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GROUNDWATER CONTAMINATION FROM STORMWATER INFILTRATION

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INTRODUCTION

The research summarized here was conducted during the first year of a 3-yr cooperative agreement (CR819573) to identify and control stormwater toxicants, especially those adversely affecting groundwater. The purpose of this research effort was to review the groundwater contamination literature as it relates to stormwater.

Prior to urbanization groundwater is recharged by rainfall-runoff and snowmelt infiltrating through pervious surfaces including grasslands and woods. This infiltrating water is relatively uncontaminated. Urbanization, however, reduces the permeable soil surface area through which recharge by infiltration occurs. This results in much less groundwater recharge and greatly increased surface runoff. In addition the waters available for recharge carry increased quantities of pollutants. With urbanization, waters having elevated contaminant concentrations also recharge groundwater including effluent from domestic septic tanks, wastewater from percolation basins and industrial waste injection wells, infiltrating stormwater, and infiltrating water from agricultural irrigation. The areas of main concern that are covered by this paper are: the source of the pollutants, stormwater constituents having a high potential to contaminate groundwater, and the treatment necessary for stormwater.

METHODOLOGY

An extensive literature review of stormwater pollutants that have the potential to contaminate groundwater was collected by searching prominent databases. This paper, a condensation of a larger, more detailed report (Pitt *et al.* 1994), addresses the potential groundwater problems associated with stormwater toxicants and describes how conventional stormwater control practices can reduce these problems. Potential problem pollutants were identified, based on their mobility through the unsaturated soil zone above groundwater, their abundance in stormwater, and their treatability before discharge. This information was used with earlier EPA research results of toxicants in urban runoff sheet flows (Pitt and Field 1990) to identify the possible sources of these potential problem pollutants. Recommendations were also made for stormwater infiltration guidelines in different areas and monitoring that should be conducted to evaluate a specific stormwater for its potential to contaminate groundwater.

RESULTS

Sources of Pollutants. Tables 1 and 2 summarize toxicant concentrations and likely sources or locations having some of the highest concentrations found during an earlier phase of this EPA-funded research (Pitt and Field 1990). The detection frequencies for the heavy metals are close to 100% for all source areas, and the detection frequencies for the organics ranged from about 10% to 25%. Vehicle service areas had the greatest frequencies and/or quantities of observed organics.

TABLE 1. CONCENTRATIONS OF HEAVY METALS IN OBSERVED AREAS

Toxicant	Highest Median	(μg/l)	Highest Observed	(μg/l)
Cadmium	Vehicle service area runoff	8	Street runoff	220
Chromium	Landscaped area runoff	100	Roof runoff	510
Copper	Urban receiving water	160	Street runoff	1250
Lead	CSO	75	Storage area runoff	330
Nickel	Parking area runoff	40	Landscaped area runoff	130
Zinc	Roof runoff	100	Roof runoff	1580

TABLE 2. MAXIMUM CONCENTRATIONS OF TOXIC ORGANICS FROM OBSERVED SOURCES

Toxicant	Concentration (μg/L)	Detection Frequency(%)	Significant Sources
Benzo(a)anthracene	60	12	Gasoline, wood preservative
Benzo(b)fluoranthene	226	17	Gasoline, motor oils
Benzo(k)fluoranthene	221	17	Gasoline, bitumen, oils
Benzo(a)pyrene	300	17	Asphalt, gasoline, oils
Fluoranthene	128	23	Oils, gasoline, wood preservative
Naphthalene	296	13	Coal tar, gasoline, insecticides
Phenanthrene	69	10	Oils, gasoline, coal tar
Pyrene	102	19	Oils, gasoline, bitumen, coal tar, wood preservatives
Chlordane	2	13	Insecticide
Butyl benzyl phthalate	128	12	Plasticizer
Bis(2-chloroethyl)ether	204	14	Fumigant, solvents, insecticides. paints, lacquers, varnishes
Bis(2-chloroisopropyl)ether	217	14	Pesticide manufacturing
1,3-Dichlorobenzene	120	23	Pesticide manufacturing

Potential Contaminates to Groundwater. NUTRIENTS. Nitrates are one of the most frequently encountered contaminants in groundwater (AWWA 1990). Phosphorus contamination has not been as widespread or as severe as that of nitrogen compounds. Nitrate is highly soluble (>1 kg/L) and will stay in solution in the percolation water.

PESTICIDES. Urban pesticide contamination of groundwater can result from municipal and homeowner use for pest control and the subsequent collection of the pesticide in stormwater runoff. The greatest pesticide mobility occurs in areas with coarse-grained or sandy soils without a hardpan layer, and with soils that have low clay and organic matter content and high permeability (Domagalski and Dubrovsky 1992). Pesticides decompose in soil and water, but the total decomposition time can range from days to years. In general, pesticides with low water solubilities, high octanol-water partitioning coefficients, and high carbon partitioning coefficients are less mobile. The slower moving pesticides that may better sorb to soils have been recommended for use in areas of groundwater contamination concern.

OTHER ORGANICS. The most commonly occurring organic compounds found in urban groundwaters include phthalate esters and phenolic compounds. Polycyclic aromatic hydrocarbons (PAHs) have also been found in groundwaters near industrial sites. Groundwater contamination from organics occurs more readily in areas with sandy soils and where the water table is near the land surface (Troutman *et al.* 1984).

METALS. Studies of recharge basins receiving large metal loads found that most of the heavy metals are removed either in the basin by sedimentation or in the vadose zone. The order of attenuation in the vadose zone from infiltrating stormwater is: zinc (most mobile) > lead > cadmium > manganese > copper > iron > chromium > nickel > aluminum (least mobile) (Harper 1988).

SALTS. Sodium and chloride used for deicing collects in the snowmelt and travels down through the vadose zone to the groundwater with little attenuation. Salts that are still in the percolation water after it travels through the vadose zone will contaminate the groundwater (Sabol *et al.* 1987; and Bouwer 1987). Studies of depth of pollutant penetration in soil have shown that sulfate and potassium concentrations decrease with depth, whereas sodium, calcium, bicarbonate, and chloride concentrations increase with depth (Close 1987; Ku and Simmons 1986).

MICROORGANISMS. Viruses have been detected in groundwater where stormwater recharge basins were located short distances above the aquifer (Vaughn *et al.* 1978). The factors that affect the survival of enteric bacteria and viruses in the soil include pH, antagonism from soil microflora, moisture content, temperature, sunlight, and organic matter (Jansons et al. 1989; and Tim and Mostaghim 1991). The major bacterial removal mechanisms in soil are straining at the soil surface and at intergrain contacts, sedimentation, sorption by soil particles, and inactivation.

Treatment of Stormwater. Table 3 summarizes the filterable (dissolved solids) fraction of toxicants found in storm runoff sheetflows from many urban areas found during an earlier phase of this EPA-funded research (Pitt and Field 1990). Pollutants that are mostly in filterable forms have a greater potential of affecting groundwater and are more difficult to control with the use of conventional stormwater control practices which mostly rely on sedimentation and filtration principles. Fortunately, most of the storm-flow toxic organics and metals are associated with the nonfilterable (suspended solids) fraction. Possible exceptions include zinc, fluoranthene, pyrene, and 1,3-dichlorobenzene. Pollutants in dry-weather storm drainage flows, however, tend to be much more associated with filtered sample fractions and would not be as readily controlled with the use of sedimentation (Pitt *et al.* 1994).

TABLE 3. FILTERABLE FRACTIONS OF STORMWATER TOXICANTS FROM SOURCE AREAS

Metals	Filterable (%) Fraction	Organics	Filterable (%) Fraction
Cadmium	20 to 50	Benzo(a)anthracene	None found in filtered fraction
Chromium	<10	Fluoranthene	65
Copper	<20	Naphthalene	25
Iron	Small amount	Phenanthrene	None found in filtered fraction
Lead	<20	Pyrene	95
Nickel	Small amount	Chlordane	None found in filtered fraction
Zinc	>50	Butyl benzyl phthalate	Irregular
		Bis(2-chloroethyl)ether	Irregular
		Bis(2-chloroisopropyl)ether	None found in filtered fraction
		1,3-Dichlorobenzene	75

Sedimentation is the most significant removal mechanism for particulate-related (nonfilterable) pollutants. Volatilization and photolysis are other important pollutant removal mechanisms in wet-detention ponds. Biodegradation, biotransformation, and bioaccumulation (into plants and animals) may also occur in larger and open ponds. Infiltration devices can safely deliver large fractions of the surface flows to groundwater, if carefully designed and located (EPA 1983). Grass-filter strips may be quite effective in removing particulate pollutants from overland flows. The filtering effects of grasses, along with increased infiltration/recharge, reduce the particulate sediment load from urban landscaped areas. Grass swales are another type of infiltration device.

CONCLUSIONS AND RECOMMENDATIONS

With a reasonable degree of site-specific design considerations to compensate for soil characteristics, infiltration may be very effective in controlling both urban runoff quality and quantity problems (EPA 1983). This strategy encourages infiltration of urban runoff to replace the natural infiltration capacity lost through urbanization and to use the natural filtering and sorption capacity of soils to remove pollutants; however, the potential for some types of urban runoff to contaminate groundwater through infiltration requires some restrictions. Infiltration of urban runoff having potentially high concentrations of pollutants that may pollute groundwater requires adequate pretreatment or the diversion of these waters away from infiltration devices. The following general guidelines for the infiltration of stormwater and other storm drainage effluent are recommended in the absence of comprehensive site-specific evaluations:

- Divert away from infiltration devices - dry-weather storm drainage effluent (probable high concentrations of soluble heavy metals, pesticides, and pathogenic microorganisms); combined sewage overflows (poor water quality with high pathogenic microorganism concentrations and clogging potential); snowmelt runoff (potential for having high concentrations of soluble salts); runoff from manufacturing industrial areas (potential for having high concentrations of soluble toxicants); and construction site runoff (high suspended solids (sediment) concentrations, which would quickly clog infiltration devices).
- Runoff from other critical source areas (e.g., vehicle service facilities and large parking areas) should receive adequate pretreatment to eliminate the groundwater contamination potential before infiltration.
- Runoff from residential areas (the largest component of urban runoff in most cities) is generally the least polluted urban runoff flow and should be considered for infiltration.

Most past stormwater quality monitoring efforts have not adequately evaluated stormwater's potential for contaminating groundwater. These are the urban runoff contaminates with the potential to adversely affect groundwater (with the most prominent and/or analyses recommendations in parentheses):

nutrients (nitrates); salts (chloride); VOCs (if expected in the runoff [e.g., runoff from manufacturing industrial or vehicle service areas] could screen for VOCs with purgeable organic carbon analyses); pathogens (especially enteroviruses, if possible, along with other pathogens [e.g., *Pseudomonas aeruginosa*, *Shigella*, and pathogenic protozoa]); bromide and total organic carbon (to estimate disinfection by-product generation potential, if disinfection by either chlorination or ozone is being considered); pesticides, in both filterable and total sample components (lindane and chlordane); other organics, as filterable and total sample components (1,3 dichlorobenzene, pyrene, fluoranthene, benzo(a)anthracene, bis(2-ethylhexyl)phthalate, pentachlorophenol, and phenanthrene); and heavy metals, as filterable and total sample components (chromium, lead, nickel, and zinc).

The following urban runoff components can adversely affect infiltration and injection operations: sodium, calcium, and magnesium (calculate sodium adsorption ratio to predict clogging of clay soils); and suspended solids (determine the need for sedimentation pretreatment to prevent clogging).

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