorobromoethane	GRN	GRN	0.006
1,1,2-trichloroethane	No dif.	No dif.	0.61
dibromochloromethane	No dif.	No dif.	0.51
1,2-dibromoethane	No dif.	No dif.	0.07
1,1,2,2-tetrachloroethylene	No dif.	No dif.	0.81
bromoform	No dif.	No dif.	0.60
1,1,2,2-tetrachloroethane	No dif.	No dif.	0.81
diiodomethane	No dif.	No dif.	0.08
total dichlorobenzene	No dif.	No dif.	0.30
m-dichlorobenzene	No dif.	No dif.	0.16
p-dichlorobenzene	GRN	GRN	0.002
o-dichlorobenzene	No dif.	No dif.	0.82
trichlorobenzene	GRN	GRN	0.0004
archlor 1242	No dif.	No dif.	0.09
archlor 1248	No dif.	No dif.	0.11
archlor 1254	No dif.	No dif.	0.14
dichloroethylene (gem)	No dif.	No dif.	0.06

TABLE 30. MANN-WHITNEY U TEST OF DETECTABLE CONCENTRATIONS OF TOXICS IN NORTHERN NEW JERSEY WATERS (Continued)

	Greater Concentrations At Significance Level		2-Tailed Probability
	0.05	0.01	
dibromomethane	No dif.	No dif.	0.17
t-dichloroethylene	SUF	No dif.	0.04
bromodichloroethane	No dif.	No dif.	0.58
BHC-Alpha	No dif.	No dif.	0.18
lindane	No dif.	No dif.	0.63
BHC-Beta	SUF	SUF	<0.0001
heptachlor	SUF	SUF	<0.0001
aldrin	No dif.	No dif.	0.75
heptachor epoxide	No dif.	No dif.	0.98
chlordane	No dif.	No dif.	0.97
o,p^{1}-DDE	No dif.	No dif.	0.07
dieldrin	GRN	GRN	0.006
endrin	No dif.	No dif.	0.10
o,p^{1}-DDT	GRN	No dif.	0.017
p,p^{1}-DDD	GRN	GRN	0.004
p,p^{1}-DDT	GRN	No dif.	0.014
mirex	No dif.	No dif.	0.13
arsenic	No dif.	No dif.	0.59
beryllium	No dif.	No dif.	1.00
cadmium	No dif.	No dif.	0.95
copper	GRN	GRN	<0.0001
chromium	GRN	GRN	0.01
nickel	No dif.	No dif.	0.79
lead	SUF	SUF	<0.0001
selenium	GRN	No dif.	0.02
zinc	GRN	GRN	0.002

substances studied. At the 0.01 significance level 39 toxics had no significant difference and 10 toxics were greater in ground water. These total to 49 toxics out of the 52 toxics (94 percent) included in the analysis.

Summary to Comparisons of Toxics Concentrations in the Ground and Surface Waters of Northern New Jersey

Analysis of the concentrations of toxic substances in the ground and surface waters of Northern New Jersey reveals that the levels of toxics in ground water are not significantly different or are more contaminated than in surface water for between 65 and 94 percent of the toxics studied depending on the method of comparison. Looking only at the highest concentration of each toxic 71 percent of the toxics are more contaminated in ground water. Comparing the probabilities of detection, 65 percent of the toxics have no significant difference or have a greater probability of detection in ground water. Comparing only those samples with detectable concentrations, 94 percent of the toxics are not significantly different or are more contaminated in ground water than in surface water in Northern New Jersey.

Because of the complexity of the tables presented during the comparison of toxics in ground and surface water in Northern New Jersey, a selected summary of Tables 28-30 is presented as Table 31. Section A presents information on the 4 toxic substances which have a

TABLE 31. SUMMARY OF COMPARISONS OF TOXICS IN THE GROUND AND SURFACE WATER OF NORTHERN NEW JERSEY

A. Toxics with Significantly Greater Probability of Detection in Ground Water

Toxic Substance	Highest Concentration Found In	Average Detectable Concentration Highest In[1]
fluoroform	Ground	No dif.
diiodomethane	Surface	No dif.
lindane	Ground	No dif.
aldrin	Ground	No dif.

B. Toxics with Significantly Greater Probability of Detection in Surface Water

Toxic Substance	Highest Concentration Found In	Average Detectable Concentration Highest In[1]
methylene chloride	Ground	No dif.
chloroform	Surface	No dif.
1,1,1-trichloroethane	Ground	No dif.
carbon tetrachloride	Surface	Ground
dichlorobromomethane	Ground	Ground
dibromochloromethane	Surface	No dif.
1,1,2,2-tetrachloroethylene	Ground	No dif.
total dichlorobenzene	Ground	No dif.
archlor 1248	Surface	No dif.
archlor 1254	Surface	No dif.
BHC-alpha	No dif.	No dif.
heptachlor epoxide	Ground	No dif.
chlordane	Surface	No dif.
o,p^1-DDE	Ground	No dif.
dieldrin	Ground	Ground
o,p^1-DDT	Ground	Ground
p,p^1-DDD	Ground	Ground
p,p^1-DDT	Ground	Ground

[1] Mann-Whitney U test at 0.05 significance level.

TABLE 31. SUMMARY OF COMPARISONS OF TOXICS IN THE GROUND AND SURFACE WATER OF NORTHERN NEW JERSEY (Continued)

C. Toxics without Significantly Greater Probability of Detection in Ground or Surface Water

Toxic Substance	Highest Concentration Found In	Average Detectable Concentration Highest In[1]
methyl chloride	Ground	No dif.
vinyl chloride	Surface	No dif.
1,2-dichloroethane	Ground	No dif.
1,1,2-trichloroethylene	Ground	Ground
1,1,2-trichloroethane	Ground	No dif.
1,2-dibromoethane	Ground	No dif.
bromoform	Ground	No dif.
1,1,2,2-tetrachloroethane	Ground	No dif.
m-dichlorobenzene	Ground	No dif.
p-dichlorobenzene	Ground	Ground
o-dichlorobenzene	Ground	No dif.
trichlorobenzene	Ground	Ground
archlor 1242	Surface	No dif.
dichloroethylene (gem)	Ground	No dif.
dibromomethane	Ground	No dif.
t-dichloroethylene	Surface	Surface
bromodichloroethane	Ground	No dif.
BHC-beta	Ground	Surface
heptachlor	Surface	Surface
endrin	Ground	No dif.
mirex	Ground	No dif.
arsenic	Surface	No dif.
beryllium	Ground	No dif.
cadmium	Ground	No dif.
copper	Ground	Ground
chromium	Surface	Ground
nickel	Ground	Surface
selenium	Surface	Ground
zinc	Ground	Ground

significantly greater probability of detection in ground water than in surface water. Section B provides information on those toxics with a greater probability of detection in surface water. Even among these substances, 61 percent had their maximum concentration detected in ground water samples. When samples with nondetectable concentrations were eliminated from the analysis, 67 percent of these 18 toxics were not significantly different and 33 percent had their average concentration greater in the ground water samples from Northern New Jersey.

Those toxic substances without significantly greater probability of detection in either ground or surface water from Northern New Jersey are reviewed in Section C of Table 31. These substances represent 58 percent of the 52 toxics included in the analysis. The highest concentration was found in ground water samples for 77 percent and in surface water samples for 23 percent of these 30 toxic substances. When the average concentrations of each toxic were compared in the ground and surface water data in only those samples in which measureable concentrations were found, the average concentration was not significantly different or was greater in ground water samples from Northern New Jersey in 87 percent of these toxic substances.

Analyses were performed on subsets of the data on toxic substances in the ground and surface waters of

Northern New Jersey. One series of analyses were performed on only those samples of ground and surface water from Northern New Jersey which were from potable water sources. Another series of analyses were performed on only those samples of ground and surface water from Northern New Jersey which were from nonpotable water sources. For both of these subsets of data the series of analyses included analyses of the maximum concentrations, the probabilities of detection, and the average rank of detectable concentrations.

The analyses of the potable and nonpotable subsets of the data on toxic substances in the ground and surface water of Northern New Jersey revealed little additional information. The results were not very different from the analysis of all ground and surface water samples from Northern New Jersey. The results were also comparable to the analyses of potable and nonpotable ground and surface water samples from the entire state. For these reasons, these analyses are not included in this report.

CHAPTER 9

COMPARISON OF THE PATTERNS OF TOXICS CONTAMINATION IN THE GROUND AND SURFACE WATERS OF NEW JERSEY

Introduction

The patterns of toxic substances in the ground water data were compared to the patterns of toxic substances in the surface water data. In Chapters 1 and 2, factor analysis was used to identify patterns of toxic substances contamination. These patterns of contamination are groups of toxic substances which were found to vary similarly in the same water samples. The factor structure identified in the ground water data was mathematically compared to the factor structure identified in the surface water data using a computer program called RELATE (Veldman, 1967). This program is based on a method developed by Kaiser (1962). This program has previously been used to compare patterns of standard water quality parameters in New Jersey river basins (Hordon, 1972).

The purpose of a factor structure comparison is to determine similarities and differences in the patterns of toxics contamination in the ground and surface waters of New Jersey. Chapters 4-8 of this report compared concentrations of individual toxic substances in the ground and surface waters of New Jersey and subsets of that data. Instead of comparing concentrations of individual substances, this chapter compares the concentrations of patterns or groups of toxics to see how similar they are in the ground and surface waters of New Jersey.

Data Description

The full data sets of toxic substances in the ground and surface water of New Jersey were used in this analysis. The ground water data set consists of 692 samples and the surface water data set consists of 320 samples. Both data sets are considered to be representative of the ground and surface water of New Jersey (see Chapters 1 and 2).

Certain toxic substances were eliminated from both data sets for this analysis. Those toxic substances with less than 10 percent of the samples having detectable concentrations were eliminated to prevent small numbers of detectable concentrations from exerting too great an influence on the patterns of contamination.

Conservative procedures were employed in the factor analysis of both the ground and surface water data sets. The nonparametric Spearman's Rank correlation procedure was used to calculate the intercorrelation matrices of both the ground and the surface water data. The conservative assumption that all variation is not explained in the data dictated the use of multiple R^2 values as the initial communality estimates. An eigenvalue cutoff of unity was used to limit the number of factors to those which explain the most significant variation in the data sets. A varimax rotation was used to maximize the independent clusters of chemical substances which explain the variation within the data thereby assisting the interpretation of the patterns of contamination identified in the ground water data and in the surface water data.

The results of the preliminary factor analyses indicated that two changes were necessary to achieve the factor structures to be compared in the ground and surface water data sets. Although an eigenvalue cutoff of unity retained 7 ground water factors and 6 surface water factors, the first four factors in both data sets explained the vast majority of the variation in the data and had sufficient strong factor loadings to allow interpretation. The final factor analyses used in the factor structure comparison were calculated for only 4 factors. For the final factor analyses six toxics were eliminated from the data sets because they were not significantly associated with any of the factors in the preliminary results. The six toxics eliminated are 1,2-dibromoethane, bromoform, beryllium, cadmium, nickel, and selenium. The final factor analyses used for the comparison were based on 23 toxic substances including light chlorinated hydrocarbons, heavy chlorinated hydrocarbons, and heavy metals.

Results of Factor Analysis

The results of the factor analysis of the New Jersey ground water data and surface water data for those 23 toxic substances common to and significant in both the ground and surface water data sets are presented in Table 32 and 33.

Factor 1 in both the ground water and surface water analyses is a pesticide factor. The pesticide factor is the strongest pattern of contamination identified, explaining 49.2 percent of the variation in the ground water data and 48.5 percent of the variation in the surface water data. Lindane, helptachlor epoxide, chlordane, o,p^1-DDE, dieldrin, endrin, o,p^1-DDT, and p,p^1-DDD are significantly associated with the pesticide factor in both the data sets. Heptachlor and BHC-alpha are significantly associated with the pesticide factor in the ground water data but are below the significance criteria of 0.40 in the surface water results.

Factors 2 and 3 are reversed in number and in importance from the analysis results of the ground water data to the analysis results of the surface water data. Factor 2 in the ground water data is a light chlorinated hydrocarbon factor which explains 23.9 percent of the variation in the data. The light chlorinated hydrocarbon

TABLE 32. ROTATED FACTOR MATRIX, TOXICS IN NEW JERSEY GROUND WATER[1]

Variables	Factors				Communalities
	1	2	3	4	h^2
methylene chloride					.10
chloroform		.59			.43
1,1,1-trichloroethane		.46			.24
carbon tetrachloride		.45			.21
1,1,2-trichloroethylene		.65			.47
dibromochloromethane					.07
1,1,2,2-tetrachloroethylene		.75			.58
BHC-alpha	.45				.26
lindane	.52				.46
BHC-beta				.67	.55
heptachlor	.44				.24
heptachlor epoxide	.57				.37
chlordane	.59				.41
o,p^1-DDE	.69				.49
dieldrin	.69				.48
endrin	.78				.64
o,p^1-DDT	.75				.58
p,p^1-DDD	.77				.63
arsenic					.18
copper			.72		.52
chromium					.12
lead			.81		.68
zinc			.47		.23
eigenvalues	4.39	2.13	1.59	0.81	
percent variation	49.20	23.90	17.80	9.10	

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[1] Varimax rotation. The squared multiple correlation coefficients were used as communality estimates. N = 692.

[2] Only factor loadings greater than 0.40 are presented.

TABLE 33. ROTATED FACTOR MATRIX, TOXICS IN NEW JERSEY SURFACE WATER[1]

Variables	Factors 1	2	3	4	Communalities h^2
methylene chloride				.71	.63
chloroform			.46		.40
1,1,1-trichloroethane			.51		.33
carbon tetrachloride			.46		.25
1,1,2-trichloroethylene					.23
dibromochloromethane			.50		.31
1,1,2,2-tetrachloroethylene			.70		.54
BHC-alpha				.47	.29
lindane	.50				.25
BHC-beta				.57	.54
heptachlor					.19
heptachlor epoxide	.41				.26
chlordane	.63				.52
o,p^1-DDE	.70				.54
dieldrin	.74				.61
endrin	.66				.46
o,p^1-DDT	.67				.47
p,p^1-DDD	.68				.52
arsenic		.43			.22
copper		.67			.48
chromium		.51			.34
lead		.79			.64
zinc		.52			.28
eigenvalues	4.50	2.79	1.26	0.74	
percent variation	48.50	30.10	13.60	7.90	

[1] Varimax rotation. The squared multiple correlation coefficients were used as communality estimates. N = 320.

[2] Only factor loadings greater than 0.40 are presented.

factor in the surface water data is factor 3 and it explains 13.6 percent of the variation in the surface water data.

The light chlorinated hydrocarbon factor in both data sets has significant associations with chloroform, 1,1,1-trichloroethane, carbon tetrachloride, and 1,1,2,2-tetrachloroethylene. In the ground water results 1,1,2-trichloroethylene is also significantly associated with the light chlorinated hydrocarbon factor. In the surface water data dibromochloromethane is also significantly associated with the light chlorinated hydrocarbon factor.

A heavy metals factor is factor 3 in the ground water analysis results and factor 2 in the surface water analysis results. The heavy metals factor explains 17.8 percent of the variation in the ground water results and 30.1 percent of the variation in the surface water results. Copper, lead, and zinc are significantly associated with the heavy metals factor in the results of both the ground water and the surface water analyses. Two additional heavy metals, arsenic and chromium are significantly associated with the heavy metals factor in the surface water results.

Factor 4 in the results of both the ground water and the surface water analyses is a BHC-beta factor. It is the least important factor in both analyses, explaining 9.1 percent of the variation in the ground water results and 7.9 percent of the variation in the surface water results. BHC-beta is the only toxic with a significant loading in the ground water data results. In the surface water results methylene chloride and BHC-alpha are also significantly associated with this pattern of contamination.

Results of Factor Structure Comparison

A quantitative measurement of the similarity of the principal patterns of toxics contamination in the ground water data with the principal patterns of toxics contamination in the surface water data was calculated. The factor loading matrices which were obtained from the orthogonal factor analysis of the ground water data and the surface water data were input to the RELATE program. The comparison is calculated by rotating the factor axes to attain maximum overlap between the corresponding test vectors in the ground water matrix and the surface water matrix. The degree of rotation required is expressed as the cosine of the angle between the factor axes and may be interpreted as correlations between the factors.

The results of comparing the patterns of toxics contamination in the ground water data with the patterns of toxics contamination in the surface water data are presented in Table 34.

TABLE 34. GROUND WATER - SURFACE WATER COMPARISON: COSINE VALUES AMONG FACTOR STRUCTURES

		Ground Water			
		Pesticide F1	LCH F2	Heavy Met. F3	BHC F4
Surface Water	Pesticide F1	0.99	0.02	-0.01	0.14
	Heavy Met. F2	-0.03	0.35	0.92	0.15
	LCH F3	0.00	0.93	-0.32	-0.20
	BHC F4	-0.14	0.13	-0.21	0.96

The pesticide factor, factor 1, is found to be extremely correlated between the ground water data and the surface water data with a cosine among the factor axes of 0.99. This informs us that the pattern of toxics contamination we have identified as the pesticide factor is almost identical in the ground and surface waters of New Jersey. The light chlorinated hydrocarbon factor has a cosine among the factor axes of 0.93 indicating a high correlation between this pattern of contamination in the ground water data and in the surface water data. The heavy metals factor has a cosine among the factor axes of 0.92 which indicates this pattern of toxics contamination is highly correlated between the ground and the surface water data. The BHC-beta factor, factor 4, has a cosine among the factor axes of 0.96 indicating a surprisingly high correlation between this pattern of toxics contamination in the ground water data and the surface water data.

Summary of the Comparison of Patterns of Toxics Contamination in the Ground and Surface Waters of New Jersey

The patterns of toxics contamination identified in the ground water of New Jersey are found to be very highly correlated with the patterns of toxics contamination identified in the surface water of New Jersey. A quantitative method was used to calculate the cosine between the factor axes as a measure of the degree of correlation between the patterns of toxics contamination in the ground water and surface water of New Jersey. The four major patterns of toxics contamination have correlation coefficients ranging from 0.92 to 0.99 between the ground water and the surface water data sets. The pesticide factor was identified as the most important pattern of contamination in both the ground water and the surface water data sets and was found to have a correlation coefficient of 0.99. The light chlorinated hydrocarbon factor was found to be more important in explaining variation in the ground water data than in the surface water data. The light chlorinated hydrocarbon factor has a correlation coefficient of 0.93 between the two data sets. The heavy metals factor was found to explain a greater proportion of the variation within the surface water data than within the ground water data. The heavy metals factor has a correlation coefficient of 0.92 between the ground water data and the surface water data. The BHC-beta factor was found to be the least important of the four patterns of toxics contamination in both the ground water and the surface water data. The BHC-beta factor has a correlation coefficient of 0.96 between the ground water data and the surface water data.

CHAPTER 10

CONCLUSIONS

The ground and surface waters of New Jersey are contaminated with a wide variety of toxic substances. The data analysed in this report indicate that up to 65 toxic substances are widely distributed in the ground water and the surface water of the state. The toxics identified are thought to be only a small percentage of the toxic substances actually present in our water. Of the toxic substances identified in the ground and surface waters of New Jersey, 21 are either confirmed or suspected carcinogens.

The health effects of exposure to carcinogenic and toxic substances in the waters of New Jersey are presently unknown. Definitive health effects studies for most of the toxics found in New Jersey ground and surface water are not yet completed. Because of the low concentrations at which these substances are present in ground and surface water, the health effects must be estimated for long term exposure to the low level toxics. While it is difficult to estimate the health impacts of exposure to toxics in water, it is widely accepted that it may be a serious problem.

In New Jersey, ground water is at least as contaminated with toxic substances as surface water. Systematic comparisons of the concentrations of toxic substances in the ground water and in the surface water reveal that for between 60 and 94 percent of the toxic substances included in the analyses ground water is at least as contaminated as surface water. These results were consistent for analyses of all ground and surface water samples from New Jersey, only potable water samples, only nonpotable water samples, only samples from Southern New Jersey, and only samples from Northern New Jersey.

Not only are the concentrations of individual toxics comparable in ground and surface water, but the patterns of toxics contamination in ground water are very similar to those in surface water. The four most important patterns of contamination in ground water are very highly correlated with the four most important patterns of contamination in surface water. These patterns of toxics contamination in both the ground and surface waters of New Jersey are the pesticide factor, the light chlorinated hydrocarbon factor, the heavy metals factor, and the BHC factor.

The results of comparing toxic substances and patterns of toxics contamination in ground and surface water indicates that those citizens of New Jersey using water from ground water sources are exposed to at least as great a potential health danger as those citizens using water from surface water sources. The potential health danger to people using water from ground water sources may be greater than to people using surface water because the maximum concentrations of toxics discovered in water samples from New Jersey were from ground water samples for most of the toxics studied. Toxic substances in ground water move as a plume of contamination without the substantial dilution which occurs in surface water.

Present and future efforts to protect the public's health from the dangers of exposure to toxics in water should treat ground water sources of supply at least as stringently as surface water sources of supply. At present both laws and policy proposals treat water from surface water sources more stringently than water from ground water sources in terms of monitoring requirements and potable water treatment requirements.

Further research is needed into all aspects of toxic substances contamination of water. Research into these issues should not accept the prevalent assumption that ground water is relatively uncontaminated with toxic substances when compared with surface water. In particular epidemiological studies of the associations of areas exposed to water supplies contaminated with toxics and cancer mortality rates should not use areas served by ground water as an experimental control.

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