

**An Assessment of -
Regional Ground-Water
Contamination in Illinois**

**John A. Helfrich,
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Thomas R. Holm,
Susan C. Schock**

Illinois State Water Survey

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HAZARDOUS WASTE RESEARCH AND INFORMATION CENTER

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Champaign, Illinois

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LIST OF ABBREVIATIONS

TOC/NPOC:	nonpurgeable fraction of total organic carbon
TOC/POC:	purgeable fraction of total organic carbon
11DCE:	1,1-dichloroethylene
MC:	methylene chloride
t12DCE:	<u>trans</u> -1,2-dichloroethylene
11DCA:	1,1-dichloroethane
c12DCE:	<u>cis</u> -1,1-dichloroethylene
CLF:	chloroform
12DCA:	1,2-dichloroethane
111TCA:	1,1,1-trichloroethane
CTC:	carbon tetrachloride
12DCP:	1,2-dichloropropane
TCE:	trichloroethylene
112TCA:	1,1,2-trichloroethane
PCE:	tetrachloroethylene (perchloroethylene)
CBZ:	chlorobenzene

EXECUTIVE SUMMARY

Problem assessment research on hazardous waste management practices and their environmental consequences is a primary thrust of the Hazardous Waste Research and Information Center's mission. The general goal of this seven-month project was to aid in the establishment of an initial organic contaminant reconnaissance program in Illinois. The project had four main objectives, which have been completed and supplemented with more recent ground-water quality data:

- 1) Review of available total organic carbon (TOC) and specific volatile organic compound (VOC) data for Illinois ground waters through 1985;
- 2) Training of Illinois Environmental Protection Agency (IEPA) field staff in state-of-the-art VOC sampling procedures for ground-water monitoring and fabrication of four custom-designed devices for the field measurement of pH, specific conductance, oxidation-reduction potential, and temperature;
- 3) Collaboration with the IEPA and the regional United States Geological Survey (USGS) office in the collection of an initial public water supply (PWS) reconnaissance data set during the spring of 1985; and
- 4) Interpretation of volatile organic compound and indicator parameter results in the 1981-1985 PWS monitoring dataset collected by IEPA.

The four objectives have been achieved as far as the available data permits. The results of the project are summarized below. It should be

noted that these results represent only an initial reconnaissance of less than half of the 3,400 public water supplies in Illinois. Due to limitations in the scope of the current database, the results are not applicable to the quality of ground water from the more than 250,000 private wells estimated to be in use in the state.

The available data on the quality of Illinois ground water as it relates to the potential effects of hazardous waste management activities are sparse. The bulk of the historical database that has been collected since 1895 is limited to major dissolved inorganic chemical constituents. It provides little insight into the ambient levels of toxic or hazardous chemical constituents, particularly organic chemical contaminants. The more recent data collected since 1970 contain substantially more information on trace element concentrations, particularly in sand and gravel and shallow bedrock aquifers. These data have been reviewed by a separate project mandated by the "Currie" bill (P.A. 83-1268), which was passed by the Illinois State Legislature (Shafer, 1985).

TOC and total organic halogen (TOX) levels in ground water are useful screening parameters that may be used in place of more sensitive (but also more expensive) compound-specific analytical procedures for comparison of moderate to grossly contaminated conditions. These techniques are used routinely in government monitoring programs. TOC is a measure of the organic carbon content of ground water and does not distinguish natural organic matter from that which may be introduced anthropogenically. Since halogenated organic compounds in ground water

are not believed to be the result of any natural process, TOX is a somewhat more useful organic contamination indicator.

Apart from determinations of TOC and TOX in ground-water samples from known or suspected sites of contamination, there is relatively little data available to address the question of regional ground-water contamination in Illinois. In the past five years the Illinois State Water Survey (ISWS) has made 411 TOC determinations and these constitute the sole database available for screening regional ground-water quality in the state. TOC levels range from 0.8 to 27.5 mg C·L⁻¹ (milligrams organic carbon per liter) in shallow sand and gravel aquifers (with a mean of 6.2 mg C·L⁻¹), and from 0.5 to 16.5 mg C·L⁻¹ in shallow bedrock aquifers (with a mean of 1.9 mg C·L⁻¹). The values for sand and gravel aquifers represent 100 determinations in 30 counties. For bedrock aquifers, there are 311 TOC values in 7 counties (292 of them having been determined in a single study). However, this limited dataset reflects "average" TOC levels, which, for sand and gravel aquifers, are nearly five times those reported in a national study of organic carbon in ground water conducted by the USGS during the mid-seventies (Leenheer et al., 1974).

In the course of the spring 1985 round of PWS data collection, 61 water samples were analyzed in our laboratories for TOC and specific VOC's. Data from those samples, together with other results collected by the federal and state governments, indicate contamination by VOC's in 5 to 10% of the PWS samples in shallow sand and gravel or shallow bedrock aquifer areas where there has been an appreciable level of hazardous waste generation and management activity. Metropolitan areas

with high ground-water use from shallow aquifer systems are particularly vulnerable in this regard. The use of TOC as a screening parameter was also evaluated as part of our study. Three of the seven PWS samples that contained measurable levels of VOC's were from shallow sand and gravel aquifers. Only one of those three samples had a TOC value in excess of the mean value for that aquifer type. This is an indication that the TOC technique may not be sensitive enough to detect very low levels of contamination. More sensitive TOC instruments are now available that may remedy this situation.

Given the vulnerability of shallow sand and gravel or bedrock aquifers to a variety of surface contaminant sources, pilot hydrogeologic and water quality characterization efforts are needed in several areas of the state. These areas include metropolitan counties in northeastern Illinois (i.e. Cook, Will, DuPage, Kane, Lake, Kankakee, McHenry, and Kendall counties), and metropolitan counties in river valleys (i.e. Winnebago, Boone, Peoria, Tazewell, Woodford, Adams, Madison, and St. Clair). Volatile halogenated organic compounds have been the most frequently observed contaminants in metropolitan areas. Suitable organic compounds for rapid screening of ground-water supplies in rural areas have not yet been identified.

The results of this study suggest that regional screening of ground-water resources that are vulnerable to surface sources of contamination from hazardous waste-related activities can be a useful tool in planning detailed evaluations of ground-water quality effects. The use of regional screening (i.e. at the county level) will permit efficient use of the limited fiscal and manpower resources that the

state has to conduct detailed ground-water contamination assessments. The study demonstrates the need for intensive regional research and investigative activities that extend beyond the monitoring of ground water from public water supply wells. The use of TOC as a more rapid and less expensive screening procedure for potential risk areas due to hazardous waste related activities can be a useful starting point in efforts to improve monitoring network performance. The existing regional ground-water database must be expanded to include the non-PWS water quality data and all regulatory monitoring information for both rural and metropolitan areas.

CHAPTER 1: INTRODUCTION

Illinois is a major agricultural and industrial state. At least half of the state's population is dependent on ground-water resources for public water supply and for industrial and irrigation usage. The state is rich with surface and ground-water resources, with quantities sufficient to supply its needs for the foreseeable future. However, water quality must be considered in the water allocation process. The quantity and dissolved mineral quality of Illinois' ground water has been reviewed by numerous publications of the Illinois State Water Survey (Gibb and O'Hearn, 1980; Sasman et al., 1981; Visocky, Wehrmann, and Kim, 1981; Schicht, Adams, and Stall, 1977). Yet, the frequent discovery of trace organic contaminants in U.S. drinking water supplies (Council on Environmental Quality, 1981; Brass, Weisner and Kingsley, 1981; Westrick, Mello, and Thomas, 1984), together with the growing apprehension surrounding the potential for water supply degradation by pesticides (Cohen et al., 1984), petroleum products (McKee, Loventy, and Hertel, 1972), and the residues of hazardous waste generation and management operations, have caused concern among government officials and the general public.

Potential regional-scale to local-scale sources of ground-water contamination are numerous. Among the more prominent regional sources are urban street runoff, and agricultural fertilizers and pesticides. Localized point sources of contamination include salt-pile runoff,

landfills, waste handling impoundments, underground storage tanks, and surface spills of chemical or animal wastes or products.

The lack of systematic data collection and interpretation during the early industrial history of the state has given rise to widespread speculation about the question of ground-water contamination. Ground-water resources are recharged slowly. Despite a history of over-pumping and "mining" of ground water in metropolitan areas, the effects have yet to be felt in many of these areas. The presence of toxic or hazardous chemical constituents in raw public water supplies at levels that may put public or environmental health at risk have not been systematically investigated. Once the contaminant distributions in the environment have been established, it will be possible to relate these distributions to the hydrologic and chemical processes which govern their transport.

A number of cases of ground-water supply contamination incidents in Illinois have been documented (Shuster, 1976; Lindorff and Cartwright, 1977). However, government officials are frequently faced with the question of whether the apparent contamination is localized, or the result of regional effects due to a multiplicity of contamination sources, or overall poor recharge quality due to coincident densities of people, industrial, or agricultural activities. The contamination of ground-water resources by organic chemicals presents a significant challenge to public health and natural resource protection agencies. This is because there are a very large number of potential synthetic organic contaminants to investigate, and because the methods for sample

collection, monitoring network design, and analysis entail substantial commitments of money and manpower.

The historical ground-water quality database does not include many of the potential toxic or hazardous inorganic and organic chemical contaminants of interest (Wehrmann, 1984). It is therefore necessary to develop a strategy for the study of regional ground-water quality as it relates to specific groups of contaminants which may then be compared to levels determined in the vicinity of potential sources. These results can be used to develop regulatory priorities or advisory concentration limits for in-depth studies of local problems and action levels for ground-water protection or remedial actions. Regional ground-water contamination is most likely where population concentration, or the past or present use of toxic or hazardous chemicals, is greatest. Greater dependency on ground-water supplies for drinking water makes regional ground-water contamination a more compelling problem. This study proceeds upon the assumption that assessment and interpretation of existing data will allow for the most efficient use of governmental expertise to solve contamination problems.

Study Scope and Objectives

This study was designed to take a close look at Illinois ground-water quality data with particular emphasis on regional distributions of total organic carbon (TOC) and specific volatile organic compounds (VOC's). It participated in a 1985 public water supply (PWS) ground-water monitoring study that was intended to supplement the efforts of another, state-mandated project (Shafer, 1985) that was

limited to PWS quality data in machine-readable form and that did not allow primary data collection.

It should be noted that the permits and compliance-monitoring files of the Illinois Environmental Protection Agency (IEPA) contain a large amount of water quality data. However, not all are easily accessible. These data have not been computerized and they frequently contain sensitive information on industrial operations or materials that are released only on a very limited basis at this time. Furthermore, such regulatory data tends to emphasize known or potentially contaminated sites, so their inclusion in either of the above studies would have biased those studies' evaluations of statewide or regional water quality. We recognize the fact that results from samples taken upgradient from such sites may be quite useful in estimating regional ground-water quality variability. This task would entail substantially more time and manpower than was available for the project.

The study objectives were:

- 1) Review of available TOC and specific VOC data for Illinois ground waters through 1985;
- 2) Training of IEPA field staff in state-of-the-art VOC sampling procedures for ground-water monitoring, and fabrication of four custom-designed devices for the field measurement of pH, specific conductance, oxidation-reduction potential, and temperature;
- 3) Collaboration with the IEPA and the regional United States Geological Survey (USGS) office in the collection of an

initial PWS reconnaissance dataset during the spring of 1985; and

- 4) Interpretation of VOC and indicator parameter results in a 1981-1985 PWS monitoring dataset collected by the IEPA.

Illinois has extensive ground-water resources. The shallow ground-water resources alone cover an area exceeding 25,000 square miles. We anticipated that the areal coverage of existing data would limit the conclusions that could be drawn from the study. Therefore, it should be noted that this study represents only an initial reconnaissance effort.

CHAPTER 2: GROUND-WATER QUALITY DATA COLLECTION

Chemical Constituents and Contamination Detection

The available ground-water quality data in Illinois are maintained by the Illinois State Water Survey (ISWS), which acts as a central repository for water quantity and quality information in the state. Most of the data have been collected since 1940. PWS, industrial, and agricultural irrigation ground-water samples make up the bulk of the database, which is maintained on magnetic tape. The chemical constituents that may be indicative of ground-water contamination fall into three categories: contaminant indicator parameters, dissolved mineral constituents, and trace element or organic compounds. These categories are detailed in Table 1.

The contaminant indicator parameters noted above provide a gross measure of the acidity or basicity, total dissolved solids (TDS), and the general levels of organic substances in ground water. They are not specific indicators of the type or source of contaminants unless specific chemical constituents are also determined in some detail. Whether a moderate increase in the organic content of ground water has occurred due to local contaminant sources can be determined by comparing TOC and total organic halogen (TOX) levels in the water with samples from an upgradient or remote site. The TOC procedures used during and preceding this project were generally not sensitive enough to detect levels of organic contaminants below $0.5 \text{ mg C}\cdot\text{L}^{-1}$. In cases of low-level contamination, ground water locally could contain hazardous

levels of one or more organic chemicals but TOC levels might indicate no elevation above background.

Potable ground water will normally show values for these parameters in the following ranges: 6-8 pH units, 150-3,000 $\mu\text{S } \Omega^{-1}$ (200-3,000 $\text{mg}\cdot\text{L}^{-1}$ total dissolved solids), 0.5-10 $\text{mg C}\cdot\text{L}^{-1}$ TOC, and TOX values generally less than 100 $\mu\text{g X}\cdot\text{L}^{-1}$ (where X denotes the organic-associated halogen: chlorine, bromine, fluorine, or iodine). The contaminant indicator parameters are most useful in detecting contamination or trends when a background dataset exists for comparison. This is because seasonal effects and the temporal correlation between parameters measured in succession can lead to false positive or negative "detections" of contamination.

The dissolved mineral constituents include major cations (i.e., positive charged ions) and anions (i.e., negative charged ions), which generally make up the largest portion of the total dissolved solids in a ground-water sample. Gradual increases in mineral content as ground water flows in porous geologic media (e.g., sand and gravel or porous limestone, dolomite, etc.) are common, particularly in waters which have high levels of dissolved CO_2 . These increases generally take place over periods of years or over the corresponding length of the flow path that the ground water would cover in this time frame. This type of increase has been observed in many areas of the state that have been investigated in detail (Gibb and O'Hearn, 1980; Sasman et al., 1981).

The effects of localized contaminant sources on the dissolved mineral content of ground water have been observed as more abrupt changes than those caused by natural increases in mineral content. For

Table 1. Chemical Constituents Determined in
Contaminant Detection Efforts

Contaminant Indicator Parameters

pH, specific conductance (Ω^{-1}), TOC, TOX

Dissolved Mineral Constituents

Ca^{2+} , Mg^{2+} , Na^{+} , K^{+} , HCO_3^{-} , Cl^{-} , NO_3^{-} , $\text{SO}_4^{=}$, SiO_2 , NH_4^{+}

Trace Chemical Constituents

Inorganic: Fe, Mn, Cu, Cd, Cr, Pb, Zn, Hg, As

Organic: volatile chlorinated compounds (e.g. chloroform, trichloroethane, trichloroethylene, tetrachloroethylene), volatile aromatic compounds (e.g. benzene, xylene, toluene), nonvolatile compounds (e.g. phenols, polynuclear aromatic hydrocarbons, pesticides, etc.)

example, sanitary landfill leachate contamination may take years to reach a well within 500 to 1000 m of the disposal site. However, the observed mineral content (i.e., particularly K^+ , HCO_3^- , Cl^-) may increase two to three times the background levels in a matter of months or over flow paths of 10 to 100 m (Hughes et al., 1971; Barcelona and Naymik, 1984). The determination of dissolved mineral constituents in contamination monitoring studies helps define the extent of contamination and the mobility of inorganic contaminants.

Ground water normally contains trace quantities (i.e., low $mg \cdot L^{-1}$, to $\mu g \cdot L^{-1}$) of both inorganic and organic chemical constituents, depending on the geochemistry of the subsurface environment and the quality of the recharge water. These trace element concentrations can be diagnostic of radical changes in solution composition or in local geochemical conditions as well as in contaminant sources, especially when used in conjunction with other parameters such as those discussed above. For example, an abrupt decrease in pH together with elevated levels of Fe, Zn, and Cr may indicate the effect of releasing an electroplating waste. Trace elements can be accurately detected at concentrations of $\sim 10 \mu g \cdot L^{-1}$ and above by atomic absorption spectrometry. Trace organic constituents, on the other hand, may include literally tens of thousands of natural or synthetic compounds from a variety of sources that cover a wide range of chemical reactivity and aqueous solubility. Organic analytical determinations in the $\mu g \cdot L^{-1}$ range are very specialized, complex procedures that require substantial care in sampling, analysis, and interpretation. Because of their widespread use, environmental stability, and mobility in the subsurface, volatile organic compounds

are among the most frequent early indicators of ground-water contamination. A relatively well-developed body of knowledge on background levels has been collected nationwide (Westrick, Mello, and Thomas, 1984; Mackay, Roberts, and Cherry, 1985). There have been well-documented cases of volatile organic contamination of sand and gravel aquifers in Illinois (Wehrmann, 1984).

It should be clear from the above discussion that ground-water contamination can be detected by the discovery of a range of dissolved chemicals. Determination of the presence of each differs substantially, however, in ease, complexity, and cost. Documented cases of local contamination of ground water in Illinois cover a range of contaminant sources. At the regional (i.e., county to multiple county) scale the existing database lacks sufficient coverage and detail to make generalizations about the quality or the extent of contamination at this time. This organic reconnaissance study represents an initial step toward establishing background levels from which contamination can be distinguished and its severity assessed.

Statewide PWS Monitoring Efforts

Over past years, state and federal agencies concerned with ground-water quality have been involved in drafting ground-water protection strategies and planning for cooperative data collection. The efforts of this task force resulted in the initiation in 1984 of ground-water monitoring at selected PWS sites. Three sampling rounds of approximately 100 sites each were completed that year. This effort was limited to the determination of dissolved mineral constituents and trace inorganic species. In the fall of 1984, planning began to expand the

suite of chemical constituents that were to be included in the fourth sampling round scheduled for winter/spring, 1985. Our project staff fabricated four flow-through monitoring devices that were delivered to IEPA in late December, 1984. They also aided in the training of IEPA field staff for the collection of samples for the contaminant indicator parameters and of trace organic constituents. The monitoring devices were found to be very effective for wellhead measurements and for following the progress of well purging (Garske and Schock, 1985).

In addition to fabrication of the devices and field training of IEPA staff, our project team was also responsible for the determination of TOC and for analyzing VOC's by purge and trap procedures during the fourth round of sampling in 1985. We received a total of 61 samples from PWS's. The TOC analytical procedures used for these determinations have been described elsewhere (Barcelona, 1984). The purge and trap procedure for VOC analysis incorporated the use of capillary-column gas chromatography into standard United States Environmental Protection Agency (USEPA) methodology (USEPA, 1982). The results of the first 1,500 samples of the PWS monitoring data collection effort of the IEPA up to 1985 were made available to the ISWS by the USGS. These data represent less than half of the PWS's in the state and only became available in early 1987.

CHAPTER 3: REVIEW OF AVAILABLE CONTAMINANT INDICATOR INFORMATION

The reliable detection of ground-water contamination from a variety of potential sources requires a well-conceived program of sampling and analysis. The detection of organic contaminants, in particular, demands substantially more sophisticated procedures than those employed in traditional water quality investigations. Since no systematic monitoring network for indicators of organic contamination had been established in Illinois prior to 1985, the available data are limited to TOC data collected by the ISWS in a number of special studies (Sasman et al., 1981; Wehrmann, 1984; Barcelona and Naymik, 1984; Barcelona, 1984). In addition, the use of TOC as an indicator of organic contamination of the regional ground-water resources of the state may be biased because the selection of sites was not made with regional concerns in mind. Also, the USEPA-approved instrumental method for TOC determinations discriminates against the purgeable fraction of the TOC (i.e., purgeable organic carbon, POC) which may be more important than the nonpurgeable organic carbon (NPOC) fraction in detecting organic contamination. The POC fraction has been observed to range from 5 to 50%, although higher percentages have been recorded in leachate from contaminated sites. The bulk of the available TOC data for Illinois was collected prior to our development of a combined POC + NPOC procedure in 1982 and thus represents only the nonpurgeable fraction (Barcelona, 1984). The TOC samples collected from the 61 PWS systems in 1985 (Table 2) were analyzed for both POC and NPOC.

Table 2. Public Water Supply Samples Analyzed by ISWS, 1985 (A,B)

Site	(mg C·L ⁻¹)			(µg·L ⁻¹)												
	TOC/ NPOC	TOC/ POC	11DCE	MC	t12DCE	11DCA	c12DCE	CLF	12DCA +	111TCA	CTC	12DCP +	TCE	112TCA	PCE	CBZ
Washington #7	7.7	BD	BD	4.4	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Morton #5	3.4	0.6	BD	4.0	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Fairbury #4	0.2	BD	BD	3.5	BD	BD	BD	BD	BD	0.4	BD	0.2	BD	0.3	BD	BD
Normal #100	7.1	BD	BD	2.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Weldon #5	BD	BD	BD	4.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Champaign #46	2.9	0.1	BD	3.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.2	BD	BD
Momence #4	BD	0.4	BD	1.5	BD	BD	BD	BD	BD	0.6	BD	BD	BD	BD	BD	BD
Momence #3	11.3	0.7	1.1	2.6	2.6	BD	2.0	BD	BD	BD	BD	0.9	BD	0.2	BD	BD
St. Anne #3	4.0	BD	BD	5.3	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Algonquin #1	0.1	BD	BD	1.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Frankfort #3	0.2	0.1	BD	2.8	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Addison #8	1.2	0.1	0.1	2.7	BD	BD	BD	BD	BD	BD	BD	0.1	BD	BD	BD	BD
Clifton #2	1.8	BD	BD	1.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.3	BD	BD
Watseka #7	5.4	BD	BD	0.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Beaverville #2	3.1	1.5	BD	0.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Chebanse #3	0.7	BD	BD	0.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Joliet #11	BD	0.4	BD	0.5	BD	BD	BD	BD	BD	BD	BD	0.1	BD	0.2	BD	BD
Joliet #205	0.6	BD	BD	0.6	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Morris #4	BD	0.5	BD	1.1	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD

continued on next page

Table 2. Public Water Supply Samples Analyzed by ISWS, 1985 (A,B) (continued)

Site	(mg C·L ⁻¹)		(µg·L ⁻¹)											
	TOC/ NPOC	TOC/ POC	11DCE	MC	t12DCE	11DCA	c12DCE	CLF	12DCA + 111TCA	CTC	12DCP + TCE	112TCA	PCE	CBZ
Lockport #5	BD	0.3	BD	0.6	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Manhattan #2	BD	0.4	BD	0.9	BD	BD	BD	BD	BD	BD	BD	BD	0.1	BD
Chicago Heights #30	1.1	BD	BD	0.5	BD	BD	BD	0.1	BD	BD	BD	BD	BD	BD
Indian Head Park #2	4.8	1.2	BD	0.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Oak Brook #6	BD	BD	BD	0.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Mendota #3	BD	0.5	BD	0.8	BD	BD	BD	0.1	BD	BD	BD	BD	BD	BD
Ottawa #8	0.2	BD	BD	0.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
De Kalb #12	BD	BD	BD	1.2	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Shabbona #4	0.7	BD	BD	0.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Rockford #28	BD	0.2	BD	1.3	BD	BD	BD	BD	BD	BD	0.2	BD	BD	BD
Rockford #11	BD	BD	0.9	1.3	BD	BD	0.4	0.1	2.9	1.0	BD	BD	0.2	BD
Belvidere #9	BD	0.1	BD	1.4	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
S. Beloit #3	8.0	BD	--	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Woodstock #6	2.7	1.1	--	1.4	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Harvard #5	BD	BD	BD	1.8	BD	BD	BD	BD	12.5	BD	1.1	BD	0.2	BD
Harvard #6	1.7	BD	BD	1.3	0.5	BD	0.4	BD	BD	BD	BD	BD	BD	BD
Mundelein #3	0.6	BD	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Mundelein #5	0.9	BD	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Schaumburg #13	0.6	0.1	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD

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Table 2. Public Water Supply Samples Analyzed by ISWS, 1985 (A,B) (continued)

Site	<u>(mg C·L⁻¹)</u>			<u>(μg·L⁻¹)</u>												
	TOC/ NPOC	TOC/ POC	11DCE	MC	t12DCE	11DCA	c12DCE	CLF	12DCA +	111TCA	CTC	12DCP +	TCE	112TCA	PCE	CBZ
Carmi #4	2.3	BD	0.1	1.3	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Saline Valley #1	0.1	0.1	BD	1.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Millstone #1	2.7	BD	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
New Shawneetown #4	BD	BD	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Brookport #3	BD	BD	BD	1.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Ullin #1	0.7	0.1	BD	1.7	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Central Alexander Co. W.D. #1	1.9	2.4	BD	1.5	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Pulaski #14	1.7	BD	BD	1.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
McClure-East Cape #1	0.8	BD	BD	1.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Anna-Jonesboro #3	5.8	0.1	BD	2.0	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Albany #2	1.5	0.1	BD	2.2	BD	BD	BD	0.2	BD	BD	BD	BD	BD	BD	BD	BD
Thomson #4	0.1	0.1	BD	3.1	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Freeport #7	0.8	BD	0.1	3.0	0.1	0.3	2.2	BD	BD	BD	BD	1.1	BD	BD	BD	BD
Chillicothe #7	BD	BD	BD	4.0	BD	BD	BD	0.1	BD	BD	BD	BD	BD	BD	BD	BD
Peoria #4	BD	BD	0.3	3.1	BD	0.1	2.0	0.2	2.2	BD	BD	0.3	BD	1.7	BD	BD
Peoria Heights #11	BD	BD	BD	3.0	BD	BD	BD	BD	BD	BD	BD	BD	BD	0.1	BD	BD
Meredosia #4	BD	21.9	BD	2.9	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Galesburg #74-3	0.6	BD	BD	3.3	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD

concluded on next page

Table 2. Public Water Supply Samples Analyzed by ISWS, 1985 (A,B) (concluded)

Site	(mg C·L ⁻¹)		(ug·L ⁻¹)											
	TOC/ NPOC	TOC/ POC	11DCE	MC	t12DCE	11DCA	c12DCE	CLF	12DCA + 111TCA	CTC	12DCP + TCE	112TCA	PCE	CBZ
Clayton-Camp Point #1	BD	BD	BD	3.3	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Geneseo #25	1.8	BD	BD	3.0	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Princeton #5	5.1	BD	BD	3.2	BD	BD	BD	BD	BD	0.8	BD	BD	BD	BD
Rock Falls #4	2.1	0.1	BD	3.3	BD	BD	BD	BD	BD	BD	BD	BD	0.2	BD
Wheeling #4	1.9	0.2	BD	3.2	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
<u>Quality Control Data</u>														
Detection Limit	0.6	0.2	NA	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2
Ave Lab. Blank Levels	2.8	0.2	BD	5.4	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
Ave. Field Blank Levels	NA	NA	BD	2.2	BD	BD	BD	BD	BD	BD	BD	BD	0.1	BD
<u>EPA Quality Control Sample (WP-781/3)</u>														
1. True Value	10	10	10.0	9.2	5.4	--	--	--	5.4 ^(C)	10.0	18.2 ^(D)	--	--	8.2
2. Ave. % Recovery	97.9	101.	119	101	152	--	--	--	102	92	96	--	--	84
3. SD of Ave. % Recovery	1.8	9.8	13	12	27	--	--	--	7	9	7	--	--	5

NOTE:

- = Not present in sample
- BD = Below detection
- NA = Not available
- (A) = Sample concentrations are not corrected for blank contributions.
- (B) = See Appendix for compound identification.
- (C) = Only 12DCA present
- (D) = 12DCP + TCE present

Total Organic Carbon in Illinois Ground Water

The usefulness of TOC determinations in the recognition of contamination can be realized when background levels have been established at locations upgradient from specific sites or by the measurement of a large number of samples within a regional area. The confidence with which conclusions can be drawn based on background versus suspect sample comparisons will depend on the number of available samples, the accuracy and precision of the sampling and analytical procedures, and the natural variability of the TOC content of the hydrogeologic formation of interest. This is demonstrated by our interpretation of the data which is presented below.

Figures 1 and 2 show the county by county numbers of TOC determinations up to August 1985 for shallow sand and gravel and bedrock aquifers, respectively. The coverage in most county or multiple-county regions is very scant. Altogether, the 411 determinations at 350 sites provide reasonable coverage in only five of the more than 50 counties with major dependence on public ground-water supplies from these shallow, vulnerable aquifer systems. When these data are grouped by aquifer type and relative depth, they show trends which are substantially different from those previously reported in a national survey of TOC data from various aquifers (Leenheer et al., 1974).

Tables 3a and 3b show the distribution of dissolved organic carbon in Illinois sand and gravel and bedrock aquifers, respectively. The data clearly show that samples from shallow sand and gravel aquifers (i.e., ≤ 200 ft, or 60 m) exhibit a wider concentration range and a mean value that is a factor of four to five higher than samples from the

Table 3a. Distribution of Dissolved Organic Carbon
in Illinois Ground Water (Sand/Gravel)*

<u>Aquifer type</u>	<u>Dissolved organic carbon (mg·L⁻¹)</u>				
	<u>Sites</u>	<u>Range</u>	<u>Mean</u>	<u>RSD (%)</u>	<u>N</u>
Shallow Sand and Gravel (≤200 ft; 60 m)					
Western	(2)	0.8-7.7	2.2	39	35
East-Central	(5)	6.9-17.8	12.5	33	5
North-East	(1)	4.8-27.5	11.3	41	21
Overall		0.8-27.5	6.2	88	61
Deep Sand and Gravel (>200 ft; 60 m)					
East-Central	(2)	1.7-5.0	3.1	107	11

* The data in the table have been collected in the past five years.

Table 3b. Distribution of Dissolved Organic Carbon
in Illinois Ground Water (Bedrock)*

<u>Aquifer type</u>	<u>Dissolved organic carbon (mg·L⁻¹)</u>				
	<u>Sites</u>	<u>Range</u>	<u>Mean</u>	<u>RSD (%)</u>	<u>N</u>
Shallow Bedrock (≤500 ft; 150 m)					
1 County					
(≤200 ft; 60 m)	(124)	0.5-12.5	2.0	82	124
(>200 ft; 60 m)	(168)	0.5-16.5	1.8	75	168
Overall	(292)	0.5-16.5	1.9	78	292
Deep Bedrock (>500 ft; 150 m)					
	(31)	0.1-8.6	1.2	169	37

* The data in the table have been collected in the past five years.

deeper aquifers of the same type. This trend is not significant in the shallow bedrock aquifers (i.e., ≤ 500 ft, or 150 m) though the mean TOC level of $1.9 \text{ mg C}\cdot\text{L}^{-1}$ is at least twice that of the samples from deeper consolidated formations. When compared to the results of the national study conducted during the mid-1970s (Leenheer et al., 1974) shown in Table 4, the Illinois data in Tables 3a and 3b suggest that either the state has shallow ground-water resources which are substantially higher in organic content than the national average or the experimental designs of one of the two data collection efforts have produced an apparent effect.

We have carefully examined the situation and conclude that the logistics of the national study, which required filtration of the samples as well as long periods of frozen storage prior to analysis, may explain part of the substantial difference in the mean values. Indeed, the bulk of the sources of error in the determination of TOC should result in predominately low values. However, we have observed variability in sample results from individual wells finished in shallow sand and gravel deposits, which suggests that TOC values substantially greater than the reported national mean are underestimates of the true organic content. These samples are from regions remote from obvious point sources of contamination and indicate that the dynamics of shallow ground-water systems must be carefully investigated when making comparisons of the sort needed to recognize organic contamination.

An example of the variability in TOC levels in a single PWS from a shallow sand and gravel aquifer in Livingston County is shown in Figure 3. These samples were taken at a public water supply well field in the

Table 4. Distributions of Dissolved Organic Carbon
in U.S. Ground Waters (Leenheer et al., 1974)

<u>Aquifer type</u>	<u>Range</u>	<u>Dissolved organic carbon mg·L⁻¹</u>		
		<u>Mean</u>	<u>RSD*</u>	<u>N**</u>
Shallow Sand and Gravel (≤200 ft; 60 m)	0.1-15.0	1.3	184	40
Deep Sand and Gravel (>200 ft; 60 m)	0.1-6.9	1.2	132	23
Sandstone	0.2-3.2	1.1	100	6
Limestone	0.2-5.0	1.6	106	17
Crystalline Rock	0.1-3.3	0.8	113	14

* RSD denotes the standard deviation of the mean expressed as a percentage of the mean value.

** N denotes the number of individual determinations.

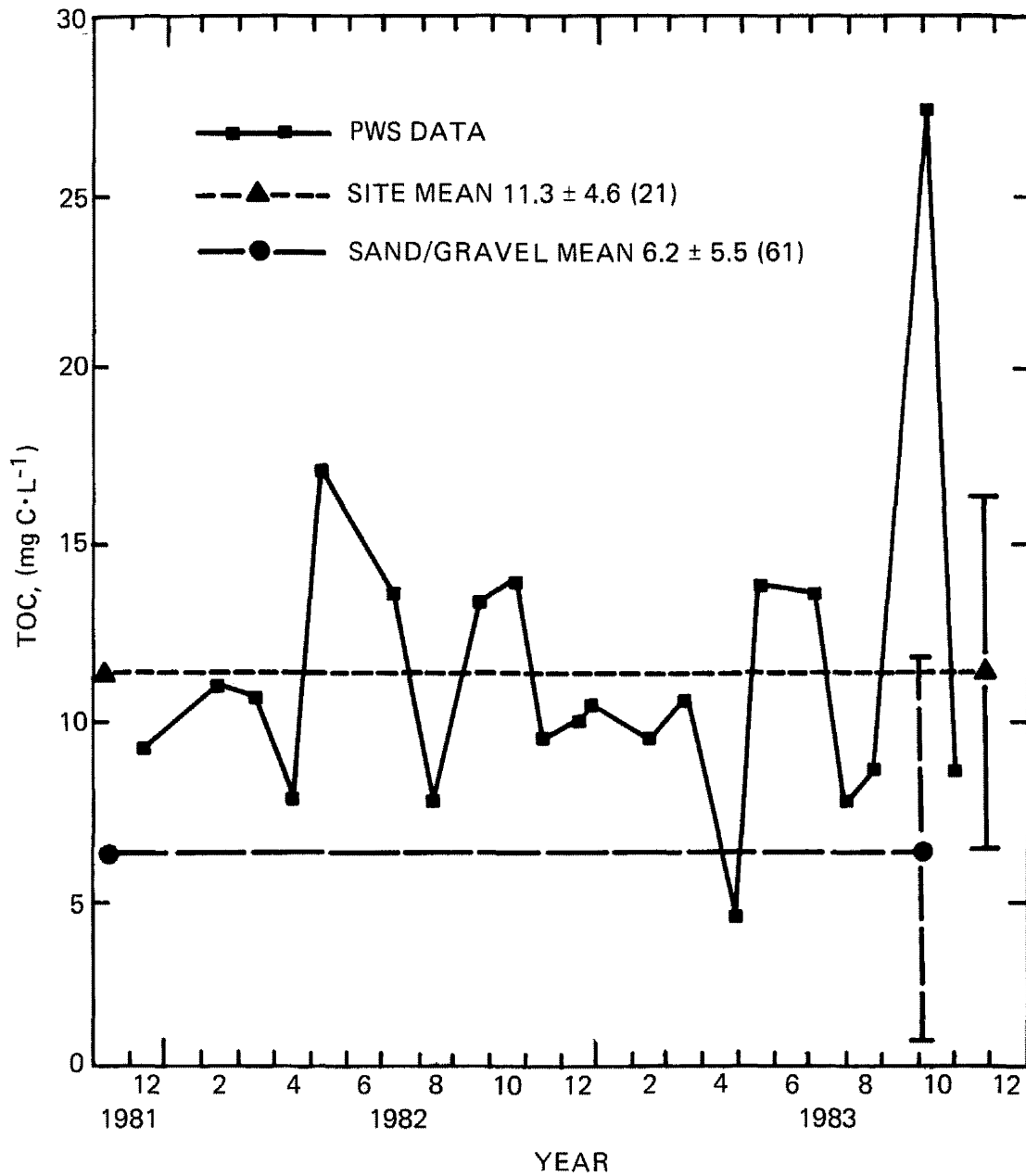


Figure 3. TOC levels in a single PWS over a two-year period compared to statewide sand/gravel mean

course of a two-year study of the corrosivity and water chemistry of 18 water systems in the state (Neff, Schock, and Marden, 1987). The majority of the data points are within one standard deviation from the mean of similar sand and gravel environments in the state. However, the mean value is about twice that of the statewide mean and the local maximum concentrations appear to peak in the late spring and early fall, times that may be linked to recharge periods.

Overall, approximately 6% of the shallow sand and gravel TOC values were greater than the statewide mean of $6.2 \text{ mg C}\cdot\text{L}^{-1}$ (Table 3a); however, the trend is not statistically significant on a statewide basis. It is apparent that the significance of a regional TOC level must be established with a relatively large number of wells sampled over a period of at least one year. The site to site and temporal variability typically is at least five times the precision of individual measurements, which are routinely better than $\pm 0.5 \text{ mg C}\cdot\text{L}^{-1}$. This "natural" variability in TOC will have a significant impact on the sampling design for any statewide ground-water monitoring network. This applies to many types of networks, whether they are set up to establish spatial or temporal trends in ground-water quality (O'Hearn and Schock, 1984), or the effects of specific types of pollutant sources (e.g., landfills, waste impoundments, etc.). The density of sampling sites and sampling frequency must be adjusted accordingly to retain a known level of confidence in the data which are collected.

TOC determinations made within a region over a relatively short period can be very useful in screening limited subregions for more intensive sampling in order to detect ground-water contamination. The

results of the study by Sasman et al. (1981), which entailed intensive sampling of shallow bedrock wells in DuPage County, Illinois, demonstrate the sensitivity of shallow aquifer systems to surface sources of contamination. They showed that populated areas which have experienced the greatest decline in historical water levels due to overpumpage for PWS also showed the highest increases in total dissolved solids, Na^+ and Cl^- , and that isolated areas of high TOC (i.e., two to eight times the mean value of $2.0 \text{ mg C}\cdot\text{L}^{-1}$) correspond reasonably well to the areas where decreased water quality and increased mineralization have been observed. These areas are shown in Figure 4. It is evident from this study that overpumpage and recharge water quality can exert gross changes in ground-water quality. These factors must be incorporated into any regional ground-water analysis.

The available TOC data in Illinois shallow ground waters suggest that apparently elevated levels within intensively sampled regional areas may be diagnostic of general quantity and quality effects on the resource. Intensive sampling and determination of more source-specific indicators of contamination must then be undertaken to identify the extent or severity of organic pollution problems. Special care must be taken to evaluate the effects of natural variability in space and time on apparent regional trends to establish confidence in the use of TOC as a contamination indicator. We were unable to identify any TOX results that could be used for the purposes of this study.

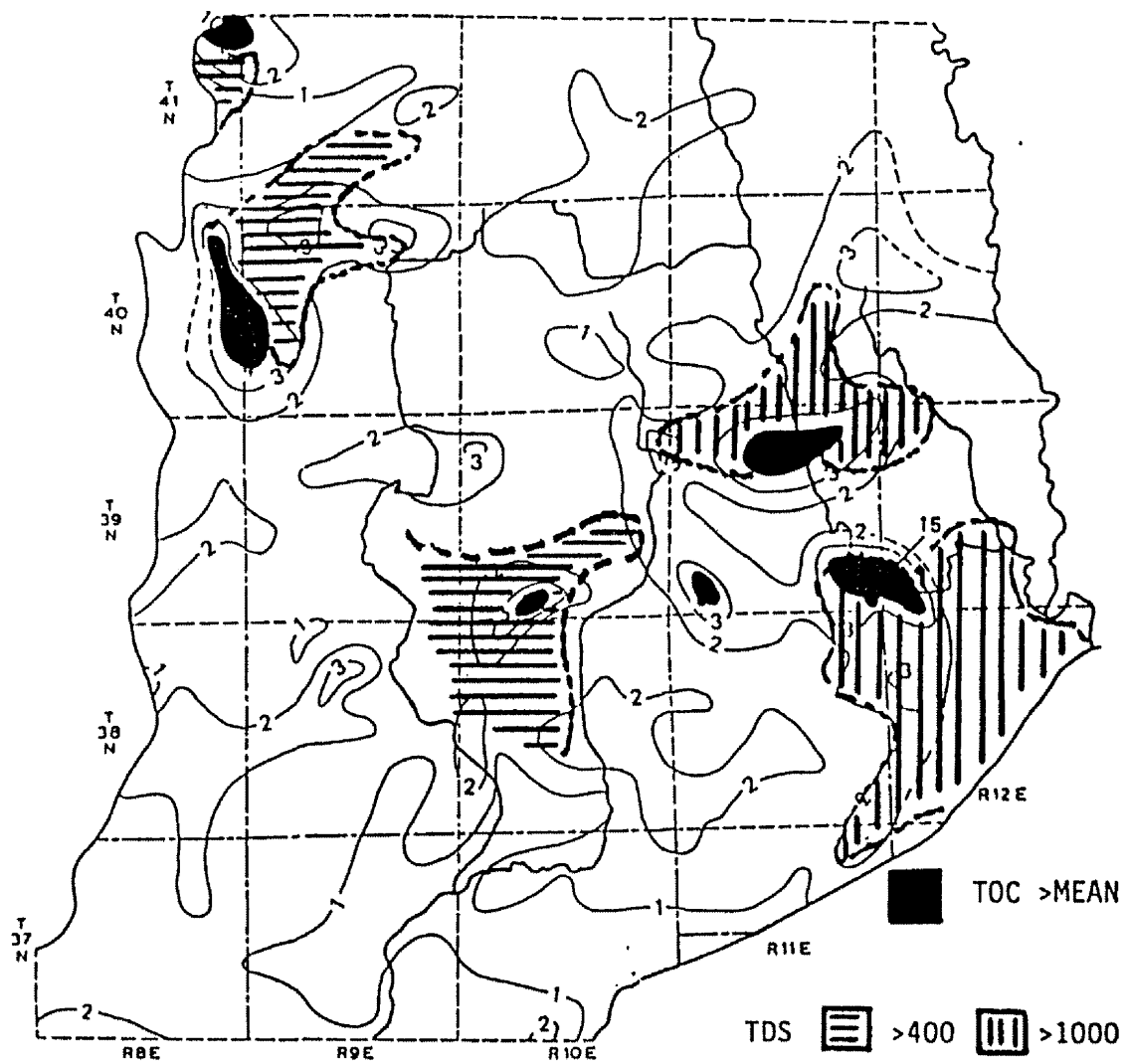


Figure 4. Coincidence of regions with TOC values significantly greater than mean of $2.0 \text{ mg C} \cdot \text{L}^{-1}$ and high TDS levels

CHAPTER 4: REVIEW OF AVAILABLE SPECIFIC VOLATILE ORGANIC CONTAMINANT DATA

The available data on specific VOC concentrations in Illinois ground water, obtained by the purge and trap technique, have been collected in the past six years. The database is made up of the results from a 1981 federal survey of raw water quality for PWS's in communities over 10,000 population, a follow-up sampling survey conducted by the IEPA from 1981 to 1983, and IEPA PWS monitoring results through 1985. The two surveys were early reconnaissance efforts which laid the groundwork for the IEPA PWS monitoring network. The quality of raw PWS samples may not accurately represent water quality in individual aquifers since many production wells are screened over multiple aquifer intervals to maximize the yield of water quantity. Well design and construction details are frequently unavailable. All results interpreted in this study have been associated with wells that could be located on a plot map by legal description and for which the principal aquifer tapped was also known with some confidence. The present study does not include any results that may have been collected in regulatory or compliance monitoring efforts at known or suspected sites of contamination.

The federal survey, conducted in 1981, was designed to provide an organic contaminant reconnaissance of PWS's using ground water and serving metropolitan populations (i.e., greater than 10,000 people). The sites were presumably selected at random in cooperation with the IEPA. In Illinois, approximately 190 communities were included in the

analysis. Of the 190 supplies, 11 raw water samples (i.e., 6% of the sample) showed "detectable" levels of volatile organic compounds. The compounds which were detected most frequently were primarily the trihalomethanes (i.e., chloroform, CHCl_3 ; bromoform, CHBr_3 ; dichlorobromomethane, CHCl_2Br ; and dibromochloromethane, CHBr_2Cl) and chlorinated ethanes and ethylenes (i.e., dichloroethane, dichloroethylene, trichloroethane, trichloroethylene, and tetrachloroethylene). The limit of detectability for these compounds was approximately $0.1 \mu\text{g}\cdot\text{L}^{-1}$.

During the two-year period following the federal survey, the IEPA resampled the PWS systems that had shown observable levels of these VOC's previously. Eighty-five water samples were collected from a number of production wells or distribution points within ten of the eleven PWS systems. Of the replicate raw-water samples collected, seven PWS well fields showed detectable levels of VOC's, which confirmed the previous study results. These 1981-1983 results are summarized in Table 5.

The data in Table 5 also reinforce the relatively high frequency (~10%) of detection of VOC's in ground water that has been observed repeatedly in both targeted and random organic contaminant reconnaissance study designs (Council on Environmental Quality, 1981; Westrick, Mello, and Thomas, 1984; Fusillo, Hochreiter, and Lord, 1985). For the most part, the positive instances of detection are below the $100 \mu\text{g}\cdot\text{L}^{-1}$ total trihalomethane regulatory threshold for PWS notification, although the limit may not be applicable to raw water. Also, the relative ease of volatile organic compound analytical determinations may account for

their high frequency of detection relative to nonvolatile organics, which call for more involved procedures.

The ISWS laboratory results from samples collected during the early round of IEPA PWS sampling completed in May 1985 confirm several of the trends noted above. These data were seen in Table 2. Of the 61 samples analyzed in duplicate, seven water supplies were observed to contain two or more of the VOC's at levels that were twice their respective detection limits. The methylene chloride (MC) data were excluded from this observation because of a persistent laboratory contamination problem with this component. The laboratory blank levels averaged $5.4 \mu\text{g}\cdot\text{L}^{-1}$ for MC; the other VOC's were not affected. Three of the positive samples were from shallow sand and gravel aquifers; however, only one sample exhibited a TOC in excess of the mean TOC value for this aquifer type. Therefore, two of the three samples from shallow sand and gravel aquifers showed some evidence of VOC contamination that was not signalled by an elevated TOC level. These observations indicate that the sum of volatile organic compounds identified at the $\mu\text{g}\cdot\text{L}^{-1}$ level of concentration account for less than 1% of the total organic matter in ground-water samples. This is also a reflection of the relative insensitivity of TOC as a contamination indicator for very low levels of VOC's in the absence of more detailed analytical results.

In areas where the 1981 to 1983 IEPA samples can be compared to the results discussed above, there is confirmatory evidence of suspected organic contamination of ground water. Sixteen PWS wells in the Rockford metropolitan area were sampled by the IEPA during the period from 1981 to 1983. The results of samples from two of these wells from

Table 5. 1981-1983 IEPA Volatile Organic Compound Reconnaissance in PWS's Served by Ground Water

Site no.	County	Confirmed previous results	Fraction of samples (%)	Principal contaminants*	Concentration Σ synthetic organics ($\mu\text{g}/\text{L}^{-1}$)
1	Cook	-			
2	Bureau	+	100	Benzene	≤ 5
3	DuPage	-			
4	DuPage	-			
5	Kane	+	100	TCE	≤ 5
6	Madison	+	100	CHCl_2Br , MC	≤ 5
7	White	+	100	CHBr_3 , Br_2ClCH	>50-100
8	Will	+	75	CHBr_2Cl , CHCl_2Br	≤ 5
9	Winnebago	+	100	1,2-DCE; TCE; 1,2-DCA	10-50
10	Winnebago	+	25	TCE, DCE, PCE	>100
			19		>50 to 100
			33		10-50

* Abbreviations are defined in Appendix I.

the more recent sampling confirmed the presence of low levels ($\sim 5 \mu\text{g}\cdot\text{L}^{-1}$) of VOC's. In the preceding work, six of the 16 wells showed levels of total VOC's exceeding $10 \mu\text{g}\cdot\text{L}^{-1}$. All of the PWS wells with probable organic contamination fall within areas of primary and secondary potential health risk via ground-water contamination as a result of hazardous waste-related activities identified by Gibb et al. (1984).

Additional VOC determinations in ground water have been made by the IEPA in the 1984-1985 round of PWS monitoring. Although all of the results were not available to this study, nearly 1,000 ground-water sample data points of the 1,500 PWS wells sampled were reviewed in detail. The samples covered a wide range of rural and metropolitan areas as well as a number of aquifer types. In this dataset, 174 of the 979 results could not be located reliably by the legal description. They were dropped from the analysis. Table 6 contains basic information on the eighteen VOC's that were detected in the 1984-1985 monitoring data available to date. They include halogenated alkanes and alkenes as well as several volatile aromatic compounds (benzene, toluene, chlorobenzene, ethylbenzene, 1,4-dichlorobenzene). Most of the compounds were reported at the apparent limit of detection of $0.1 \mu\text{g}\cdot\text{L}^{-1}$. However, those samples with levels equal to the detection limit comprised more than 90% of the observations. In some cases (i.e., carbon tetrachloride, the aromatics and dichlorobenzene) only a few samples were reported above the detection limit. In these instances, the mean and standard deviation would not be very meaningful, representing less than 0.1% of the original sample, and they have not been tabulated. Judging from the mean

Table 6. Volatile Organic Compound Determinations
in the 1984-1985 IEPA PWS Monitoring Dataset

#	Compound/Class	N	LD $\mu\text{g}\cdot\text{L}^{-1}$	$N \geq \text{LD}$	$N > \text{LD}$	\bar{X}	σ
P32101	Bromodichloromethane	979	0.1	833	19	2.5	3
32102	Carbon Tetrachloride	979	0.1	831	*	*	*
32103	1,2-Dichloroethane	979	0.1	833	16	3.2	6
32104	Bromoform	979	0.1	833	10	3.5	3
32105	Dibromochloromethane	979	0.1	837	17	3	3
32106	Chloroform	979	0.1	830	57	2.3	5
34010	Toluene	517	0.1	374	*	*	*
34030	Benzene	517	0.1	372	*	*	*
34301	Chlorobenzene	517	0.1	371	*	*	*
34371	Ethylbenzene	977	0.1	372	*	*	*
34423	Methylene Chloride	517	0.1	823	34	*	*
34475	Tetrachloroethylene	979	0.1	836	35	5.2	27
34496	1,1-Dichloroethane	978	0.1	838	49	22	96
34501	1,1-Dichloroethylene	979	0.1	507	24	9.6	22
34506	1,1,1-Trichloroethane	979	0.1	844	29	3.6	5
34546	t-1,2-Dichloroethylene	643	0.1	463	44	4.2	8
34571	1,4-Dichlorobenzene	979	0.1	97	*	*	*
39180	Trichloroethylene	979	0.1	853	56	10.2	26

* Insufficient number of samples for calculation of meaningful statistics

N = Number of reported observations

\bar{X} = Mean value in $\mu\text{g}\cdot\text{L}^{-1}$ of samples reported above $0.1 \mu\text{g}\cdot\text{L}^{-1}$

σ = Standard deviation about the mean

LD = Limit of detection

values and the rather high standard deviations it should be clear that the relatively few values above the detection limit were spread over a wide range of concentration.

The same type of pattern emerged from this data as had been observed previously in the 1981-1983 results and those from early 1985. The principal contaminants most frequently detected were trichloroethylene, trichloroethane, trans-1,2-dichloroethylene and tetrachloroethylene. Similarly, more than 60% of all the above-detection limit values for these compounds resulted from samples taken from shallow aquifer systems. The mean values for these four compounds in principal shallow aquifer systems are shown in Table 7. The mean concentration values from sand and gravel systems are not significantly different from those in the shallow bedrock aquifers. Samples from metropolitan counties in northeastern Illinois also showed elevated levels of these contaminants, as had previous samples from these areas. At least 21 wells in the Rockford metropolitan area showed signs of contamination, some at levels substantially below previous observations. It would not be unusual to have contaminated wells in heavily-pumped metropolitan areas show wide variations in contaminant concentrations. This phenomena has been documented in the literature by Fischer, Rowan, and Spaulding (1987).

Overall, at least 80 of the 979 samples collected from PWS wells showed definite signs of contamination with VOC's. The principal contaminant was trichloroethylene, particularly in shallow aquifer samples. The average concentration of trichloroethylene in these wells was generally above the maximum contaminant level (MCL) of $5 \mu\text{g}\cdot\text{L}^{-1}$ established in the National Primary Drinking Water Regulations by the 1986

Table 7. Average Concentrations* Above Detection Limit for Principal Volatile Organic Contaminants of Shallow Aquifers

<u>Sand/ Compound</u>	<u>Aquifer type</u>		
	<u>Gravel</u>	<u>Bedrock</u>	
		<u>Silurian</u>	<u>Ordovician</u>
Trichloroethylene	8.4	36	4.0
Trichloroethane	4	1.2	3.4
trans-1,2-dichloroethylene	3.2	4.9	7.8
Tetrachloroethylene	8.6	1.4	2

* Concentrations are in $\mu\text{g}\cdot\text{L}^{-1}$ as reported by the IEPA for samples which could be located, $N \leq 805$.

amendments to the Safe Drinking Water Act (Anon., 1987). These regulations take effect in December 1988 and require far more extensive monitoring of PWS's for organic compounds in the future. At levels above the MCL, utilities would be required to notify the public and treat the water to reduce or eliminate the contaminants.

The results of this limited analysis strongly suggest that utilities in high-use, metropolitan areas using ground water from shallow aquifers take precautions well ahead of time to meet future MCL regulatory thresholds. They should also be aware that the long time frames involved in ground-water recharge, transport, and contamination identification may result in more serious future problems.

Specific VOC determinations in ground water seem to indicate that somewhere between 5 and 10% of existing PWS's using it may have significant water quality problems. These results do not adequately reflect the quality of Illinois ground-water resources due to the problems in production well design and the inclusion of only PWS sample data. Rural areas with their large number of private ground-water supplies certainly must be included in future studies.

The available data do not permit strict delineation of regional ground-water contamination. However, the repetitive connection of metropolitan areas and elevated VOC concentrations in PWS data certainly warrants more detailed study toward developing designs for effective ground-water quality monitoring networks. This type of analysis would lend itself to application in a number of regions of the state with heavy dependence on ground water and a long history of commercial or industrial activity. There are at least 10 metropolitan counties and

several rural areas which have these characteristics. The areas suggested as targets for intensive study in previous ground-water quality monitoring network design studies (Shafer, 1985; O'Hearn and Schock, 1984) are supported by the limited data available to this study.

CHAPTER 5: CONCLUSIONS

The effect of hazardous waste management on ground-water quality is a potentially serious threat to drinking water supplies in Illinois. The available data on ground-water quality, however, are rather sparse and limited in scope. The bulk of the historical database is limited primarily to major dissolved inorganic constituents. More recent data collection efforts have included trace element and TOC determinations, but they are generally confined to areas of known contamination or limited regional surveys.

In the past five years 411 TOC determinations have been made in samples from shallow sand and gravel and shallow bedrock aquifers in the northern half of the state. TOC levels range from 0.8 to 27.5 mg C·L⁻¹ (mean = 6.2 mg C·L⁻¹) in shallow sand and gravel and from 0.5 to 16.5 mg C·L⁻¹ (mean = 1.9 mg C·L⁻¹) in shallow bedrock formations. Once regional background levels are established, much work remains to be done before we can effectively use TOC levels as screening parameters. The confidence with which conclusions can be drawn will depend on the number of available samples, the accuracy and precision of the sampling and analytical procedures, and the natural variability of the TOC content of the hydrogeologic formation of interest. TOX determinations are far too limited at this time to evaluate their usefulness for screening regional water quality.

Specific VOC's have been detected and confirmed in PWS samples by several laboratories and agencies using purge and trap techniques over the past six years. Volatile chlorinated alkanes and alkenes have been

detected in 5 to 10% of the raw ground-water samples analyzed in these PWS water quality monitoring efforts. Trichloroethylene has been the most frequently observed contaminant in these samples, followed by trichloroethane, dichloroethylene, and tetrachloroethylene. Many samples have shown the presence of VOC's at levels near their limits of detection. Samples from shallow sand and gravel or shallow bedrock aquifers, however, accounted for most of the concentration values above the detection limit. The coincidences of high ground-water use for PWS's in metropolitan areas served by vulnerable shallow aquifers accounted for the vast majority of organic contaminated ground-water samples.

Regional screening by TOC and TOX procedures of ground-water resources that may be vulnerable to organic contamination from hazardous waste-related activities can be a valuable tool in planning evaluations of ground-water quality effects. Given the vulnerability of shallow sand and gravel or shallow bedrock aquifers to a variety of contaminant sources, pilot hydrogeologic and water quality characterization efforts are needed in several areas of the state. These areas include metropolitan counties in northeastern Illinois (Cook, Will, DuPage, Kane, Lake, Kankakee, McHenry, and Kendall), and metropolitan counties in major river valleys (Winnebago, Boone, Peoria, Tazewell, Woodford, Adams, Madison, and St. Clair).

The existing ground-water database should be expanded to include the non-PWS water quality and regulatory monitoring data. Efforts should be made to insure compatibility in both reporting format and data quality among cooperating agencies.

Recommendations for Additional Research

1. Expand regional ground-water monitoring studies into rural areas to develop more representative TOC and VOC background data.
2. Find suitable analytical methods for organic compound class determinations for rapid screening of ground-water supplies in rural areas.
3. Target those areas identified in this report having known ground-water contamination and/or vulnerability to contamination for intensive study to determine sources and magnitude of the problem.
4. Include TOX in future regional monitoring studies to determine its usefulness as a screening parameter in areas other than those known to be affected by hazardous waste or materials handling.
5. Make efforts to ensure comparability in both reporting format and data quality in future monitoring studies.

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