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DEVELOPMENT AND TESTING OF A NEW PHOSPHORUS INDEX FOR KENTUCKY

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Introduction: The phosphorus index (PI) is a tool developed by USDA-NRCS to evaluate a field's risk of P loss and has been adopted by KY as part of its 590 Nutrient Management Standard. USDA-NRCS recently revised their 590 Standard, now requiring that states test the accuracy of their PI against measured P loss data or simulated P loss data generated from a P loss model. A recent study comparing output from the KY PI to output from an empirically-based P loss model highlighted several important deficiencies with the existing KY PI. To address these limitations, a committee consisting of scientists from federal, state, and local government agencies was formed to formulate a new PI for KY. Here we briefly describe the new KY PI and compare output from the new PI with measured P loss obtained from a variety of sites outside KY.

Methods: Given the lack of field-scale P loss data available in Kentucky, we developed the new PI based on published studies in the literature, professional judgment of the PI revision committee, and methods used in existing PIs from several states. The new KY PI uses a component formulation to assess risk of P loss in surface runoff from a given field. In this formulation the risk of P loss is calculated as the sum of P loss risk from each P loss pathway. For the new KY PI, the P loss pathways we have included are P loss through soil erosion, and dissolved P loss in surface runoff yielding:

$$Risk\ of\ P\ Loss = Particulate\ P\ Loss + Dissolved\ P\ Loss\ in\ Surface\ Runoff \qquad [1]$$

The particulate P loss component in the new KY PI is calculated as:

$$Particulate\ P\ Loss\ = 10 \cdot STP \cdot SED \cdot ER \cdot SDR \cdot BMP \qquad [2]$$

where soil test P (STP) is Mehlich-3 STP (lbs P/ac); SED is the long-term average annual erosion rate (tons/acre/year) calculated from RUSLE2; SDR is the sediment delivery ratio; ER is enrichment rate; BMP is a best management practices factor which accounts for various conservation practices which meet NRCS Conservation Practice Standards; and 10 is a weighting factor to convert STP to total soil P.

Dissolved P loss in surface runoff in the new KY PI includes P loss from three sources: STP, applied inorganic fertilizers, and applied manures:

$$Dissolved\ P\ Loss\ from\ Soil\ = 0.12 \cdot STP \cdot RO \qquad [3]$$

where RO is average annual runoff in cm and 0.12 is a soil extractability coefficient based on published values. To calculate RO we developed an emprical relationship relating runoff to curve number values based on long-term precipitation data for each county in KY.

Dissolved P loss in surface runoff from applied inorganic fertilizers is calculated as:

$$Dissolved\ P\ Loss\ from\ fertilizer\ =\ 0.9 \cdot 0.43\ \cdot FERTP \cdot AF \cdot RO \qquad [4]$$

where FERTP is amount of fertilizer P applied (lbs P_2O_5/acre), AF is an application factor based on time of year and application method, the weighting factor of 0.9 is adopted from the GA PI where it is assumed that only 90% of applied fertilizer P is water-soluble, and 0.43 is a conversion factor to convert from lbs P_2O_5/acre to lbs P/acre.

Similarly, dissolved P loss in surface runoff from applied manures is calculated as:

$$Dissolved\ P\ Loss\ from\ Manures\ = 0.43 \cdot \mathrm{MANP} \cdot (\mathrm{WSP}\ +\ \mathrm{MNRL}[1 - \mathrm{WSP}]) \cdot \mathrm{INF} \cdot \mathrm{AF} \cdot RO \qquad [5]$$

where MANP is the amount of P applied in manure (lbs P_2O_5/acre), WSP is the fraction of manure P that is water soluble, MNRL is a mineralization rate, and AF is an application factor.

The new KY PI was evaluated by comparing output against measured P runoff data published in the literature collected from a variety of sites outside KY representing different soil types, climatic and physiographic regions, and P management strategies.

Results: Significant modifications to the KY PI include treating runoff as a continuous variable, development of county-specific relationships between curve number and runoff, inclusion of P application rates from both fertilizer and applied manures, and directly accounting for P loss through soil erosion. Moreover, the new KY PI uses a component formulation whereas the original PI used what is termed an "additive" formulation which has been shown to be inadequate for describing P loss risk from fields. A good correlation (r^2 = 0.76) between the updated KY PI and the observed P loss data was observed. Indeed, the new KY PI was much better correlated with the observed P loss data set than the GA PI (r^2 = 0.15), which we used as a guide in developing the new KY PI. The improved correlation was likely a result of our updating the PI weights to be more consistent with published observations of P loss from field studies and how P loss is calculated in process-based and empirical P loss models.

Summary: The KY PI was initially developed in 2001 and has not been updated to reflect current knowledge of the factors controlling P loss from agricultural fields. Here we develop a new PI for KY based on observations in the literature, which allowed us to develop a more process-based PI that included all of the major factors controlling P loss in surface runoff. Although output from the new KY PI was well correlated with P runoff data collected from a variety of sites through the U.S., the new PI still needs to be evaluated against P loss data collected in KY. The new PI is currently being integrated into a GUI format to make it more accessible to end users.

THE NEW KENTUCKY NITROGEN AND PHOSPHORUS RISK ASSESSMENT TOOL TO PROTECT WATER QUALITY

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ABSTRACT

Agricultural systems require nitrogen (N) inputs to maximize yields and economic returns for farmers, but when N is applied at higher rates than necessary, there is potential for increased N and phosphorus (P) losses that can negatively impact groundwater quality (N), air quality (N), and surface water quality (N and P). New tools are needed that can be used by nutrient managers and conservationists to quickly assess the risk of N and P losses and determine alternative management practices that could reduce off-site losses of these nutrients. A new N and P Index for Kentucky was developed to enable quick assessments of the effects of management practices on the risk of N and P losses. The N Index component of this tool has been compared with experimental field data and been shown to estimate the effects of management practices on N loss pathways (P < 0.001). Nitrate-nitrogen (NO_3-N) leaching losses estimated by the tool correlate with measured NO_3-N leaching values (P < 0.001). Results for the P Index component of the tool suggest that its estimations of P loss risk correlate with measured risk values.

Tools like this are of key importance. A study released in September 2011 by the USDA found that only about a third of U.S. cropland is applying all of three best management practices (BMPs) for N in terms of application rate, time, and method, and that it costs billions of dollars annually to remove nitrate from drinking water (http://www.ers.usda.gov/Publications/ERR127/). To help reduce negative impacts to the environment the new National 590 Nutrient Management Standard was released in January 2013. The standard requires the development of state specific N risk assessment tools if N leaching and runoff from agricultural land presents a resource concern in the state. It also gives instructions for updating existing P risk assessment tools, focusing on the transport factor of P entering surface waters from crop fields.

Tools like the Kentucky N and P tool will help implement conservation on the ground to minimize environmental impacts from nutrient losses. The Kentucky N and P Index for laptop and desktop computers can be downloaded from the USDA-ARS-SPNR webpage at http://www.ars.usda.gov/Services/docs.htm?docid=20334. Additionally, the

N Index component of the tool is already available in the mobile application, and the P Index component will be released in the near future. This new tool developed for Kentucky is a new, cutting-edge prototype that is being used by the USDA Natural Resources Conservation Service (NRCS) in Kentucky as a conservation planning tool to enhance efforts to reduce non-point source nutrient pollution in the state that is generated from animal manure and commercial fertilizer applications on crop fields.

HERBICIDE TRANSPORT WITHIN SHALLOW KARST GROUNDWATER ON KENTUCKY'S PENNYROYAL PLATEAU BENEATH ROW CROP AGRICULTURE

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Agricultural land use impacts more than 10,000 km^2 of Kentucky's limestone karst regions where fecal bacteria, pesticides and excess nutrients are introduced into karst aquifer systems. In this region these introduced contaminants typically pass through the perched, saturated epikarstic zone in the shallow bedrock before reaching the main part of the karst aquifer. Transport behavior through the epikarstic zone has potential implications for timing, storage, and exposure to a variety of geochemical and biological environments and thus potential transformations.

We are investigating transport, storage and biogeochemistry of the shallow karst system in a small (~1 hectare) epikarstic drainage system fed by autogenic recharge influenced by active row-crop farming in the well-developed karst aquifer system of south-central Kentucky's Pennyroyal Plateau. We measure 10-minute resolution rainfall recharge rates and hydrochemical parameters (temperature, pH, discharge, specific conductance (spC) and carbonate chemistry) below within Crumps Cave at a discrete epikarst drain about 200 m laterally and 25 m below the field's surface. This is augmented by hourly to weekly grab samples. Direct connection between the farm field and underground monitoring site has been established by tracing experiments.

We present here one year (2011) of data describing the transport and fate of atrazine and its principal metabolites from field application through the soil and into the karst groundwater system. During the growing season corn was grown in the study catchment, with application of the broadleaf herbicide atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) in early spring. Sampling indicates that low concentrations of atrazine (about 0.04 μg/L) and the metabolites deethyl atrazine (DEA, about 0.2 μg/L) and deisopropylatrazine (DIA, about 0.1 μg/L) permeated epikarst water prior to spring application. New atrazine itself began to move from the epikarst to the main part of the karst aquifer some two months after application, with concentrations reaching at least 38 μg/L), exceeding both Kentucky and US standards for drinking water (3 μg/L) by more than an order of magnitude. Relatively high concentrations of atrazine came through during several storm events followed by relatively stable concentrations of about 0.1 μg/L for the rest of the year.

The hydrology of the soil and epikarstic zone thus impacts fate and transport of these contaminants, with storage and continuous leakage of atrazine metabolites for at least a year after application. The main pulse of new atrazine into the karst aquifer was retarded for several months over just a few hundred meters. During this time was it in the soil or epikarst?

We computed the dealkylated metabolite to parent ratio (DMPR) and the DEA to atrazine ratio (DAR). Both ratios reflect the same pattern, showing high levels of metabolite to parent during the winter, a precipitous drop in the ratio with the atrazine transport in early May and then a near linear increase through the summer and early fall. Summer ratios reach nearly twice that of ratios in the winter, pre-application period, showing that the metabolites dominate the transport through the course of the summer and early fall. These observations support the hypothesis of atrazine slowly leaching through the soil column such that significant degradation occurred as opposed to fast atrazine transport to the epikarst aquifer and subsequent storage before eventual breakthrough to the cave and the main part of the aquifer system. In other words, this is a type of column breakthrough in which most of the atrazine stayed in the biologically active soil zone and degraded through the course of the year. The parent that did make it was simply a small portion of the applied atrazine that was not subject to microbial breakdown as it must have been transported deeper into the soil and slowly moved through the sub-soil before reaching the epikarst and eventually to the cave monitoring site.

The chemical entered the karst aquifer directly through the soil on the flank of a large closed depression with little or no overland flow, and in which there are no soil collapse features (cover collapse sinkholes). This calls for reevaluation of commonly prescribed Best Management Practices for karst in Kentucky, which limit application within 15 meters (50 feet) of a “sinkhole.” What is meant by “sinkhole” in this case? If it refers to cover collapse sinkholes within the soil, then the 50-foot buffer might not have much impact where atrazine moves directly downwards with recharge. If sinkhole instead refers to the larger closed depressions that make up much of the Pennyroyal Plateau, then in many places there is no location 50 feet from a sinkhole; the drainage divide where one sinkhole ends is where the next one begins.

GROUNDWATER TRACING IN THE WEST PENNYRILE KARST REGION

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The Kentucky Division of Water (DOW) has conducted extensive groundwater tracing in the western part of the Pennyrile Karst Region in western Kentucky. The study area is in the Lower Cumberland River Basin and includes the Claylick Creek, Eddy Creek, Skinframe Creek and Livingston Creek watersheds in portions of Caldwell, Crittenden, Lyon, Livingston and Trigg counties.

Previous groundwater tracing in the study area, conducted by Ewers Water Consultants and DOW, was limited to three springs in and near Princeton (Caldwell Co.). Numerous cave maps have been completed by various groups and have been compiled and published by the Western Kentucky Speleological Survey. Several regional and statewide hydrogeological assessments have also been conducted and published by the US Geological Survey for this area. These works span six decades, from the 1950s to the 2000s, and provide a solid foundation for further study.

Several of the previous researchers developed groundwater flow hypotheses that had not been verified through dye tracing, which date as far back as 1962. Some of the recent tracer tests have verified these hypotheses, whereas other tracer tests are at odds with the previously proposed subsurface connections. Tracer results indicate an interesting relationship between groundwater flow and regional fault systems. Local hydrology is further complicated by several of the spring drainage systems that deviate from surface watersheds. To date, nearly 40 dye injection sites have been connected to more than 30 springs, caves and karst windows.

While minor dye tracing continues, efforts have turned to groundwater monitoring. This project, funded in part by a Clean Water Act Section 319(h) grant, will integrate surface water assessment protocols and the water quality standards found in 401 KAR 10:031. The goal is to provide a comprehensive assessment of groundwater quality and karst groundwater basin delineation for the area. As in previous DOW studies, this integrated approach is an attempt to better define the relationship between groundwater and surface water systems in karst areas.

NOTES