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The Risk of Groundwater Contamination from Infiltration of Stormwater Runoff

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Few pollutants ever disappear from the urban landscape. They are merely transferred from one medium to another—from air to land, from land to surface water, or from soil to groundwater. This last interaction is of great interest when it comes to the infiltration of urban stormwater. What is the risk that pollutants in urban stormwater might contaminate groundwater as a result of infiltration?

Infiltration is used as a technique to treat both the quality and quantity of urban runoff. It diverts runoff back into the ground in an attempt to replicate the normal hydrological cycle, whereby most rainfall infiltrates into the soil. Infiltrating runoff, rather than rainfall, can create some risks, particularly since runoff is likely to have picked up pollutants along the way.

To answer these questions, the University of Alabama-Birmingham and EPA Office of Research and Development embarked on a three-year cooperative study to define the nature of the potential risks to groundwater. Their preliminary results are shown in Table 1. The risk analysis is based on three key factors that influence a compound's movement into groundwater: its relative mobility, concentration and solubility. For example, a compound present at high concentration that is both mobile and soluble in soils and groundwater is a much greater risk than a relatively immobile and particulate-oriented compound.

The next stage of the risk assessment evaluates the ease of entry into groundwater. Typically, stormwater runoff is introduced to groundwater in one of three ways:

1. Sedimentation or filtration prior to infiltration into soils
2. Surface infiltration into soil
3. Subsurface injection into groundwater

An example of the first infiltration method would be a sedimentation chamber leading to an infiltration trench. In this instance, some compounds could be trapped in the sedimentation chamber and never enter the trench. A typical example of the second method is a grass swale without any pretreatment. Here, the compound percolates through the surface soils before reaching groundwater. Depending on the distance, the compound may be adsorbed and fixed onto soil. The last infiltration method involves routing stormwater deep into the ground, such that it does not pass through or come into contact with the soil layer. Consequently, there is little chance that a compound will be removed before it enters groundwater.

The analysis should only be used for an initial screening estimate of contamination potential because of its simplifying assumptions. These include the assumption that underlying soils are sandy and of low organic matter content, which represents a worse case scenario in many communities. Second, the values for a compound's abundance and solubility in runoff were derived from residential and commercial areas only. Urban hotspots, such as vehicle service operations and industrial areas, were not explicitly included in the analysis. Recent research indicates that these land uses may often have both higher concentrations and frequency of detection for many compounds (see Table 2).

The stormwater pollutants with the greatest potential for possible groundwater pollution are highlighted in Table 1 and include the following:

- *Nitrate-nitrogen.* This mobile compound has a low to moderate potential for groundwater contamination, but only because nitrate is generally found in relatively low concentrations in urban stormwater (1 to 3 mg/l).

- *Pesticides.* Lindane and Chlordane both have moderate contamination potential for surface infiltration or subsurface injection. The contamination potential can be greatly reduced, however, if runoff is pretreated before entering an infiltration facility.

- *Other organic compounds.* 1,3 dichlorobenzene, pyrene and fluoranthene all are predicted to have a high groundwater contamination potential for subsurface stormwater injection. Again, their contamination potential drops sharply for surface infiltration due to their sorption onto soils in the vadose zone. Thus, most organic compounds have a low risk of contamination with adequate runoff

Table 1: Groundwater Contamination Potential for Selected Stormwater Pollutants (Pitt *et al.*, 1994)

Compounds	Risk Factor: Mobility in soil	Risk Factor: Abundance in stormwater	Risk Factor: Filterable fraction	Contamination Potential: No pretreat-ment	Contamination Potential: Pretreat-ment*	Contamination Potential: Sub-surface injection
nitrate	H	L-M	H	L-M	L-M	L-M
2,4-D	H	L	L	L	L	L
lindane	M	M	L	M	L	M
malathion	H	L	L	L	L	L
atrazine	H	L	L	L	L	L
chlordane	M	M	VL	M	L	M
diazinon	H	L	L	L	L	L
VOCs	H	L	VH	L	L	L
1,3-dichloro benzene	L	H	H	L	L	H
anthracene	M	L	M	L	L	L
benzo(a) anthracene	M	M	VL	M	L	M
bis(2-ethyl hexyl) pthalate	M	M	L?	M	L?	M
butyl benzyl pthalate	L	L-M	M	L	L	L-M
fluoranthene	M	H	H	M	M	H
fluorene	M	L	L?	L	L	L
napthalene	L-M	L	M	L	L	L
pentachloro phenol	M	M	L?	M	L?	M
phenanthrene	M	M	VL	M	L	M
pyrene	M	H	H	M	M	H
entroviruses	M	P	H	H	H	H
Shigella	L-M	P	M	L-M	L-M	H
Pseudomonas	L-M	VH	M	L-M	L-M	H
protozoa	L-M	P	M	L-M	L-M	H
nickel	L	H	L	L	L	H
cadmium	L	L	M	L	L	L
chromium	VL-M	M	VL	L-M	L	M
lead	VL	M	VL	L	L	M
zinc	L-VL	H	H	L	L	H
chloride	H	H	H	H	H	H

VL, Very low; L, Low; M, Moderate; H, High; VH, Very high

* by sedimentation filtration

pretreatment and soil percolation.

- *Pathogens*. Enteroviruses and other pathogens all have a high groundwater contamination potential. The actual risk, however, depends on their presence in urban stormwater, of which not much is reliably known, based on current monitoring data. Clearly, the risk is greatest in areas where sewage is mixed with stormwater (e.g., combined sewer overflows and illicit connections).

- *Heavy Metals.* Zinc and nickel pose a risk of groundwater contamination under subsurface injection. The risk is sharply reduced, however, when runoff is pretreated and percolates through the soil layer.

- *Salts*. Chlorides appear to be a chronic risk for groundwater contamination, particularly in northern areas where they are applied on roads and highways. No method of pretreatment of percolation appears capable of reducing this potential.

Based on the risk assessment and current knowledge about pollutant source areas, Pitt and his colleagues offer several guidelines on using infiltration practices. For example, it is recommended that runoff be diverted away from an infiltration practice if it is generated from one of the following source areas:

- *Dry weather flows from a storm drain pipe.* These flows often are generated by illicit or illegal connections to the storm drain system, and thus have a strong probability of containing high concentrations of soluble heavy metals, pesticides, and pathogenic microorganisms.

- *Combined sewer overflows (CSOs)*. CSO discharges should be kept away from infiltration practices given their poor water quality (especially pathogens) and high clogging potential.

- *Snowmelt runoff from roads and parking lots.* These areas produce high concentrations of chlorides that cannot be effectively treated with infiltration.

- *Manufacturing sites.* Stormwater from these sites has a high potential for elevated concentrations of organic compounds and heavy metals.

- *Construction sites.* While stormwater from construction sites does not normally contain toxicants, the high sediment levels quickly clog infiltration practices.

Adequate pretreatment of runoff prior to the use of infiltration is recommended for other critical source areas, such as gas stations, vehicle maintenance operations, and large commercial parking lots.

Table 2: Detection Frequency and Maximum Concentrations for Selected Organic Compounds (Pitt *et al.*, 1994)

Toxicant	Detection Frequency (%)	Maximum observed concentration (µg/l)
Benzo-(a) anthracene	12	60
Benzo(b) fluoranthene	17	226
Benzo(k) fluoranthene	17	221
Benzo(a) pyrene	17	300
Fluoranthene	23	128
Naphthalene	13	296
Phenanthrene	10	69
Pyrene	19	102
Chlordane	13	2.2
Butyl benzyl phthalate	12	128
Bis (2-chloroethyl) ether	14	204
Bis(2-chloroisopropyl) ether	14	217
1,3 dichlorobenzene	23	120

Residential areas pose the least risk of groundwater contamination, and therefore, infiltration practices can be located without extensive pretreatment. However, the use of grass buffer strips and other forms of pretreatment is still advisable to prevent premature failure of the infiltration practice due to clogging.

Additional monitoring and testing of stormwater/groundwater interactions is being conducted to further refine these recommendations.

References

Pitt, R., K. Parmer, S. Clark and R. Field. 1994. Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration-1993 Research Project. Cooperative Agreement No. CR 819573 EPA/600/SR-94/051. Storm and Combined Sewer Pollution Control Program US. EPA. Cincinnati, OH. Avail. from NTIS (703) 487-0650.