Final Report on the DATCP Study of Water Quality at Infiltration Basins in Residential Subdivisions

Wisconsin Department of Agriculture, Trade and Consumer Protection

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Background

In recent years infiltration basins have been installed in residential subdivisions to manage stormwater runoff and reduce negative impacts to nearby surface water bodies. The basins are designed to capture stormwater runoff and encourage it to infiltrate into the ground after which it ultimately reaches groundwater. In many cases infiltration basins are installed to meet the requirements of local and state stormwater control ordinances. For instance, NR 151, Wisconsin Administrative Code, requires that new residential developments attain 90% of pre-development infiltration. Some local governments have even stricter requirements for stormwater management. Construction of infiltration basins is one common method of meeting these requirements.

It has been well documented that urban stormwater runoff can contain a wide variety of contaminants such as pathogens, heavy metals, nutrients, volatile organic compounds, pesticides, and salt (Pitt et al., 1996 and Banneman et al., 1996). Because of this, many newer infiltration basins are designed to mitigate the transport of contaminants to groundwater. Even though the potential for groundwater contamination at infiltration basins has been recognized and discussed in the literature, few actual groundwater monitoring studies have been conducted to measure impacts on the groundwater beneath the basins.

A considerable number of pesticides are used in urban and suburban landscapes to control pests in turf areas, on ornamental trees and shrubs, and in gardens. Pesticides may be used by both private homeowners and municipalities to control weed and insect pests. In addition to normal use, pesticides can also enter the environment through misuse, spillage, and improper storage. These compounds have the potential to be picked up by stormwater runoff and travel to infiltration basins where they could pose a threat to groundwater quality.

Purpose of the Study

The purpose of the study was to determine whether infiltration basins for surface water runoff control might be a route for groundwater contamination by pesticides used in urban/suburban settings. Specifically, the objectives of the study were to: 1) determine whether pesticides used in urban/suburban settings are transported to infiltration basins by stormwater runoff and 2) determine whether infiltration basins can be a route for groundwater contamination by pesticides. The results of the study may be useful in designing basins that could mitigate potential groundwater impacts by any contaminants transported into the basins by runoff water. The results may also be useful for municipalities and other agencies in their efforts to protect groundwater and municipal water supplies.

Methods

Groundwater monitoring wells were installed at two separate basins in Cross Plains, Dane County, WI (referred to as sites DN2 and DN3) and one basin in Oconomowoc, Waukesha County, WI (referred to as site WK1). Groundwater flow direction was determined or estimated at each site and an attempt was made to place wells downgradient of the basins. (Upgradient wells were also installed at sites DN2 and WK1.) Each well had a 10 foot screen with 3-4 feet of open interval below the water table. The wells were installed near the basins and at the water table to maximize the probability that any contaminants detected in the wells entered the groundwater via the basins. Wells were sampled following established sample collection procedures designed to minimize the possibility of cross contamination.

Samples from the monitoring wells and grab samples from ponded water in the basins were collected and analyzed for 20 pesticides that are commonly used on lawns and gardens. The samples were also analyzed for nitrate and ammonium nitrogen which, in a residential subdivision can come from sources including lawn fertilizer or pet waste. In addition to the 20 compounds specifically selected for this study, the DATCP laboratory is capable of detecting and reporting other pesticides that may be present in the water samples.

Surface water samples were collected following runoff events when the basins temporarily contained water. Groundwater samples were generally collected at a specific time interval following runoff events to determine if groundwater impacts had occurred. All samples were analyzed at the DATCP-BLS laboratory in Madison, WI. The limits of detections for the pesticide compounds ranged from 0.20-0.50 ug/l or parts per billion (ppb). Department chain-of-custody requirements were followed to ensure adequate documentation of laboratory results.

Site Descriptions of the Basins

Site DN2 (see Figure 1) is located in Cross Plains, Dane County, WI and consists of three sub-basins with a combined surface area of approximately one acre. The native soil materials at the site are silty clay over sandy glacial deposits. In the western-most sub-basin native soil materials were removed from a trench and this excavation was then filled with gravel to promote infiltration. The depth to groundwater is approximately 20 ft. Groundwater flow direction is to the west.

Site DN3 is also located in Cross Plains and consists of one basin with a sediment settling pond and a flow spreader. The single basin is approximately one acre in size. The native soil materials are planted with prairie plants with deep roots to promote infiltration. The depth to groundwater is approximately 10 ft. and the groundwater flow direction is assumed to be to the north towards the Black Earth Creek.

Site WK1 is located in Oconomowoc, Waukesha County, Wisconsin and consists of two sub-basins. The total area of the basins is approximately one-half acre. The upper

(north) basin has a sediment settling area and artificial wetlands and the lower basin has a French drain to promote infiltration. The upper five feet of soil material is silty clay which is underlain by sand and gravel glacial deposits. The depth to the water table from the original grade was approximately 7 ft. and the groundwater flow direction is to the southwest.

It should be noted that the requirements for the design of infiltration basins have changed over time. Current stormwater infiltration performance standards in Wisconsin, for example, require some form of treatment for water infiltrating through infiltration basins. An example of this is the use of engineered soil in the basins that can mitigate the downward transport of contaminants to groundwater. The current standards for infiltration basins took effect in late 2004 and the basins in this study were installed prior to these changes.

Figure 1. Basin site DN2 in dry and ponded condition showing monitoring wells.

Figure 2. Basin site DN3 showing the monitoring well and native vegetation at the site.

Results and Discussion

Surface Water Sampling

Table 1 shows that nine pesticide compounds were detected in ponded surface water at the basins following runoff events. Of the nine pesticides, eight are herbicides and one (carbaryl) is an insecticide. The most frequently detected compound was dicamba followed by 2,4-D, MCPA and MCPP. Concentrations of the detections ranged from 0.251 ppb for one of the detects of dicamba to 62.0 ppb for MCPA.

Table 1. Results of the Surface Water Sampling in the DATCP Water Quality Study at Infiltration Basins

Compound	***Type***	***Concentration Range in Surface Water (ppb)***	***Sites with Detects***	***Groundwater Standard# (ppb)***
Pendimethalin	herbicide	not detected (ND)		
Clopyralid	herbicide	ND		
Dicamba	herbicide	0.251-2.51	DN2, DN3, WK1	300
2,4-DP	herbicide	ND		
2,4-D	herbicide	0.43-4.12	DN2, DN3, WK1	70
Triclopyr	herbicide	0.314-1.94	DN2, DN3	
Quinclorac	herbicide	ND		
MCPA	herbicide	0.931-62.0	DN2, DN3	
MCPP	herbicide	0.506-1.06	DN2, DN3, WK3	
Prometone	herbicide	ND		90
Trifluralin	herbicide	ND		7.5
Benefin	insecticide	ND		
Carbaryl	insecticide	0.521-1.13	DN2	960
Chlorpyrifos	insecticide	ND		
Diazinon	insecticide	ND		
Imidocloprid	insecticide	ND		
Bifenthrin	insecticide	ND		
Cyfluthrin	insecticide	ND		
Lambda-cyhalothrin	insecticide	ND		
Permethrin	insecticide	ND		
Atrazine*	herbicide	0.62	WK1	3.0
Metolachlor*	herbicide	0.37-10.5	DN2	15
Simazine*	herbicide	0.449	WK1	4.0
Nitrate-N	nutrient	0.84-1.28 ppm	DN2, DN3	10 ppm
Ammonium-N	nutrient	ND		

*These herbicides are only used on agricultural crops. Although they were not part of the specific list of analytes for the study, the lab was able to detect and quantify them.
Groundwater enforcement standards are provided here for reference since surface water standards have not been established for ponded water in drainage basins.

An unexpected finding in the study was the detection of atrazine, simazine and metolachlor in surface water samples. These three herbicides are used on agricultural crops and have no uses in turf and landscape settings in Wisconsin. Further investigation did confirm that there were corn fields in the catchment areas for the infiltration basins in Oconomowoc and Cross Plains (sites DN2 and WK1) where these three herbicides could have been used. It was beyond the scope of this project to document the pesticides used on the agricultural land in the catchment areas.

Groundwater Sampling

Table 2 shows that eight pesticide compounds were found in groundwater compared to nine pesticides in surface water. All eight pesticides detected in groundwater were herbicides or herbicide metabolites. (A metabolite is a chemical that is formed when a pesticide breaks down in soil or water.) The herbicides found more than once in groundwater were clopyralid, dicamba and MCPP. It is interesting to note that clopyralid was found in groundwater at site DN3 but not in surface water. It is known however, that clopyralid was used at site DN3 for thistle control when prairie plants were being established in the basin to promote infiltration.

The concentrations of the herbicides detected in groundwater ranged from 0.244 ug/l for clopyralid to 6.02 ug/l for metolachlor ESA. Metolachlor ESA and metolachlor OA are metabolites of metolachlor and alachlor ESA is a metabolite of alachlor. Metolachlor and alachlor are herbicides that are only used on agricultural crops. No herbicide was detected over an enforcement standard, although no standards have been established for clopyralid, MCPP and the two metabolites of metolachlor.

Since parent metolachlor was detected in surface water in the same basin (DN2) where metolachlor metabolites were detected in groundwater, it is likely that the metolachlor originated in runoff from cropland, traveled to the basin in overland flow, and infiltrated to groundwater beneath the basin. It is not possible to confirm this route, however, since metolachlor metabolites are common contaminants in Wisconsin groundwater due to leaching to groundwater directly beneath agricultural fields (DATCP, 2008). Alachlor ESA was also detected in groundwater at site DN2 but alachlor parent was not detected in surface water.

As mentioned earlier, the basins studied in this project were installed prior to 2004 when current design standards for basins were put in place. Current standards require either pretreatment of runoff water, such as a settling basin, or the use of engineered soil which is a mixture of sand, compost and gravel. It is likely that these standards will reduce the potential for contaminant movement to groundwater as compared to earlier practices. In particular, the high organic matter content in the engineered soil placed in the bottom of the newer basins should attenuate the downward migration of pesticide compounds.

Table 2. Results of the Groundwater Sampling in the DATCP Water Quality Study at Infiltration Basins

Compound	***Type***	***Concentration Range in Groundwater (ug/l)***	***Site(s) with Detects***	***Groundwater Standard (ppb)***
Pendimethalin	herbicide	not detected (ND)		
Clopyralid	herbicide	0.244-0.372	DN3	
Dicamba	herbicide	0.085-0.289	WK1	300
2,4-DP	herbicide	ND		
2,4-D	herbicide	2.34	WK1	70
Triclopyr	herbicide	ND		
Quinclorac	herbicide	ND		
MCPA	herbicide	ND		
MCPP	herbicide	0.261-0.546	WK1	
Prometone	herbicide	ND		90
Trifluralin	herbicide	ND		7.5
Benefin	insecticide	ND		
Carbaryl	insecticide	ND		960
Chlorpyrifos	insecticide	ND		
Diazinon	insecticide	ND		
Imidocloprid	insecticide	ND		
Bifenthrin	insecticide	ND		
Cyfluthrin	insecticide	ND		
Lambda-cyhalothrin	insecticide	ND		
Permethrin	insecticide	ND		
Atrazine*	herbicide	0.173	WK1	3.0
Alachlor ESA*	herbicide	6.51	DN2	20
Metolachlor ESA*	herbicide	6.02	DN2	
Metolachlor OA*	herbicide	0.33	DN2	
Nitrate-N	nutrient	0.523-16.7	DN2, DN3, WK1	10 ppm
Ammonium-N	nutrient	0.502-1.33	DN2, DN3, WK1	

*These are herbicides or herbicide metabolites used on agriculture crops and were not part of the specific list of analytes for the study

Discussion

For the pesticides detected in the surface water and groundwater in this study, it was difficult to identify the exact source of the detections. That is, we were not able to identify the specific land areas where the pesticides detected in this study were originally used. There are two reasons for this difficulty.

First, we discovered during the study that two of the basins received runoff from nearby agricultural fields. Because of this, it was not possible to determine the source of detections for the pesticides that can be used on both agricultural fields and in residential settings such as lawns. Pesticides in this category include dicamba, 2,4-D, clopyralid and carbaryl. It is likely that the source of these compounds was use on turf since they are less commonly used on agricultural (corn) crops, but this can not be confirmed.

Of the pesticide compounds detected in water samples in this study, two (MCPA and MCPP) are used mainly on turf, four (carbaryl, dicamba, triclopyr, and 2,4-D) are used on both turf and agricultural crops, and four (atrazine, simazine, alachlor and metolachlor) are used only on agricultural crops.

Second, it was not possible to distinguish between detections of pesticides used on the basins themselves (public land) versus on nearby private lawns. In particular, the herbicides used for weed control on public and private land are often the same so distinguishing between these sources was not possible.

Because it was beyond the scope of the study to collect pesticide use data for the land (agricultural and residential) within the catchments for the basins, we don't know all the pesticides that had been used. Therefore, for the compounds of interest in the study that were not detected, we don't know if this was because 1) they were not used or 2) they were used but were not transported to the basins where they could be detected in surface or groundwater samples.

It was also difficult to determine the best timing for sampling the monitoring wells following rainfall/infiltration events. Although groundwater flow velocity was calculated based on the aquifer materials encountered during drilling, it was not possible to confirm travel times in the field. Since groundwater contamination from water infiltrating into infiltration basins would likely occur in pulses, more frequent sampling following infiltration events may have produced more detections of pesticides.

Although the monitoring wells were installed to detect pesticides that entered the groundwater via the basins, because pesticides were used on the land areas surrounding the basins, it is possible, but unlikely, that the compounds detected in the wells infiltrated though the soil outside the basins and then traveled via groundwater flow to the monitoring wells. It is more likely that the pesticides traveled to the basins in overland flow and infiltrated to groundwater through the basins.

Summary and Conclusions

This study was designed and conducted to determine whether infiltration basins in residential settings could be a route of groundwater contamination for pesticides used on lawns and gardens. The results of the study indicated that pesticides were transported to

the basins in stormwater runoff. Nine pesticides were detected in ponded water at concentrations ranging from 0.251 – 62 ppb. Eight pesticides were detected in monitoring wells at concentrations ranging from 0.173-6.51 ppb. The higher concentrations in groundwater were from metabolites of agricultural herbicides that were likely used on nearby cropland. No enforcement standards were exceeded, although many of the compounds detected do not yet have standards.

An interesting finding, which in retrospect is not surprising, is that agricultural land in the catchment area for the infiltration basins can also be a potential source of contaminants. Residential developments are often sited on recently-converted farm land, and the runoff from these two land uses can become co-mingled in the infiltration basins. Municipalities and developers should recognize this when locating and designing infiltration basins.

In summary, this study shows that infiltration basins in residential areas can potentially be a route to groundwater for contaminants in stormwater runoff. However, in this study the concentrations of the pesticide compounds detected in groundwater were quite low and no water quality standards were exceeded.

Literature Cited

Pitt, R.; Clark, S.; Parmer, K.; and Field, R. 1996. *Groundwater Contamination from Stormwater Infiltration.* CRC Press, 219 Pages.

Bannerman, R.; Legg, A.; and Greb, S. 1996. *Quality of Wisconsin Stormwater, 1989-1994.* USGS Open-File Report #96-458.

Wisconsin Department of Agriculture, Trade and Consumer Protection, 2008. *Agricultural Chemicals in Wisconsin Groundwater.* Agricultural Resource Management Division publication 180.