

***SMALL SCALE WASTE MANAGEMENT PROJECT***

**VOC and Heavy Metal Treatment and Retention  
In Wastewater Infiltration Systems Installed In  
Loam Sand and Silt Loam Soils**

by

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VOC AND HEAVY METAL TREATMENT AND RETENTION  
IN WASTEWATER INFILTRATION SYSTEMS INSTALLED  
IN LOAMY SAND AND SILT LOAM SOILS

P.A. Sauer, E.J. Tyler\*

ABSTRACT

Volatile organic chemicals (VOCs) and heavy metals are found in spent oils, greases, and solvents from routine vehicle maintenance. In Wisconsin, these motor vehicle waste fluids (MVWF) enter catch basins along with rinse waters and are discharged to soil infiltration systems after mixing with domestic wastewater in a septic tank (systems installed prior to 1992). The purpose of this study was to determine if retention/treatment of VOCs and heavy metals occurs in drainfields that receive MVWFs. Toluene, 1,3,5-trimethylbenzene, and acetone were found beneath beds in loamy sand soils; concentrations of detected VOCs ranged from 19-270 mg/kg. Volatile organic chemicals were not detected beneath the bed in silt loam soils. Thus, drainfields in loamy sand soil appear to provide less treatment of VOCs compared to drainfields in silt loam soils. Volatile organic chemicals were found in soil gas above drainfields in both soil types. Some loss of VOCs from drainfields in loamy sand and silt loam soils occurs as they diffuse from the drainfield to the soil surface. Cadmium, chromium, and lead concentrations in soil 15 cm and greater beneath beds in loamy sand and silt loam soils typically were similar to background concentrations. Heavy metals in drainfields would most likely be found in the clogging layer at the infiltrative surface of gravel and soil.

**Keywords:** VOCs, heavy metals, drainfield, motor vehicle waste fluids, soil

INTRODUCTION

Volatile organic chemicals and heavy metals are found in septic tanks when catch basins are connected to service station disposal systems that receive motor vehicle waste fluids (MVWF) from motor vehicle maintenance. The purpose of this study was to determine if VOCs and heavy metals from MVWF are treated/removed in soil absorption systems. This study serves as a preliminary assessment and recommends further research to characterize treatment/degradation and removal processes associated with these contaminants in drainfields. A detailed description of this study including wastewater stream characterization and groundwater studies are provided in Sauer et al. (1993). Literature was not found regarding VOC degradation in soil surrounding drainfields receiving MVWF contaminants. However, Sauer and Tyler (1991) and Sherman and Anderson (1991) have shown removal of VOCs, possibly through degradation, in drainfields. Limited literature is available regarding heavy metals in soil beneath gravelbeds. Lead was found in low concentrations in soil collected from motor vehicle service station (MVSS) disposal wells (that received only MVWF) in an unpublished United States Environmental Protection Agency (U.S. EPA) study (U.S. EPA,

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unpublished data, 1989). Peterson (1992) and McGrath and Lane (1989) found that the majority of metals applied in sewage sludge remains in the cultivated soil layer (0-27 cm). It is anticipated that heavy metals discharged into a soil absorption system would most likely remain near the infiltrative surface of gravel and soil in the drainfield.

## MATERIALS AND METHODS

Three publicly-owned MVSS located in Oneida, Portage, and Columbia counties in northern, central, and southern Wisconsin respectively were chosen for the study. Sites selected for inclusion in this study had Wisconsin Department of Industry Labor and Human Relations (DILHR)-approved (DILHR, 1983; DILHR, 1985) catch basin/septic tank/soil absorption systems and employed at least one full-time mechanic. The soil absorption systems were installed in silt loam or loamy sand soils. Soil absorption systems in Wisconsin are commonly installed in these types of soils. The Oneida county site soils are described as Vilas loamy sand (sandy, mixed, frigid, Entic Haplorthods) (USDA, 1993); the Portage county site soils are Friendship loamy sands (mixed, frigid, Typic Udipsamments) and Plainfield loamy sands (mixed, mesic, Typic Udipsamments) (Otter and Fiala, 1978); and the Columbia county site soils are Plano silt loams (fine-silty, mixed, mesic, Typic Argiudolls) (Glocker and Patzer, 1978). Preliminary sampling at these sites found cadmium, chromium, and lead and VOCs in catch basin wastewater and septic tank effluent and sludge at all sites. Septic tank effluent quality with regard to common wastewater parameters at the MVSS was similar to domestic septic tank effluent (Sauer et al., 1993).

At all sites, soil samples were collected beneath the area of bed identified as receiving effluent. Observation ports installed in the Columbia county drainfield in silt loam soils were used to confirm the presence of effluent in the bed. Ground-penetrating radar (GPR) was used to identify the area of bed receiving effluent at the sites in loamy sand soils (Kung and Donahue, 1991).

Soil samples were collected on two occasions beneath gravel beds at each site. At the Oneida county site, samples were collected on October 3, 1991 and July 9, 1992; Portage county site samples were collected on July 14, 1992 and August 11, 1992; and Columbia county samples were collected on April 23, 1991 and June 16, 1992. Figure 1 shows approximate soil sample locations, indicated by a dot, beneath gravel beds. The first set of soil samples at the Oneida county site were collected beneath the gravel bed using a truck-mounted, hydraulically-operated soil probe. After rotary drilling through the gravel bed, soil samples were collected beneath the bed by inserting a stainless steel tube, fitted with a removable acrylic liner, into the soil. The gravel-bed portion of the borehole was not cased so that effluent may have leaked into the soil collected beneath the bed. Soil was immediately removed from the liner, and prepared for analysis.

All subsequent soil samples were collected from pits dug adjacent to the drainfields at each site. Pits were dug with one sidewall approximately 15 cm from the outside edge of the gravel bed, and to the sampling depth below the bed. Soil pits at the Portage and Columbia county sites were hand dug; at the Oneida county site, they were dug using a backhoe because there was approximately 1.5 to 1.8 m of soil over the drainfield. 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 from the site of the pits 15 and/or 30 cm beneath the bed, depending on site soil conditions. Figure 2 shows the approximate sampling locations beneath a gravel bed.

background samples were also collected at each site outside of the drainfield area at the same depth that soil samples were collected beneath gravel beds. All soil and background samples were prepared for analysis using the same techniques. Soil samples were scanned for 40 VOCs and analyzed for cadmium, chromium and lead. The first set of soil samples for VOC analysis collected at the Oneida county site were stored in 200-mL glass vials with Teflon caps, preserved in 100 mL methanol, and refrigerated at 4°C until analysis. All subsequent soil samples for VOC analysis were stored in 40-mL glass volatile organic analysis (VOA) vials with Teflon™ caps, preserved in 25 mL methanol, and refrigerated at 4°C until analysis (Jiegriest and Jenssen, 1990; Urban et al., 1991). Soil samples for heavy metals analysis were stored in plastic bags and frozen until analysis.

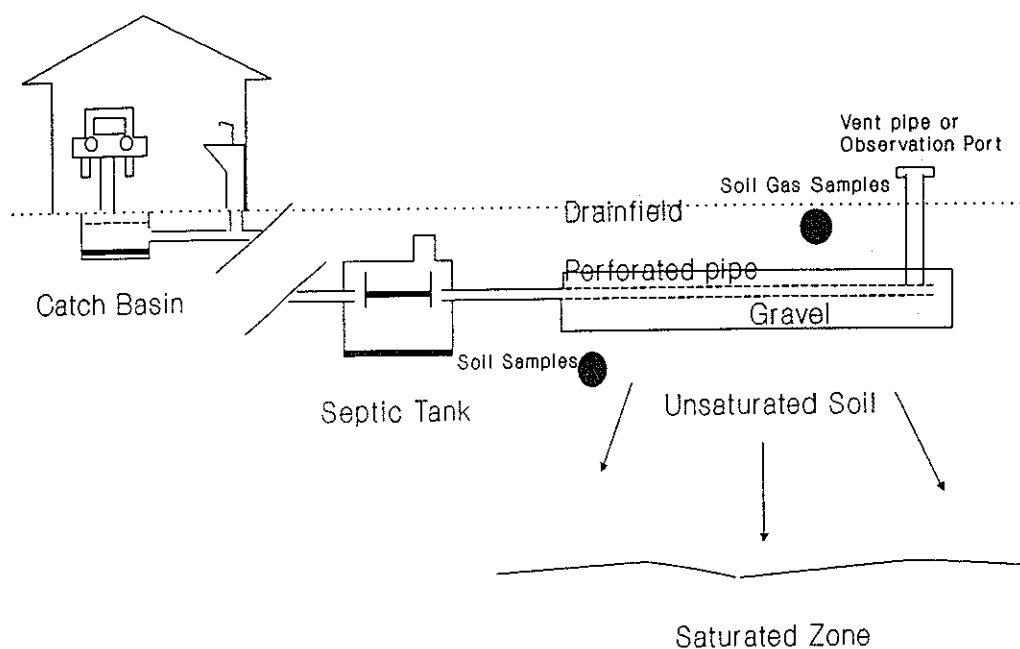


Figure 1. Approximate Location Where Soil and Soil Gas Samples Were Collected Beneath and Above Gravel Beds in MVSS Drainfields.

The first set of soil samples for VOC analyses collected at the Oneida county site were analyzed using gas chromatographic-mass spectroscopic method 624 (U.S. EPA, 1984). All other soil samples were analyzed using gas chromatographic methods 601, 602 (U.S. EPA, 1984) and 8021 (U.S. EPA, 1987). Standard methods for atomic absorption spectroscopy section 303A for total cadmium and chromium and section 304 for total lead were used for analyses of metals in soil samples (APHA, AWWA, and WPCF, 1985).

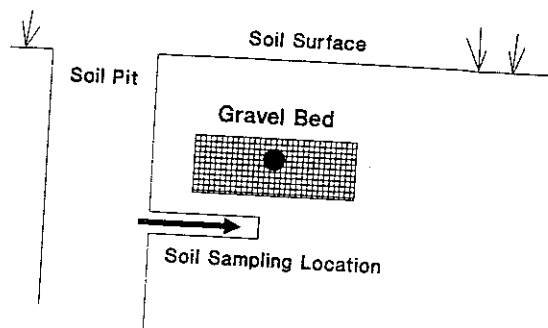


Figure 2. Soil Sampling Location Beneath Gravel Beds.

### Gas Sampling

Gas samples for VOC analyses were collected from vent pipes or observation ports in each drainfield at each site (Fig. 1). Samples for VOC analysis were collected on 150 mg of activated charcoal in tubes placed in-line between tubing lowered into the vent pipe or port and an air sampling pump. Samples were collected for 15 to 60 minutes at flow rates from 500 to 1000 mL/min.

After exposure, tubes were sealed at both ends, maintained at 4°C until delivered to the laboratory for analysis. Activated charcoal was desorbed in carbon disulfide and analyzed using Occupational Safety and Health Administration (OSHA)-approved gas chromatographic methods (OSHA, 1990).

### Soil Gas Sampling

The VOCs in soil gas were sampled at each site to monitor the movement of gas phase VOCs between the drainfield and soil surface (Fig. 1). Sauer and Tyler (1991) have shown that VOCs added to a drainfield may be found in gas phase near the soil surface.

Passive soil gas sampling was used at each site. Organic vapor monitors (model 3520 with back-up section), manufactured by 3-M corporation, Occupational Health and Safety Division, St. Paul, Minnesota, with activated charcoal were attached to the bottom of shallow, 20-cm diameter, tin cans.

The badges were covered with screens and cans were inverted and buried 15 cm beneath the soil surface at each site. One sampler was buried outside the drainfield area to determine background VOC concentrations while the other four cans were buried in pairs above the drainfield. Samplers were buried at the Oneida county site on July 10, 1992; the Portage county site on July 28, 1992; and the Columbia county site on June 19, 1992. One can of each pair of cans was removed after 14 days of exposure to soil gas. Exposure times were estimated based on studies conducted by Kerfoot and Mayer (1986). The remaining three cans, including the background sample, were removed after 21 days of exposure to soil gas. After removal from the soil, badges were maintained at 4°C until analysis. Activated charcoal in the badges was desorbed and analyzed using the same methods mentioned previously for gas samples.

## VOCs in Observation Ports and Vent Pipes

Toluene, limonene, and/or petroleum distillates were usually found in gas in vent pipes or observation ports at all sites. Toluene was typically found in septic tank effluent at all sites. Effluent samples were not analyzed for limonene and petroleum distillates. Limonene is a citrus-derived solvent used for parts and hand cleaners (Merck, 1989). Petroleum distillates include low molecular weight aliphatics such as hexane and hexane isomers (LaVonne Matthews, Wis. Occupational Health Laboratory, personal communication, 1992). Detection of volatile organics in vent pipes and observation ports confirms their presence in drainfields at all sites.

## VOCs in Soil Beneath Gravel Beds

Only three VOCs, m- and p-xylenes and 1,3,5-trimethylbenzene of the 40 that were scanned for, were found at quantifiable levels in three of the 22 soil samples collected beneath gravel beds. At the Oneida county MVSS, 19 and 24  $\mu\text{g/kg}$  m- and p-xylenes were found in soil samples collected October 3, 1991 at 20-48 cm and 8-46 cm depths, respectively. Trace levels of 1,4-dichlorobenzene and o-xylene were also found. Volatile organic compounds were not found in samples collected on July 9, 1992 at 30 cm depths. Xylenes and 1,4-chlorobenzene along with many other VOCs were found in septic tank effluent and sludge at this site.

Trace levels of acetone and m- and p-xylenes were found in soil samples collected on July 9, 1992 at 15 cm depths at the Portage county MVSS. In samples collected on August 11, 1992 at 15 cm depths, m- and p-xylenes and 1,3,5-trimethylbenzene were found at concentrations of 180 and 270,  $\mu\text{g/kg}$  respectively, along with trace levels of 2-butanone at 15 and 30 cm depths. Volatile organic compounds, including those found in soil beneath the bed at this site, were found in septic tank effluent and sludge.

Volatile organic compounds were not found at 15 and 30 cm depths for soil samples collected on April 23, 1992 and June 16, 1992 at the Columbia county MVSS. They were found in septic tank effluent at this site. Thus, VOCs were found only beneath gravel beds in loamy sand soils, whereas they were not found beneath the bed in silt loam soils.

Motor vehicle service station drainfields in loamy sand soils provide less treatment of VOCs compared to drainfields in silt loam soils. However, Sauer and Tyler (1991) have shown that the degradation of toluene, chloroform, and 1,1,1-trichloroethane occurred in sandy soil beneath a model soil absorption system. Volatile organic compounds were removed from sandy soils beneath drainfields that received only domestic septic tank effluent in a study conducted by Sherman and Anderson (1991). Wilson et al. (1981) and Anderson et al. (1991) laboratory studies have shown VOC degradation in sandy and silt loam soils. Thus, treatment of VOCs occurs in drainfields in silt loam and loamy sand soils, treatment being more effective in silt loam soils. This study was unable to determine if treatment occurred in or on the infiltrative surface of the gravel and soil beneath the crust layer.

In a II U.S. EPA studies at MVSS (U.S. EPA, unpublished data, 1989) found VOCs in fine and coarse-textured soils near disposal wells (privately-owned) that received only domestic wastewater (WF). Benzene, ethylbenzene, xylene, and toluene were commonly found in soil samples collected near disposal wells at concentrations ranging from several  $\mu\text{g/kg}$  to greater than 100  $\mu\text{g/kg}$ . At one MVSS, 15,165, 27,299, 62,898, and 9,047  $\mu\text{g/kg}$  benzene, toluene,

xylene, and ethylbenzene, respectively, were found in sandy and coarse-textured soils depths of 3.7 to 4.3 m beneath the soil surface surrounding a disposal well. Concentrations of many VOCs found in soil beneath disposal wells in this study were several tens to hundreds of times greater than found in soil beneath the gravel bed at the Portage county site. Drainfields in sandy soils that receive domestic waste and MVWF may provide more treatment of VOCs than disposal wells in similar soils. Other considerations: higher VOC concentrations were found in disposal well effluent at many sites in the U.S. EPA study as compared to septic tank effluent in this study; MVWF disposal activities in Wisconsin may differ from other states and regions, more fluids may be recycled in Wisconsin; and there may be differences in MVWF disposal activities between privately- and publicly-owned facilities.

#### VOCs in Soil Gas Above Drainfields

Tetrachloroethylene was found in soil gas samples collected above the Oneida county drainfield. Although this VOC was not analyzed in catch basin and septic tank effluent samples, tetrachloroethene and 1,1,1-trichloroethane were found at these sampling locations. Volatile organic compounds were not found in soil gas samples at the Portage county site. Soil gas samplers at this site may have required longer exposure to soil gas due to soil temperature and moisture content. Petroleum distillates were found in soil gas samples collected above the Columbia county drainfield. Sauer and Tyler (1991) have shown that VOCs added to a model soil absorption system in sandy soil volatilized from the soil and were found above the soil surface. Rodgers et al. (1980) mention that VOCs such as benzene may volatilize from silty clay loam soils. Some loss of VOCs occurred in MVSS drainfields in loamy sand and silt loam soils, as they diffused from the drainfield to the soil surface and were found in soil gas.

#### Heavy Metals

Cadmium, chromium, and lead concentrations in soils beneath gravel beds at the three study sites are shown in Table 1. Heavy metal concentrations in soil beneath beds at all sites typically were less than or within the same range as background. All metals were also found in septic tank effluent at the three study sites. Chromium concentrations were greater than lead which were greater than cadmium at all sites. Metal concentrations were greater in silt loam soils than loamy sand soils.

Heavy metals discharged from septic tanks to the drainfields at MVSS would most likely be found at the infiltrative surface. Peterson (1992) has shown that metals in land-applied sludge remain where applied in the zone of cultivation. Metals in drainfields may behave similarly to sludge-borne metals in soil in that they may bind through organometallic complexation and cation exchange to organic substances in the crust layer at the infiltrative surface (Logan and Chaney, 1983).

In a U.S. EPA Region II study (U.S. EPA, unpublished data, 1989), lead was typically the only metal found in soil samples collected near disposal wells in sand and gravel soils. Lead concentrations ranged from 0.01 to 0.053 mg/L (results were not provided in mg/kg). Soil samples were collected from 1.5 to 8.3 m beneath the soil surface at varying distances from several disposal wells that received only MVWF.

Cumulative loading rates of each metal for the lifetime of each drainfield were estimated by multiplying the average concentration of each metal found in the septic tank effluent by the average daily flow rate to each drainfield. An average service station flow rate of 2982

Table 1. Heavy Metals in Soil Beneath Gravel Beds at MVSS in Wisconsin.<sup>a</sup>

Sampling Depth	Cadmium	Chromium	Lead
	mg/kg	mg/kg	mg/kg
<b>Manitowish County</b>			
sandy soil			
<b>10/3/91</b>			
10-48 cm (N=1) <sup>b</sup>	0.37	5.6	0.9
1-45 cm (N=1)	0.54	7.3	0.5
<b>10/9/92</b>			
10 cm (N=4)	≤0.1	4.3-6.9	0.6-1.4
Background	<0.1	8.1	1.9
<b>Portage County</b>			
sandy soil			
<b>10/14/92</b>			
15 cm (N=4)	0.1	4.5-6.5	0.7-1.4
Background	0.1	4.6	0.9
<b>10/11/92</b>			
15 cm (N=2)	<0.042	4.9-6.3	1.2-1.3
10 cm (N=2)	<0.04	3.6-4.3	1.2
Background	<0.038	5.3	1.4
<b>Columbia County</b>			
light loam soil			
<b>10/23/92</b>			
15 cm (N=2)	0.41-0.9	11.8-31.9	6.8-11.9
10 cm (N=2)	0.94-0.95	7.3-32.4	4.0-11.3
Background	0.88	31.6	12.1
<b>10/16/92</b>			
15 cm (N=2)	<0.16-0.25	9.6-26.9	4.8-11.6
10 cm (N=2)	<0.16-0.14	6.2-22.5	2.7-7.3
Background	<0.08	28.6	10.6

Detection limits based on 2-g samples are as follows: cadmium is 0.25 mg/kg; chromium is 1.0 mg/kg; and lead is 0.1 mg/kg or 1.0 mg/kg, depending on metal concentration.

N = number of samples collected at specified depth.



in a year and age of the system to determine the kilograms of each metal. Kilograms of each metal were divided by the area of the drainfield to determine loading rates in kg/ha. In order to compare these loading rates to maximum cumulative application rates for metals in sludge applied to agricultural fields, loading rates were multiplied by 15. This is the ratio between the thickness of the crust layer estimated to be 2 cm and a 30-cm plow layer.

Estimated cumulative loading rates for each metal are provided in Table 2. Maximum cumulative application rates from Wisconsin Department of Natural Resources (WDNR) WI NR 204 (WDNR, 1985) for cadmium and lead in sludge are also provided for comparison (chromium values were not provided in WI NR 204). Cation exchange capacities of 3.5 and 17 m.e./100 g were used for determining application rates for loamy sand sites and the silt loam site, respectively (Buckman and Brady, 1970).

As shown in Table 2, lifetime cumulative loading rates for cadmium in loamy sand soils were 40-170 times greater and for silt loam soils 8 times greater than the WI NR 204 maximum cumulative application rate for cadmium in sludge-amended soils. Estimated lifetime cumulative loading rates for lead in loamy sand soils was up to 8 times greater than the allowed application rate. Loading rates for the site in silt loam soils was less than the required application rate. Thus, there may be greater cumulative loading of cadmium and lead on a 2-cm thick crust in drainfields installed in loamy sand and silt loam soils, that receive MVWF and domestic wastewater, than are allowed to accumulate on a sludge-amended agricultural field with a 30-cm plow layer.

Table 2. Estimated Lifetime Cumulative Cadmium, Chromium, and Lead Loading Rates for MVSS Drainfields in This Study. <sup>a</sup>

Location and Soil Texture	Cadmium kg/ha	Chromium kg/ha	Lead kg/ha
Oneida County loamy sand	855	1815	4200
Portage County loamy sand	210	645	2580
Maximum Cumulative Appl. (WI NR 204) sandy soil	5	NA <sup>b</sup>	500
<hr/>			
Columbia County silt loam	81	195	330
Maximum Cumulative Appl. (WI NR 204) silt loam soil	10	NA	2000

<sup>a</sup> Maximum cumulative application rates for cadmium and lead in sludge in soil from WI NR 204 are provided for comparison (WDNR, 1985).

<sup>b</sup> NA = values not available.

## CONCLUSIONS

Only three VOCs, m- and p-xylenes and 1,3,5-trimethylbenzene of the 40 that were scanned for, were found at quantifiable levels in three of the 22 soil samples collected beneath gravel beds in drainfields that received MVWF. The VOCs were found only in drainfields installed in loamy sand soils. Variation occurred in the types and concentrations of VOCs found beneath gravel beds in loamy sand soil at any given time. Motor vehicle service station drainfields in silt loam soils treat VOCs, loamy sand soils provide less treatment of VOCs. Further research is needed to determine if treatment/degradation of VOCs occurs in the clogging layer at the infiltrative surface of gravel and soil in drainfields.

Concentrations of VOCs found in loamy sand soil in drainfields at MVSS in this study were less than those reported in sandy and coarse-textured soil near disposal wells in an U.S. EPA Region II study (U.S. EPA, unpublished data, 1989). Drainfields that receive domestic waste and MVWF may provide more effective treatment of VOCs than disposal wells that receive only MVWF. Motor vehicle waste fluid disposal activities in Wisconsin may be different than other states; more MVWF in Wisconsin may be recycled than disposed of into septic tank/soil absorption system. There may also be differences in MVWF disposal activities between privately- and publicly-owned facilities.

Volatile organic chemicals were found in soil gas above MVSS drainfields in silt loam and sandy sand soils. Thus, some loss of VOCs from drainfields in silt loam and loamy sand soils also occurs as they diffuse from drainfield to soil surface.

Heavy metal concentrations in soil beneath beds at all sites typically were less than or within the same range as background. Heavy metals in drainfields would most likely be found in the clogging layer at the infiltrative surface of gravel and soil. Further studies are needed to confirm this.

It is estimated that cadmium and/or lead lifetime cumulative loading rates for drainfields receiving MVWF contaminants in loamy sand and silt loam soils may exceed WI NR 204 maximum cumulative application rates for cadmium and lead in sludge-amended soils. There may be greater cumulative loading of cadmium and lead on a 2-cm thick crust in drainfields at MVSS than is allowed to accumulate on a sludge-amended agricultural field with a 30-cm thick plow layer.

Based on the results of this study, recommendations are to phase out connection of floor drains and catch basins to on-site wastewater infiltration systems, especially those installed in sandy soils, due to the risk of intentional or accidental introduction of MVWF. Also, it is important to develop educational programs to inform MVSS operators of the potential health and environmental hazards of improper waste disposal activities and provide guidance for safe handling of MVWF. The U.S. EPA is currently developing rules for existing systems that may require sampling of the wastewater streams at MVSS to determine if the wastes are hazardous (Rich Roth, Wis. Department of Natural Resources, personal communication, 1990). They may require that catch basin wastes discharge to hazardous waste holding tanks. Soil and groundwater beneath drainfields may have to be monitored to determine the extent of MVWF contamination and remedial action may be necessary if extensive contamination is found.

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