

Pollutant Capacity within the Vadose Zone of Soils

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As urban sprawl continues to increase, a landscape dominated by impervious surfaces grows and surface stormwater runoff peak rates and volumes rise. This not only amplifies erosion rates and flood occurrences but also flushes increased levels of suburbia's pollutants into waterways. These pollutants from multiple urban/suburban sources are washed into streams at levels that may damage recreational facilities and aquatic life and habitat, as well as increasing the cost of drinking water treatment.

Soils can be defined as the ground existing between an upper limit of air and a lower limit at the end of biological activity. The transitions of biological activity levels, chemical reactions, and physical parameters that occur between the surface and the end of biological activity are labeled by soil horizons usually parallel to the surface and distinguished by color and texture. Most soils have five basic horizons: O, A, B, C, and R. The O-horizon, or organic horizon, consists of vegetative matter ranging from leaf litter to compost. Once this organic matter begins to mix with and coat mineral particles, an A-horizon, commonly referred to as topsoil, is defined. Towards the bottom of the A-horizon, clay, iron, and aluminum have become leached from the soil and the B-horizon develops. Within the B-horizon, leached substances accumulate, most noticeably clay, and the structural development of a soil peaks. Finally, the C-horizon is a mineral layer formed by weathered material raised by groundwater from the consolidated bedrock of the R-horizon.

Recently, infiltration has become seen as an excellent method to reduce runoff rates, volumes and pollutant loads, with a side benefit of restoring groundwater recharge. Unfortunately contamination of groundwater has occurred at some sites where soils were not suited for infiltration. To prevent future accidental contamination of groundwater while also preserving infiltration devices as a method of reducing surface runoff, methods of evaluating a soil's suitability for infiltration are required.

Part 1 of this study used the SESOIL model to simulate the 1-year migration of two pollutants, zinc and sodium chloride, through eight unsaturated soils covering the range of several soil parameters (pH, organic content, intrinsic permeability). The results of this computer modeling indicated that rainfall quantity is a controlling factor in the migration of Zn^{2+} , Na^+ , and Cl^- ions. Also, Zn^{2+} migration was affected by pollutant concentration; and the intrinsic permeability of soils influenced the migration of Na^+ and Cl^- ions. The influence of soil pH and organic content was found to be minor but this may have been due to the low zinc concentrations that were run through the system. (Mikula, 2005)

Part 2 of this study will, to some extent, validate the results of the earlier modeling using undisturbed natural soil columns while also observing several other pollutants and soil parameters. To do so, four inch diameter PVC drainage pipe will be used to vertically encase and remove intact soil columns, representing 4 groups of soil horizons, from a silt loam and a sandy loam of naturally structured soils. The soils will remain in the PVC pipe throughout the study and natural storm runoff will be used to create artificial storm events which will be infiltrated through the columns weekly to keep the columns hydrated, preventing soil shrinkage and disconnection between the PVC and soil. Bi-weekly, the influent stormwater runoff and individual effluents of each column will be tested for pollutant concentrations. At the start of the trial and at two month intervals, a column of each representative test group of each soil type will be sacrificed for soil testing at the Penn State College of Agricultural Sciences Agricultural Analytical Services Lab.

To simulate rainfall events, stormwater runoff will be pumped from a stormwater collection box and transferred into an indoor storage tank. This stored water will allow us to create weekly artificial storm events all year long but, when possible, fresh stormwater runoff will be infiltrated through the columns. When tank stored stormwater runoff is used, the tank will be circulated for 30 minutes before use. Infiltration will be controlled with gradual measured quantities until roughly 400 mL of effluent is recovered. Bi-weekly, the influent stormwater runoff and individual effluents of each column will be tested for pH and conductivity (dissolved salts); heavy metals such as copper, cadmium, lead, and nickel by graphite furnace; total carbon by TOC analyzer; and total hardness (calcium/magnesium), total nitrogen, total phosphorus, potassium, sulfur (sulfate), and zinc spectrophotometrically.

At the moment, columns of Wharton silt loam have been collected from Fallentimber, Cambria County, Pennsylvania and there are plans to collect a sandy loam from State College, Centre County, Pennsylvania. The study will use twenty-two columns of each soil type, composing 4 test groups: 2 OAB controls representing pre-study conditions, 5 OAB, 5 AB, 5 A, and 5 O. The Wharton silt loam columns come from a shallow soil and are 15, 13, 6, and 2 inches deep; with the organic horizon depth being slightly exaggerated in order to keep all columns intact and stable.

One soil column from each test group will be sacrificed every 2 months for soil analysis. A control column and each sacrificed column will be subdivided into ~3 inch segments and tested at the Penn State College of Agricultural Sciences Agricultural Analytical Services Lab for water pH, buffer pH, soluble salts, total carbon and total nitrogen through combustion, and phosphorus, potassium, magnesium, calcium, zinc, copper, and sulfur by process of the Mehlich 3 extractant. Soil testing performed at Penn State Harrisburg will include texture and porosity evaluated once for every sample segment of a control column; and % organic matter and cation exchange capacity evaluated for every sample segment of a control column and each sacrificed column. Samples taken from each soil horizon of a control column and each sacrificed column will be digested and then tested with a graphite furnace for heavy metals such as cadmium, lead, and nickel.

In the end, correlations between soil parameters and pollutant migration will be studied

and the results incorporated into design guidance for determining the life of and maintenance requirements for an infiltration device. This research, in particular, focuses on soil removal capacity below the organic horizon of the soil where it has been documented that much removal occurs.

References

Mikula, J.B. 2005. *Using SESOIL to Predict the Fate and Transport of Zinc and Sodium Chloride in the Vadose Zone after Stormwater Infiltration*. Masters of Science in Environmental Pollution Control. Penn State Harrisburg, Middletown, PA.