Small Scale Waste Management Project

University of Wisconsin–Madison

Publication 1.18 / 7.13

Motor Vehicle Waste Fluid Impacts on Septic Tank / Wastewater Infiltration Systems

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Citation: Sauer, P. and E. Tyler, "Motor Vehicle Waste Fluid Impacts on Septic Tank / Wastewater Infiltration Systems," Small Scale Waste Management Project publication, University of Wisconsin, Madison, Wisconsin, 1992.

(17 pages.)

MOTOR VEHICLE WASTE FLUID IMPACTS ON SEPTIC TANK/WASTEWATER INFILTRATION SYSTEMS[1]

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ABSTRACT

Spent oils, greases and solvents from routine maintenance of motor vehicles contain heavy metals and volatile organic chemicals (VOCs). In Wisconsin, these fluids enter catch basins along with rinsing waters and are ultimately discharged to soil infiltration systems after mixing with domestic wastewaters in a septic tank. This study characterizes catch basin and septic tank wastewaters and determines treatment of contaminants discharged to wastewater infiltration systems in loamy sand and silt loam soils. Toluene,

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methylene chloride and acetone along with many other VOCs and lead, cadmium, and chromium were found in catch basins and septic tanks at four publicly-owned motor vehicle service stations. VOC and heavy metal concentrations varied considerably with time and sampling location. The highest concentrations of contaminants were in septic tank sludge. The source products of many of the VOCs and metals found in septic tanks and the mixture of these contaminants with wastewater in the septic tank may be hazardous as defined by the United States Environmental Protection Agency (USEPA) and Wisconsin Department of Natural Resources. VOCs were not detected beneath a drainfield in silt loam soils and were found only once beneath a drainfield in loamy sand soils. Cadmium, chromium, and lead concentrations in soil 15 cm and greater beneath drainfields in loamy sand and silt loam soils were similar to background sample concentrations. VOCs were not found in soil gas above a drainfield in silt loam soils. Tetrachloroethylene was found only in soil gas above one of two drainfields in loamy sand soils. Some treatment of VOCs in drainfields occurs in silt loam and loamy sand soils. Cadmium, chromium, and lead may be retained by loamy sand and silt loam soils in drainfields.

INTRODUCTION

The United States Environmental Protection Agency (USEPA) designated wastewater disposal systems receiving motor vehicle waste fluids and discharging to soil at motor vehicle service stations as Class V Underground Injection Wells (1). Motor vehicle waste fluids such as oil, grease, antifreeze, and solvents may contain many volatile organic chemicals and heavy metals (2,3,4). Volatile organic chemicals include benzene, toluene, methylene chloride, and dichloromethane. Heavy metal contaminants include lead, chromium, cadmium, and mercury.

In rural unsewered areas of Wisconsin, wastewater generated at motor vehicle service stations is typically disposed of through approved catch basin/septic tank/wastewater infiltration systems (5,6). Many of the volatile organic and metal contaminants in motor vehicle waste fluids may not be retained or degraded in this type of wastewater treatment system. These contaminants may impact soil and groundwater quality beneath wastewater infiltration systems.

The first objective of this study was to identify contaminants in wastewater streams at motor vehicle service stations. The second objective of this study was to determine if treatment of these contaminants occurs in wastewater infiltration systems installed in loamy sand and silt loam soil.

MATERIALS AND METHODS

Wastewater Characterization

Four publicly-owned wastewater systems from 7-14 years old were selected for the study. Two of the systems were at Wisconsin Department of Natural Resources service stations, one at a town service station, and one at an agricultural research station. These sites do not represent worst-case contamination, having motor vehicle waste fluid disposal and recycling plans. However, these were the only systems available for study as private service station owners were unwilling to cooperate. To qualify for study, the service station had to employ at least one full-time mechanic, have a catch basin in the service bay that discharged to a septic tank/wastewater infiltration system and the drainfield had to be installed in loamy sand or silt loam soil.

Samples were collected quarterly for 1 year from the catch basin and septic tank at each site. Sample locations are shown in Figure 1 as dots. Catch basin wastewater was collected, beneath the surface floating layer and above the grit layer, either by lowering a bottle into the basin or lowering a weighted tube into the basin and hand pumping the wastewater into a glass flask. Septic tank effluent and sludge samples were collected using a hand pump with weighted tube and side-arm glass flask.

Samples for VOC analysis were stored in 40-ml glass VOA (volatile organic analysis) vials with Teflon caps and refrigerated at 4°C (40°F) until analysis. Samples for metal analysis were preserved with nitric acid, stored in 1-L plastic bottles, and refrigerated at 4°C (40°F). Samples for wastewater parameter analysis were stored in plastic 1-L bottles. Biochemical oxygen demands (BOD_5) were run immediately on subsamples. All samples were then frozen until used for further analysis.

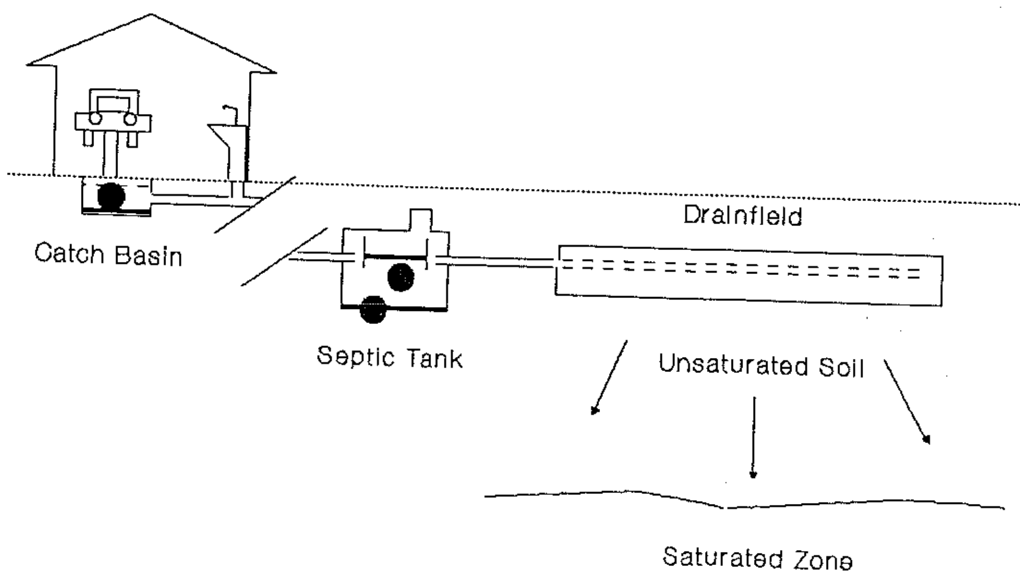

Figure 1. Catch basin, septic tank, and wastewater infiltration system at a motor vehicle service station. Dots represent sampling locations.

Wastewaters were scanned for 32 VOCs and analyzed for cadmium, chromium, lead and wastewater parameters such as chemical oxygen demand (COD), nitrogen series and conductivity. Laboratories certified by USEPA were used for organic and metal analysis of samples. VOCs were analyzed using gas chromatographic methods 601, 602, 8010, 8020 (7,8). Metals were analyzed using standard methods for atomic absorption spectroscopy (9). Standard methods were used for wastewater parameter analysis (9).

Soil and Soil Gas Sampling

Three of the four sites were used to study soil treatment of contaminants from wastewater infiltration systems. Two of the drainfields were installed in loamy sand soils and one site silt loam soils. Wastewater infiltration systems in Wisconsin are commonly installed in sandy and silt loam soils. These soil types also represent extremes in hydraulic conductivities.

Soil Sampling:

Soil samples were collected beneath the area of gravel trench or bed receiving effluent. Observation ports installed in the drainfield in silt loam soils were used to identify which trench was receiving effluent. The drainfields in loamy sand soils did not have observation ports. Ground-penetrating radar, effective only in sandy soils, was used to identify the area of trench or bed receiving effluent and the location of the plume.

Soil samples were collected twice beneath drainfields at three sites. The first set of soil samples was collected beneath a drainfield in loamy sand soils using a truck-mounted, hydraulic-operated soil probe. After rotary drilling through the gravel bed, soil samples were collected beneath the trench by pushing a stainless steel tube, fitted with a removable acrylic liner, into the soil. Samples were removed from the liner and processed. The gravel bed portion of the borehole was not cased so that effluent may have leaked into the soil collected beneath the bed. Thus, subsequent soil samples were collected from pits with one sidewall 15 cm (6 inches) from the outside edge of the drainfield trench. Two or three pits were dug at each site for each sampling event. Stainless steel soil probes or hand shovels were used to collect soil samples horizontally in from the side of the pits 15 and/or 31 cm (6 and/or 12 inches) beneath trenches. Control or background samples were also collected at each site outside of the drainfield area at the same depth as soil samples were collected beneath drainfields.

Soil was analyzed for the same contaminants using the same analytical methods as in the wastewater characterization excluding wastewater parameters such as solids and BOD_5. VOC samples were stored in 40-ml glass VOA vials with Teflon caps, preserved in 25-ml methanol and refrigerated at 4°C until analysis (10,11). Metals and wastewater parameter samples were stored in plastic bags and frozen until analysis.

Soil Gas Sampling:

Soil gas sampling was conducted at each site to monitor the movement of gas phase VOCs between the drainfield and the soil surface. Sauer and Tyler (12) have shown that VOCs added to a drainfield may be found in gas phase near the soil surface. Passive soil sampling was used at each site. Occupational health badges manufactured by 3-M (13) with activated charcoal were attached to the bottom of shallow, 20-cm (8-in) diameter, tin cans. The top of the cans were covered with screens. Five cans were inverted and buried 15 cm (6 in) beneath the soil surface at each site. A control or background sampler was buried outside the drainfield area. The other four cans were buried in pairs above the drainfield.

One can of each pair of cans buried was removed after 14 days of exposure to soil gas. The exposure times were estimated based on studies conducted by Kerfoot and Mayer (14). The remaining three cans including the control sample were removed after 21 days of exposure to soil gas. The badges were maintained at 4°C (40°F) until delivered to the laboratory for analysis.

The activated charcoal was desorbed in carbon disulfide and analyzed at an USEPA certified laboratory using OSHA-approved gas chromatographic methods (15).

RESULTS AND DISCUSSION

Wastewater Characterization

Volatile Organic Chemicals:

VOCs were found at all sampling locations at all sites. There was great variability in the types and concentrations of VOCs found in quarterly wastewater samples for each sampling location, at all sampling locations at each site and between sites. Table 1 lists the 31 VOCs found in catch basins, septic tank effluent and sludge. Some of the same VOCs, albeit fewer than this study, were found in catch basins and disposal wells in a study by Mahadevaiah and Council (16). As shown in Table 1, the majority of the VOCs found were substituted aromatics and aliphatics along with a few ketones. These VOCs were found in motor vehicle waste fluids (2,3,4).

Table 2 lists the VOCs that were usually found in more than one sample in catch basins, septic tank effluent, and sludge. Also listed in this table are the range of VOC concentrations and percentage of samples with concentrations exceeding detection limits for each VOC at each sampling location at all sites. VOCs often were found in higher concentrations at sampling locations at sites servicing more vehicles.

Table 1. VOCs in catch basins, septic tank effluent and sludge at motor vehicle service stations in Wisconsin.

Acetone	Ethylbenzene
Benzene	Isopropylbenzene
Bromobenzene	p-Isopropylbenzene
2-Butanone	p-Isopropyltoluene
n-Butylbenzene	Methylene chloride
sec-Butylbenzene	4-Methyl-2-Pentanone
tert-Butylbenzene	Napthalene
Carbon disulfide	n-Propylbenzene
Carbon tetrachloride	Tetrachloroethane
Chlorobenzene	1,1,1-Trichloroethane
1,2-Dichlorobenzene	Trichloroethene
1,3-Dichlorobenzene	Toluene
1,4-Dichlorobenzene	1,3,5-Trimethylbenzene
1,1-Dichloroethane	1,2,4-Trimethylbenzene
cis-1,3-Dichloroethane	o-,m-,p-Xylenes
Dichloromethane	

Table 2. VOCs commonly found in catch basins, septic tank effluent and sludge at motor vehicle service stations. VOC concentration ranges and percentage of samples with concentrations exceeding detection limits for each VOC for all sampling quarters are also provided.

VOC	Catch basins		Septic tank effluent		Septic tank sludge	
	µg/L	(%)	µg/L	(%)	µg/L	(%)
Acetone	39-340	(38)	110-260	(38)	200-860	(25)
Benzene	18-88	(19)	2-88	(13)	6	(6)
2-Butanone	21-55	(19)	12-110	(19)	35-57	(13)
Dichloromethane	2-4	(19)	6-26	(13)	2	(6)
1,4-Dichlorobenzene	ND	(0)	10-60	(13)	115-250	(25)
1,2-Dichlorobenzene	4	(6)	9-48	(13)	75-150	(13)
Ethylbenzene	3-98	(38)	7-23	(25)	9-53	(25)
Methylene chloride	2-18	(25)	9-15	(19)	1-13	(19)
n-Propylbenzene	13	(6)	2-230	(13)	110-470	(13)
Tetrachloroethene	2-1400	(25)	31-45	(19)	37-900	(25)
Toluene	3-15,800	(63)	4-760	(75)	23-3600	(75)
1,3,5-Trimethylbenzene	6-230	(19)	11-710	(25)	63-150	(13)
1,2,4-Trimethylbenzene	2-270	(25)	11-470	(31)	150	(6)
Xylenes	2-490	(56)	6-56	(38)	7-130	(38)

As shown in Table 2, acetone, toluene, and xylenes were found most often at all sampling locations and at concentrations higher than the other VOCs.

Table 2 shows the variability in VOCs and VOC concentrations at sampling locations. VOCs such as 1,4-dichlorobenzene, 1,2-dichlorobenzene and n-propylbenzene were found more often in septic tank effluent and sludge and at higher concentrations than in catch basins. As shown in Table 2, acetone, benzene, 2-butanone, dichloromethane, 1,3,5-trimethylbenzene and 1,2,4 trimethylbenzene were found more often in catch basins and septic tank effluent than in septic tank sludge. Acetone, 1,4-dichlorobenzene, 1,2-dichlorobenzene and n-propylbenzene were usually found in higher concentrations in septic tank sludge than in septic effluent and catch basins.

Mahadevaiah and Council (16) reported variability in frequency of detection and concentrations of VOCs in catch basins and disposal wells (liquid and sediment samples). The most commonly found VOCs in catch basins and disposal wells were ethylbenzene, benzene, and toluene. The highest concentrations of VOCs was usually found in sediment samples from disposal wells.

The Wisconsin drinking water standards, NR109, for benzene is 0 (17). As shown in Table 2, the concentration of benzene at all sampling locations before soil infiltration exceeded the drinking water standard. The mixture of VOCs from spent solvents and degreasers and wastewater may be hazardous as defined in Wisconsin Hazardous Waste Code NR605 (18).

Metals:

Cadmium, chromium, and lead were found in all samples at all sampling locations at each site. The concentrations varied between sampling locations sites and metals. Table 3 lists the range of concentrations for each metal at each sampling location for all sites and sampling quarters. Lead was found at the highest concentration at all sampling locations. As shown in Table 3, the highest concentration of all metals was in the septic tank sludge. Municipal sludge, which is similar to septic tank sludge in that it contains settled solids, accumulates metals (19).

Table 3. A summary of cadmium, chromium and lead concentrations in catch basin, septic tank effluent and sludge at service stations. New York study results (3), Wisconsin NR109 maximum contaminant levels (17) and USEPA Toxicity Characteristic levels (20) are provided for reference.

Sample location	Concentration range		
	Cadmium	Chromium	Lead
	mg/L		
Catch basin	0.004-0.10	0.02-0.32	0.021-1.0
Septic tank effluent	0.002-0.04	0.01-0.06	0.009-1.0
Septic tank sludge	0.01-0.15	0.02-1.92	0.02-2.70
Catch basins New York	0.031-0.70	0.016-0.60	0.71-49.0
Disposal wells New York (liquid)	0.018-0.37	0.028-0.69	0.29-33.0
Wis. NR109 Safe Drinking Water Act	0.01	0.05	0.05
USEPA Toxicity Characteristic Rule		1.0	5.0 5.0

As shown in Table 3, the concentrations of metals found in catch basins and septic tank effluent for this study were often less than metals concentrations reported in a New York study by Mahadevaiah and Council (16). Cadmium, chromium, and lead concentrations in catch basins, septic tank effluent and sludge as shown in Table 3, were greater than Wisconsin Safe Drinking Water Code NR109 but were less than values reported in

USEPA Toxicity Characteristic Rule (17,20), indicating that the wastewater at these two locations may not be hazardous with regard to heavy metals by this rule. However, these wastewaters could be hazardous by definition because the source product (spent solvent, degreaser) may be listed as hazardous in Wisconsin Hazardous Waste Code NR605 (18). The Toxicity Characteristic Rule values are used only as a general reference. In order for a wastewater to be hazardous it must be analyzed using the Toxicity Characteristic Leaching Procedure (TCLP) extraction method and exceed one of the toxicity levels for a constituent in the Toxicity Characteristic Rule.

Wastewater Parameters:

Catch basin wastewater quality varied between sites. Chemical oxygen demand (CODs) were typically two to six times greater than typical septic effluent (21). This may be due to the oxidizable organic contaminants such as VOCs that are found in catch basin wastewater. Total kjeldahl nitrogens were near analytical detection limits and less than typical septic tank effluent. Conductivities and chlorides in catch basin waste ranged from 320 to 15,500 μmhos/cm and 40 to 3600 mg/L, respectively.

Septic tank effluent quality varied between quarterly sampling periods at each site and between sites. Chemical oxygen demands were two to nine times greater than typical septic tank effluent (21). Total kjeldahl nitrogens were similar to typical domestic septic tank effluent (21). The higher concentration of nitrogen in septic tanks compared to catch basins results from the addition of domestic wastewater. The high COD values may be attributed to the oxidizable organic contaminants found in service station septic tank effluent. Conductivities and chlorides ranged from 600 to 19,800 μmhos/cm and 76 to 9,309 mg/L, respectively.

Soil Treatment of Contaminants

Soil Samples:

Volatile Organic Chemicals: All soil samples from each site have been collected but not all analytical results are available. Thus far, VOCs have been found in only one set of soil samples collected at one site in loamy sand soils. These samples were collected using the hydraulic soil probe. VOCs were not detected in the second set of soil samples collected from soil pits at this site. VOCs were not detected in soil beneath the drainfield in silt loam soils. These results suggest that some treatment of VOCs in drainfields occurs in silt loam and loamy sand soils. Sauer and Tyler (12) have shown that some degradation of VOCs (especially toluene) occurred in sandy soil in a laboratory model of a wastewater infiltration system. They also found VOCs in soil solution 90 cm (3 feet) beneath the gravel trench.

Researchers from the University of Wisconsin-Stevens Point have installed ground-water monitoring wells near the drainfields in loamy sand soils. VOCs have been found in groundwater beneath drainfields at both sites (G. Lueck, 1992, personal communication). The detection of VOCs in groundwater and not in soils beneath these drainfields suggests that the drainfields are contributing VOCs to groundwater. There is need for further investigation.

Metals: All soil samples have been collected at each site but only the analytical results for soil samples collected beneath the drainfield in silt loam soils and one drainfield in loamy sand soils are available. Cadmium, chromium, and lead concentrations beneath the drainfield in silt loam and loamy sand soils were similar to background metals concentrations. Thus, metals in septic tank effluent may not be transported far beneath drainfields in silt loam and loamy sand soils. Samples closest to the drainfield were collected at 15 cm (6 in) and 30 cm (12 in) beneath the infiltrative surface. Metals would likely be found at the infiltrative surface. Peterson (19) and Kelling et al. (22) along with many others have shown that cadmium, chromium, and lead added to soil in sludge applications tend to remain in the zone of application.

Wastewater Parameters: Wastewater parameter results are not yet available for soil samples.

Soil Gas:

VOCs were not detected in gas samplers buried above the drainfield in silt loam soils and one of the drainfields in loamy sand soils. Tetrachloroethylene was found at 66 and 120 μg for the 14-day exposure samples and 100 and 120 μg in the 21-day exposure samples at one site in loamy sand soils. This VOC was found in septic effluent at this site. Sauer and Tyler (15) have shown that VOCs added to a laboratory model of a wastewater infiltration system in loamy sand soils may diffuse through the soil and be found in gas phase at or near the soil surface. Thus, some loss of VOCs may occur in a drainfield as VOCs diffuse in gas phase after partitioning from liquid from the point of discharge in a drainfield to near the soil surface.

CONCLUSIONS

Metals such as cadmium, chromium, and lead and VOCs are found in septic tank effluent and sludge when catch basins are connected to disposal systems that receive motor vehicle waste fluids from motor vehicle maintenance. The wastewater in septic tanks at motor vehicle service stations may be hazardous as defined by Wisconsin hazardous waste code NR605(18) and USEPA Toxicity Characteristic Rule (20).

Some treatment of VOCs in drainfields occurs in silt loam and loamy sand soils. The detection of VOCs in groundwater and not in soil beneath drainfields in loamy sand soil suggests the need for further investigation.

Cadmium, chromium, and lead are not found 15 and 30 cm (6 and 12 in) beneath drainfields in loamy sand and silt loam soils. Metals in drainfields would likely be found at the infiltrative surface.

VOCs added drainfields in loamy sand soils may diffuse in gas phase to the soil surface above the drainfield. Thus, some loss of VOCs occurs by diffusion of VOCs in gas phase through drainfields in loamy sand soils.

It is recommended that motor vehicle service stations implement waste minimization programs and eliminate or reduce the discharge of motor vehicle waste fluids into catch basins. Catch basin waste should be separated from domestic wastewater and handled as hazardous wastes if necessary. Further research is needed to identify VOC treatment processes in soil beneath drainfields.

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