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Volatile Organic Compounds (VOCs) in Small Community Wastewater Disposal Systems Using Soil Absorption

by

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VOLATILE ORGANIC COMPOUNDS (VOCs) IN SMALL COMMUNITY WASTEWATER DISPOSAL SYSTEMS USING SOIL ABSORPTION

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The Office of Technology Assessment (OTA) identified domestic wastewater subsurface percolation (e.g., septic tanks and cesspools) as the largest source of discharge to groundwater, approximately 820-1460 billion gallons per year (OTA, 1984). The report indicated the presence of organic chemicals, inorganic chemicals, and biological sources of contamination in the subsurface percolation systems.

In October of 1985, the Wisconsin Department of Natural Resources promulgated Wisconsin NR 140 for the protection of groundwater quality in the state of Wisconsin. This statute set standards for both inorganic and organic contaminants. The use of and array of commercial products such as disinfectants, solvents, and cleaners is increasing. Organic compounds, specifically VOCs, that may be present in these products are of concern with respect to septic tank effluent and the receiving groundwater. The presence of priority pollutants in septic tank soil absorption systems has only recently been investigated with respect to groundwater pollution (Tomson et al., 1984). This paper presents a summary of the results of a field study of six subsurface soil absorption systems with respect to VOCs present in the effluents and adjacent groundwater (Greer, 1987).

In the first phase of this study, the concentrations of VOCs were analyzed and quantified in effluents from six septic tank systems. Five of the systems investigated were small community septic tank soil absorption systems (STSAS) ranging in age from zero to eight years. The sixth system analyzed was a mobile home park. Three samples were collected over a four-month period from the dosing chamber at each site.

The second phase of the investigation involved the installation of groundwater monitoring wells at four of the small community sites. During this phase, four samples of septic tank effluent (STE) were collected at the six sites from Phase 1, and four groundwater samples were collected from four of the sites. Septage samples were also collected at two of the small community sites using a central septic tank. The six sites sampled are listed in Table 1 and the number and type of samples collected are indicated.

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Table 1. Samples Collected During the Investigation

Site	STE samples	Groundwater wells installed	Groundwater samples	Septage samples
Kingston (KS)	7	3	12	3
Town of Scott (TS)	7	4	16	0
Maplewood (MW)	7	4	16	0
Wyeville (WV)	7	4	16	3
Westboro (WB)	7	0	0	0
Dons Mobile (DONS)	7	0	0	0

System Descriptions

Site #1, Village of Kingston, Wisconsin: The design service population of Kingston was approximately 400 persons at 70 g.p.c.d. for a design flow of 32,800 g.p.d. The design flow includes an assumed inflow of clear water of 4800 g.p.d. The actual population during the study was 343 persons. Commercial businesses in Kingston included an automotive garage, two restaurants, one woodworking shop, and a metal fabricator. The system was served by a 3 compartment, 47,175 gallon central septic tank. The required infiltrative area for the design flow rate of 32,800 g.p.d. was 36,000 ft^2. Fifty percent excess infiltrative area was provided by designing 3 beds at 18,000 ft^2 (180 ft x 100 ft). The system was placed into service during December of 1981.

Site #2, Town of Scott Sanitary District, Wisconsin: The design service population of the Town of Scott was approximately 215 persons at 120 g.p.c.d. with an estimated 3700 g.p.d. commercial flow. The design flow rate for the system was 29,500 g.p.d. The actual population during this study was approximately 180 persons. Commercial businesses in the Town of Scott included two restaurants. Each residence was served by an individual septic tank during the study. The infiltrative area used for the average design flow rate of 29,500 g.p.d. was 57,344 ft^2. Three beds were provided--two beds at 100 ft x 192 ft and the third at 128 ft x 148 ft. The system was placed into service during September of 1985.

Site #3, Maplewood Sanitary District, Maplewood, Wisconsin: The design service population of Maplewood was approximately 310 persons at 65 g.p.c.d. for a design flow rate of 20,150 g.p.d. The actual population during the study was approximately 200 persons. Commercial businesses in Maplewood included a service station, one restaurant, one auto parts supply store, one implement shop, and one welding shop. Each residence was served by an individual septic tank during the study. The infiltrative area used for the design flow of 20,150 g.p.d. was 37,400 ft^2. Three beds were provided--two beds at 180 ft x 70 ft and a third bed at 138 ft x 100 ft with triangular 800 ft^2 area not used in Bed 3. The system was placed into service during 1981.

Site #4, Wyeville, Wisconsin: The design service population of Wyeville was 293 persons at approximately 60 g.p.c.d. for a design flow rate of 17,600 g.p.d. The actual population was approximately 163 at the time of the study. Commercial businesses in Wyeville included two service stations. The system was served by a three compartment 25,200 gallon central septic tank. The infiltrative area used for the design flow of 17,600 g.p.d. was 40,000 ft^2. Three mounds were provided with the following dimensions: Mound 1 (229 ft x 54 ft), Mound 2 (229 ft x 59 ft), Mound 3 (231 x 61 ft). The system was placed into service during September of 1985.

Site #5, Westboro, Wisconsin: The design service population in Westboro was approximately 300 persons at 100 g.p.c.d. for a design flow rate of 30,000 g.p.d. The service population during the study was approximately 210 persons. Commercial businesses in Westboro included two service stations and one machine shop. Each residence was served by an individual septic tank during the study. The infiltrative area used for the design flow of 30,000 g.p.d. was 39,000 ft^2. Three beds each 130 ft x 100 ft were provided. Fifty percent excess area was provided by the design of three beds. The system was placed into service during May of 1977.

Site #6, Don's Mobile Manor Trailer Home Park, Dane County, Wisconsin: The system was designed to serve 10 mobile home trailers at a design flow rate of 2000 g.p.d. The system discharged wastewater to a 3750 gallon septic tank. The soil absorption bed was approximately 2940 ft^2 in area. The system was placed into service during 1984.

METHODS

Septic tank effluent was collected from the dosing chamber at each of the six sites. The composition of STE was determined during both phases of the study from grab samples collected between March 1986 and March 1987. Samples for VOC analysis were collected using a specially constructed apparatus consisting of a 300 ml wide-mouth teflon container mounted on a portable aluminum frame. The sample jar was capped with a teflon cap liner which could be remotely opened and closed by pulling or releasing a wire attached to it. The sample jar was submerged so that the lid was approximately 2 ft below the liquid level and then the lid was raised and a 300 ml samples was collected. The lid was closed prior to removing the jar from the liquid. Sampling in this manner excluded any scum or floating debris from the sample collected.

After the samples were collected, the sample jar was removed from the sampling device and a teflon lid was screwed onto the sample jar. The lid was fitted with two teflon straight bulk head fittings. One of the fittings terminated at the surface of the sample collection jar and was connected to a cylinder containing purified nitrogen. The other bulk head fitting extended to the bottom of the sample collection jar and was connected to a 2 ft length of 1/4 in. teflon tubing. The cylinder was used to place a slight positive pressure inside the sample jar and forced sample from the bottom of the jar through 1/4 in. tubing to the collection vials. The pressure was maintained to produce laminar flow in the sample discharge tube. The sample was collected in a 40 ml VOC sampling vial. The vial was filled to the top and allowed to overflow for four seconds and then sealed with a screw on teflon-lined cap. Four vials were filled for each sample and a trip blank was carried with every two samples.

The sampling apparatus could also be fitted with a 4-liter, wide-mouth polyethylene bottle. The contents of the 4-liter sample bottle were divided into two one-liter samples for subsequent physical and chemical analyses. The remaining sample volume was utilized for on-site determination of pH, temperature, and conductivity.

The apparatus was used in the same manner to collect samples of septage from the community septic tanks at Kingston and Wyeville. Septage samples were collected and divided at the same time as were STE samples.

The sampling apparatus was thoroughly cleaned with deionized water after each sampling. At sites where both STE and septage were sampled, STE was sampled first and the apparatus cleaned before sampling septage.

Groundwater Monitoring

Groundwater monitoring wells were installed at four sites, the Village of Kingston, the Town of Scott, the Village of Wyeville, and the Village of Maplewood. At each site, one monitoring well was located upgradient of the system and the remaining monitoring wells were located within the discharge plume.

The groundwater monitoring wells were installed using a Wisconsin State Geological Survey truck-mounted rotary drill head and 6 in. continuous-flight hollow stem auger. Inspection of soil cuttings during the drilling operations at each site confirmed previous subsoil classification below the absorption systems. The wells were constructed of 2 in Schedule 40 threaded flush joint PVC pipe. Each well was screened with 5 ft of 2 in. slotted 0.010 in. Schedule 40 PVC well screen. The screened portion of each well was back filled with sand cuttings and capped with a bentonite seal. The bore hole was then filled to grade and a protective steel casing was installed and secured with a concrete plug.

Sampling of groundwater wells was accomplished by use of a 5 ft stainless steel bailer. The bailer was attached to 15 ft of 5/64 in. teflon-coated stainless steel wire. Attached to the wire was 25 ft of 3/16 in. polypropylene cord. This was done so that all sampling apparatus contacting groundwater was either stainless steel or teflon. A large plastic cloth was placed on the ground around the base of a well when sampling to prevent the bailer line from touching the ground. The bailer was lowered slowly into contact with the water surface in each well. Six volumes of standing water were removed from each well and discarded before actual sample collection. This was done to assure the collected sample was representative of actual groundwater and not stagnant water in the wells. The bailer, cord, and emptying device were thoroughly rinsed with deionized water after sampling each well.

Two samples were collected of STE, septage and groundwater, in 1-L acid-washed plastic bottles and transported on ice to the University of Wisconsin Department of Civil and Environmental Engineering laboratory. One sample was preserved with appropriate acid to a pH less than 2.0 and the other sample was not preserved. Both samples were stored at 4°C prior to analysis. BOD_5, solids, chloride and nitrite analyses were performed on unacidified samples. TOC and ammonia were determined on acidified samples. Analyses conducted on samples followed standard methods (E.P.A., 1979; U.S.G.S., 1979; Fed. Reg., 1984).

A teflon bailer bottom emptying device was used to collect VOC samples. The sample was collected on a fresh bailer full of water and emptied into 40 ml vials until slightly overflowing and a positive meniscus was formed. The samples were capped immediately and checked to make sure no air bubbles were present in the vial. The samples were transported on ice to the Wisconsin State Laboratory of Hygiene. Samples were delivered in Styrofoam mailers to the lab and stored at 4°C pending analysis.

The presence of 45 VOCs were screened in all samples using G.C./M.S. headspace analysis. VOCs detected in the screening were quantified using G.C. analysis. The G.C. methods used in analysis were E.P.A. Method 601 and 602 (Fed. Reg., 1984).

In order to verify that downstream groundwater monitoring wells were within the contaminant plume discharging from the soil absorption system, analyses of typical contaminants including TOC, nitrogen, chloride, pH, and conductivity were conducted on groundwater samples along with VOCs. At all sites sampled, it was verified that the downgradient monitoring wells were all screened within the contaminant plume.

RESULTS

The occurrence of the 45 screened volatile organic compounds in STE from the six sites examined are presented in Table 2. The table delineates the percent of samples in which a given VOC was detected during this 12-month study. The other 35 VOCs were not detected during this study. The "total" column represents the average results from the 42 STE samples collected at the six sites. The maximum concentrations of VOCs detected at each site are presented in Table 3.

Table 2. Percent of the Samples in which VOCs were Detected in STE Samples at Six Small Community Sites in Wisconsin

	WV n=7	MW n=7	WB n=7	KS n=7	TS n=7	DONS n=7	Total n=42
P-Dichlorobenzene	100%	28.6%	71.4%	85.7%	57.1%	14.3%	59.5%
Toluene	100	85.7	100	100	71.4	100	92.9
1,1,1-Trichloroethane	0	0	0	28.6	0	0	4.8
Tetrachloroethylene	0	0	0	14.3	14.3	14.3	7.1
Xylenes	85.7	0	57.1	14.3	0	0	26.2
Ethylbenzene	57.1	0	28.6	0	0	0	14.3
1,2-Dichloroethane	0	0	28.6	0	0	0	4.8
Chloroform	28.6	14.3	14.3	28.6	0	0	14.3
Benzene	0	14.3	57.1	14.3	0	0	14.3
Carbon Disulfide	0	0	14.3	0	0	0	2.4

WV = Wyeville, MW = Maplewood, WB = Westboro, KS = Kingston, DONS = Don's Mobile Manor

Table 3. Maximum STE Concentration of VOCs for Seven Sample Periods (Concentrations in ug/l)

	WV	MW	WB	KS	TS	DONS
P-Dichlorobenzene	39.0	2.6	13.0	2.8	20.0	2.2
Toluene	40.0	38.0	30.0	200.0	76.0	160.0
1,1,1-Trichloroethane	-	-	-	19.0	-	-
Tetrachloroethylene	-	-	-	1.2	2.0	1.2
Xylenes	15.0	-	28.0	3.7	-	-
Ethylbenzene	4.4	-	1.8	-	-	-
1,2-Dichloroethane	-	-	3.6	-	-	-
Chloroform	2.8	2.2	D	2.1	-	2.5
Benzene	-	2.1	5.1	1.4	-	-
Carbon Disulfide	-	-	D	-	-	-

(WV = Wyeville, MW = Maplewood, WB = Westboro, KS = Kingston, DONS = Don's Mobile Manor)
(D = detected but not quantified, - = below detection limit)

Table 4. Percentage of VOCs Detected in Septage Samples at Two Small Community Sites in Wisconsin

	WVSS n=3	KSSS n=3	Total n=6
P-Dichlorobenzene	100%	33.3%	66.7%
Toluene	100	100	100
1,1,1-Trichloroethane	0	0	0
Tetrachloroethylene	33.3	0	16.7
Xylenes	33.3	0	16.7
Ethylbenzene	33.3	0	16.7
1,2-Dichloroethane	0	0	0
Chloroform	33.3	0	16.7
Benzene	0	0	0
Carbon Disulfide	0	0	0

Table 5. Maximum Septage Concentrations of VOCs for Three Sample Periods (Concentration in ug/l)

	WVSS	KSSS
P-Dichlorobenzene	44	4.4
Toluene	360	160.0
1,1,1-Trichloroethane	-	-
Tetrachloroethylene	1.4	-
Xylenes	-	-
Ethylbenzene	1.4	-
1,2-Dichloroethane	-	-
Chloroform	1.3	-
Benzene	-	-
Carbon Disulfide	-	-

(WVSS = Wyeville septage, KSSS = Kingston septage, - = below detection limits)

Table 6. Concentration of Volatile Organic Compounds in Groundwater at Town of Scott, Wisconsin

	October 1986 to March 1987			
Parameter	8/19/86	10/4/86	10/4/86	3/20/87
1,1,1-Trichloroethane	1.9	2.8	2.20	1.7

(- = below detection limit; concentration in ug/l)

The occurrence of volatile organic compounds in septage from Kingston and Wyeville are presented in Table 4. The central septic tank at each of these sites was sampled three times. The "total" column represents the average results from the six septage samples collected. The maximum concentration VOCs detected at each site are presented in Table 5.

Groundwater sampling of three monitoring wells at Kingston and four monitoring wells at Maplewood over four sampling periods indicated that none of the 45 screened VOCs were present in detectable concentrations. The results of VOCs detected in groundwater samples at the Town of Scott are presented in Table 6, and those detected in groundwater samples at the Village of Wyeville, Wisconsin, are presented in Table 7.

Table 7. Concentration of Volatile Organic Compounds in Groundwater at Village of Wyeville, Wisconsin

Parameter	October 1986 to March 1987			
	8/23/86	10/11/86	1/14/87	3/16/87
Chloroform	1.4	-	-	-
P-Dichlorobenzene	-	2.6	-	-

(- below detection limit; concentration in ug/l).

DISCUSSION

The frequency of occurrence of 45 screened volatile organic compounds present in STE from six small community soil absorption systems are presented in Table 2. Ten VOC's were detected in STE samples at some point during the investigation. Eight of the ten VOCs detected were considered priority pollutants. Two of the compounds, p-dichlorobenzene and toluene, were detected in at least 50 percent or greater of STE samples during the investigation. Xylenes were detected in 26.2 percent of the STE samples. Toluene occurred at an average maximum concentration of 90.7 ug/l in the STE samples and p-dichlorobenzene occurred at an average maximum concentration of 13.3 ug/l. Xylenes occurred at an average maximum concentration of 7.8 ug/l. These results are similar to those reported by other investigators (Dewalle et al., 1982; Tomson et al., 1984; and Viraragavan and Hashem, 1986).

The greatest number of VOCs that were detected in STE samples were found at two sites, Kingston and Westboro. Kingston produced seven VOCs and Westboro had eight VOCs that were detected. The two sites also had the largest service populations and the largest design flow rates of those tested. The design flow rate at Kingston was 32,800 g.p.d. and that at Westboro was 30,000 g.p.d. The increased number of VOCs detected at both sites may have been the result of a larger fraction of commercial wastewater inputs to the wastewater flow. Kingston had the largest number of commercial businesses operating of the six sites, most notably two restaurants, a metal fabricator, a woodworking shop, and an automotive garage. These businesses would have the potential for input of VOCs from cleaning solvents and disinfectants at the restaurants, varnishes and paint products from the woodworking shop, and oil and hydrocarbons from the automotive garage.

The potential input of VOCs from commercial units in Westboro was less diverse than that in Kingston. The most notable businesses in Westboro were two service stations and a tavern. The input of VOCs could be from hydrocarbons at the service station and cleaning solvents from the tavern. These businesses, however, were not notably different from those found in some of the smaller communities. It was found during the study that many of the private groundwater wells in Westboro had been contaminated by a leaking underground storage tank. The residents were still using their water supplies for all household activities except for drinking water. It was not possible to test the individual residential wells during the study, but tests conducted on certain individual wells by the Wisconsin Department of Natural Resources indicated that xylene, benzene, ethyl benzene, toluene, and 1,2-dichloroethane were present in the water supplies of several residences at Westboro. Thus, the presence of VOCs in residential water supplies could result in the presence of these compounds in the STE at Westboro.

The results of STE analysis at the four smaller communities, Wyeville, Maplewood, Town of Scott, and Dons Mobile Manor, indicated that fewer VOCs were present as compared to the larger sites. Wyeville had five VOCs present, Maplewood and Don's Mobile Manor each had four VOCs present, and the

Town of Scott had three VOCs present in STE samples. The three community sites each serviced approximately the same population with the Town of Scott servicing 215 residences, Maplewood servicing 200 residences, and Wyeville 163 residences. The commercial inputs from these communities was similar. Don's Mobile Manor services approximately 10 residences and had no commercial inputs. The VOCs detected at Don's were similar to those found in the three smaller communities suggesting that these communities were all representative of residential inputs of VOCs to wastewater. Among the predominant VOCs present in these residential wastewaters were toluene and p-dichlorobenzene. Sources of these compounds in households would include paint products, degreasers, cleans, and deodorizers. Dewalle et al. (1985) found similar compounds in his studies of residential wastewaters.

The frequency of occurrence of the 45 screened volatile organic compounds present in septage from two small community central septic tanks is presented in Table 4. Six VOCs were detected in septage samples at some point during the investigation. Five of the VOCs detected were considered priority pollutants. Two of the components, p-dichlorobenzene and toluene, were detected in at least 50 percent or more of the septage samples. When comparing the septage results with grab samples of STE, there are no clear trends. With the exception of toluene, VOCs detected in septage generally were also found in STE, and they are found in approximately the same concentration. In the case of toluene, septage concentrations tend to be an order of magnitude higher than those found in STE. These concentrations of toluene were also found by Galvin and Ridgley (1982).

The results of monitoring for 45 screened volatile organic compounds in groundwater from four small community systems indicated the presence of three VOCs. Groundwater samples from two sites, Kingston and Maplewood, produced no VOCs during the period of sampling. Both systems had been in operation for some time. The Kingston system was 5 years old and the Maplewood system was 8 1/2 years old. The older systems may have had a greater treatment capacity for VOCs as the result of a more mature biological system below the absorption beds. It is also interesting to note that Kingston was underlain by loamy sand and Maplewood was underlain by a sandy loam. The organic content of these soils may have resulted in an increased absorption of VOCs in the soil treatment zone.

The results of groundwater monitoring at the Town of Scott (Table 6) revealed the presence of one compound. The compound, 1,1,1-Trichloroethane, was detected twice in Monitoring Well 1 and twice in Monitoring Well 2. The concentrations detected are below the Preventive Action Limits set by the Wisconsin Department of Natural Resources. This compound was not detected in STE samples during the investigation. It is suspected that the compound may have been derived from solvent cement used during the construction of the septic tank soil absorption system.

The results of groundwater monitoring at Wyeville demonstrated the presence of two VOCs (Table 7). The compounds were chloroform and p-dichlorobenzene. Chloroform was detected at a concentration of 1.4 ug/l. P-dichlorobenzene was detected at a concentation of 2.6 ug/l. Both of these compounds were also detected in the STE samples at Wyeville (Table 2). P-dichlorobenzene was detected in every sample of STE collected at an average concentration of 22 ug/l, indicating that a significant amount of p-dichlorobenzene was being removed in the soil zone. Chloroform was detected in three STE samples at an overall average concentration of 1.0 ug/l in STE samples. This would indicate that there was minimal removal of chloroform in the soil zone.

P-dichlorobenzene is listed as substance of public health concern by the Wisconsin Department of Natural Resources. The preventive action limit set by the WDNR is 150 ug/l. The concentrations at Wyeville are significantly

below this concentration. Chloroform is not listed in the groundwater quality standards.

Both the Wyeville and Town of Scott systems were underlain by predominately sandy soils. This would suggest that soils low in organic matter content are not as efficient in the removal of VOCs as higher organic content soils. A second point of interest was that both the Wyeville and Town of Scott systems were relatively new systems, both being placed into service during September of 1985.

SUMMARY AND CONCLUSIONS

A one-year study was conducted to determine the presence of 45 screened VOCs in STE, septage, and groundwater at communities using septic tank soil absorption systems. Six communities serving populations ranging from 10 to 346 persons and ranging in age from 1 to 9 years were surveyed. The results of this study indicate that:

1. Ten VOCs were found in STE from small community soil absorption systems with toluene and p-dichlorobenzene being found at the greatest frequency.

2. Larger communities appear to have more VOCs present in STE, possibly the result of larger commercial wastewater inputs.

3. Septage samples generally showed no significant increase in concentrations of VOCs over STE; one exception was toluene which was found at approximately an order of magnitude greater concentration in septage than in STE.

4. Several VOCs were occasionally detected in groundwater below sites underlain by sandy soils and sites relatively young in age (approximately 1 year old).

5. VOCs detected in groundwater were below preventive action limits set by the WDNR.

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