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Poster Session 2

Kentucky Water Resources Research Institute, University of Kentucky

GIS AS A TOOL TO INFORM FIELD STUDIES AND REDUCE HUMAN HEALTH EXPOSURE RISKS

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Classically, vapor intrusion has been defined as the upward movement of soil vapors originating from contaminated soil and groundwater plumes into overlying buildings through holes, cracks, and gaps in building foundations. Vapor intrusion is estimated to be a potential concern at thousands of hazardous waste sites throughout the United States; and millions of Americans may be experiencing increased exposure risks as a result of living near these sites. This problem is further exacerbated by recent evidence suggesting the existence of "alternative pathways" for vapor intrusion, such as the sewer gas to indoor air pathway.

Sewer systems can serve as transport networks to convey contaminated groundwater and vapors far from their source. The infiltration of sewer gas, and thereby hazardous vapors, can occur in homes and other buildings when plumbing systems are defective. The unintended entry of sewer gas may be relevant for human health if contaminant concentrations exceed protective risk levels. Previous research funded by KWRRI investigated the sewer gas to indoor air pathway using GIS maps of sewer lines and hazardous waste sites in Kentucky. Aging sewer lines susceptible to degradation were identified near known geographic locations of contamination. It was thus hypothesized that vapors could enter broken sewer mains near hazardous waste sites, and then unintentionally spread contamination to other areas. Figure 1 shows a map of Fayette County hazardous waste sites with the sewer map superimposed. Blue circles denote the 13 active or managed hazardous waste sites in the county and green lines represent sewer mains.

Figure 1: Fayette County active and managed sites, with sewer lines overlaid

The information on Figure 1 was combined with attribute data collected for each sewer line of interest, which was then used to assess areas of concern for increased vapor intrusion exposure risks. This spatial analysis allows users to consider geographic areas that are prone to elevated exposure risks based on deteriorated sewer conditions.

More recently, we conducted field studies funded in part by the National Science Foundation and the National Institute of Environmental Health Sciences in the California Bay Area to further develop our hypothesis. The field study site comprises a zone immediately outside of a previously defined vapor intrusion study area, which has elevated groundwater concentrations of trichloroethylene and other volatile organic compounds. Figure 2 shows the general sampling area.

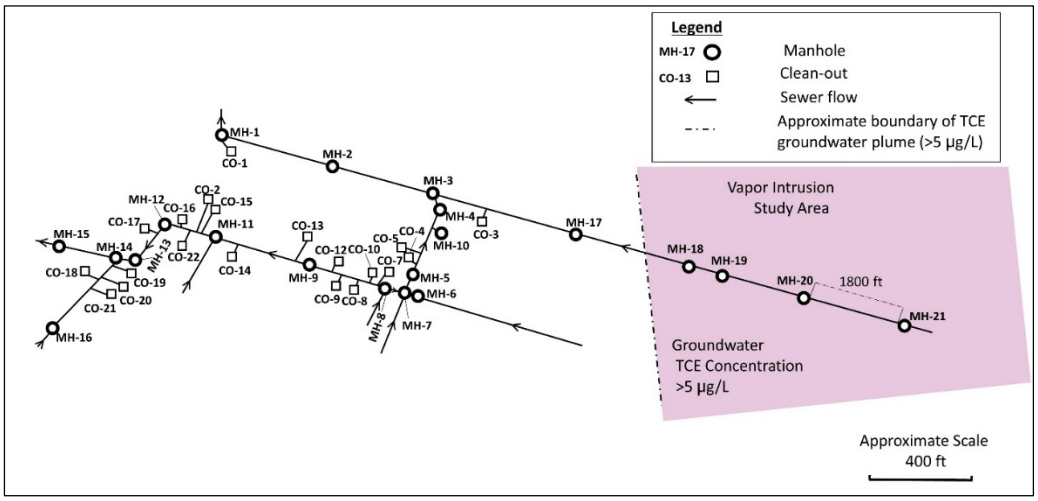

Figure 2: Site map showing sampling location

A sewer system connects the two areas in the subsurface. The preliminary field study, completed in summer 2015, involved collaboration between the United States Environmental Protection Agency, the University of Kentucky, and Clearwater Group. Approximately 40 locations were sampled to assess the spatial variability of volatile organic compounds in the sewer system of the study site. Another field study, completed in fall 2016, evaluated the temporal variability in sewer gas concentrations at two target locations and additional exploratory locations. Rapid screening of sewer gas concentrations was accomplished using AROMA, a novel chemical spectroscopy technology developed by Entanglement Technologies. Data collected from these studies demonstrate that sewers and other subsurface conduits can transport chemical vapors via unconventional pathways. The data also show considerable temporal and spatial variations.

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THE USE OF ENVIRONMENTAL DNA TO DETECT BACTERIAL MOLECULAR MARKERS IN THE TRIPLETT CREEK WATERSHED, ROWAN COUNTY, KENTUCKY

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The objective of this study is to develop and evaluate the use of bacterial genetic targets as markers of fecal contamination in the Triplett Creek Watershed. The Triplett Creek Watershed has been the focus of assessment and research activities by Morehead State University scientists for well over ten years now. Our lab has been assessing *Escherichia coli* contamination at 36 well-established sampling sites in the watershed throughout that period of time. In this project, three-liter water samples were collected from six watershed sampling sites. The sites were chosen because they exhibit chronically high *E. coli* counts (>240 *E. coli* CFU/100 mL), or acceptable *E. coli* counts (<240 *E. coli* CFU/100 mL). DNA was extracted from the water samples and purified using commercial kits, then assessed spectrophotometrically for quantity and purity. The environmental DNA (eDNA) was used as a target for polymerase chain reaction to detect markers for enteric bacteria (16SrRNA), *E. coli* (uidA), and a variety of antibiotic resistance genes (bla^{CMY}, bla^{SHV}, bla^{TEM}, ereA, msrA/B, sulI, sulII, TetO, and TetW). DNA yields from the water samples were sufficient for PCR analysis. PCR was conducted, and PCR products were analyzed by agarose gel electrophoresis. Some of the eDNA samples were positive for enteric bacteria, *E. coli* and the ß-lactamase gene, bla^{TEM}. The results demonstrate the ability to detect bacterial molecular markers in DNA collected directly from environmental water samples, allowing us to develop this further for *E. coli* source tracking in the Triplett Creek Watershed. This project is supported by a KWWRI 104b Student Enhancement Project grant via the U. S. Geological Survey.

NOTES

DETECTION OF *Percopsis omiscomaycus* (TROUT-PERCH) USING eDNA in EASTERN KENTUCKY STREAMS

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Environmental DNA (eDNA) provides an effective, non-invasive method to detect the presence of rare organisms in aquatic systems, provided sufficient molecular tools are available. *Percopsis omiscomaycus* is a small fish with a limited, disjunct distribution in central and eastern Kentucky. We amplified and sequenced a 769 BP region of *Percopsis omiscomaycus* cytochrome b and used this sequence to design eDNA primers that selectively amplify *P. omiscomaycus* DNA from filtered water samples. One liter water samples were collected from 28 locations in northeastern Kentucky, filtered, and DNA was extracted in a manner consistent with established methods. Additionally, each location was intensively sampled for *P. omiscomaycus* by seining. Initial results indicate eDNA successfully detected *P. omiscomaycus* at sites where specimens were collected using seines in addition to at least one site in which suitable habitat was observed but no specimens were collected. These data add to the body of knowledge concerning *P. omiscomaycus* distribution and provide a useful tool for detecting cryptic populations for this and other species.

NOTES

SEASONAL FLUCTUATIONS IN SALAMANDER eDNA IN CENTRAL KENTUCKY STREAMS

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Environmental DNA (eDNA) provides an effective, non-invasive method to determine organism presence or absence in an efficient manner. The majority of salamanders native to central Kentucky have an aquatic phase to their life cycle. Some *Ambystomid* species persist as aquatic larvae for just a few months while other sympatric species spend more than one year in the juvenile aquatic phase. We developed species specific eDNA primers for streamside (*Ambystoma barbouri*) and cave (*Eurycea lucifuga*) salamanders that effectively amplify salamander DNA filtered from stream water. We collected 1 liter water samples biweekly from February to July 2015 in three small streams in Jessamine County to examine season fluctuation in eDNA levels of different salamander species. Initial data reveal a complete absence of *A. barbouri* eDNA in early spring samples but high levels later in the spring corresponding with breeding and larval presence. RT PCR analysis is in progress in order to determine quantitative levels of both salamander species DNA at each collection. These data add to the growing pool of knowledge concerning eDNA monitoring of species and should provide useful reference data for future monitoring or range delineation studies.

NOTES

VIRTUAL 3D SEPTIC SYSTEM FOR EDUCATION AND OUTREACH

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Septic Systems are used as on-site waste water treatment systems for the homes which are not connected to city sewer lines. Domestic waste water drains to the septic tank where waste water is digested through low rate anaerobic processes in the tank (Bounds, 1997). After treatment, the water infiltrates into the ground through a drain field. When a septic system is not properly maintained, the treating efficiency of the system decreases. Poorly functioning septic systems can affect groundwater quality. If the system is in close proximity to streams, it may also affect the adjacent stream water quality. In Northwest Indiana, complete details of existing septic systems are not fully documented yet.

In this study, a virtual 3D septic system was created as an education and outreach tool. The main objective of this work was to create a user friendly web based tool to provide better understanding of the backyard septic system and present the importance of maintaining them periodically. This tool was created based on the Indiana State Department of Health – Environmental Public Health Division 2014 publication called Residential On-Site Sewage Systems Rule 410 IAC 6-8-3.

A virtual 3D environment was created in Unity 3D platform. Groundwater movement with contamination was simulated using GW Vistas – MODFLOW- MT3D modeling scheme. Entire septic system which includes models of residential house, drains, main septic tank with components, dosing tank, filters and drain field were built together in the virtual environment. Simulated results of the groundwater movement flow field were also included with this system. Using this system (Figure 1), a user can input few basic details (example: number of individuals in household). Users can visualize the difference between a properly maintained system and a poorly maintained system. They can study the sludge deposition with time and the residence time of waste water in the tank. This tool facilitates user understanding of the importance of regular maintenances to the septic system.

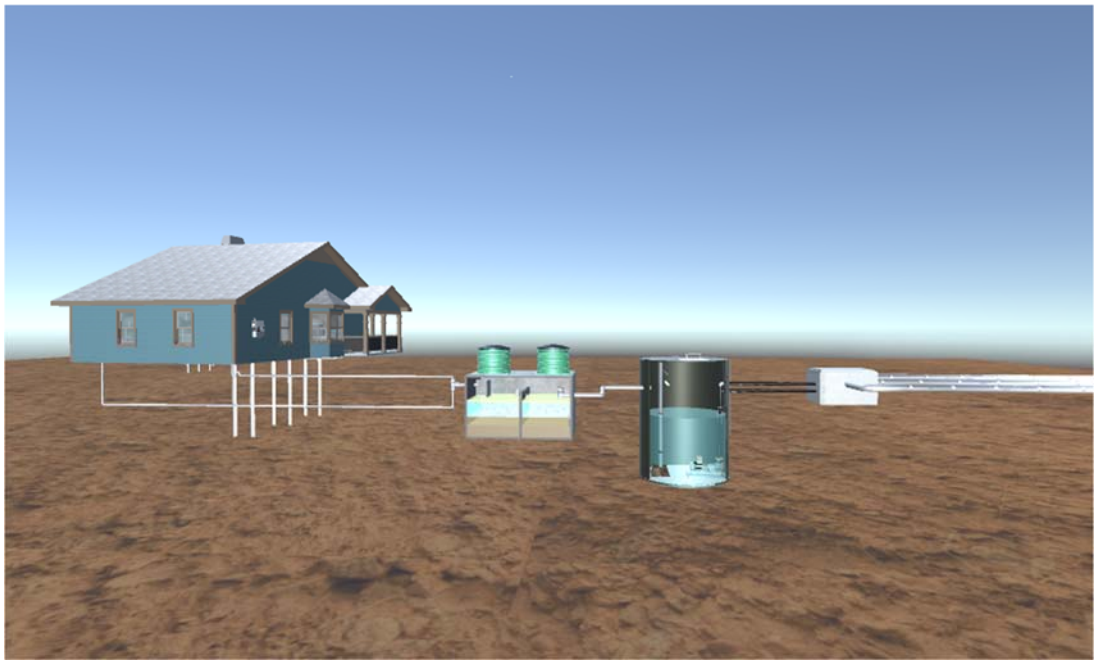

Figure 1: Virtual Septic System

Acknowledgement

Authors acknowledge the IDEM -DNR Coastal Grants for supporting this research study.

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RAINFALL TRENDS IN INDIANA AND ADJACENT STATES AFTER WIND FARM INSTALLATIONS IN INDIANA

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Large wind farms were installed in Benton, White and Jasper counties of Indiana after 2008. The production capacity of these installations account to 1895 MW. This green renewable energy is due to general wind patterns existing in these counties. In this research study, a preliminary analysis was conducted by considering raingages from Illinois, Indiana, Kentucky, Ohio, Pennsylvania and West Virginia to study the influence of new wind farms on rainfall (Keith *et al.* 2004, Krik Davidoff *et al.* 2008). The previous study done by Keith *et al.*, 2004 discussed the influence of large wind farms on global climate. In total, 130 stations which had continuous data documentation from these states were used (Source: NOAA National Climatic Datacenter).

Monthly rainfall and snowfall data from 1950 to 2015 were used to find decade level precipitation averages. Decadal averages were compared to the most recent decade. These analyses were done for each month to overcome seasonal characteristics by considering individual states initially. Figure 1 provides decade level averages in the past 70 years for the month May in Indiana. There is no significant change in mean values in 24 Indiana stations.

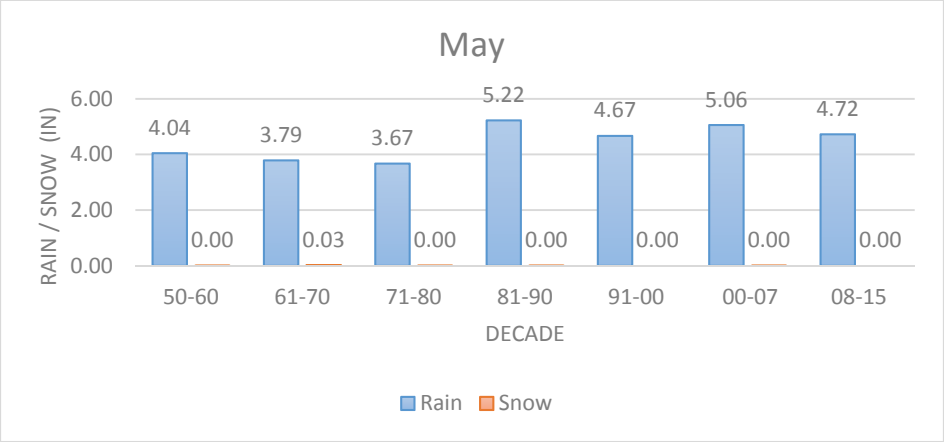

Figure 1. Variations in decadal averages for Month May – Indiana Raingage Stations

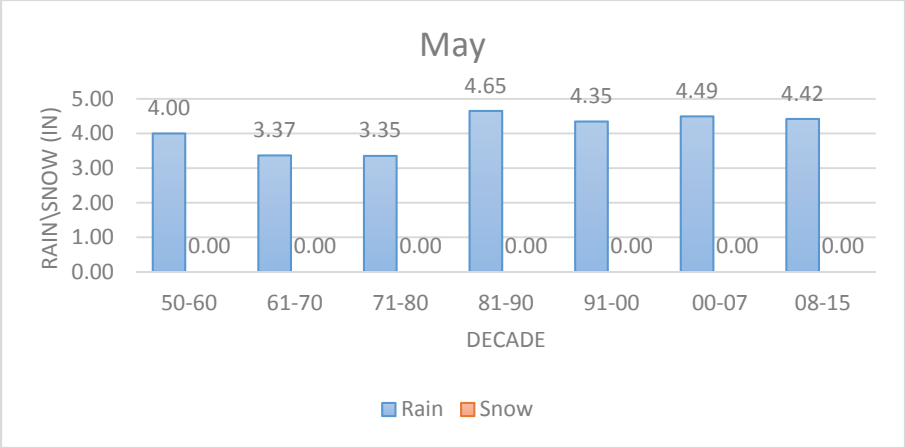

Figure 2. Variations in decadal averages for Month May – Indiana Raingage Stations – Wind Farm Region

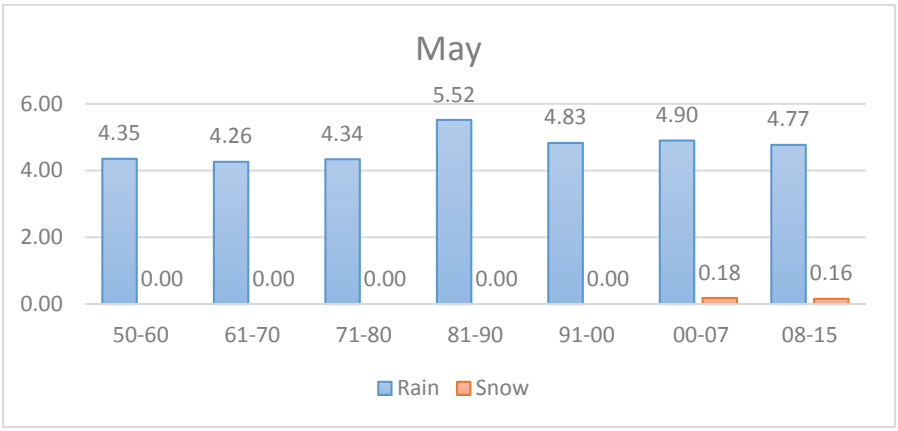

Figure 3. Variations in decadal averages for Month May – Kentucky Raingage Stations

In the next stage of the investigation, the entire region was subdivided into two zones (namely wind farm zone and other zone). Stations were clustered to two groups using these zones and the decadal averages were studied. Figure 2 shows the decadal variations in stations located in the wind farm zones. Kentucky state rainfall data is shown in Figure 3. For each month, decade level variations were examined for both snow and rainfall by considering the entire region, each state and wind farm zones. Preliminary results indicate no significant changes in the recent decade (after wind farm installation).

Acknowledgement: Authors acknowledge the support given by SURE program, Mechanical & Civil Engineering, Purdue Northwest to conduct this study.

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CURVE NUMBER ANALYSIS WITH HEC-HMS USING ARCGIS AND HEC-GEOHMS DATA PROCESSING

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There are continued efforts to understand the effects of surface coal mining and subsequent restoration on the hydrology of the Appalachian coal region. Surface mining has been implicated in increased flood events in downstream communities. There is a need for accurate modeling of mining impacts on the hydraulics of an area to assess downstream flood risks and to plan control and prevention measures. The study objective is to model the hydrologic peak flow and surface runoff for pre- and post-mine land use conditions in the Guy Cove basin using Digital Elevation Models (DEM) and curve number analysis in HEC-HMS.

Mature forest was modeled using a DEM from the National Elevation Database collected prior to mining activity. Post mine conditions were modeled using LIDAR DEM collected after mining activity had concluded. Two post mine conditions were studied based on current reclamation techniques. The Guy Cove site has been restored using the Forest Reclamation Approach (FRA), however, for comparison purposes, both conditions have been modeled.

The Surface Mining Control and Reclamation Act (SMCRA) encourages the use of heavy soil compaction and seeding with aggressive grass cover. The Forest Reclamation Approach encourages the use of loose-dump spoils to encourage tree growth and simulate more native soil conditions. Land use and soil conditions were modeled using a range of curve numbers due to the variability in field measurements cited in the literature.

Elevation changes were evident in the DEMs pre- and post-mining, however hydrologic effects were very similar when the same curve number was used (implying the same land conditions pre- and post-mining). This shows that imperfections in restoring the approximate original contour do not impact runoff or peak flows.

Peak flow increased by approximately 40% for a five number increase in curve number, with larger increases for very high curve numbers. This aligned with results by Taylor et al. (2009) that found peak flows increased by 20-45% (and runoff by 20-40%) for an increase in CN of five. The sensitivity to curve number and correspondingly to land conditions demonstrates the importance of the restoration approach used when mining activity concludes.

NOTES

WAVES: A COMPREHENSIVE VISUAL ASSESSMENT OF WATERSHED SEDIMENTATION PROCESSES

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The Watershed Assessment and Visualization of Erosion and Sedimentation (*WAVES*) Protocol was designed to elucidate perceptible watershed conditions and overall governing processes controlling watershed sedimentation in the field. The study of sedimentation in watersheds is particularly important because of the harmful impact sediments can have on aquatic life, algae, civil infrastructure, water supply, and water quality. Previous qualitative assessments of stream networks and watersheds, while abundant, have seldom focused on watershed sedimentation processes and sediment (dis)connectivity. Sediment (dis)connectivity, defined as the detachment and transport of sediment from source to sink between geomorphic zones, controls sediment transport rates but is rarely the focus of watershed field assessments. The quantification of watershed sedimentation has proven to be precarious over years due to what Walling (1983) has dubbed the sediment delivery problem; i.e. only a fraction of eroded sediment is yielded at the basin outlet. In order to quantify sedimentation, it is important to first gain field-based knowledge of the watershed's governing processes. The authors, therefore, formulated the *WAVES* Protocol to: (1) understand qualitatively the hydrological and sedimentological processes occurring within the watershed; (2) obtain field-based knowledge of the watershed's (dis)connectivity; and (3) to identify sediment sources, sinks, and pathways in the field through one comprehensive field assessment.

The *WAVES* Protocol was created via the review of sediment connectivity literature and various contemporary methods to visually assess streams. *WAVES* assesses five general parameters of the watershed and stream network in the field: (1) (dis)connectivity, (2) streambank and floodplain conditions, (3) streambed conditions, (4) upland land use, and (5) other miscellaneous qualities. These parameters were chosen based upon their suspected influence on sediment delivery at the watershed outlet as well as their suspected influence on sediment movement between various compartments within a catchment. The condition of each parameter is assessed *in situ* and rated via an index reflecting the quality of the compartment.

WAVES was applied to a bedrock-controlled catchment in the Bluegrass physiographic region of Kentucky. A stream initiation algorithm was used to delineate tributaries with catchment areas greater than approximately 0.5 square kilometers, an area iteratively chosen based on aerial indication of stream initiation. Each of these streams and tributaries were mapped in a GIS and then visited in the field. Information and geo-located photographs collected from the field were uploaded into a GIS database for further analysis. "Hotness/coolness" maps created from this data show prominent hydrologic and sedimentologic processes at numerous resolutions (i.e. hillslope-scale, reach-scale, and watershed-scale). These maps show spectrums of erosion, deposition, and (dis)connectivity severity throughout the catchment. Geomorphologic features and stream parameters (i.e. connectivity impedances, channel bathymetry, bed roughness, land cover/management, and outfall locations) were digitized via the database to be used as future model inputs. Coupling the "hotness/coolness" maps with the digitized geomorphologic features shows how sediment is connected or disconnected from one compartment of the catchment to another.

The presented protocol assesses the regional impacts of natural and anthropogenic sources of sediment that lead to problems such as water quality degradation and water supply loss. While focusing primarily on watershed sedimentation processes and sediment (dis)connectivity, *WAVES* has the capacity to elucidate nutrient connectivity as well through the identification of nutrient-source hotspots along the stream corridor. Locating and analyzing outfalls, livestock interference, agricultural land uses, and erosional scars through *WAVES* allows for the identification of these hotspots. The *WAVES* Protocol was initially created for a lowland, bedrock controlled stream system with a moderate-humid subtropical climate and limited karst. However, the protocol can be applied/altered to assess the effects of sediment in any region or watershed of small-moderate size.

FOOD AND WATER CONSUMPTION ANALYSIS IN HUNGARY

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In Hungary, water consumption and the purchase of water rights play an important role in the livelihood of many Hungarian citizens. With the increase of health-awareness and relative cost of the water, consumer behaviour patterns have changed over time. This study focused on two parts of this phenomenon which include water marketing and consumer behaviours with water consumption. The complete process from the G2B (government to business) to the B2C (business to consumer) market was analyzed.

The first aspect represents a difficult situation concerning the sale of water and rights to the water by the Hungarian government (G2B). The second reveals water consumption trends, which tell more about food and water consumer behaviours in Hungary (B2C). In addition, we also compared trends of water consumption and consumer behaviour patterns between Hungarians and Americans to determine selected commonalities and differences. Content analysis was used as a qualitative research method in our study. This was based on published resources as well as our own analysis of the behaviour patterns of a sample of the population in Hungary related to water and food consumption. We used previously collected data from the first author about Hungarian food consumers as well as data queried from IPSOS Ltd. In Hungary, the data were based on 883 people participating in the sample. Quantitative research techniques were used to target the group of food and water consumption habits in Hungary through survey research. The differences and connections of the groups created during the analyses were examined by multivariate statistical analysis and factor analysis.

Our subject will never lose its relevance, since water will be one of the important natural resources that cause many companies to strive to understand the behaviour of their consumers, but no matter how much knowledge we have, it will never be enough.

NOTES

FIELD VARIABILITY OF SOIL WATER CONTENT AND ORGANIC MATTER IN PEMACULTURE ECOSYSTEMS

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Soil quality evaluation has been postulated to be highly affected by spatial effects of individual indicators. Permaculture ecosystems consisting of varied native vegetation may create variability within the field and between fields. This study examined field variability of soil water properties and soil organic matter in young permaculture ecosystems of less than three years in western Kentucky. Soil samples were collected from eight field types, 1) Vineyard, 2) Vegetable Garden, 3) Blueberry, 4) Pasture, 5) Orchard, 6) Bare land, 7) Edible Bamboo and 8) Kiwi - Raspberry. Prior to establishing the permaculture, the land was in forest for about 30 years. The results show that the vegetable garden and the bare land areas have the highest soil water content at air dry condition (7.68% and 8.26, respectively) with high variability within the field (41% and 49%, respectively) as indicated by the highest coefficient of variation. The average of soil water content at air dry was 4% with the lowest found in the kiwi-raspberry field (1.58%). The highest soil organic matter content was found in the areas of kiwi-raspberry (8%) and blueberries (8.17%). The field variability for soil organic matter content (14%) is lower than soil water content at air dry (27%). The highest field variability of soil organic matter was observed in pasture and vegetable garden at 20-23%. There is high correlation between soil water content and soil organic matter content. The data from this study can be used to map the baseline of the ability of soil to supply water and to sequester carbon.

NOTES

EVALUATING SOIL WATER HOLDING CAPACITY AND OTHER PHYSICAL PROPERTIES OF SILT LOAM IN NATURAL AND AGRICULTURAL ECOSYSTEMS

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Land cultivation has been found to affect the ability of soil to hold water as well as other physical properties. The objective of this research was to evaluate the changes in soil water holding capacity (WHC) and selected physical soil quality indicators under two natural and two agricultural ecosystems. Soil properties of water holding capacity, macroporosity, bulk density, soil compaction, soil organic matter, and aggregate stability were chosen as they are sensitive to indicate soil quality changes. The study was conducted in silt loam soils collected from Lyons and Trigg County, Kentucky. Natural ecosystems included undisturbed grasslands and undisturbed deciduous woodlands while agricultural ecosystems included conventionally tilled soils and no-till soils. Agricultural soils were cultivated in a corn, soy, wheat, tobacco rotation. Subsoil compaction was measured with a penetrometer. Undisturbed soil cores were sampled from topsoil at 0 - 7.5 cm and 15 – 21 cm depth interval to measure WHC, bulk density, and macroporosity. The data was statistically analyzed using ANOVA single factor at α 5%. The results from the topsoil indicated that the range of WHC was 36.8 to 40.8% and macroporosity was 34.6% to 37.5%. The range of bulk density was 1.26 to 1.74 g/cm^3. Subsoil had WHC from 24.3 to 26.3%, macroporosity of 21 to 24% with the bulk density of 1.47 to 1.56 g/cm^3. Compaction measured by penetrometer was between 121 and 230 psi with the highest compaction detected in conventional tilled systems. The highest soil organic matter content and aggregate stability were observed in grassland areas. Overall, natural ecosystems showed higher variation across the fields compared to agricultural ecosystems. The findings revealed that bulk density and soil compaction are more sensitive indicators than water holding capacity and macro porosity; and that conventionally tilled soils suffer from significantly higher soil compaction.

NOTES

EFFECT OF HISTAG ON THE PRODUCTION OF WATER CHANNEL PROTEIN AQPZ

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Biomimetic membranes that are useful for the filtration and purification of water are highly desirable, due to the increase of world population and dwindling of natural resources. A popular protein used in the development of water filtration membranes is the *Escherichia coli* water channel, AqpZ. Several groups have used AqpZ in their membranes and tested the performance of the protein. A critical step for the broad application of AqpZ in biotechnical industry, and also a bottle neck, is high yield production of the protein with the subsequent integration of the protein into the supporting matrix.

In this project we investigated the effect of histag on the production yield of AqpZ. Histag is useful in protein purification, and also provides a potential approach for AqpZ immobilization/integration. We found that AqpZ cannot be expressed when a histag was connected right after the C-terminus of the protein, but tolerates the histag at the N-terminus well. To further investigate the effect of the histag on AqpZ production, we determined the effect of spacer length on the expression of AqpZ with C-terminal histag. The cytoplasmic domain of the C-terminal end of AqpZ protein is relatively short. We hypothesized that inserting histag at the C-terminal end interferes with protein folding and thus causes degradation of the protein. To test this hypothesis, we examined the effect of spacer length on protein expression and found clear correlation between the linker length and AqpZ expression level, which supports our hypothesis.

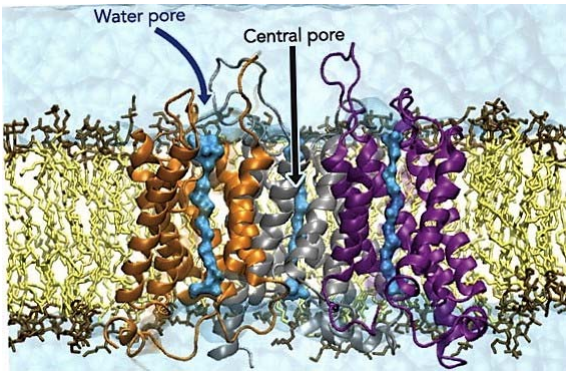

Figure 1. AqpZ is an integral membrane protein that acts as a water channel (Figure taken from Wang et al., 2010, Exploring Transmembrane Diffusion Pathways With Molecular Dynamics. Physiology 2010, 25, 142-154)

NOTES

SEGMENT BASED ASSESSMENT FOR WATER DISTRIBUTION SYSTEMS

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In water distribution systems (WDS), a common concern is the possibility of failure. With vast areas and a multitude of components, WDS are particularly susceptible to experiencing a failure state during their lifetime. Thus, estimating how well a network continues to fulfill its mission during various operating conditions becomes relevant in the effort to build better distribution systems. This ability to perform under multiple restricted conditions is frequently identified as reliability.

In recent years, water utilities have placed a greater emphasis on the reliability and resilience of their water distribution networks. This focus has increased due to the continuing aging of such infrastructure and the potential threat of natural or man-made disruptions. As a result, water utilities continue to look for ways to evaluate the resiliency of their systems with a goal of identifying critical elements that need to be reinforced or replaced.

In the past, it has been generally assumed that a pipe failure can be represented as the loss of one pipe. This assumes that each pipe has an isolation valve on both ends of the pipe that can be readily located and operated under emergency conditions. This is seldom the case. Generally the number of surrounding pipes that would be taken out of service in case of a pipe failure in addition to the initial pipe (i.e., “segment”) will depend on the location of the operable isolation valves.

A simple graphical metric is presented to evaluate the performance of a system in response to a pipe failure using three different performance metrics: percent loss of system demand, percent loss of acceptable pressures, and percent loss of adequate water age. Since each segment could affect the performance in different ways, the performance metrics provide a way to identify the most critical areas under a pipe failure and consider different aspects. This information could be used by system managers in deciding which segments to prioritize for upgrades or replacement.

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NUTRIENT EVENT MEAN CONCENTRATION AND EXPORT LOAD DATA COMPILATION

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This paper compiles nutrient (Total Nitrogen (TN) and Total Phosphorus (TP)) event mean concentration (EMC) and export load values released from urban and agricultural landuses. The data were pulled together from different nation-wide literature and studies that report nutrient EMC and export load values in the state of Kentucky. Then, different types of statistical plots were created for each urban and agricultural landuse, separately. In some cases, the EMC or export load values reported in the studies had a wide range of magnitude for a specific landuse. The sources of the difference in the pollutant loading values for each of the landuses could be due to the region and physical characteristics of watershed (e.g. slope and soil type), methods of measuring EMCs and loads, the number of samples taken from the watershed outlet and rainfall intensity. The resulting ranges of EMC and load values can be very beneficial for the users of water quality models who need to have a holistic idea of nutrient magnitudes released from each landuse at watershed outlets. The nutrient EMC and export load values are being used as an input for the Kentucky Nutrient Model (KYNM).

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