The occurrence of volatile organic compounds in wastewater, sludges and groundwater at selected wastewater treatment plants in Wisconsin. [DNR-018] 1988

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Madison, Wisconsin: Wisconsin Department of Natural Resources, 1988

Wisconsin Groundwater Management Practice Monitoring Project No. 21

GROUNDWATER
Wisconsin's buried treasure

Wisconsin Department of Natural Resources

The Occurrence of Volatile Organic Compounds in Wastewater, Sludges and Groundwater at Selected Wastewater Treatment Plants in Wisconsin

By

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Wisconsin Department of Natural Resources

June 12, 1988

FINAL REPORT BY CAROLYN HUNGER JUNE 12, 1988

THE OCCURRENCE OF VOLATILE ORGANIC COMPOUNDS IN WASTEWATER, SLUDGES, AND GROUNDWATER AT SELECTED WASTEWATER TREATMENT PLANTS IN WISCONSIN

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ACKNOWLEDGEMENTS

I thank the following people for their contributions to this study and report:

Those who collected samples and delivered them to the lab for analysis, most especially Cindy Lukas (Project Position Employee), Wendy Call, Brian Gorman and Shakker Amer (all Limited Term Employees) of the Bureau of Wastewater Management.

Also, Cindy Lukas for coordinating site selection and sampling in 1986 and for maintaining field and lab data files.

The wastewater treatment facilities staffs, the State Lab of Hygiene, and the Central, District and Area DNR staff for their cooperation and assistance which allowed this research to proceed smoothly.

Tom Portle, Environmental Specialist, and John Schwalbe, Environmental Specialist LTE, of the Bur. of Wastewater Management, for their periodic reviews of this project and their knowledgable advice. I especially thank John for his technical guidance and support.

The Occurrence of Volatile Organic Compounds in Wastewater, Sludges and Groundwater at Selected Wastewater Treatment Plants in Wisconsin

INTRODUCTION

Over the past decade, researchers have focussed increasing attention on volatile organic compounds (VOC's) as groundwater pollutants. VOC's have a variety of domestic, commercial and industrial sources, including household cleaners, pesticides, paint thinners, dry cleaning agents and metal degreasers. As the manufacture and use of products containing VOC's increases, the chance for them to contaminate groundwater also increases. VOC's can enter the groundwater when chemical spills occur, from waste disposal to land, and from leaky underground storage tanks. Another means by which VOC's enter the groundwater is from the land disposal of wastewater effluents and sludges containing VOC's. This pathway of contamination has only recently been recognized and researched.

Thirty-one of the 129 compounds on the United States Environmental Protection Agency's (USEPA) Priority Pollutant list are VOC's (Namkung and Rittman 1987). Currently, EPA drinking water standards exist for eight of these (Fed Reg 1987). Additionally, Wisconsin established groundwater

standards for several VOC's in its groundwater quality code, NR 140 (WDNR 1985).

The removal of VOC's from wastewater occurs primarily through volatilization, adsorption to biomass (e.g. sludge), biodegradation and chemical transformations, all of which are incidental to wastewater treatment. The degree to which these processes contribute to the removal depends on the chemical and physical properties of the compound and the characteristics of the matrix in which it exists (Kincannon et al 1983 and Strier and Gallup 1983). Consequently, complete removal of VOC's from the water is rarely accomplished during conventional wastewater treatment. VOC's remaining in effluent which is discharged to seepage cells are thereby given a pathway to the groundwater. Furthermore, VOC's which adsorb to sludge may subsequently desorb in the disposal environment and eventually reach groundwater (Bell and Tsezos 1987). Once in the groundwater, VOC's may be removed by airstripping. Unfortunately, this removal technology can be costly and time consuming.

In this survey, we were interested in gathering data on VOC's in Wisconsin municipal wastewaters and sludges, examining the degree to which the VOC's are reduced during wastewater treatment, and documenting occurrences of VOC's in groundwater near effluent seepage cells, unlined sludge

storage lagoons and drying beds. (Lined sludge storage lagoons were not studied due to limited funding and time restrictions.) The primary objective was to determine the extent to which VOC's are found in Wisconsin's wastewater systems and to establish whether or not they contaminate groundwater at treatment plant sites. We also cursorily investigated the fate of VOC's in sludge spread as an agricultural soil conditioner and fertilizer. To meet our objectives, the following matrixes were collected and analyzed for VOC's: influent; effluent; wastewater sludges; groundwater from monitoring wells around effluent seepage ponds, sludge drying beds, and sludge storage lagoons; and agricultural soils treated with sludges which contained VOC's. This survey includes sites throughout Wisconsin and is part of a continuing Wisconsin Department of Natural Resources (WDNR) research effort on groundwater quality in Wisconsin.

METHODS

A. Site Selection

Fifty-six Wisconsin communities were studied in this

survey (Fig.I). The criteria below were used in the following order for site selection:

1. Past evidence of VOC's in a municipality's groundwater. Public and private well water supply records were reviewed; those municipalities with ten or more VOC detections were candidates.

2. Municipal facilities receiving industrial or commercial discharges suspected or known to contain VOC's.

3. Municipal facilities using effluent seepage cells.

4. Availability of existing monitoring wells in proximity to effluent seepage cells.

5. Municipal facilities producing primary and secondary wastewater sludge.

6. Availability of existing monitoring wells in proximity to sludge storage lagoons or drying beds.

7. Sites representing the geographic and geologic variability of the state.

Sites for soil collection were chosen after the extent of sludge contamination was known from the initial stages of data collection. Soil sites were chosen according to the following criteria:

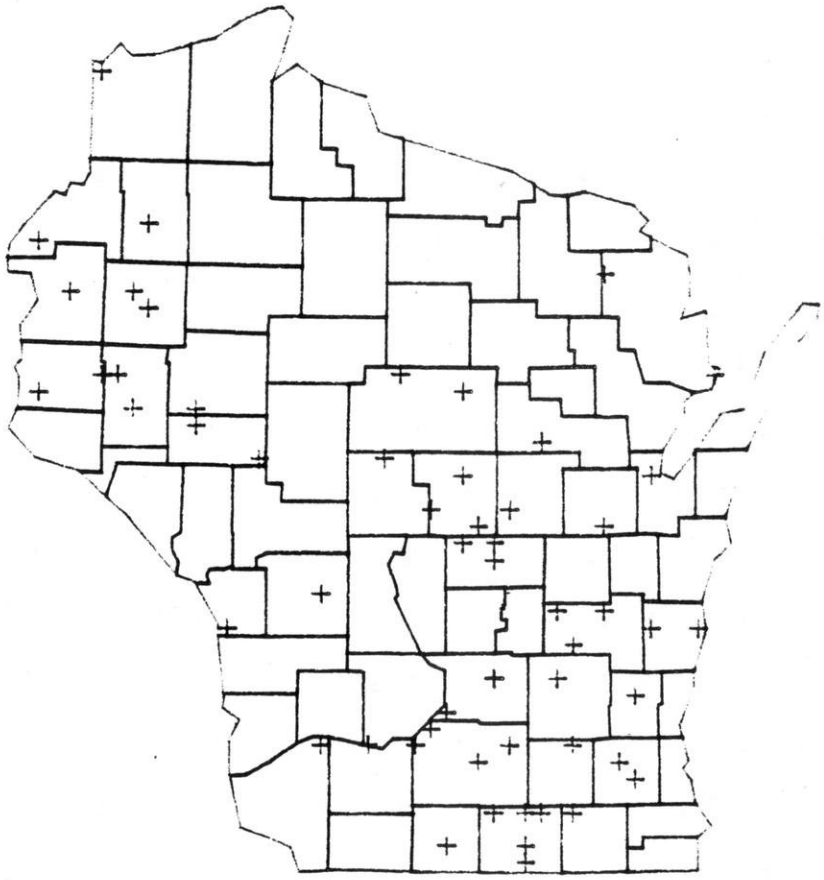
1. The sludge contained VOC's and was applied by injection to the soil within the last two years.

2. Soil characteristics similar at all sites. All sites fell into the silt loam class.

3. Accessibility of a sludge-treated site.

4. Accessibility of a control site in the same soil series as the sludge-treated site.

Figure 1. Sampling Locations



Almond
Appleton
Arena
Athens
Barron-Cameron
Beaver Dam
Beloit
Boyceville
Caroline
Chippewa Falls
Cumberland
Delafield-Hartland
Eau Claire
Edgerton
Evansville
Fairchild
Fond du Lac
Glenwood City
Goodman
Grantsburg
Green Bay
Hudson
Janesville
La Crosse
Lone Rock
Madison
Marinette
Marshfield
Menomonie
Merrimac
Milltown
Milton
Monroe
Muscoda
Northern Moraine
Pardeeville
Plainfield
Ripon
Sauk-Prairie
Sheboygan
Spooner
Stevens Point
Sun Prairie
Superior
Tomah
Watertown
Waukesha
Waupun
Wausau
Wautoma
West Bend
Whitewater
Wild Rose
Wisconsin Rapids
WI State Veterans' Home
Wyocena

B. General Sampling Background and Information

A total of 223 samples were collected. Sampling of influent, effluent, groundwater and sludge was conducted throughout the four seasons. Soil sampling occurred during the summer months of 1987 only.

All samples were collected in standard 40 ml glass VOC collection vials with Teflon /silicon rubber-faced septum screw caps. Four vials constituted one sample. For preservation, samples were stored with ice pacs in styrofoam coolers. A trip blank of distilled water accompanied each set of four vials and was kept with the other vials and closed at all times. Samples, field blanks and trip blanks were analyzed within 14 days of collection at the State Laboratory of Hygiene (SLH), Madison, Wisconsin.

B1. Grab Samples

Influent, effluent, and sludge samples were all grab sample collections. Influent was obtained prior to in-plant recycled flows (e.g. wastewater from a sludge press). Effluent was sampled at a point prior to chlorination in plants which disinfect with chlorine and at the point of discharge to seepage cells in those plants discharging to

seepage cells. Sludge samples taken from digesters were collected from faucets of access on the digesters after mixing of digeter contents was completed. Sludge from drying beds and lagoons was collected within two feet of the edge of the lagoon or bed. Depth of collection varied according to amount of sludge present, but was typically at a depth of 2-8". When vacuum-filtered or other cake sludge was collected, it was removed from the press when possible and taken from stockpiles (approximately 2-8" beneath surface) when the presses were not in operation.

Influent, effluent and sludge samples were first collected in a glass beaker and then transferred to the 40 ml vials. Liquid samples were poured into the vials with as little turbulence as possible and capped immediately after a positive meniscus formed. Dry sludges were placed into the vials with forceps and lab spatulas until vials were half full, as per SLH protocol (Organic Chemistry 1984).

B2. Groundwater Samples

Groundwater monitoring wells were sampled in accordance with the "Draft Groundwater Sampling Procedures Guidance Document" (Lindorff et al 1985) and as recommended in "Suggestions for Sampling Groundwater for Volatile Organic Compounds (VOC's)" (Stensby 1985). A 5' x 1.66" Teflon

Point Source bailer was used to purge wells and collect samples from them. All wells were purged six well volumes and allowed to recharge before samples were collected. A 1-1/4" Teflon bottom emptying device was used to minimize turbulence when transferring the samples from the bailer to the collection vials.

B3. Soil Samples

Soil samples were collected using the method in Appendix A.

ANALYTICAL METHODS

The SLH, Madison, Wisconsin, performed all VOC analysis. Samples were qualitatively screened using the cryogenic headspace technique described in the SLH's GC/MS Methods Manual. When screening revealed the presence of VOC's, a quantitative analysis was performed when possible. Liquid samples, including liquid sludges, were analyzed following Section 1332, "Volatile Organic Compounds by Purge and Trap Method" (Organic Chemistry 1984, 1987). Sludges which were too high in solids to allow GC quantification were not quantified. Soils were tested according to Section

1550 "Volatile Organic Compounds in Soil by Purge and Trap Method" (Organic Chemistry 1987).

RESULTS

A total of 223 samples were collected over an 18-month period. All samples were qualitatively screened for 45 compounds. Of these 45, 21 were detected in at least one of the samples (Table 1).

Table 2 summarizes the number 223 samples, categorized by sample type (Table 2, column 2). It also indicates the variety of compounds found in the sample types (Table 2, column 1). Finally, (column 3) Table 2 expresses the percentage of samples of a given sample type containing one or more compounds.

Table 1. Compounds detected.

Benzene*	Ethyl Benzene*
Carbon Disulfide	Fluorotrichloromethane*
Chlorobenzene*	Methyl ethyl ketone
Chloroform*	Tetrachloroethylene*
Chlorotoluene	Tetrahydrofuran
o-Dichlorobenzene	Toluene*
m-Dichlorobenzene	1,1,1-Trichloroethane*
1,1-Dichloroethane*	Trichloroethylene*
1,2-Dichloroethane*	Vinyl Chloride*
1,2-Dichloroethylene	Xylenes

*Priority Pollutants (Namkung and Rittman 1987)

TABLE 2. Summary of occurrence of the 21 detected compounds among the 223 samples.

MEDIUM	# DIFFERENT COMPOUNDS	# SAMPLES	% SAMPLES WITH DETECTS
INFLUENT	13	16	100
DRIED SLUDGE	14	13	100
SECONDARY SLUDGE	18	35	83
PRIMARY SLUDGE	6	5	80
WELLS, SLUDGE STORAGE	8	14	43
EFFLUENT	12	43	26
WELLS, EFFLUENT	2	29	7
SOIL, CONTROL	2	24	4
SOIL, TREATED	0	24	0

No VOC's were detected in soil samples from fields treated with sludge which contained VOC's. However, tetrachloroethylene and 1,2-dichloroethylene were detected at 0.41 and 0.43 micrograms per gram (mcg/g) respectively in one of the control field soil samples from Appleton.

Two soil samples were spiked at the Janesville sample site with an aliquot containing 1,2-dichloroethylene, benzene, tetrachloroethylene and ethyl benzene as a quality control measure. Recoveries from these spiked samples were low, ranging from <5.0% to 20% recovery (Table 3).

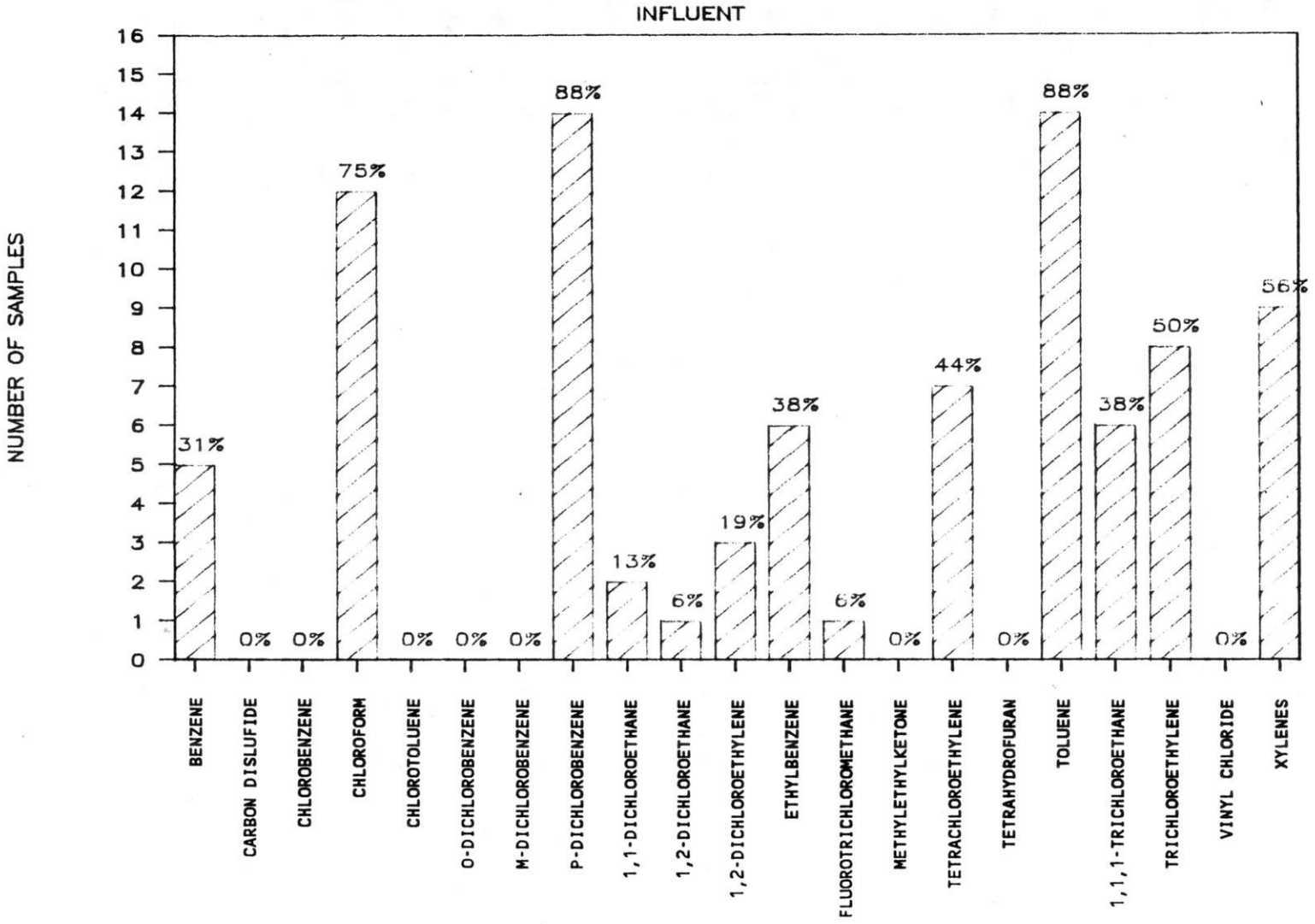
Table 3. VOC recoveries (%) from field spiked soil samples.

level of spike (mcg/g)			recovery (%)	
sample		compound	sample	
1	2		1	2
1.1	0.96	1,2-dichloroethylene	<5.0	5.2
1.1	0.96	benzene	<5.0	7.3
1.1	0.96	tetrachloroethylene	16.0	20.2
1.1	0.96	ethyl benzene	16.0	15.0

Of the 49 well water samples collected from wells positioned around effluent seepage cells, only two samples contained detectable levels of VOC's. Both samples came from downgradient well 104 in Milton. Tetrachloroethylene and trichloroethylene were quantified in the first sample at 7.5 and 3.3 micrograms per liter (mcg/l), respectively. The same two chemicals were detected in the second sample at 9.5 and 2.4 mcg/l, respectively. No VOC's were detected in the third sample collected from this well.

Summarized results for influent, effluent, and sludge samples, and samples from monitoring wells at sludge storage facilities or drying cells are presented in Figs. 2-7.

Figure 2. Frequency of detection.



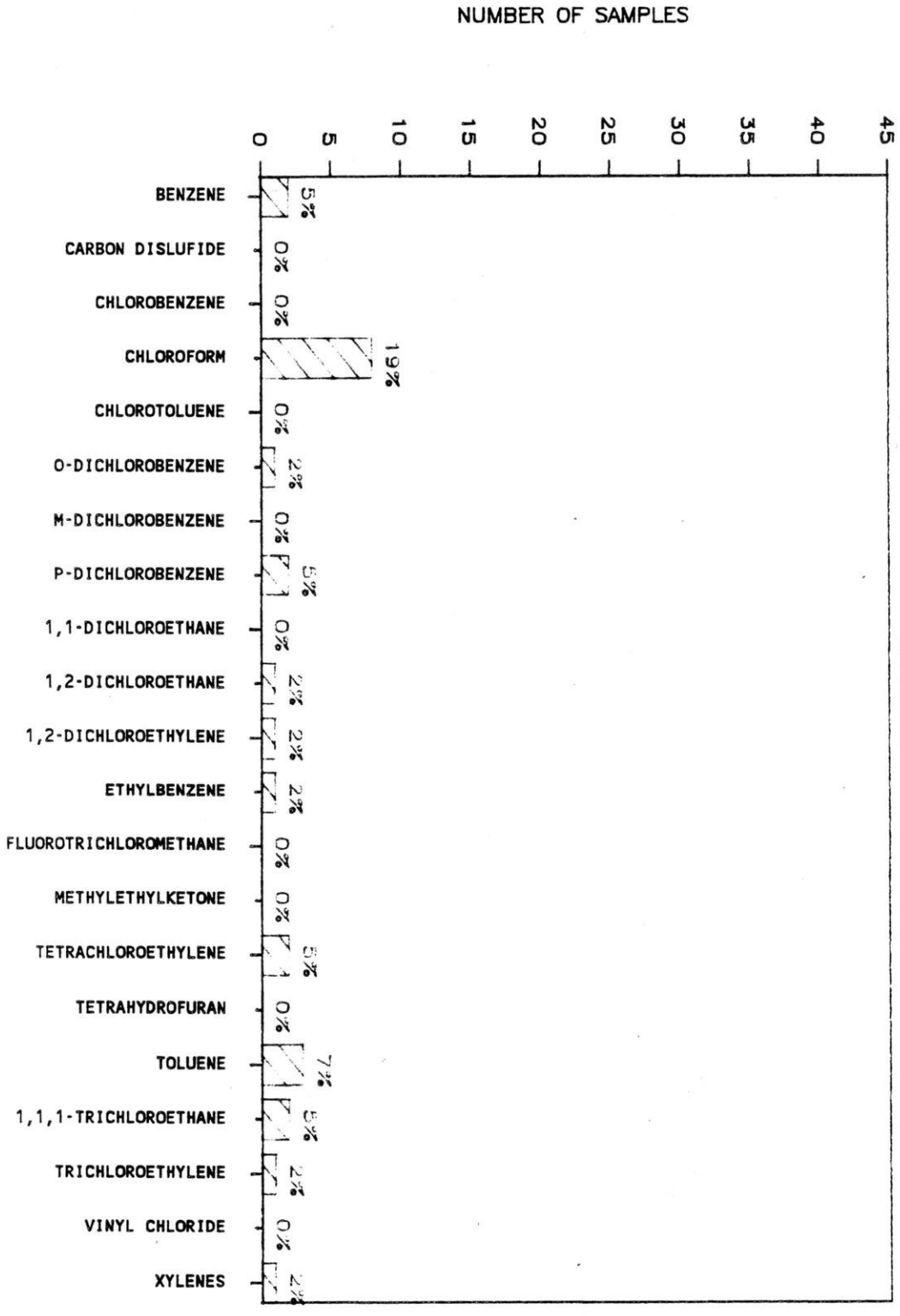


Figure 3. Frequency of detection.

Figure 4. Frequency of detection.

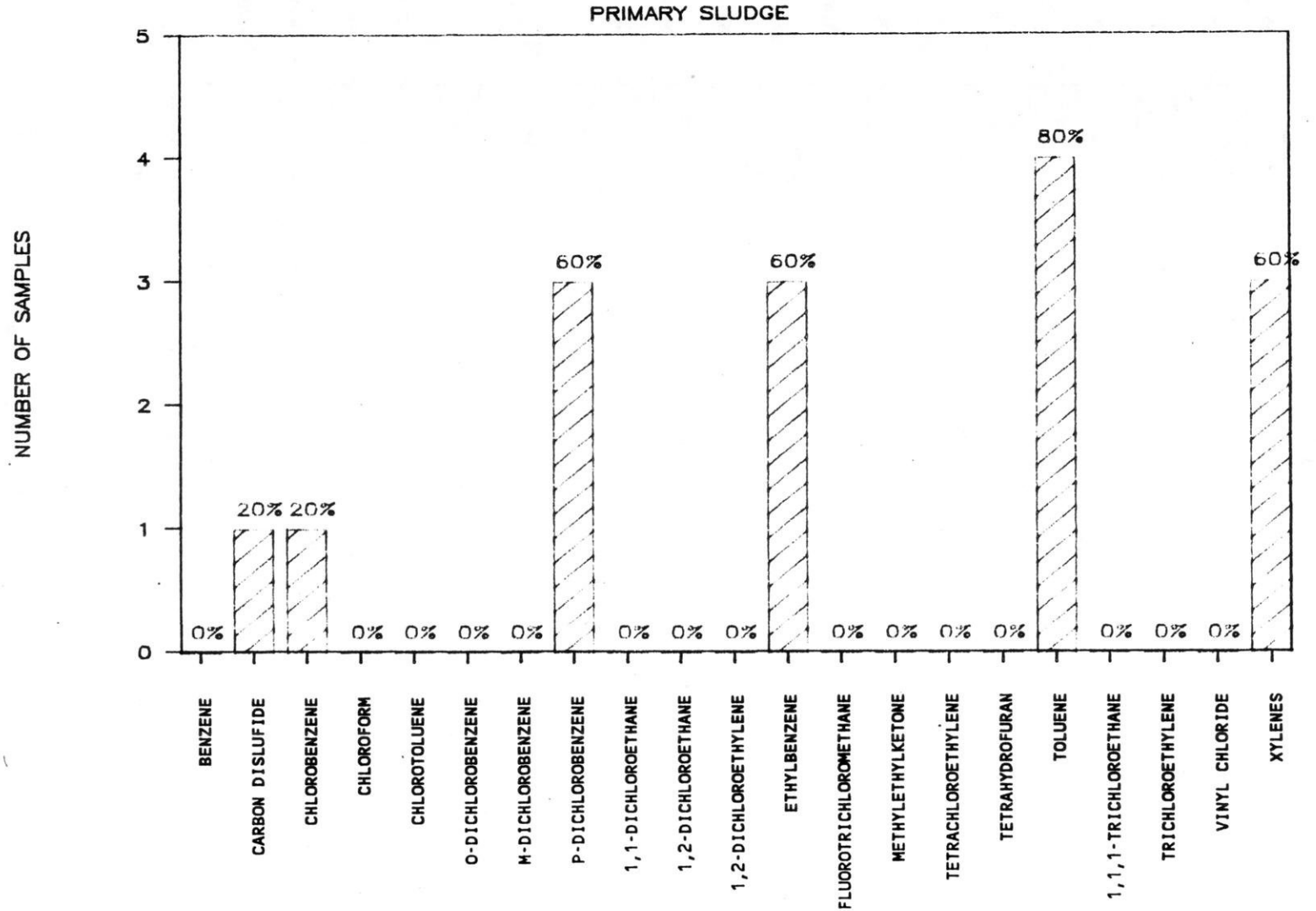


Figure 5. Frequency of detection.

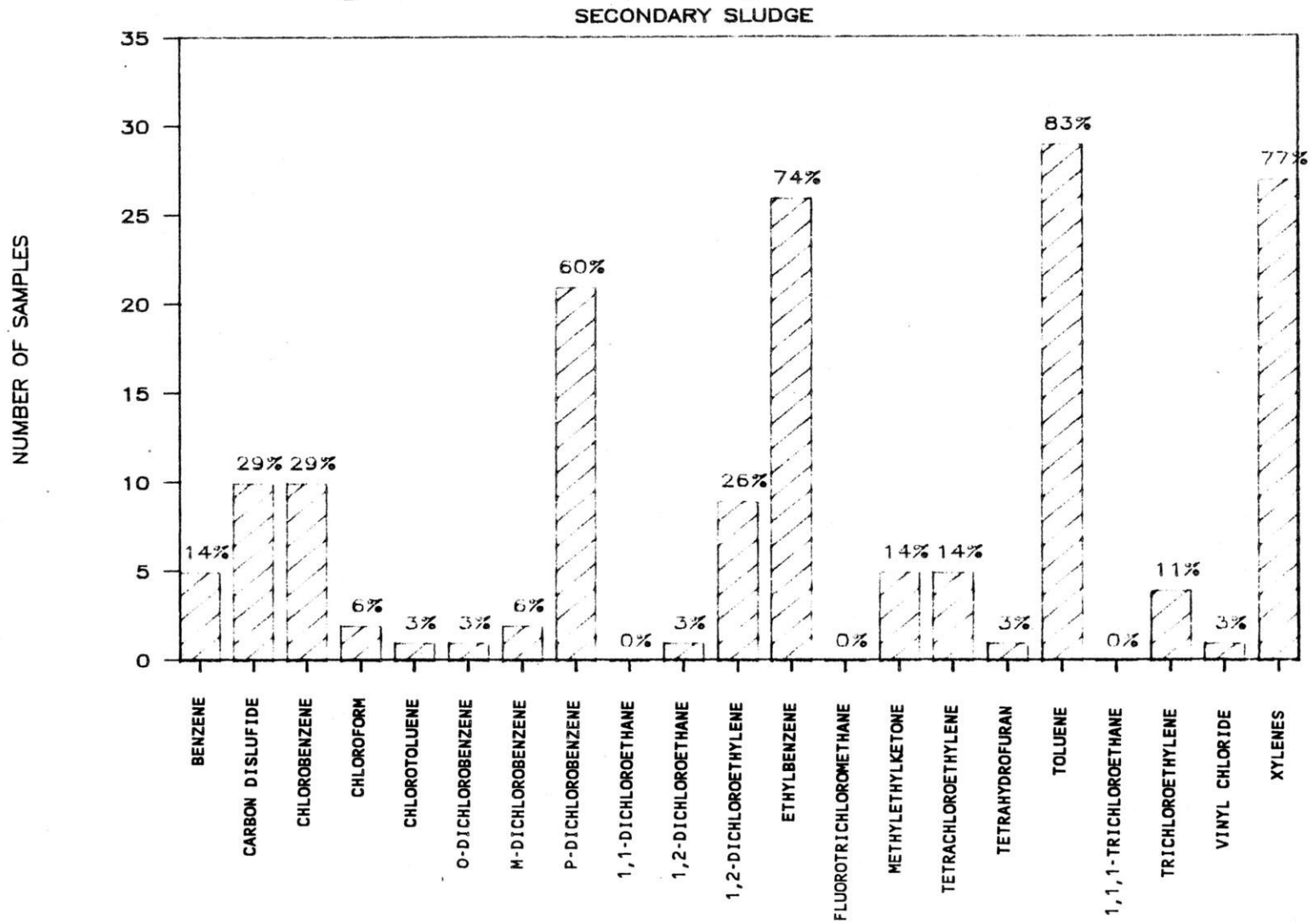


Figure 6. Frequency of detection.

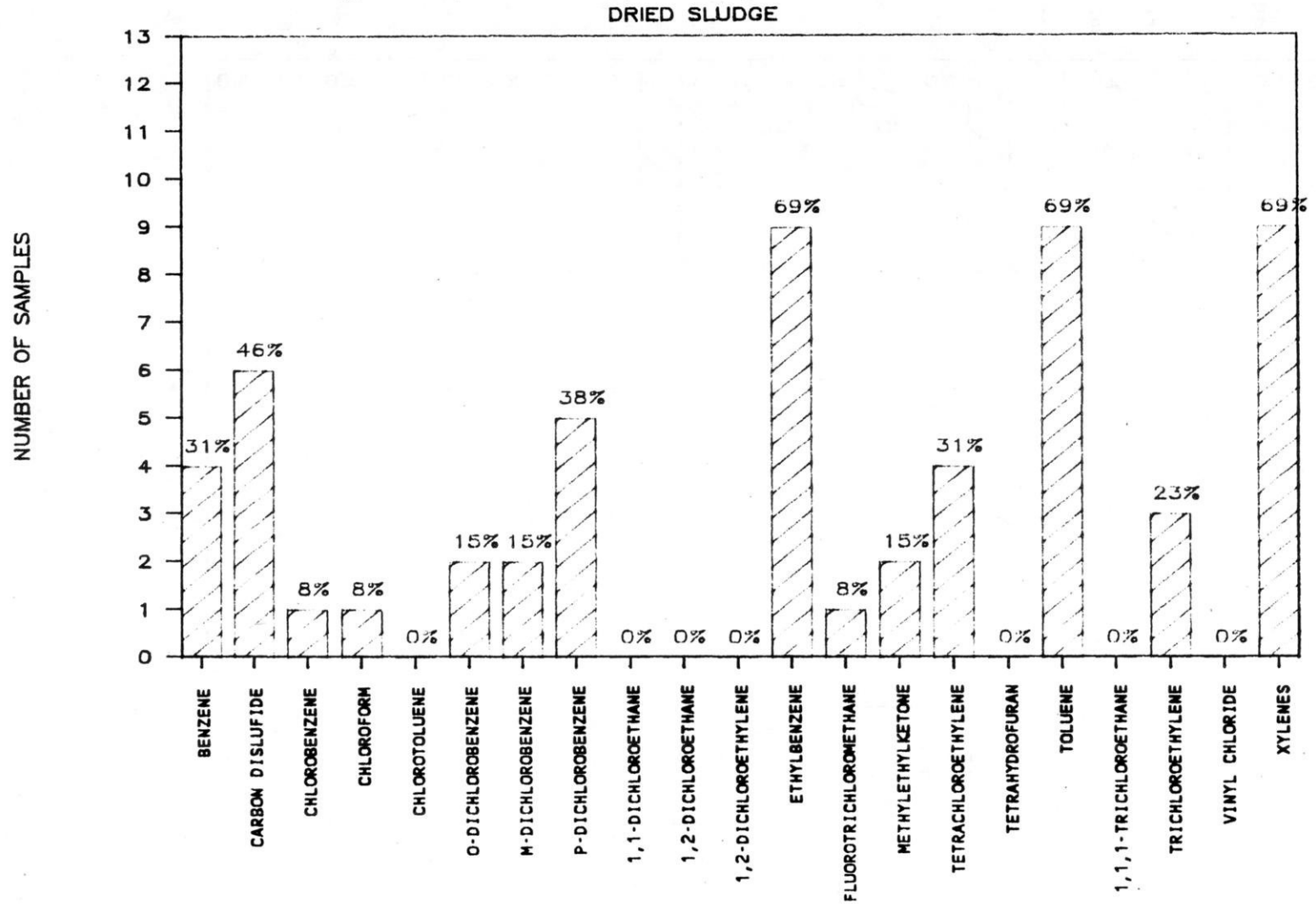


Figure 7. Frequency of detection

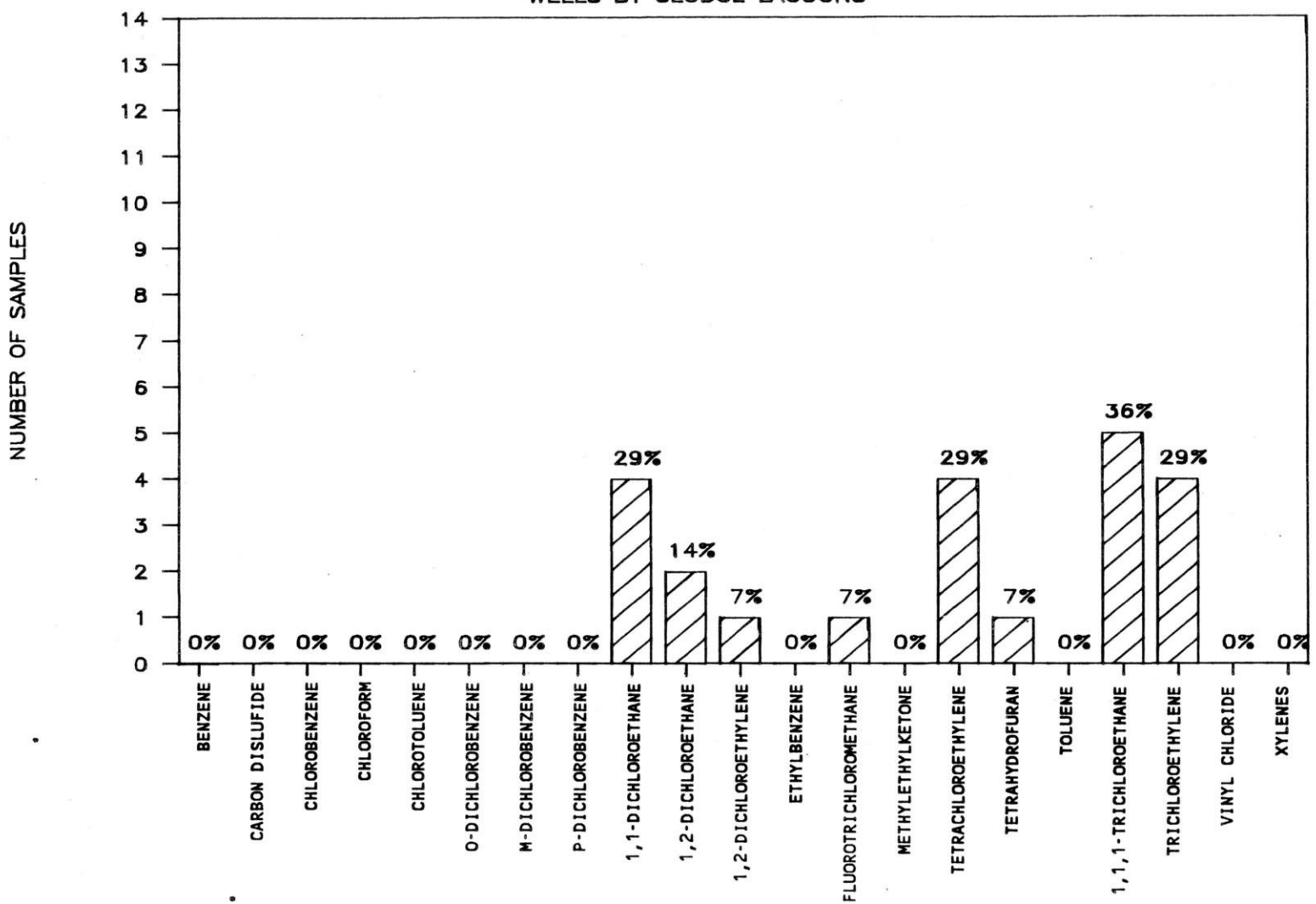


Table 4 summarizes concentrations of VOC's in those samples where quantification was possible. Sample specific test results are provided in Tables 5-12. Tables 5-7 (below) present individual sample test results, grouped by municipality for those communities where influent, effluent and other samples were collected. Tables 13-18 (Appendix B) provide sample specific test results, grouped by sample type. Tables 8-12 (Results in Relation to State Regulations and with Respect to Toxicity Data) contain data collected in this survey along with LD50 toxicity data for oral dosages to rats and VOC limits set by NR 140, the Wisconsin Administrative Code for Groundwater Quality. (Note: even though they have no meaning in terms of regulatory control for VOC levels in influent, effluent, sludge and soils, I have compared the NR 140 groundwater standards to the VOC levels found in these matrixes for lack of any more appropriate standard.)

TABLE 4. Distribution of concentrations of VOC's among the matrixes.

CONCENTRATION	# QUANTIFIED DETECTIONS						
MCG/L	INFLUENT	EFFLUENT	PRIMARY SLUDGE	SECONDARY SLUDGE	SOIL (CONTROL)	WELLS** (EFFLUENT)	WELLS*** (SLUDGE)
0-10	77	24	1	3	2	2	17
11-20	1	1	2	1	0	0	2
21-30	2	0	1	1	0	0	0
31-40	1	0	1	0	0	0	0
41-50	2	0	1	0	0	0	0
51-60	0	0	0	1	0	0	0
>60	5	0	2	8	0	0	3
TOTAL:	88	25	8*	14*	2	2	22

* more detections made, but not quantified
** wells which monitor groundwater at effluent seepage cell sites.
*** wells which monitor groundwater at sludge storage sites.

Table 5. Test results from municipalities where influent, effluent and sludge were collected. Units are micrograms/liter.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
APPLETON	INFLUENT	-	-	-	6.9	-	-	-	-	-	-	-	320	-	-	50	-	180	7.9	82	-	1100
	SECONDARY SLUDGE	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	9200	-	-	-	120
	DRIED SLUDGE	*	*	-	-	-	-	-	-	-	-	-	*	-	-	*	-	*	-	*	-	*
	DRIED SLUDGE	*	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	*	-	-	-	*
	EFFLUENT	-	-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BEAVER DAM	INFLUENT	-	-	-	1.5	-	-	-	2.3	-	-	-	-	-	-	-	-	2.4	-	1.7	-	-
	SECONDARY SLUDGE	-	*	*	-	-	-	-	*	-	-	*	*	-	*	-	-	*	-	-	-	*
	SECONDARY SLUDGE	-	*	-	-	-	*	-	-	-	*	*	*	-	-	-	-	*	-	-	-	*
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BELOIT	INFLUENT	-	-	-	2.3	-	-	-	3.1	-	-	-	1	-	-	2.9	-	4.1	1.5	-	-	4
	SECONDARY SLUDGE	-	*	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	SECONDARY SLUDGE	-	-	-	-	*	-	-	*	-	-	-	*	-	-	*	-	*	-	*	-	*
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JANESVILLE	INFLUENT	7.1	-	-	4.1	-	-	-	2.7	-	-	-	7	-	-	2.7	-	67	1.3	1.9	-	42
	SECONDARY SLUDGE	-	-	-	-	-	-	-	-	-	-	-	98	-	110	4.3	-	29000	-	-	-	560
	SECONDARY SLUDGE	*	-	-	-	-	-	*	*	-	-	-	*	-	-	*	-	*	-	*	-	*
	EFFLUENT	-	-	-	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified
- not detected

Table 5 continued.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
MADISON	INFLUENT	-	-	-	4.6	-	-	-	2.1	-	-	-	-	-	-	4.6	-	4.8	-	2.6	-	3.9
	SECONDARY SLUDGE	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	*	-	-	-	*
	SECONDARY SLUDGE	-	-	-	-	-	-	*	-	-	-	-	*	-	-	-	-	*	-	-	-	*
	DRIED SLUDGE	-	-	-	-	-	*	*	-	-	-	-	*	-	-	-	-	*	-	-	-	*
	EFFLUENT	-	-	-	3.2	-	-	-	-	-	-	-	-	-	-	1.4	-	-	-	-	-	-
MONROE	INFLUENT	1.5	-	-	6.9	-	-	-	4.8	2.6	-	-	1.2	-	-	-	-	3.4	5.9	-	-	7.2
	PRIMARY SLUDGE	-	-	-	-	-	-	-	25	-	-	-	10	-	-	-	-	12	-	-	-	46
	SECONDARY SLUDGE	-	-	-	-	-	-	-	*	-	-	*	*	-	-	-	-	*	-	-	-	*
	SECONDARY SLUDGE	54	-	-	-	-	-	-	30	-	-	-	61	-	-	-	-	19	-	-	-	79
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIPON	INFLUENT	-	-	-	-	-	-	-	5.2	-	-	-	-	-	-	-	-	34	-	-	-	-
	SECONDARY SLUDGE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DRIED SLUDGE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
	DRIED SLUDGE	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified

- not detected

Table 5 continued.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
WAUPUN	INFLUENT	-	-	-	9	-	-	-	4.8	-	-	-	-	-	-	-	-	3.3	-	5.3	-	-
	SECONDARY SLUDGE	-	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	SECONDARY SLUDGE	-	-	-	-	-	-	-	6.4	-	-	-	-	-	-	-	-	2.4	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified
- not detected

Table 6. Test results from municipalities using effluent seepage cells where influent, effluent, and well samples were taken. Units are micrograms/liter.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
CAROLINE	INFLUENT	2.8	-	-	2.7	-	-	-	4.8	-	-	-	1.7	-	-	-	-	2.5	-	-	-	6.7
	EFFLUENT	6.8	-	-	-	-	-	-	-	-	1.5	-	1.7	-	-	-	-	11	-	-	-	8.5
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GOODMAN	INFLUENT	-	-	-	6.8	-	-	-	3.9	-	-	-	-	-	-	-	-	2.8	-	-	-	-
	EFFLUENT	-	-	-	1.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	2.1	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 404	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUTOMA	INFLUENT	-	-	-	1.3	-	-	-	3.2	-	1.6	1.6	-	-	-	2.1	-	3.3	-	-	-	-
	EFFLUENT	-	-	-	1.2	-	-	-	-	-	-	1.5	-	-	-	-	-	-	9.3	-	-	-
	EFFLUENT	7.2	-	-	4	-	-	-	2.9	-	-	-	-	-	-	2.9	-	9.5	-	-	-	-
	WELL 402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 401	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified

- not detected

Table 6 continued.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
MILTON	INFLUENT	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	-	-	-	3.3	-	-
	WELL 104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.5	-	-	-	2.4	-	-
	WELL 104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	DRIED SLUDGE	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	-
	PRIMARY SLUDGE	-	*	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	PRIMARY SLUDGE	-	-	-	-	-	-	-	15	-	-	-	35	-	-	-	-	150	-	-	-	160
	SECONDARY SLUDGE	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	*	-	-	-	*

* detected but not quantified

- not detected

Table 7. Test results from municipalities with sludge drying beds or storage lagoons and having groundwater monitoring wells. Units are micrograms/liter.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
EDGERTON	INFLUENT	4.6	-	-	1.6	-	-	-	3	-	-	2.3	1	4.3	-	2	-	7.1	4.5	5.9	-	3.4
	SECONDARY SLUDGE	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	DRIED SLUDGE	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-
	WELL 1	-	-	-	-	-	-	-	-	13	-	-	-	100	-	4.1	-	-	64	2.5	-	-
	WELL 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.5	1.2	-	-
SUN PRAIRIE	INFLUENT	2.8	-	-	-	-	-	-	2.1	-	-	-	-	-	-	-	-	5.5	-	-	-	2.1
	SECONDARY SLUDGE	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	DRIED SLUDGE	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	-	-	-	-	*
	WELL 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified

- not detected

Table 7 continued.

		BENZENE	CARBON DISLUFIDE	CHLOROBENZENE	CHLOROFORM	CHLOROTOLUENE	O-DICHLOROBENZENE	M-DICHLOROBENZENE	P-DICHLOROBENZENE	1,1-DICHLOROETHANE	1,2-DICHLOROETHANE	1,2-DICHLOROETHYLENE	ETHYLBENZENE	FLUOROTRICHLOROMETHANE	METHYLETHYLKETONE	TETRACHLOROETHYLENE	TETRAHYDROFURAN	TOLUENE	1,1,1-TRICHLOROETHANE	TRICHLOROETHYLENE	VINYL CHLORIDE	XYLENES
WAUKESHA	INFLUENT	-	-	-	2.8	-	-	-	5	3.4	-	2.3	-	-	-	24	-	4.3	26	14	-	2.4
	SECONDARY SLUDGE	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	SECONDARY SLUDGE	-	*	*	-	-	-	-	*	-	-	*	*	-	*	-	-	*	-	-	-	*
	DRIED SLUDGE	-	*	-	-	-	*	*	*	-	-	-	*	-	-	-	-	*	-	-	-	*
	WELL 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 2	-	-	-	-	-	-	-	-	5.9	1.8	-	-	-	-	4	-	-	12	2.7	-	-
	WELL 2	-	-	-	-	-	-	-	-	9.1	-	-	-	-	-	4.2	-	-	8.4	2.7	-	-
	WELL 2	-	-	-	-	-	-	-	-	10	1.3	1.9	-	-	-	6	-	-	7.5	3.1	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	260	-	-	-	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	WELL 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	EFFLUENT	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* detected but not quantified

- not detected

RESULTS IN RELATION TO STATE REGULATIONS AND WITH RESPECT TO TOXICITY DATA

See Tables 8-12.

Table 8. Summary of detections in 16 influent samples from 16 municipal wastewater treatment facilities, with NR 140 (WDNR 1985) and LD50 doses (Sax 1984) for perspective. LD50 data were converted from mg/kg body weight to mcg/kg body weight.

COMPOUNDS DETECTED IN INFLUENT	# SAMPLES WITH DETECTS	# DETECTS QUANTIFIED	MEAN (MCG/L)	MEDIAN (MCG/L)	LOW & HIGH (MCG/L)	LIMIT OF DETECTION (MCG/L)	NR 140 ES (MCG/L)	NR 140 PAL (MCG/L)	LD50 (MCG/KG BODY WT)
P-DICHLOROBENZENE	14	14	3.7	3.6	2.1 - 5.2	2	750	150	5E +5
TOLUENE	14	14	23.2	4.2	2.4 - 180	1	343	68.6	5E +6
CHLOROFORM	12	12	4.2	3.5	1.3 - 9.0	1	**	**	8E +5
XYLENES	9	9	130.2	4.0	2.1 - 1100	2	620	124	4.3E +6
TRICHLOROEHTYLENE	8	8	14.7	4.7	1.7 - 82	1	1.8	0.18	4.92E +6
TETRACHLOROETHYLENE	7	7	12.6	2.9	2 - 50	1	1	0.1	2.0E +5
1,1,1-TRICHLOROETHANE	6	6	7.9	5.2	1.3 - 26	1	200	40	1.03E +7
ETHYLBENZENE	6	6	55.3	1.5	1 - 320	1	**	**	3.5E +6
BENZENE	5	5	3.8	2.8	1.5 - 7.1	1	0.67	0.067	3.8E +6
1,2-DICHLOROETHYLENE	3	3	2.1	2.0	1.6 - 2.3	1	0.5	0.05	^
1,1-DICHLOROETHANE	2	2	3.0	3.0	2.6 -3.4	1	**	**	7.25E +5
1,2-DICHLOROETHANE	1	1	-	-	1.6*	1	**	**	^
FLUOROTRICHLOROMETHANE	1	1	-	-	4.3*	1	**	**	^

* single occurrence value
** no limit set forth in NR 140
^ no LD50 data available

NR 140 = Wisconsin Administrative Code for Groundwater Quality
ES = Enforcement Standard established in NR 140
PAL= Preventive Action Limit established in NR 140

LD50 = calculated dose suspected to cause the death of 50% of a defined experimental population. LD50 values here are for oral dosage to rats (Sax 1984).

Table 9. Summary of detections in five primary sludge samples from four municipal wastewater treatment facilities, with NR 140 limits (WDNR 1985) and LD50 doses (Sax 1984) to lend perspective. LD50 data were converted from mg/kg body weight to mcg/kg body weight.

COMPOUNDS DETECTED IN PRIMARY SLUDGE	# SAMPLES WITH DETECTS	# DETECTS QUANTIFIED	MEAN (MCG/L)	MEDIAN (MCG/L)	LOW & HIGH (MCG/L)	LIMIT OF DETECTION (MCG/L)	NR 140 ES (MCG/L)	NR 140 PAL (MCG/L)	LD50 (MCG/KG BODY WT)
TOLUENE	4	2	81	81	12 - 150	1	343	68.6	5.0E +6
ETHYLBENZENE	3	2	22.5	22.5	10 - 35	1	**	**	3.5E +6
P-DICHLOROBENZENE	3	2	20	20	15 - 25	2	750	150	5.0E +5
XYLENES	3	2	103	103	46 - 160	2	620	124	4.3E +6
CARBON DISULFIDE	1	0	-	-	-	5	**	**	^
CHLOROBENZENE	1	0	-	-	-	2	**	**	2.9E +6

** no limit set forth in NR 140
^ no LD50 data available

NR 140 = Wisconsin Administrative Code for Groundwater Quality
ES = Enforcement Standard established in NR 140
PAL= Preventive Action Limit established in NR 140

LD50 = calculated dose suspected to cause the death of 50% of a defined experimental population. LD50 values here are for oral dosage to rats (Sax 1984).

Table 10. Summary of detections in 35 secondary sludge samples collected from 27 municipal wastewater trea facilities, with NR 140 limits (WDNR 1985) and LD50 doses (Sax 1984) to lend perspective. Origin LD50 data were converted from mg/kg body weight to mcg/kg body weight.

COMPOUNDS DETECTED IN SECONDARY SLUDGE	# SAMPLES WITH DETECTS	# DETECTS QUANTIFIED	MEAN (MCG/L)	MEDIAN (MCG/L)	LOW & HIGH (MCG/L)	DETECTION (MCG/L)	ES (MCG/L)	PAL (MCG/L)	(MCG/KG BODY WT)
TOLUENE	29	4	9555	4609.5	2.4 - 29000	1	343	68.6	5.0E +6
XYLENES	27	3	253	120	79 - 560	2	620	124	4.3E +6
ETHYLBENZENE	26	2	79.5	79.5	61 - 98	1	**	**	3.5E +6
P-DICHLOROBENZENE	21	2	18.2	18.2	6.4 - 30	2	750	150	5.0E +6
CARBON DISULFIDE	10	0	-	-	-	5	**	**	^
CHLOROBENZENE	10	0	-	-	-	2	**	**	2.91E +6
1,2-DICHLOROETHYLENE	9	0	-	-	-	1	**	**	^
BENZENE	5	1	-	-	54*	1	0.67	0.067	3.8E +6
METHYLETHYLKETONE	5	1	-	-	110*	12	**	**	3.4E +6
TETRACHLOROETHYLENE	5	1	-	-	4.3*	1	**	**	2.0E +5
TRICHLOROETHYLENE	4	0	-	-	-	1	1.8	0.18	4.92E +6
M-DICHLOROBENZENE	2	0	-	-	-	2	**	**	^
1,2-DICHLOROETHANE	1	0	-	-	-	1	0.5	0.05	^
O-DICHLOROBENZENE	1	0	-	-	-	2	**	**	5.0E +5
CHLOROFORM	2	0	-	-	-	1	**	**	8.0E +5
CHLOROTOLUENE	1	0	-	-	-	1	**	**	^
TETRAHYDROFURAN	1	0	-	-	-	200	**	**	^
VINYL CHLORIDE	1	0	-	-	-	***	0.015	0.0015	5.0E +5

* single occurrence value
** no limit set forth in NR 140
*** laboratory currently does not quantify this compound
^ no LD50 data available

NR 140 = Wisconsin Administrative Code for Groundwater Quality
ES = Enforcement Standard established in NR 140
PAL= Preventive Action Limit established in NR 140

LD50 = calculated dose suspected to cause the death of 50% of a defined experimental population.
LD50 values here are for oral dosage to rats (Sax 1984).

Table 11. Summary of VOC detections in 14 water samples from wells monitoring sludge storage lagoons or drying beds at wastewater treatment facilities in Wisconsin. NR 140 limits (WDNR 1985) and LD50 data (Sax 1984) are provided to lend perspective.

COMPOUNDS DETECTED IN SLUDGE MONITORING WELLS	# SAMPLES WITH DETECTS	# DETECTS QUANTIFIED	MEAN (MCG/L)	MEDIAN (MCG/L)	LOW & HIGH (MCG/L)	LIMIT OF DETECTION (MCG/L)	NR 140 ES (MCG/L)	NR 140 PAL (MCG/L)	LD50 (MCG/KG BODY WT)
1,1,1-TRICHLOROETHANE	5	5	19.2	8.4	4 - 64	1	200	40	1.03E +7
1,1-DICHLOROETHANE	4	4	9.5	9.6	5.9 - 13	1	**	**	7.25E +5
TETRACHLOROETHYLENE	4	4	4.6	4.2	4 - 6	1	1	0.1	2.0E +5
TRICHLOROETHYLENE	4	4	2.8	2.7	2.5 - 3.1	1	1.8	0.18	4.92E +6
1,2-DICHLOROETHANE	2	2	1.6	1.6	1.3 - 1.8	1	0.5	0.05	^
1,2-DICHLOROETHYLENE	1	1	-	-	1.9*	1	**	**	^
FLUOROTRICHLOROMETHANE	1	1	-	-	100*	1	**	**	^
TETRAHYDROFURAN	1	1	-	-	260*	200	**	**	^

* single occurrence value
** no limit set forth in NR 140
^ no LD50 data available

NR 140 = Wisconsin Administrative Code for Groundwater Quality
ES = Enforcement Standard established in NR 140
PAL= Preventive Action Limit established in NR 140

LD50 = calculated dose suspected to cause the death of 50% of a defined experimental population. LD50 values here are for oral dosage to rats (Sax 1984).

Table 12. Summary of 43 effluent samples from 37 municipal wastewater treatment facilities, wtih NR 140 limits (WDNR 1985) and LD50 data (Sax 1984) provided to lend perspective. Original LD50 data (Sax 1984) were converted from mg/kg body weight to mcg/kg body weight.

COMPOUND DETECTED IN EFFLUENT	# SAMPLES WITH DETECTS	# DETECTS QUANTIFIED	MEAN (MCG/L)	MEDIAN (MCG/L)	LOW & HIGH (MCG/L)	LIMIT OF DETECTION (MCG/L)	NR 140 ES (MCG/L)	NR 140 PAL (MCG/L)	LD50 (MCG/KG BODY WT)
CHLOROFORM	8	8	2.5	2.6	1 - 4	1	**	**	8.0E +5
TOLUENE	3	3	7.3	9.5	1.4 - 11	1	343	68.6	5.0E +6
1,1,1-TRICHLOROETHANE	2	2	5.4	5.4	1.5 - 9.3	1	200	40	1.03E +7
BENZENE	2	2	7	7	6.8 - 7.2	1	0.67	. 0.067	3.8E +6
P-DICHLOROBENZENE	2	2	2.9	2.9	2.8 - 2.9	2	750	150	5.0E +5
TETRACHLOROETHYLENE	2	2	2.2	2.2	1.4 - 2.9	1	1	0.1	2.0E +5
1,2-DICHLOROETHANE	1	1	-	-	1.5*	1	0.5	0.05	^
1,2-DICHLOROETHYLENE	1	1	-	-	1.5*	1	**	**	^
ETHYLBENZENE	1	1	-	-	1.7*	1	**	**	3.5E +6
O-DICHLOROBENZENE	1	1	-	-	2.7*	2	**	**	5.0E +5
TRICHLOROETHYLENE	1	1	-	-	1.2*	1	200	40	4.92E +6
XYLENES	1	1	-	-	8.5*	2	620	124	4.3E +6

* single occurrence value
** no limit set forth in NR 140
^ no LD50 data available

NR 140 = Wisconsin Administrative Code for Groundwater Quality
ES = Enforcement Standard established in NR 140
PAL= Preventive Action Limit established in NR 140

LD50 = calculated dose suspected to cause the death of 50% of a defined experimental population. LD50 values here are for oral dosage to rats (Sax 1984).

DISCUSSION

VOC's were detected in all matrixes, except soils treated with sludge. The degree (percentage of samples with detects, number of compounds per matrix, number of detections per sample and concentration of the compounds) varied among sample types. Presence, variety and concentrations at which the compounds occurred are of most importance in this survey.

All influent samples contained at least one VOC at or above the detection limit. Concentrations of the individual VOC's were less than 10 mcg/l 88% of the time (Table 13, App. B) with the median for each of the 13 compounds less than 6 mcg/l (Table 8). These relatively dilute concentrations are expected, given the volumes of water entering a wastewater treatment plant each day. Only four compounds were found at concentrations greater than 60 mcg/l (Table 13); these occurrences of ethyl benzene, toluene, trichloroethylene and xylene were restricted to two samples (Janesville and Appleton). The apparently unusual, high levels could be the result of a pulse of concentrated industrial or commercial discharge entering the plant at the time of sampling rather than representing a typical daily level of these compounds. More sampling is needed at these sites to determine whether or not these are typical or

unusual concentrations for these facilities.

In comparison to 100% of the influent samples, only 26% of the effluent samples tested positively for VOC's (Table 14, App. B). Ninety-six percent of the detections in the effluent were less than 10 mcg/l (Table 14). The median was less than 10 mcg/l for all samples (Table 12). Overall, effluent samples contained fewer VOC's, and lower concentrations of VOC's, than influent samples. Assuming the influent and effluent were representative samples, VOC's were removed from the wastewater stream during treatment.

Results from samples of groundwater at effluent seepage ponds further reflect the reduction of VOC concentrations during the treatment process. Despite the presence of VOC's in the effluent, only one well (#104 in Milton) monitoring the effluent cells contained compounds at detectable levels. Reduction in VOC's at this point in the treatment process may be a result of volatilization from the water's surface or chemical degradation or transformation, aided by environmental forces such as wind, rain and sun. Further reduction could take place in the soil at the site of infiltration, either in the form of adsorption, chemical and biological degradation, or simply dilution.

While the concentrations of VOC's found in the influent, the effluent and the groundwater associated with the discharged effluent are low (below 10 mcg/l for the most

part), it is necessary to recognize that these levels exceed the limits set by the USEPA and the WDNR (Tables 8-12 in Results and 13-14 in Appendix B) for drinking water safety and groundwater quality. Although confirmation of VOC concentrations has not been made by repeated sampling, I conclude from the current data set that VOC's occur at elevated levels at the sites surveyed and anticipate the same is true in other communities not included in this survey.

Sludge clearly contains more VOC's than any other matrix collected, both with regard to variety of compounds detected and the higher concentrations of those compounds. Eighteen different compounds were detected in the secondary sludges, more than in any other matrix (Table 2). Chlorotoluene, methyl ethyl ketone, carbon disulfide, m-dichlorobenzene and vinyl chloride are found only in the sludges. Sludges have a much longer retention time in treatment plants than influent or effluent; the greater variety of VOC's seen in sludge may be a reflection of this and the consequent increased chance for the subsample we collected to have come in contact with many more compounds (produced by local industry and homeowners) than what was found in the influent or effluent on the day(s) of sampling.

As seen in Tables 15-17, Appendix B, many VOC detections in sludges were not quantified. Typically, those

unquantified detections were left unquantified due to the extreme difficulty or impossibility of quantification posed by the matrix (i.e. % total solids prevented GC analysis). At the time of collection, SLH did not have the capability to quantify VOC's in dry sludges. Consequently, none of the VOC detections in dry sludges were quantified. We can, however, gain a perspective on the concentrations of VOC's in sludge from the sludges that were quantified, even though they represent only a small percentage of the total primary and secondary sludges collected, and none of the dry sludges.

VOC's apparently accumulate and concentrate in sludge. This is seen in both primary and secondary sludge samples. Of the quantified results, 25% of the compounds in primary sludge were at concentrations greater than 60 mcg/l; 63% of the detections were greater than 11 but less than 60 mcg/l; and only 7% of the detections were 10 or fewer mcg/l. Where quantification was possible, the majority (57%) of secondary sludge samples had concentrations higher than 60 mcg/l, 21% were greater than 11 but less than 60 mcg/l, and another 21% were less than 10 mcg/l (Tables 4 and 15-16). When compared to the concentrations found in the influent and effluent (the majority of which fell below 10 mcg/l), the levels found in sludge clearly demonstrate a pattern of VOC concentration. The occurrence of compounds at higher

concentrations in the sludges is most probably a result of the adsorption of organics to sludge and a function of the longer retention times of sludges in the plants.

Because organics can desorb from biomass, the ultimate disposal of sludge containing concentrated VOC's poses a threat to the environment. One area of concern which has received research attention, is the potential for organics to desorb when the sludge is applied to farmland, thus entering the soils and, potentially, the groundwater (Jacobs and Zabik 1984). Our survey detected no evidence of this occurring under current practice in the three sites where collections of soil from fields treated with sludges containing VOC's were made. However, poor recoveries from the spiked control samples (Table 3) suggest the recoveries from the soil samples themselves may not have been true. VOC concentrations in fields treated with sludge should be further researched since sludge disposal through land spreading is a common practice in Wisconsin and the results obtained here are inconclusive. An elevated concentration of VOC's in sludge will not necessarily mean the sludge cannot be land spread. As Jacobs and Jabik point out in their study of VOC's in Michigan sludges (Jacobs and Zabik 1984), acceptable application rates for sludges which contain VOC's can be calculated in a similar manner to application rates for fertilizers, once concentrations in

the sludges are known.

Another concern is the desorption of volatile organics from sludge at unlined storage sites, such as short retention time drying beds and long term storage lagoons. Our survey indicates this is occurring at municipal treatment plants in Wisconsin. In Edgerton, VOC's were detected in the groundwater at the drying cells; in Waukesha VOC's were detected in the groundwater at the sludge storage lagoons (Table 7). The median detection values for 1,2-dichloroethane, tetrachloroethylene and trichloroethylene exceeded both the Preventive Action Limits (PAL) and Enforcement Standard (ES) in NR 140 (Table 11). Five other VOC's were also found in the groundwater at these sludge storage sites, but the median levels did not exceed the PAL and ES set by the state. Certainly, more collections are needed to ascertain the accuracy of the levels detected; currently there are not enough data for statistical verification. Also, more investigation is needed to positively identify the sources of the VOC's found in the groundwater. Potentially, the VOC's came from sources other than the sludge lagoons and seepage cells (e.g. nearby underground storage tanks).

As seen in Figures 2-7, the heavier aromatic compounds prevail in the sludges and lighter organics appear in the groundwater.

The partitioning of certain compounds into specific matrixes and the variability of removal of compounds may be understood by studying each compound and the conditions the treatment technique provides. During wastewater treatment each VOC will be removed primarily by one of the four pathways of removal (adsorption, volatilization, chemical transformation or biodegradation) (Kincannon et al 1983 and Strier and Gallup 1983). However, as Strier and Gallup point out (Strier and Gallup 1983), many factors influence the behavior of VOC's in the treatment plant and dictate which pathway will predominate. Pollutant characteristics influencing the behavior of the compound are: water solubility, partition coefficient, molar volume, volatility, oxidizability, aromaticity (polarizability), chemical reactivity, vapor pressure, ionic character, and toxicity (to microorganisms playing a role in biological oxidation of the compound). Wastewater and sludge characteristics influencing the removal pathways for a compound include: the presence or absence of emulsifiers, dissolved salts concentration, total suspended solids, temperature and pH (Strier and Gallup 1983).

Further study of each treatment plant in light of its influent composition and specific treatment attributes could prove useful in identifying potential groundwater contaminating sites and in designing system additions or

alterations to mediate or eliminate the chance of VOC's entering the groundwater.

CONCLUSIONS

In summary, results from this study show that VOC's are prevalent in Wisconsin municipal wastewater treatment plants, that their concentrations are reduced in the water portion of the wastewater during treatment and that many are partitioned to the sludge and concentrated there. Furthermore, we can conclude that VOC's are not commonly entering the groundwater via the discharge of effluent to seepage cells. Apparently, though, they are reaching the groundwater through unlined sludge storage and drying sites. The data set reveals heavier aromatics prevailing in the sludges with lighter compounds appearing in the groundwater. Application of sludges containing VOC's to agricultural soil does not appear to elevate VOC levels in the soil, based on the limited data we obtained.

Among the matrixes, 21 compounds were detected. In many samples, the concentrations of these compounds exceeded the limits set by the USEPA and WDNR for drinking water safety, groundwater quality and aesthetics. The concentrations were small for the majority of compounds, although levels in the sludges were greater on the whole

than those in the water samples. Compared to toxic (LD50) levels (Tables 8-12), the concentrations found in this survey were minute. Apparently the occurrence of VOC's in Wisconsin's municipal wastewater facilities is widespread, but the concentrations generally low.

RECOMMENDATIONS

Due to limited data at each site, additional sampling is needed to provide statistical confidence to the data set.

Research is needed to confirm the source(s) of VOC's found in the groundwater at effluent seepage cell sites and sludge drying and storage sites, since, at this point, we only assume compounds in the groundwater came from the effluent or sludge.

More sludge and soils research is needed to determine if VOC's are entering the groundwater at agricultural sites where sludge containing VOC's is spread.

An area of research not addressed in this survey is VOC emissions at treatment plants and the potential health hazard they present to workers. Future investigation should consider this aspect.

APPENDIX A

APPENDIX A

Sampling for VOC's in Soil

Equipment:

Soil sampling tube - Chrome plated stainless steel, 1/2" diameter, 22" length, 12" side opening.

Knife

40 ml tared glass vials with septum caps

tape measure or ruler

Procedure:

1. The soil tube was inserted to a depth of 12" and withdrawn. When the core of soil was not continuous in the tube, the soil was discarded and another core taken.

2. The core was marked off at 4", 6", 10" and 12" through the side opening using the tape measure and knife. Two samples from each core were taken. To represent the topsoil, the segment of core between 4" and 6" was removed

and immediately transferred to a 40 ml vial. To represent the subsurface, the segment of core between 10" and 12" was removed and transferred to another 40 ml vial. The vials were placed in the styrofoam field pack.

3. Sampled as in #1 in triplicate at each site.

Field Quality Control

1. Trip blank of deionized water in each field pack.

2. Four field spiked samples, two topsoil and two subsurface, in triplicate.

3. Samples transported with ice pacs.

APPENDIX B

KEY to Tables 13-18

1. Benzene
2. Carbon Disulfide
3. Chlorobenzene
4. Chloroform
5. Chlorotoluene
6. o-Dichlorobenzene
7. m-Dichlorobenzene
8. p-Dichlorobenzene
9. 1,1-Dichloroethane
10. 1,2-Dichloroethane
11. 1,2-Dichloroethylene
12. Ethylbenzene
13. Fluorotrichloromethane
14. Methyl ethyl ketone
15. Tetrachloroethylene
16. Tetrahydrofuran
17. Toluene
18. 1,1,1-Trichloroethane
19. Trichloroethylene
20. Vinyl Chloride
21. Xylenes

Table 13. Volatile organic compounds found in 16 influent samples from 16 municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in any of the influent samples were detected in at least one other matrix and are listed here for comparison. Units = micrograms/liter.

INFLUENT SAMPLE LOCATION	COMPOUNDS, SEE KEY																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
APPLETON	-	-	-	6.9	-	-	-	-	-	-	-	320	-	-	50	-	180	7.9	82	-	1100
BEAVER DAM	-	-	-	1.5	-	-	-	2.3	-	-	-	-	-	-	-	-	2.4	-	1.7	-	-
BELOIT	-	-	-	2.3	-	-	-	3.1	-	-	-	1	-	-	2.9	-	4.1	1.5	-	-	4
CAROLINE	2.8	-	-	2.7	-	-	-	4.8	-	-	-	1.7	-	-	-	-	2.5	-	-	-	6.7
EDGERTON	4.6	-	-	1.6	-	-	-	3	-	-	2.3	1	4.3	-	2	-	7.1	4.5	5.9	-	3.4
GOODMAN	-	-	-	6.8	-	-	-	3.9	-	-	-	-	-	-	-	-	2.8	-	-	-	-
JANESVILLE	7.1	-	-	4.1	-	-	-	2.7	-	-	-	7	-	-	2.7	-	67	1.3	1.9	-	42
MADISON	-	-	-	4.6	-	-	-	2.1	-	-	-	-	-	-	4.6	-	4.8	-	2.6	-	3.9
MILTON	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-
MONROE	1.5	-	-	6.9	-	-	-	4.8	2.6	-	-	1.2	-	-	-	-	3.4	5.9	-	-	7.2
RIPON	-	-	-	-	-	-	-	5.2	-	-	-	-	-	-	-	-	34	-	-	-	-
SUN PRAIRIE	2.8	-	-	-	-	-	-	2.1	-	-	-	-	-	-	-	-	5.5	-	-	-	2.1
WATERTOWN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
WAUKESHA	-	-	-	2.8	-	-	-	5	3.4	-	2.3	-	-	-	24	-	4.3	26	14	-	2.4
WAUPUN	-	-	-	9	-	-	-	4.8	-	-	-	-	-	-	-	-	3.3	-	5.3	-	-
WAUTOMA	-	-	-	1.3	-	-	-	3.2	-	1.6	1.6	-	-	-	2.1	-	3.3	-	-	-	-

- compound not detected

Figure 8. Distribution of compounds.

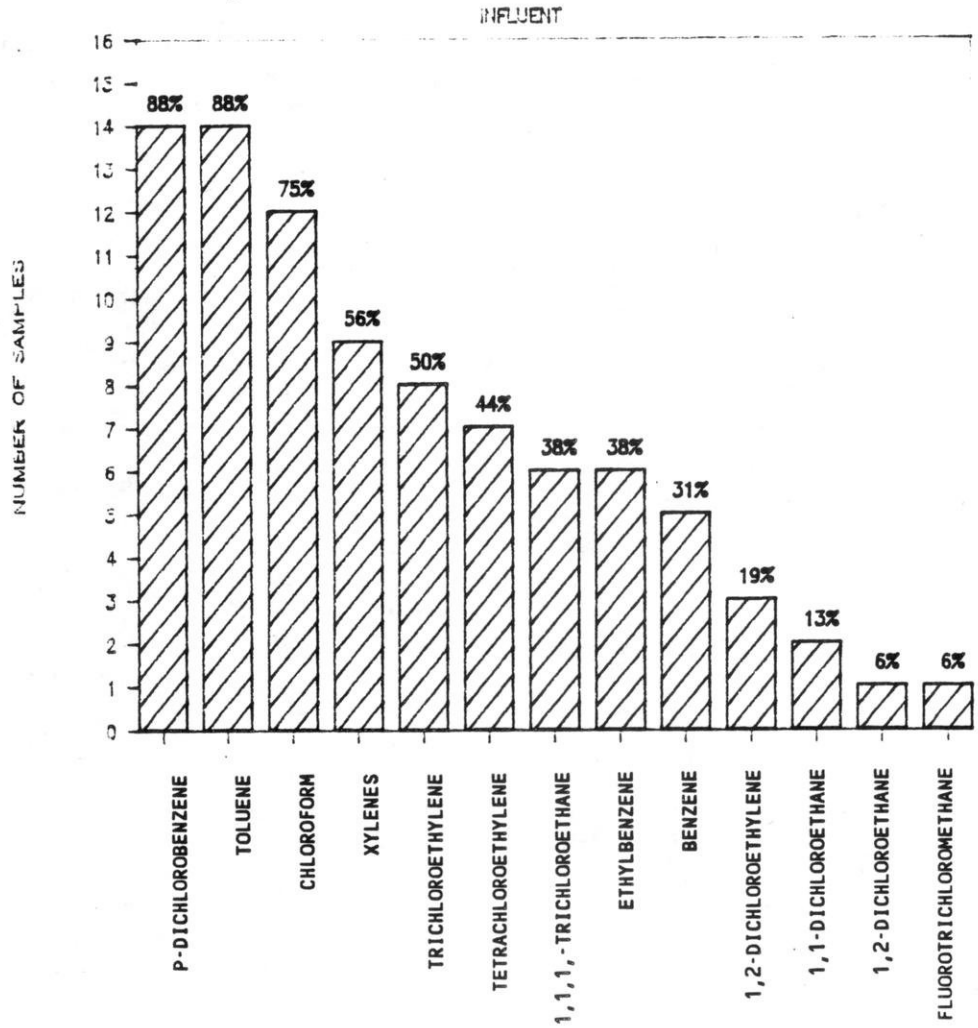


Table 14. Volatile organic compounds found in 43 effluent samples from 37 municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in any of the effluent samples were detected in at least one other matrix and are listed here for comparison. Units = micrograms/liter.

EFFLUENT SAMPLE LOCATION	COMPOUNDS, SEE KEY																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALMOND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
APPLETON	-	-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ARENA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ATHENS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BARRON-CAMERON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BEAVER DAM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BELOIT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BOYCEVILLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAROLINE	6.8	-	-	-	-	-	-	-	-	1.5	-	1.7	-	-	-	-	11	-	-	-	8.5
CAROLINE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EDGERTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.5	1.2	-	-
EVANSVILLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FAIRCHILD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GLENWOOD CITY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GOODMAN	-	-	-	1.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GOODMAN	-	-	-	2.1	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GRANTSBURG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JANESVILLE	-	-	-	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LONE ROCK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MADISON	-	-	-	3.2	-	-	-	-	-	-	-	-	-	-	1.4	-	-	-	-	-	-
MERRIMAC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MILLTOWN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MILTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MILTON	-	-	-	-	-	-	-	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-
MILTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MONROE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MUSCODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NORTHERN MORAINE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PARDEVILLE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLAINFIELD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIPON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SAUK-PRAIRIE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPOONER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WATERTOWN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUKESHA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUKESHA	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUPUN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUTOMA	-	-	-	1.2	-	-	-	-	-	-	1.5	-	-	-	-	-	-	9.3	-	-	-
WAUTOMA	7.2	-	-	4	-	-	-	2.9	-	-	-	-	-	-	2.9	-	9.5	-	-	-	-
WILD ROSE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WI ST VET HOME	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WYOCENA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- compound not detected

Figure 9. Distribution ofcompounds.

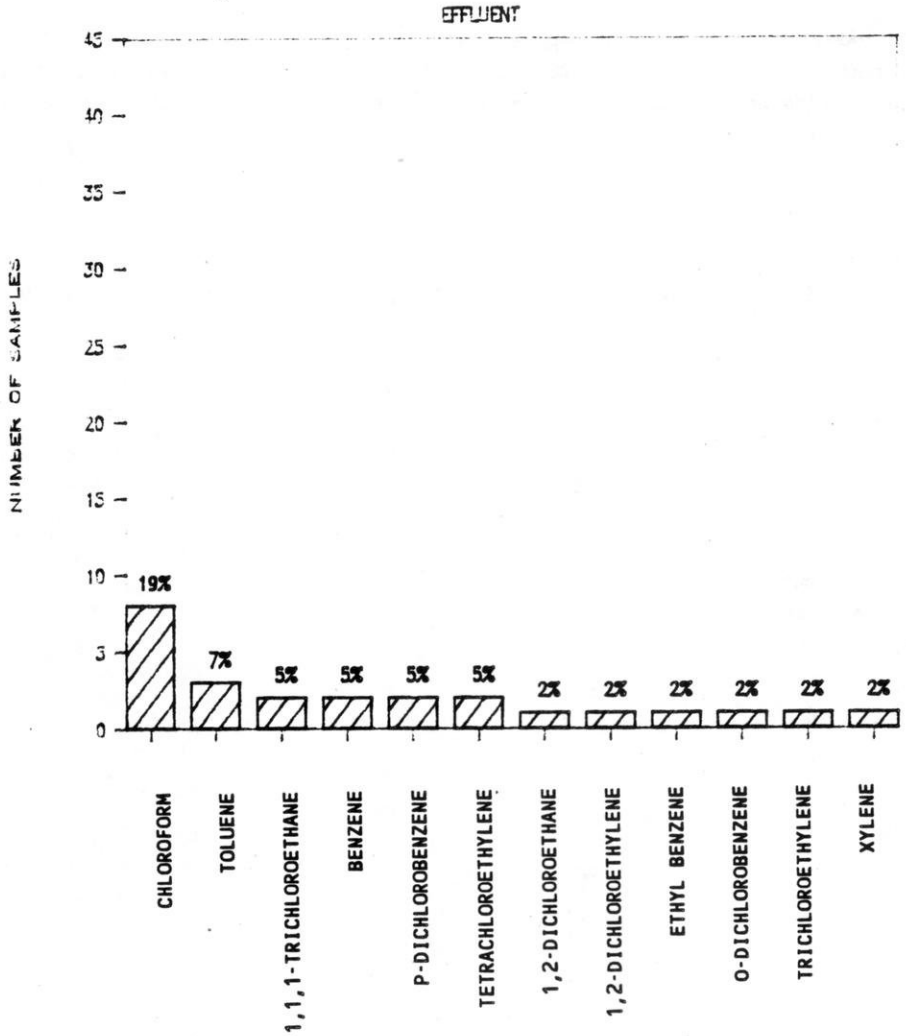


Table 15. VOC's found in five primary sludge samples from four municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in any of the primary sludge samples were detected in at least one other matrix and are listed here for comparison. Units = micrograms/liter.

PRIMARY SLUDGE SAMPLE LOCATION	COMPOUNDS, SEE KEY																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
LA CROSSE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MARSHFIELD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
MILTON	-	*	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
MILTON	-	-	-	-	-	-	-	15	-	-	-	35	-	-	-	-	150	-	-	-	160
MONROE	-	-	-	-	-	-	-	25	-	-	-	10	-	-	-	-	12	-	-	-	46

* detected but not quantified

\- not detected

Figure 10. Distribution of compounds.

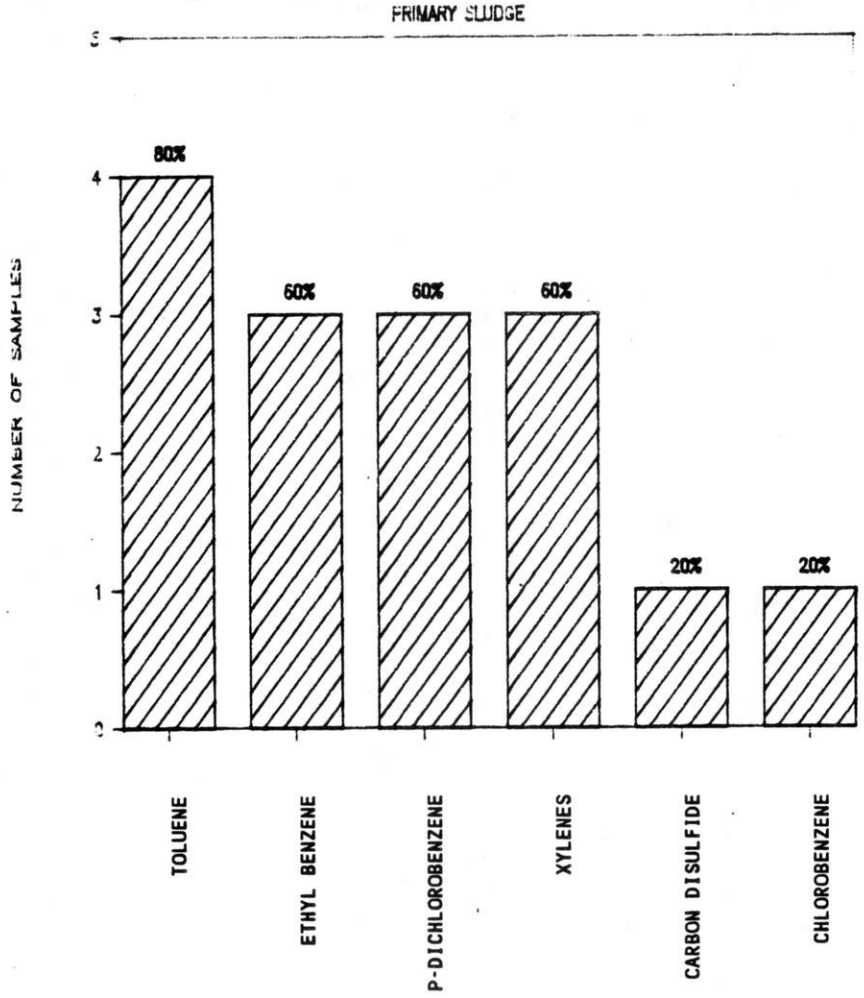


Table 16. VOC's in 35 secondary sludge samples at 27 municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in these samples were detected in at least one other matrix and are presented here for comparison. Units = micrograms/liter.

SECONDARY SLUDGE	COMPOUNDS, SEE KEY																				
SAMPLE LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
APPLETON	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	9200	-	-	-	120
BEAVER DAM	-	*	*	-	-	-	-	*	-	-	*	*	-	*	-	-	*	-	-	-	*
BEAVER DAM	-	*	-	-	-	*	-	-	-	*	*	*	-	-	-	-	*	-	-	-	*
BELOIT	-	*	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
BELOIT	-	-	-	-	*	-	-	*	-	-	-	*	-	-	*	-	*	-	*	-	*
CHIPPEWA FALLS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CUMBERLAND	*	*	-	-	-	-	-	*	-	-	*	*	-	*	-	-	*	-	*	-	*
DELAFIELD-HARTLAND	-	*	*	-	-	-	-	*	-	-	-	*	-	-	-	*	*	-	-	-	*
EAU CLAIRE	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	-	-	-	*
EDGERTON	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
JANESVILLE	-	-	-	-	-	-	-	-	-	-	-	98	-	110	4.3	-	29000	-	-	-	560
JAVESVILLE	*	-	-	-	-	-	*	*	-	-	-	*	-	-	*	-	*	-	*	-	*
MADISON	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	*	-	-	-	*
MADISON	-	-	-	-	-	-	*	-	-	-	-	*	-	-	-	-	*	-	-	-	*
MARINETTE	-	-	-	*	-	-	-	-	-	-	-	*	-	-	-	-	*	-	-	-	*
MARSHFIELD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
MENOMONIE	-	*	*	-	-	-	-	*	-	-	*	*	-	*	*	-	*	-	*	-	*
MILTON	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	*	-	-	-	*
MONROE	-	-	-	-	-	-	-	*	-	-	*	*	-	-	-	-	*	-	-	-	*
MONROE	54	-	-	-	-	-	-	30	-	-	-	61	-	-	-	-	19	-	-	-	79
RIPON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHEBOYGAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STEVENS POINT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
SUPERIOR	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
TOMAH	-	*	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	*	*
WATERTOWN	-	*	*	-	-	-	-	*	-	-	*	*	-	-	-	-	*	-	-	-	*
WATERTOWN	-	*	-	-	-	-	-	*	-	-	*	*	-	-	-	-	*	-	-	-	*
WAUKESHA	*	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
WAUKESHA	-	*	*	-	-	-	-	*	-	-	*	*	-	*	-	-	*	-	-	-	*
WAUPUN	-	-	*	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
WAUPUN	-	-	-	-	-	-	-	6.4	-	-	-	-	-	-	-	-	2.4	-	-	-	-
WEST BEND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WHITEWATER	-	-	*	*	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	*
WISCONSIN RAPIDS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
# TIMES DETECTED	5	10	10	2	1	1	2	21	0	1	9	26	0	5	5	1	29	0	4	1	27

* detected but not quantified

\- not detected

Figure 11. Distribution of compounds.

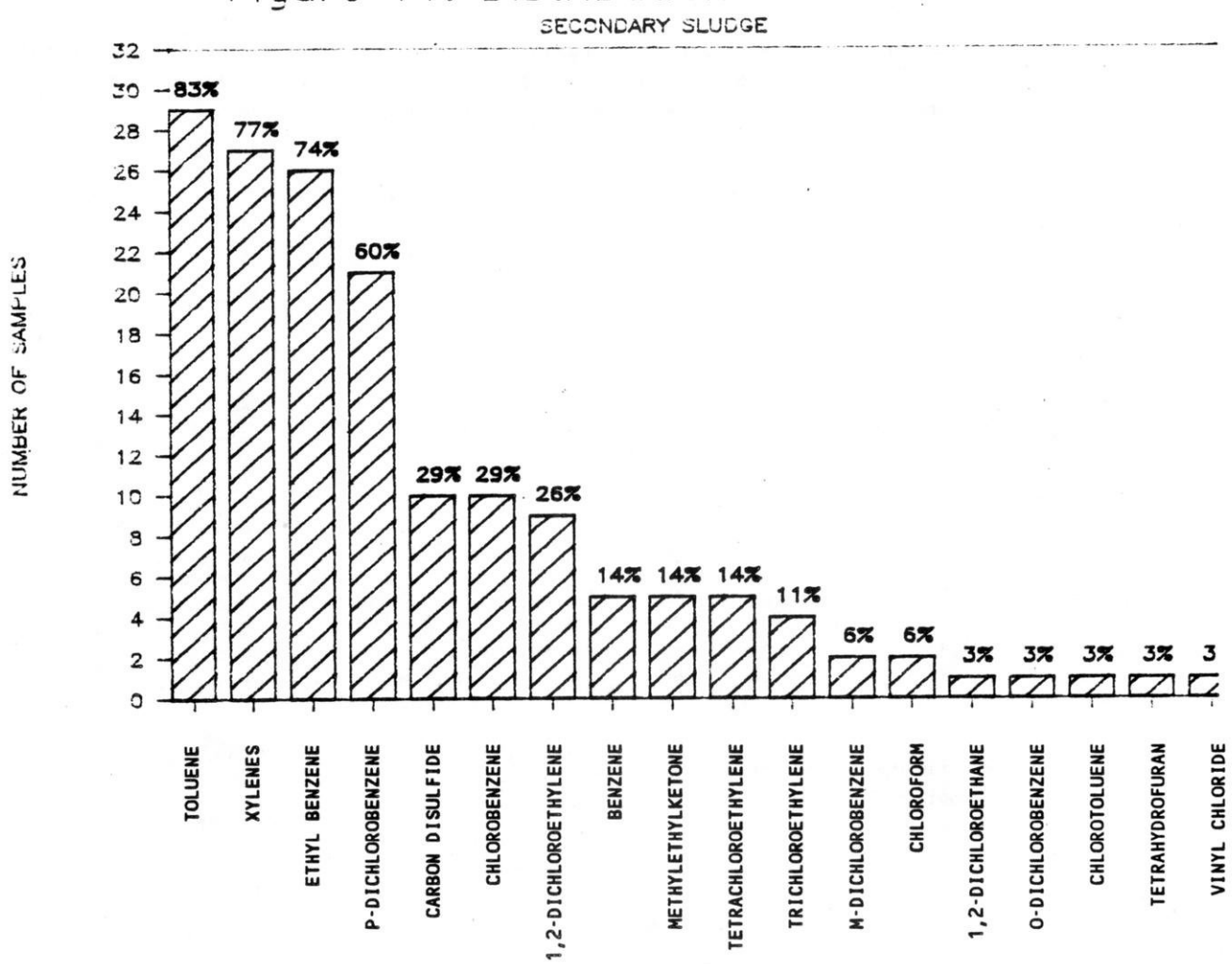


Table 17. VOC's in 13 dried sludge samples from 11 municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in any of these samples were found in at least one other matrix and are presented here for comparison. Units = micrograms/liter.

DRIED SLUDGE	COMPOUNDS, SEE KEY																				
SAMPLE LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
APPLETON	*	*	-	-	-	-	-	-	-	-	-	*	-	-	*	-	*	-	*	-	*
APPLETON	*	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	*	-	-	-	*
EDGERTON	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-
FOND DU LAC	*	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	*	-	*	-	*
GREEN BAY	-	*	-	*	-	-	-	-	-	-	-	*	-	-	*	-	*	-	*	-	*
HUDSON	-	*	*	-	-	-	-	*	-	-	-	*	-	*	-	-	*	-	-	-	*
MADISON	-	-	-	-	-	*	*	-	-	-	-	*	-	-	-	-	*	-	-	-	*
MILTON	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	*	-	-	-	-
RIPON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
RIPON	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	-	-	-	-	*
WAUKESHA	-	*	-	-	-	*	*	*	-	-	-	*	-	-	-	-	*	-	-	-	*
WAUSAU	*	*	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-	-	-	-	*

* detected but not quantified
\- not detected

Figure 12. Distribution of compounds.

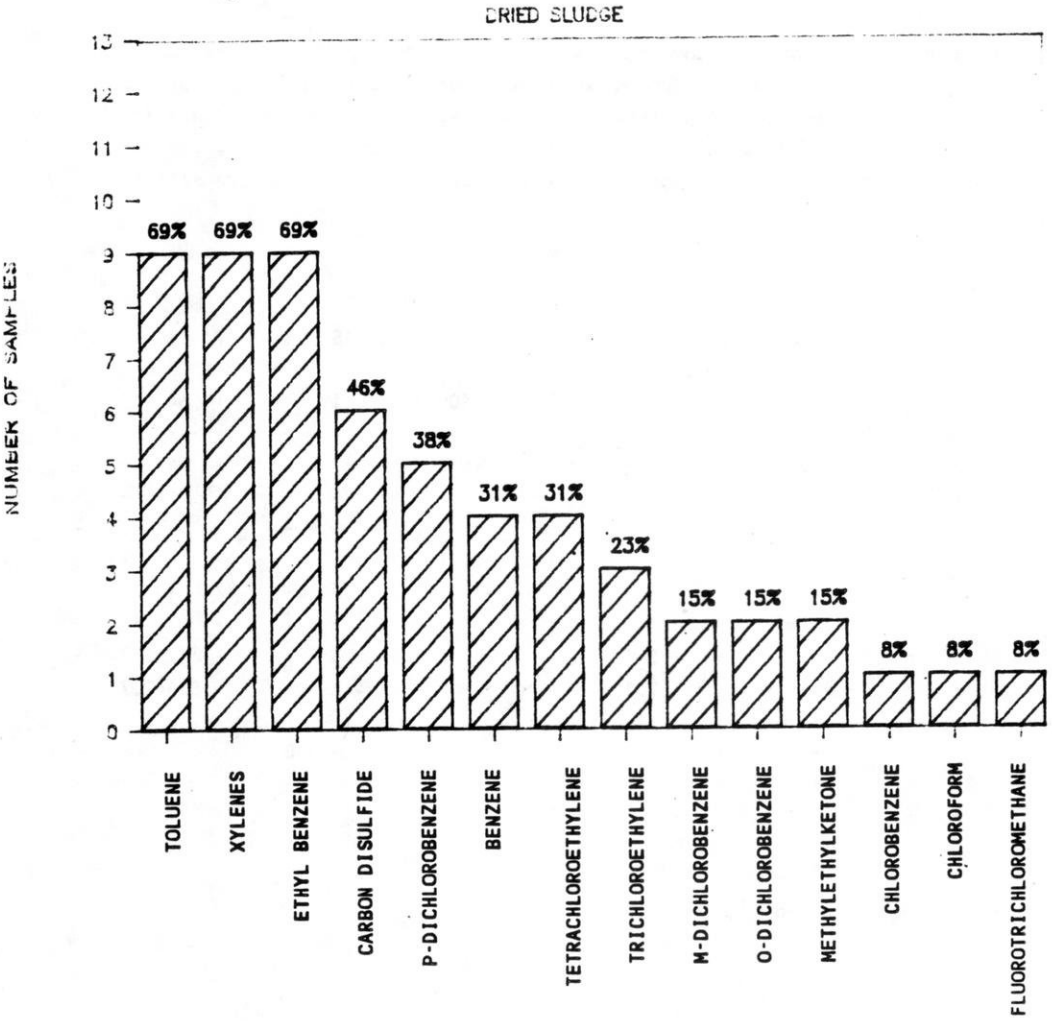
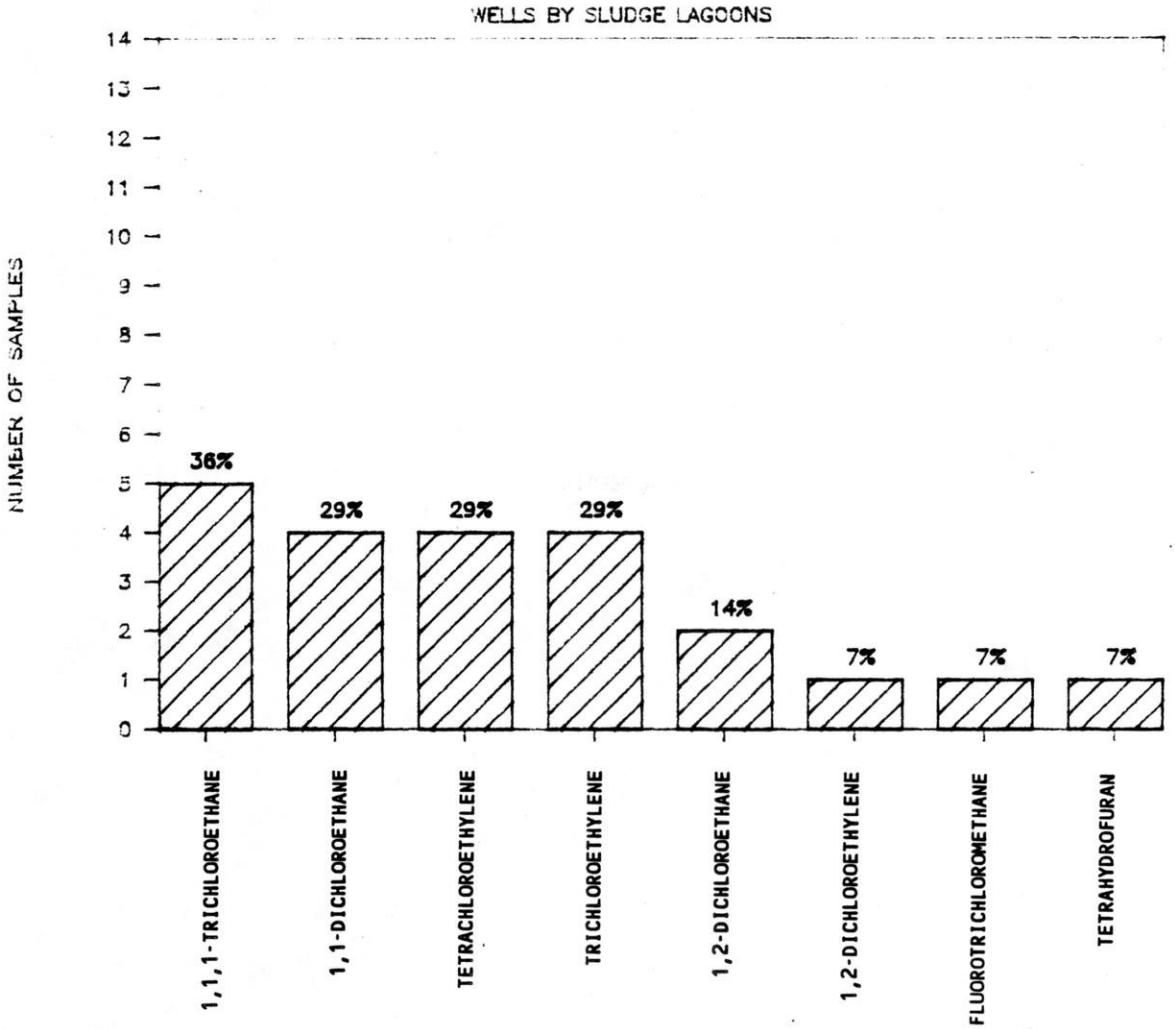


Table 18. Volatile organic compounds found in 14 well samples from 3 municipal wastewater treatment plants in Wisconsin. Compounds listed but not detected in any of the well samples were detected in at least one other matrix and are listed here for comparison. Numbers in parentheses are well identification numbers. Wells were located around sludge storage lagoons or drying beds. Units = micrograms/liter.

WELL WATER	COMPOUNDS, SEE KEY																				
SAMPLE LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
EDGERTON (1)	-	-	-	-	-	-	-	-	13	-	-	-	100	-	4.1	-	-	64	2.5	-	-
EDGERTON (2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EDGERTON (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
SUN PRAIRIE (5)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE (6)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE (7)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN PRAIRIE (8)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUKESHA (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUKESHA (2)	-	-	-	-	-	-	-	-	5.9	1.8	-	-	-	-	4	-	-	12	2.7	-	-
WAUKESHA (2)	-	-	-	-	-	-	-	-	9.1	-	-	-	-	-	4.2	-	-	8.4	2.7	-	-
WAUKESHA (2)	-	-	-	-	-	-	-	-	10	1.3	1.9	-	-	-	6	-	-	7.5	3.1	-	-
WAUKESHA (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	260	-	-	-	-	-
WAUKESHA (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WAUKESHA (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- compound not detected

Figure 13. Distribution of compounds.



APPENDIX C

APPENDIX C

COMPOUND	WISCONSIN NR 140 ES (MCG/L)	WISCONSIN NR 140 PAL (MCG/L)	EPA DRINKING H2O STDS (MCG/L)	LD50 DOSES RATS, ORAL (MCG/KG BODY WT)
BENZENE	0.67	.067	5.0	3.8E +6
CARBON DISULFIDE	*		*	*
CHLOROBENZENE	*		*	2.91E +6
CHLOROFORM	*		*	8.0E +5
CHLOROTOLUENE	*		*	*
O-DICHLOROBENZENE	*		*	5.0E +5
M-DICHLOROBENZENE	*		*	*
P-DICHLOROBENZENE	750	150	75.0	5.0E +5
1,1-DICHLOROETHANE	*		*	7.25 E +5
1,2-DICHLOROETHANE	.5	.05	5.0	*
1,2-DICHLOROETHYLENE	*		*	*
ETHYL BENZENE	*		*	3.5E +6
FLUOROTRICHLOROMETHANE	*		*	*
METHYL ETHYL KETONE	*		*	3.4E +6
TETRACHLOROETHYLENE	1	.1	*	2.0E +5
TETRAHYDROFURAN	*		*	*
TOLUENE	343	68.6	*	5.0E +6
1,1,1-TRICHLOROETHANE	200	40	200.0	1.03E +7
TRICHLOROETHYLENE	1.8	.18	5.0	4.92E +6
VINYL CHLORIDE	.015	.0015	2.0	5.0E +5
XYLENES	620	124	*	4.3E +6

* no value given

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