CONTAMINATION ATTENUATION INDICES FOR SANDY SOILS: TOOLS FOR INFORMATION TRANSFER

Wisconsin Groundwater Research Project Summary No. GCC-UWS-09

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ABSTRACT

Soil Survey Information (SSI) is the most comprehensive natural resource repository of maps, reports, and databases available in the United States to support agricultural practices. At its most detailed level, the classification system used in soil mapping selects attributes important for plant growth. Hence, the system which guided SSI's implementation was not designed to address problems related to fate and transport of agricultural chemicals. For example, previous investigations in Wisconsin showed that the degree of susceptibility for groundwater contamination in sandy soils varies considerably. Studies using intact soil columns showed that the rate and amount of atrazine transport were much greater in a Sparta sandy soil from the Lower Wisconsin River Valley (LWRV) than in a Plainfield sandy soil from the Central Sands, a trend also supported by groundwater monitoring data. This is not unexpected because the existing SSI does not adequately group sandy soils with an accountability for chemical, mineralogical, and morphological properties and their relationship to contaminant sorption and water flow rates and pathways. The present study was designed to investigate the role that variation in intrinsic soil properties might play in affecting the fate of atrazine in a range of Wisconsin sandy soils and to highlight those properties that by addition to the existing SSI might provide a more comprehensive formulation to aid in protection of groundwater quality. Five soils were selected to span a broad range of variation in mineralogy, grain size, organic matter content and type, and geological origin found in Wisconsin. The soils were analyzed to determine chemical, mineralogical, and morphological properties and to relate these to atrazine sorption and hydrological properties that might affect fate and transport of atrazine. The study confirms the important role of topsoil organic matter content in sorption and retardation of atrazine, suggesting a small but important similar role for subsoil mineral constituents, and supporting the interpretation that flow rates in sandy soils of uniform grain size are faster than in those with major hydrological discontinuities.

TECHNICAL SUMMARY

INTRODUCTION: Sandy soils in Wisconsin cover 20% of the State or 7 million acres. The inherent characteristics of sandy soils--rapid permeability and low organic matter and clay contents--limit their ability to retard movement and enhance degradation of contaminants. For example, atrazine, the most widely used pesticide in Wisconsin, has been detected with the greatest frequency beneath the sandy soils of the LWRV. Yet aquifers beneath characteristically similar sandy soils elsewhere (e.g., Central Sands region) do not display a similar high frequency and degree of contamination despite similar agricultural practices. Hence small differences in intrinsic soil properties, such as organic matter and clay content and grain size and uniformity, are likely to underlie differences in contaminant transport rates between the two regions. The SSI repository is not structured for providing a comprehensive overview of such information and only scattered studies now link differences in contaminant transport to changes in intrinsic soil properties. This study was undertaken to identify the intrinsic soil properties that most influence contaminant transport as a first step to the inclusion of these properties in the SSI repository. The objectives are to: 1. Characterize the chemical properties of the mineral and organic components of a broad range of 5 sandy soils found in diverse locations in Wisconsin; 2. determine the adsorption coefficient for atrazine by horizon in these soils and correlate with data obtained in objective (1); and 3. characterize physical and morphological properties of these soils that influence their hydrology.

METHODS: Five sandy soils were selected: 1. Sparta sand from the LWRV; 2. Plainfield sand from the Central Sands area; 3. Tarr sand from the Black River Valley; 4. Shawano sand from Shawano County; and 5. Rousseau fine sand from Marinette County. The soils were chosen to represent a broad range of differences in morphology, mineralogy, origin of organic matter, particle size, and geomorphic/geologic settings. Soil samples were taken from several different horizons, air-dried in a greenhouse, and passed through a 2 mm sieve. The following analyses were determined on all horizons of all samples: pH (1:1), organic matter content (Walkley Black method) and cation exchange capacity (0.1 M barium chloride). For characterization of mineralogy, samples were pretreated with hydrogen peroxide to remove organic matter and with citrate-bicarbonate-dithionite to remove free iron oxides. The sand was separated from silt and clay by wet sieving (53 μm sieve), dried at 105^{O} C, and sieved into coarse, medium, fine, and very fine sand fractions and weighed. Mineralogy of the sand fractions was determined optically with a petrographic microscope. Mineralogical analysis of the clay fraction was determined semi-quantitatively by X-ray diffraction analysis with peak area integration. Soil coatings were individually characterized for the organic and oxide portions. The organic portion was sequentially extracted to determine percent fulvic acid (FA), Humic acid (HA), and Humin. For the oxide portion, selective dissolution of Fe and Al was used to quantify Fe- and Al-humus complexes. Fe, Al, Si, and Mn concentrations in the extracts were determined using an inductively coupled plasma emission (ICP) spectrophotometer. Atrazine adsorption coefficients of soil samples were determined in 100 ppb ^{14}C labeled atrazine in 0.01 M $CaCl_2$ using a liquid scintillation system for radioassay.

Table 1. Properties of Shawano Sand

Horizon	Depth (cm)	pH	Atrazine Kd	Component Percent			
				Organic	Sand	Silt	Clay
A	0-13	6.2	4.69	1.83	89.8	5.7	4.5
B1	13-34	5.5	0.41	0.31	90.3	5.2	4.6
B2	34-66	5.8	0.28	0.22	91.7	4.6	3.7
B3	66-92	5.6	0.20	0.11	97.0	2.9	0.1
B4	92-113	5.6	0.14	0.05	97.2	1.5	1.3
B5	113-124	5.6	0.15	0.05	97.3	1.7	1.0
C1	124-158	5.8	0.09	0.03	98.6	1.0	0.4
C2	158-180	5.7	0.18	0.07	72.3	24.6	3.1

RESULTS: Table 1. below shows the chemical/physical properties that might affect the fate and transport of organic chemicals for one of the 5 soil samples investigated. Other properties which are enumerated in the Final Technical Report but not shown here include **Koc**, percent heavy minerals, acid-oxalate extractable silica, secondary Al- and Fe-oxide content, grain size, and presence of lenses or boundaries. The two most significant soil properties likely to affect atrazine transport to groundwater are hydrological attributes and organic content of the soils. The textures of the Sparta and Tarr soils are fairly uniform with depth and sand coarseness increases with depth. By increasing grain size, the size of pores created by the sand grains increases. Since the clay and silt contents decrease in these soils with depth, there is less fine material filing these pore spaces. Hence water flow rate should increase with depth. The Shawano and Plainfield soils are texturally stratified with depth and the Shawano soil has an abundance of silt in the lower horizon. These characteristics are likely to cause impeded or horizontally directed water flow with depth. Evidence of impeded and slowed water flow is depicted by the presence of mottles in the lower horizons and is in agreement with the attenuated movement of atrazine to groundwater observed in these soils. The second most significant property affecting atrazine movement is organic content of the soil. "A" horizon soils from all five samples possessed the highest content of organic matter and the organic content decreased sharply with depth in all cases. The correlation coefficient ($\mathbf{R^2}$) between the adsorption coefficient for atrazine (**Kd**) and the organic matter content was 98% and 84% respectively in the A and B horizons of all samples. No significant correlation occurred when the organic contents of C horizon soils were regressed against **Kd**, but a moderate correlation ($\mathbf{R^2}$=60%) occurred between **Kd** and clay content in these soils. Hence lower horizon clay-mineral soils with low organic content are likely to play an important role in retardation of atrazine movement. No other significant relationships were found between **Kd** and other soil properties.

PROJECT INFORMATION: This summary is based on the Geochemical Processes Project 91-GCP-2 which was conducted between July 1, 1990 and June 30, 1991. The project was supported in part by General Purpose Revenue Funds of the State of Wisconsin through the University of Wisconsin System. Administrative management of the project was provided by the UW-Madison Water Resources Center (WRC). The final technical report for this project has not been published and is in final author review before publication.