Water Resources Center

Annual Technical Report

FY 2000

Introduction

Delaware has more than 2,509 miles of rivers and streams, and 2,954 acres of lakes and ponds that have been classified using the federal Clean Water Act's rating system of designated uses (such as drinking water supply, swimming, fishing, etc.). Delaware has promulgated surface water quality standards which are designed to protect the designated uses of each classified water body in the State. While Delaware's rivers and streams generally meet the standards for their designated uses, the Department of Natural Resources and Environmental Control (DNREC) has found that 79% do not support the swimming use and 62% do not support the fish and wildlife uses. The major causes of non-attainment of designated uses of Delaware's water resources are high levels of pathogenic bacteria, nutrient over-enrichment, toxics, and degradation of physical stream habitat. The majority of the water quality standard violations are due to nonpoint source poution impacts. Bacteria concentrations above the level considered acceptable for primary conract recreation are found in 79% of Delaware's rivers and streams, 40% of ponds and lakes and 16% of estuarine waters (excluding the Delaware River and Bay). Safe shellfish harvesting and consumption is also adversely impacted by high bacteria levels in many of Delaware's estuarine and tidal waters. Nutrient over-enrichment of Delaware's water bodies is due to soil erosion, failing septic systems, and nutrient losses from land application of manure and fertilizer. Lowered dissolved oxygen levels and nuisance plant growth result from excess nutrients in Delaware's waterbodies. Toxics, such as Polychlorinated Biphenyls (PCB's), dioxin, chlorinated benzenes and pesticides persist in the environment and accumulate in the flesh of fish. Several rivers and streams in Delaware, as well as the Delaware Bay, have fish consumption advisories due to toxics. Finally, physical habitat of 87% of Delaware's nontidal perennial streams is degraded due to several factors including increases in impervious surfaces as a result of urban land uses in the Piedmont, and stream channelization to improve drainage on agricultural lands in the Coastal Plain. Physically degraded stream habitats generally have decreased shade, less channel stability, and a reduction in runoff filtering vegetation. Results of degradation of physical stream habitat include reduced aquatic life diversity and violations of water quality standards for dissolved oxygen and temperature.

Ground water in Delaware is impacted by nitrate contamination, particularly in the agricultural areas of Kent and Sussex counties. High nitrate levels in underground sources of drinking water are a potential health concern, as well as a source of nutrients to surface water. Synthetic organic compounds, such as cleaning solvents and degreasers have been detected in Delaware's gound water, primarily due to leaking underground strorage tanks, landfills, septic systems, chemical spills and leaks and abandoned hazardous waste sites. Elevated dissolved iron concentrations in well water and salt water intrusion are also ground water concerns for the State. The protection of the quality and quantity of the State's aquifers is a key concern, particularly given the fact that reliance on ground water for drinking water supplies has been increasing in Delaware. Priority areas for overall water quality and quantity research and implementation in Delaware include: enhanced management and control of stormwater runoff, erosion and sediment, a better understanding of the sources, transport, fate and remediation of toxics, comprehensive management of agricultural nutrients and sources of pathogenic bacteria, increased understanding of the response of aquatic systems to specific pollutants, identification and protection of key aquifer recharge areas, better managment of water supply and demand (including the financing of water supply infrastructures), treatment and disposal of on-site sewage, protection and restoration of wetlands and better understanding and prevention of saltwater intrusion to potable water supplies. Due to the development pressures in northern Delaware and the coastal resort areas, attention to these issues is essential to protect the State's water supply. Delaware Water Resources Center Program Goals and Priorities

The primary goal of the Delaware Water Resources Center is to support research that will provide solutions to the State's priority water problems. A secondary goal is to serve as a source of information to water researchers, decision makers, natural resource protection agency personnel and to the public through technology transfer projects. A third goal is to promote the training and education of future water scientists and engineers.

Research Program

Basic Information

Title:	Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
Project Number:	G-01
Start Date:	1/2/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Sediments
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Stefan Hunger, Stefan Hunger

Publication

1. Hunger, S. and D.L. Sparks, "Reactions of Phosphate at the Gibbsite-Water Interface: A Molecular Scale Study", Annual Meetings of the Soil Science Society of America, Minneapolis, MN, 2000, p. 222.

"Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation"

Dr. Donald L. Sparks and Stefan Hunger, University of Delaware

Final products that have been generated as a result of the research project: Hunger, S. and D.L. Sparks, "Reactions of Phosphate at the Gibbsite-Water Interface: A Molecular Scale Study", Annual Meetings of the Soil Science Society of America, Minneapolis, MN, 2000, p. 222.

Despite decades of research, the reactions of phosphorus that determine its mobility in the soil and related environments are not well understood on a molecular level. The availability of advanced molecular spectroscopic techniques makes it possible to study reactions of phosphorus in more depth and knowledge gained from such studies will help further efforts to minimize phosphorus loss from agricultural areas to the aquatic environment.

It is planned to study reactions of phosphorus on a macroscopic scale using batch and stirred flow systems and determine the dependence of phosphate sorption to soil minerals on reaction conditions such as pH, reaction time and presence of competing organic material. It is further projected to use Nuclear Magnetic Resonance spectroscopy (NMR) and X-ray absorption spectroscopy (XAS) to determine the speciation of the sorbed phosphorus.

It was possible to distinguish three to five different phosphate species at the surface of gibbsite, an aluminum hydroxide common in soils. Citric acid was used as a model for low molecular weight organic acids present in soils. It was found that citric acid slows down the sorption reaction of phosphate to gibbsite and reduces the amount of phosphate sorbed. It does however not significantly change the phosphate speciation at the gibbsite surface as could be shown by NMR spectroscopy.

The names and degree level (highest level during the reporting period) of all students who worked on the research project:

Stefan Hunger, PhD candidate

Basic Information

Title:	A Baseline Nutrient Export Budget for Sussex County, Delaware for Environmental Planning
Project Number:	G-02
Start Date:	1/2/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Lynette Ward, Lynette Ward

Publication

1. Ward, Lynette, March 2001, "A Baseline Nutrient Export Budget for Sussex County, Delaware for Environmental Planning", Center for Energy and Environmental Policy, University of Delaware, 34 pgs.

A Baseline Nutrient Export Budget for Sussex County, Delaware for Environmental Planning

PhD Student: Lynette Ward
Center for Energy and Environmental Policy,
University of Delaware
(abstract)

Research supervised by:
William F.Ritter, Bioresources Engineering Department
John Byrne, Center for Energy and Environmental Policy
Young-Doo Wang, Center for Energy and Environmental Policy

Nitrogen and phosphorus are considered the primary water pollutants in Sussex County Delaware's Inland Bays basin and the Nanticoke River and Broad Creek sub-basins. Excess nutrients lead to eutrophication and groundwater contamination. This paper is part of a larger research effort to evaluate the economic feasibility of methods to reduce the phosphorus content of poultry manure or to find beneficial uses other than direct land application. The purpose of this paper is to quantify present nitrogen and phosphorus transport to water bodies in Sussex County and their sources, based upon a literature review of relevant reports on nutrient production in the study area. The paper concluded that the flow rate method of calculating phosphorus loading results may have yielded more accurate estimates than the area loading method. The flow rate method requires stream flow and nutrient concentration monitoring data to correlate nutrient concentrations to flows. However, stream monitoring has not been done on enough Sussex County waterways to create a long term monitoring record of concentrations so that a correlation between given flows and nutrient concentrations could be established for the major tributaries. The area loading method may tend to over predict phosphorus loads as it does not fully account for natural phosphorus removal processes, however this method can be utilized without gathering further field data. The area loading method enables one to get a sense of the quantity of nutrients entering the waterways. With an annual estimated nitrogen load of 9,142,493 pounds and a phosphorus load of 388,674 pounds it is clear that significant load reductions are necessary. The estimated loads are supported by data on large nutrient surpluses in the county, as documented by both Martin (1998) and Sims (1999) nutrient mass balances, which evaluated available nutrients against crop requirements.

In addition to the nutrient budget, an evaluation and ranking of various options for poultry manure use, treatment and disposal is being conducted with the objectives of :

1. Reducing the nutrient inbalance in Sussex County
2. Reducing N and P loads to surface water and groundwater in the Inland Bays and Nanticoke watersheds

The following options for poultry manure are being evaluated:

1. Direct land application as a fertilizer.
2. Drying and pellitizing the manure and using it as a fertilizer outside the region.
3. Composting and using as a horticulture product.
4. Use as a feed for beef cattle
5. Biogas production and generation of electricity.
6. Adding the phytase enzyme to the feed to reduce the P content of manure.
7. Reduce P content of manure through use of low phytase corn in the feed.
8. Adding alum to the soil or litter to reduce P in the surface runoff.

The economics and nutrient reduction potential of each of these options are to be evaluated using an economic-engineering simulation approach.

A number of the options for poultry manure have been evaluated. More options for poultry manure management will be evaluated and a linear programming modeling effort applied to the options.

Basic Information

Title:	Land Use/Land Cover and Nutrient Discharges to Delaware’s Inland Bays
Project Number:	G-03
Start Date:	1/2/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	Water Quality, Nutrients, Non point Source pollution
Lead Institute:	Water Resources Center
Principal Investigators:	Jennifer Jennings

Publication

1. Jennings, Jennifer, "Land Use/Land Cover and Nutrient Discharges to Delaware’s Inland Bays" (a MS Power Point slide show generated for the Delaware Water Resources Center Student Research Conference, February 9, 2001)

Land Use/Land Cover and Nutrient Discharges to Delaware's Inland Bays.

Graduate Fellow: Jennifer A. Jennings, College of Marine Studies, University of Delaware
Faculty Advisors: Dr. William J. Ullman and Mr. Joseph R. Scudlark, both of the College of Marine Studies, University of Delaware

Final products that have been generated as a result of the research project: .

Land Use/Land Cover and Nutrient Discharges to Delaware's Inland Bays
(a MS Power Point slide show generated for the Delaware Water Resources Center Student Research Conference, February 9, 2001)
Anticipated MS thesis: Spring 2003.

Delaware's Inland Bays suffer from nutrient over-enrichment, due to agricultural, municipal, domestic and industrial practices, which affect the water quality and ecosystem health of the bays. This project explores the seasonal variations in nutrient fluxes, the effects of storm discharges, and the role of land use and land cover on these nutrient loadings. A more thorough understanding of these aspects will aid in the development of Total Maximum Daily Loads (TMDLs) for the nutrients in question.

Nutrient data from base flow samples are being collected and analyzed for seasonal variations in nutrient loadings at all 14 sampling locations. Nutrient fluxes due to storm discharges are also being examined in the storm samples collected from six of these same sites. With the use of geographic information systems, these nutrient concentrations and fluxes can be related to the land use and land cover of the sub-watersheds.

Nitrogen loadings, due to the high concentrations of dissolved nitrogen in the ground water, are driven by base flow. Storm events tend to dilute these concentrations. Phosphorus loadings, on the other hand, are driven by storm events because phosphate, which is often attached to soil particles, is flushed into the waterways with the resulting runoff. I have most recently been examining the role of land use and land cover on the differences found between atmospheric nitrogen deposition and base flow output at different locations within the Inland

Bays Watershed. Future work will concentrate on land use relationships.

Names and degree level (highest level during the reporting period) of all students who worked on the research project.

Jennifer A. Jennings, MS in Marine Studies student (matriculated 9/00).

Basic Information

Title:	Development of the University of Delaware Experimental Watershed Project
Project Number:	G-04
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Management and Planning
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Jennifer Campagnini

Publication

1. Campagnini, Jennifer and Gerald Kauffman, March 2001, "Development of the University of Delaware Experimental Watershed Project", 32 pages, Delaware Water Resources Center, University of DE, Newark, DE
2. Campagnini, Jennifer, and Gerald Kauffman, "Development of the University of Delaware Experimental Watershed Project" in Proceedings of the American Geophysical Union, Spring Conference, Boston, MA, June 1, 2001.

DEVELOPMENT OF THE UNIVERSITY OF DELAWARE EXPERIMENTAL WASTERSHED PROJECT

Jennifer L. Campagnini, Gerald Kauffman, Martha Corrozi, Justin Bower

ABSTRACT: In 2000, a team of University of Delaware undergraduate and graduate students developed the University of Delaware Experimental Watershed Project with a grant from the Delaware Water Resources Center. The University of Delaware (UD) is a land- and sea-grant institution in Newark, Delaware and is perched along the Atlantic seaboard's fall line. A critical mass of UD faculty and students in water resources and related disciplines are interested in the development of an experimental watershed on campus to provide (1) interdisciplinary undergraduate, graduate and faculty research opportunities, and (2) an outdoor education laboratory. Using GIS and field reconnaissance techniques, the three students delineated two small experimental watershed regions respectively located in the Piedmont and Coastal Plain provinces of the White Clay Creek Wild and Scenic River Valley on the UD campus. The Piedmont watershed drains 416 acres of the northern area of campus while the Coastal Plain watershed drains 896 acres including the central and southern sections of campus. The students then developed an ArcView GIS atlas integrating geology, soils, topography, land use, and impervious cover layers with a rating system for water quality and habitat characteristics to issue a "report-card" assessing each watershed's overall health. The White Clay Creek Wild and Scenic River Valley is an ideal on campus location for an outdoor education and research laboratory because of its manageable scale, the diversity of its characteristic land uses and physical environment, and above all its accessibility for students, faculty, researchers, and the public.

Basic Information

Title:	A Spatial Analysis of the Distributional Effects of Water Quantity Management
Project Number:	G-05
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Not Applicable
Focus Category:	Water Supply, Economics, Management and Planning
Descriptors:	Water Use Management and Conservation
Lead Institute:	None
Principal Investigators:	Robert Ehemann

Publication

1. Ehemann, Robert W., Joshua M. Duke, and John Mackenzie. 2001. The distributional effects of water quantity management: A spatial analysis. Under review at a professional journal.
2. Ehemann, Robert W., Joshua M. Duke, and John Mackenzie. 2001. A spatial analysis of the distributional effects of water quantity management. FREC Research Report RR 01-04, Department of Food and Resource Economics, University of Delaware, Newark, DE (37 pages)
3. Ehemann, Robert W. 2001. A spatial analysis of the distributional effects of water quantity management. Undergraduate Degree with Distinction Thesis, University of Delaware, Newark, DE (37 pages)

A Spatial Analysis of the Distributional Effects of Water Quantity Management

(abstract)

Robert W. Ehemann

Joshua M. Duke

John Mackenzie

This paper investigates the relationships among the spatial distribution of a region's residential population, water deficits, and the response of residential water demand to three institutional environments. Specifically, the distributional effects of water-scarcity pricing, water rationing, and mandatory water restrictions are compared using spatial data from New Castle County, Delaware. The application demonstrated that a 591 percent increase in the marginal price of water in times of deficit would achieve the same aggregate conservation goals as rationing and mandatory restrictions—a 25 percent reduction in consumption. The distributional effects of these policies are quite distinct. Rationing forced households with lower consumption to forgo essential uses, while households with high consumption were able to conserve at the nonessential margin. The mandatory restriction was more equitable in the treatment of low consumptive households, but provided a rather blunt incentive for efficient consumption among high consumptive households. Only pricing water above a threshold to reflect its scarcity allows consumers to decide efficiently how to conserve by eliminating the less-valued uses.

Basic Information

Title:	Biodiversity of the atrazine chlorohydrolase (atzA) gene in soil microbial communities as a function of triazine treatment history
Project Number:	G-06
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Not Applicable
Focus Category:	Water Quality, Toxic Substances, Treatment
Descriptors:	Microbial degradation of atrazine
Lead Institute:	Water Resources Center
Principal Investigators:	

Publication

Biodiversity of the atrazine chlorohydrolase (*atz*A) gene in soil microbial communities as a function of triazine treatment history

Melissa M. Weitz[1], E. Danielle Rhine[2], and Mark Radosevich[2]Department of Animal and Food Sciences[1], Department of Plant and Soil Sciences[2]

s-Triazines are the most widely used pesticides globally and are moderately persistent and mobile in soils. They are the most commonly detected pesticides in surface and ground water as well as in precipitation. s-Triazines are carcinogenic and believed to act as endocrine-disruptors. Due to their widespread use and frequent detection in the environment, there is ongoing concern regarding their impact on human and ecosystem health. The catabolic genes *atz*ABC and *trz*D in the degradative pathway of atrazine, a widely used chloro-s-triazine, are highly conserved (99 to 100% sequence identity for *atz*A) in all known atrazine-degrading bacteria (approximately six bacterial cultures). While *atz*A has been detected in soils with a high capacity to degrade atrazine it is not known if indigenous soil bacteria responsible for mediating atrazine biodegradation possess these genes or closely related homologs. The purpose of this study was to develop a PCR method based on primers derived from *atz*A of *Pseudomonas* ADP that could be used to monitor the frequency of *atz*A in agricultural soils with the long term goal of investigating the diversity of *atz*A PCR products with denaturing gradient gel electrophoresis (DGGE). Genomic DNA was extracted and purified from agricultural soil with a long-term atrazine exposure history and high capacity to degrade atrazine. A PCR method was developed that could amplify *atz*A homologs from soils but it suffered from a high detection limit based on experiments with *atz*A-amended soils. Our preliminary results suggest that the frequency of *atz*A in the soils we examined is low and atrazine degradation is mediate by an alternate pathway or by homologs of *atz*A that were not detectable by our PCR assay. However, optimization of the method to lower the detection limit must be made before further gene diversity studies can proceed.

Basic Information

Title:	Feasibility of Using a Fungal Bioreactor in Treating Industrial Wastewater
Project Number:	G-07
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Treatment, Toxic Substances, Waste Water
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Jason Hetrick

Publication

1. Hetrick, Jason and Anastasia E. M. Chirnside, March 2001, Feasibility of Using a Fungal Bioreactor in Treating Industrial Wastewater, Delaware Water Resources Center, Newark, DE 24 pages.

Feasibility of Using a Fungal Bioreactor in Treating Industrial Wastewater (an abstract)

Jason Hetrick, undergraduate intern
Anastasia E. M. Chirnside, faculty advisor

Phanerochaete chrysosporium, a species of the white rot fungus (WRF), has gained exposure in recent years due to its unique biodegradation capabilities. It is capable of degrading a variety of organic pollutants including chlorophenols, nitrotoluenes, and polycyclic aromatic hydrocarbons. The white rot fungi have an unique exracellular enzyme system which is used to degrade lignin, the structural polymer of wood. This system has been shown to mineralize a wide range of recalcitrant environmental compounds. WRF produces lignin peroxidases and other extracellular enzymes which have extensive biodegradation properties. The wastewater to be used came from a industrial factory in which soy flour is produced. It contains a high amount of Total Kjeldahl Nitrogen, on average about 300 PPM, and a high Chemical Oxygen Demand, about 4000 PPM. Traditionally these contaminants have been resistant to normal bacterial wastewater treatment schemes.

In this study, a white rot fungus, "Phanerochaete chrysosporium", was grown in a bioreactor and used to evaluate the effectiveness of treating the industrial soy processing plant's wastewater in order to reduce the TKN and the complex organic compounds. The specific objectives were:

1. To evaluate the hydrodynamic parameters of the laboratory scale bioreactor in order to define the hydraulic retention time (HRT) and bioreactor type
2. To evaluate the ability of Phanerochaete chrysosporium, (WRF) , using a fungal bioreactor, to degrade industrial wastewater containing high concentrations of Total Kjeldahl Nitrogen (TKN) and complex organic compounds.

_Methodology:

Experiment Biodegradation of wastewater

A laboratory scale bioreactor containing WRF was used. The reactor is an aerobic, attached growth, packed bed type. The reactor was packed with polyurethane foam cubes which act as a fixed support on which the fungus grows. The reactor is maintained at 37° C using a jacketed water column surrounding the column. The wastewater and oxygen is introduced at the bottom of the column and exits at the top. The effluent travels to a separate container where a portion is recycled back into the reactor. The hydrodynamic parameters were analyzed by introducing a tracer of Manganese Sulfate. The 1200 PPM $MnSO_4$ tracer was pumped through the reactor, with the effluent being sampled every 10 minutes for 10 hours

The WRF when not degrading wastewater was maintained on a feed/nitrogen
starvation cycle. Both solutions were buffered to a pH of 4.5 so that optimal fungus activity was achieved. When in nitrogen starvation the WRF produces ligninolytic enzymes which react with hydrogen peroxide to produce hydroxyl radicals through a series of oxidations, which degrades

the wastewater.
 Before the wastewater was introduced, the fungus was placed in nitrogen
starvation for a period of 5 days, so that the ligninolytic activity was
at a maximum.
Once the wastewater was introduced the effluent was sampled every day.
The samples were then tested for Total Kjeldahl Nitrogen, pH, and Chemical Oxygen Demand.

Experiment 1: Determination of HRT
A 1200 PPM solution of $MnSO_4$ was prepared and autoclaved. The solution
was then pumped through the reactor at a flow of .34 ml/min and a recycle flow of .78 ml/min. Every ten minutes a sample was taken from the bioreactor.
The samples were then analyzed for the concentration of $MnSO_4$. The concentrations over time was divided by the original concentration and then plotted versus time. A 6th order polynomial was then fitted to this plot.
The derivative of the polynomial was taken, then using the following equation, the HRT was determined.
The HRT of the bioreactor is 8.71 hours.

Experiment 2:
A residence time of 8.71 hours, determined by the tracer test, was used.
A feed flow of .34 ml/min and recycle flow of .78 ml/min was used.
The fungus was placed on a starvation solution for a period of 5 day prior to the introduction of the wastewater.
A full strength solution of wastewater was introduced into the reactor, at a pH of 9.84
At 8.7 hours at the HRT, the first sample was taken, and from that time a 25 ml sample was taken at roughly 12:00 PM every day for a period of 11 days.
Total Kjeldahl Nitrogen, Chemical Oxygen Demand and pH was analyzed on all samples
On Day 11 the fungus was placed back on the nutrient solution.

Results and Discussion:

__The first several days the WRF seemed to readily degrade the wastewater. The TKN had decreased to under half the original value. By day 3 the TKN of the effluent started to increase until day 7 in which the TKN of the effluent was equal to the influent. The COD behaved like the TKN in degradation.
As the pH increased, the degradation of COD and TKN decreased, supporting that enzyme activity is optimal at a pH of 4.
The color of the wastewater was unchanged by the WRF.
The WRF did not seem to be affected by the wastewater, following the experiment, and being placed back on the nutrient solution, the WRF returned to its previous state.

Future Work:

To achieve a more suitable pH for the fungus, the wastewater will be buffered with the Sodium Acetate, the nitrogen starvation solution. Different HRT times will be evaluated.

Basic Information

Title:	Attitudes of Consumers Towards Bottled Water
Project Number:	G-08
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Social Sciences
Focus Category:	Water Use, Economics, Management and Planning
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Emily Gonce

Publication

1. Gonce, Emily, James L. Morrison, Ed.D. and Hye-Shin Kim, March 2001, Attitudes of Consumers Towards Bottled Water, Delaware Water Resources Center, Newark, DE

Attitudes of Consumers Towards Bottled Water
(a summary of full report)

Emily Gonce, Undergraduate Student Intern, Department of Consumer Studies

Dr. James L. Morrison, Ed.D., Professor, Department of Consumer Studies

Dr. Hye-Shin Kim, Ph.D., Assistant Professor, Department of Consumer Studies

Reason for this research

The reason for this research is to investigate the influence that environmental factors, such as the weather and water related diseases, and consumer lifestyle factors, such as health, fitness, and occupation, have on water quality needs. By combining water quality needs with the cost and availability of bottled water, in consideration of environmental influences, one can predict bottled water consumption. Using the Water Perceptions Indicator, one will be able to predict bottled water consumption.

Objectives

1. To investigate the influence that environmental factors and consumer lifestyles have on water quality needs, combined with cost and availability, so that one can predict bottled water consumption patterns.
2. To learn how the Water Perceptions Indicator can predict bottled water consumption patterns.

Methodology

Data were collected using a survey methodology. The research instrument is composed of questions addressing the following factors related to bottled water consumption: environmental (weather related and waterborne disease outbreak related), water quality needs (functional and aesthetic), consumer lifestyle (convenience, availability, heath and fitness), and cost and availability. Survey participants also answered demographic questions.

The instrument consists of 66 items. Items were presented on a 5-point Likert-type scale or were open- ended questions. The instrument was reviewed by experts in water quality and consumer research, and was approved by the CHEP Human Subjects Review Committee before distribution. Approximately 300 students attending a Mid Atlantic university were asked to participate in the study.

Data were analyzed using SPSS 10.0 software. Factor analysis was used to determine the unique dimensions that measure the Water Perceptions Indicator. Cronbach's alpha was used to measure the reliability of the combination of items for each dimension. Multiple items measuring each dimension were summed to create indicies. Summated multiple item indicies were then analyzed using multivariate analysis to create the basis for a Water Perceptions Indicator. Frequency tables, histograms, and cross tabulations were developed. Factorial analysis, analysis of variance, logistical regression and regression analysis will be used to evaluate relationships between various factors.

Results and Discussion

Results of the research focus on water consumption patterns and attitudes towards bottled water. As explained in the data analysis, consumer attitudes toward bottled water are based on items included in three attitudinal dimensions: lifestyles, purchase decision-making, and risk aversion/health. Interpretation of results are based on significant relationships found in the correlation table.

Lifestyle factors and water consumption

Bottled water consumers integrate bottled water drinking in their every day routines in comparison to tap water drinkers and filtered water drinkers. For example, significant relationships are found between bottled water drinking and bottled water behavior in automobiles, preference for bottled water compared to other types of beverages, and preference of bottled water in restaurants. On the other hand, tap water and filtered water drinkers express less inclination to prefer bottled water compared to other types of beverages and fewer tendencies to order bottled water in restaurants. Tap water drinkers generally feel that drinking bottled water is a fad whereas bottled water drinkers do not. For all three types of water consumption, image has no relationship to bottled water usage.

Purchase decision- making

It may be concluded that tap water drinkers are sensitive to the price cost of bottled water. On the other hand, tap water drinkers purchasing of bottled water are influenced by availability as well as purchasing behavior of friends and family. Interestingly, bottled water behavior is not influenced by media and advertising.

Risk aversion and health

Bottled water drinkers indicate that bottled water is safe and less harmful than tap water. Bottled water drinkers consume bottled water because of its tendency to be safe and void of contaminants. On the other hand, tap water drinkers have a significant tendency to be less alarmed about health and safety of tap water. Results show no indication of water consumption behavior and its' relationship to one's trust in water quality data provided by local and state governments or the reliance on some media and friends for information on water quality issues.

Implications

This study lays the ground work for developing a Water Perceptions Indicator (WPI) using three dimensions (lifestyle, purchase decision-making, and risk aversion/ health) derived from the data. The indicator, once fully developed, can be used as a marketing tool for bottled water companies. They will know who their customers are, thus be able to target them and increase profits.

An important find in the research is the importance of availability and value-oriented strategy for bottled water marketers. Bottled water companies and government agencies such as the Food and Drug Administration and the Environmental Protection Agency could join forces to improve perceptions of bottled water quality and safety. Knowing that bottled water is regulated by a government agency could change the attitudes of bottled water speculators. In regard to availability, it would be best for marketers to flood the markets with their particular brand to increase sales. Availability has more of an influence in the purchase process than brand name or cost. Advertising is not an effective strategy for increasing sales.

Lifestyle may be a factor that discriminates bottled water users from tap water users. Bottled water is not integrated into the lifestyles of tap water users. There is a "drinking water divide" between the two water types.

Basic Information

Title:	Functional Assessment of Wetlands Using a Hydrogeomorphic Model
Project Number:	G-09
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Ground-water Flow and Transport
Focus Category:	Wetlands, Hydrology, Models
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Maeve Desmond

Publication

1. Desmond, Maeve and Bruce Vasilas, March 2001, Functional Assessment of Wetlands Using a Hydrogeomorphic Model, Delaware Water Resources Center, University of DE, Newark, DE

Functional Assessment of Wetlands Using a Hydrogeomorphic Model

(excerpts from full report)

Intern: Maeve Desmond

Advisor: Dr. Bruce Vasilas, Department of Plant and Soil Sciences

Background/Justification

The Hydrogeomorphic (HGM) Method for wetland functional analysis relies on rapid assessment techniques to collect data that can be used in a model that establishes how that wetland functions in comparison to reference standards developed using data collected from wetlands in the same wetland HGM class. The HGM class is based on the wetlands hydrogeomorphic setting. In the Mid-Atlantic Piedmont a model will be developed for wetlands in the slope class. Slope wetlands are wetlands that get their hydrology through ground water discharge.

Hydrogeomorphic refers to: (1)geomorphic setting--position in the landscape, (2)hydrology--water source, and (3) hydrodynamics--flow and fluctuation of water once in the wetland. The hydrogeomorphic(HGM) method refers to the observation and analysis of a wetland in its natural state of functioning. The HGM method involves collecting data from known wetlands, allowing the information produced to be referenced as standard wetland processes.

Reference wetlands are the places for data collection and initial analysis. They are selected because they have a range of characteristics for a specific kind of wetland. Reference wetlands are valuable because they are used to develop HGM models for specific wetland types. These models are used in jurisdictional cases involving questions of wetland identification and delineation. The models are also important for wetland restoration and construction projects. The information produced from the reference wetland serves as a guide and as an objective resource for these projects.

Objectives

In this project two subclasses of slope wetlands are being developed as HGM models using reference wetlands: (1) slope discharge seeps which discharge water most of the year and (2) slope discharge seeps found at the toeslope of floodplains and discharge water seasonally. The long term data collected from the reference sites will be used to develop these models.

Materials and Methods

Woody Debris and Leaf Litter

Analysis of woody debris and leaf litter involves data collection in the field. For each site the occurrence of woody debris is recorded along each transect and size of each twig is noted(fine >12cm; medium 12-40cm; coarse <40cm). Leaf litter for the plot is recorded in terms of percent cover and depth. This occurs along the transect as well, in 3m radius plots which have previously been selected. In these collections of data I also noted the presence of vertebrates and invertebrates.

Full Soil Characterization

This is an intensive study of soil in a particular site and it was done for several of the reference wetlands. Full soil characterization involves analysis of soil in an 6' soil pit and examines soil texture, bulk density, water retention, cation exchange capacity, extractable bases, base saturation, organic carbon, mineralogy, and pH.

Microtopography

For every site, topography has been measured along each transect. The differences in elevations for points along the transects have been noted and analyzed. These differences make up the micotopography and are significant for wetland sites because greater variation in microtopography means greater potential for such sites to hold water.

Hydrology

Hydrology of a site refers to the presence, source, and energy of water in a wetland. It involves how the water moves once within a wetland and why this is so. Monitoring wells are used to measure the hydrology of wetlands throughout the year. The reference wetlands used in this project have three monitoring wells per site, each measuring a different depth(20", 40", 80"). The information derived from these wells tells us the depth of the water table throughout the year in additon to flow rate and direction..

Plant Community Assessment

For wetland criteria to be met, the plant community in a wetland must be considered hydrophytic. To make this determination it is necessary to select a center point and flag a 30' radius. First, we make an estimate for absolute coverage of vegetation for each of the three strata (trees, saplings, herbaceous). Next, we identify all plant species for each stratum. For a stratum, we list the dominant species in descending order, selecting those species with relative coverage of greater than 5% of their strata. The true dominant species of a stratum are those whose relative coverages for that stratum add up to greater than 50%. Finally, we consult the *National List of Plant Species that Occur in Wetlands* and determine the rating of each species. If greater than 50% of the dominant species are facultative or wetter, the community is hydrophytic.

Results and Discussion

Graphs were developed to depict hydrology, or water table fluctuations, of Park Office and Possum Hill, respectively. These results were derived from electronic monitoring wells at each site. After a weather event, such as hurricane Floyd, the Park Office site is much more likely to hold water for extended periods of time because of its low position in the landscape and high water table. Park Office also receives water from three seeps in addition to overland flow.

Plant community assessments for these sites conclude that each site supports a hydrophytic (“water loving”) plant community.

Analysis of full soil characterization and coarse woody debris at the sites are ongoing at this time.

Conclusion and Implications

This study of wetland functions is significant because the long term data is quite valuable. The data will be compiled into a model which will be used for wetland functional assessments. In terms of wetland conservation this is an important step because the model is a tool to rapidly gauge the value of particular wetlands and save them from development and unnatural disturbances.

Basic Information

Title:	The Feasibility of Composting Poultry Litter and Food Residuals
Project Number:	G-10
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Nutrients, Water Quality, Agriculture
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Leigh Johnson

Publication

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The Feasibility of Composting Poultry Litter and Food Residuals

(an excerpt from full report)

Advisor: Dr. William F. Ritter, Bioresources Engineering, University of Delaware

Student: Leigh K. Johnson

Background

Agriculture is an essential industry to the state of Delaware. This industry is costly for both the state's land and waters. Replenishing soils of nutrients lost to growing plants is a large part of this problem. Monoculture agriculture, as practiced widely in the state is nearly impossible for the soil to maintain a good nutrient status. In nature nothing is monoculture and at the same time nothing is wasted (Howard 3-4).

Often chemical fertilizers or fresh poultry manures are used to replenish nutrients to the soil. Both of these methods have potentially harmful consequences. Run-off occurs when the rate of water infiltration into a soil is less than the amount of precipitation or irrigation (Epstein 360). This is often the case when fertilizers and manures are being applied to soils. Chemical fertilizers cannot maintain soil quality because it does not contribute to physical qualities such as porosity and water-holding capacity (Howard 18). Direct application of poultry manure is problematic due to the high pH of the manure, and high volatilization of nitrogen in the form on ammonia (NRAES 15). Fresh organic matter incorporated into soil also lowers the oxygen content of the soil, causing the plant to compete with the microbes for oxygen (Epstein 108).

In 1931, Sir Albert Howard, a British agronomist now known as the father of the modern era of composting, described a method he called the "Indore method" for maintaining soil fertility by the manufacture of humus from vegetable and animal wastes (Howard, ix). It was a process involving the piling of plant and animal wastes in pits or heaps to promote microbial degradation of organic matter. The piles would be turned once over the course of several months and then used as a soil amendment (Howard 39-51). Howard referred to the material "humus" as"soil cement" that leads to "better health of crops and livestock" (24, 166). He emphasized the importance of the balance of nutrients within the agricultural system, and emphasized the maintenance of soil physical quality in order to improve crop yield (39).

Knowledge of the details of the composting process has grown significantly since the time Howard did his research, but the same principles are still applicable. Basically it can be examined as a stepwise reduction of complex substances to simpler compounds (Epstein 22). Most definitions of the process require that thermophillic temperatures are reached, pathogens are eliminated, plant seeds are deactivated, and nutrients are mineralized (Haug 1, Zucconi & de Bertoldi, 2.1).

Often the finished composting product is mistaken for the humus that Howard discussed. Humus is a semi-finite decompositional state and a result of the long-term decomposition of organic matter in soil (Epstein 22, 102). Although Howard recognized the importance of humus to soil quality, we now know that it returns nutrients to the soil, increases the cation exchange capacity of the soil (the availability of nutrients to the plants) and enhances microbial populations within the soil (Epstein 101-2). Stabilized compost product and humus are sometimes referred to collectively as "humic substances," yellow to black-colored high molecular weight organic based substances comprised mainly of humic acid, fulvic acid and humin (Sparks 57, Epstein 101). These are part of the broader category of "soil organic matter." Because of the functional groups and chemically bonding properties associated with soil organic mater, it is the part of the soil responsible for nutrient retention, porosity and thus aeration, containment of metals and organic contaminants, and water retention (Sparks 53).

Objectives

The objective of these experiments is to determine the efficacy of composting a mixture of food residuals and poultry litter to produce an acceptable soil amendment. The food residuals will be diverted from the municipal solid waste stream and ultimately the landfill. This helps to decrease leaching of acids and organic contaminants from the landfill. The poultry litter will be diverted from direct soil application. This prevents increased nutrient loss due to volatilization and run-off to surface waters due to insufficient infiltration.

The ultimate objective of this project would be to combine poultry litter with municipal solid waste organics to produce a composted product for mainly agricultural, but also other applications.

The application of stabilized composted product as a soil amendment has several direct implications. Compost decreases erosion when compared to application of chemical fertilizers because of the colloidal-particles formed with the soil. The larger-sized particles not only keep water from carrying particles away, but also help to hold the water in the soil (Epstein 360). Stabilized compost also serves to increase nutrient availability to plants and increase aeration to plant roots because of increase porosity.

Methodology

The study was divided into three experiments. The first experiment was small-scale and used an in-vessel composting method. A variety of mixes of food residuals and litter were studied. The degradation seen in this experiment was used to determine the mixes to be studied in the subsequent experiments. The piles were held in ten-gallon containers. The piles were monitored for temperature and odor, and turned weekly. They were then tested based on criteria that will be discussed later.

The second experiment used the windrow composting method. The Windrow method is the most popular composting method because it is adaptable to a variety of raw materials (Haug 42). It is a non-reactor system consisting of rows that are turned periodically (Haug 31). The windrow method takes advantage of three aeration processes; physical turning of the piles, convective air flow, and mechanical aeration (Epstein 22). Two 400-gallon piles were formed at ratios of 1:1 and 2:1 food residuals to poultry litter. The piles were formed over the course of two weeks. Layers of food residuals and litter were alternately stacked. Although Windrow piles usually add raw material to the end of rows, this method was found to be more effective in terms of space and of mixing ingredients. The piles were then monitored for temperature and odor, and turned weekly.

The third experiment used an aerated in-vessel method. Some studies have shown that closed systems shorten the mesophillic and thermophillic stages resulting in higher process efficiency and a lower number of pathogenic organisms (Viel, Sayag, & Andre 231). Two trials of 1:1 and 2:1 ratios of food residuals to poultry litter were composted with this method. The system used to compost consisted of a five-gallon bucket with a hole drilled into the top. An aquarium pump was used to aerate the vessel by way of a tube going into the bucket. The pump was left running 24 hours a day for the duration of the experiment. The piles were monitored for odor.

For all the experiments, food residuals were collected from a dining hall on campus. Poultry litter was taken from piles stored on the campus farm. Newspapers used in experiment one were collected from the discards of area businesses and from residential waste.

The goal of successful composting is to achieve a high rate of microbial degradation. Because degradation is difficult to quantify directly, measurements are made both during the composting process and after to determine the efficacy of the process. Potential rate limitations of the composting process include moisture, aeration, nutrient levels, and pH (Haug 205). The composting product was also tested for such qualities as cation exchange capacity, soluble salt concentration, and organic content. These factors determine its quality as a soil amendment.

Temperature measurements are highly important in the composting process because heat is a product of microbial respiration, a function of both aeration and moisture (Epstein 20). A rise in temperature measurement of the compost signals acceleration in the growth rate of microorganisms (Epstein 56). If the temperature of a compost pile fails to rise significantly, the cause is likely that of either low moisture or inadequate aeration. There is much debate over the optimum temperature of compost piles, but it is generally accepted to be between 135^0F and 145^0F. Microbes in this temperature range degrade easily degradable organics and eliminate pathogens (Epstein 21). The debate over the minimum period of time of elevated temperatures in order for definite deactivation of human, animal, and plant pathogens and seeds is mainly determined by the end use of the composting product (Haug 161). Temperature measurements were made regularly for experiments one and two.

The next important characteristic of the compost pile is the carbon to nitrogen ratio. Because these nutrients form the basis of all plant and animal cells it is important to take into consideration their role in the composting process together (Epstein 113). Carbon is the basis for cellular growth while nitrogen is needed for protein synthesis. An ideal carbon to nitrogen ratio (C:N) for raw materials is between twenty-five and thirty (Haug 248-9). If more nitrogen is present ammonia will volatilize before degradation. If less nitrogen is present, composting rate and cellular growth will slow (Epstein 43). Although the C:N of humus is around ten, a stable compost should reach a C:N of about twenty (Epstein 113). Total C:N was evaluated at the start and end of each experiment.

Although the organic carbon: organic nitrogen is a more direct measurement of the desired characteristics, an equivalent value of the total amounts of these nutrients is reflective of the same quality (Epstein 114). Because both food residuals and poultry litter are highly nitrogenous materials, newspaper was added to the mixtures in experiment one. Yard waste and straw were also considered as possible high-carbon amendments, but newspaper was easier to obtain in the desired quantity. The amendments were determined to be unnecessary for experiments two and three.

A proper balance of water is essential to microbial growth. Water is used in biological oxidation of organic matter and also lost through evaporation, particularly at increased temperatures (Epstein 32). At a moisture level below 40% microbial activity cease, but at above 60% water fills the pore spaces leaving the system to become anaerobic (Epstein 34). The moisture was measured directly at both the start and end of the experiments. During the course of the experiments, moisture was determined by sight and indirectly by temperature and scent. The Northeast Regional Agricultural Engineering Service suggests that the compost should be wet to the touch, but not so wet that water can be squeezed out of a handful (9). If temperatures are very high, then moisture evaporates at a higher rate. If sulfur-like odors start to develop, the compost has most likely gone anoxic. This is a result of moisture levels that are too high. Anaerobic microorganisms produce hydrogen sulfide, an odorous compound. Water was added on an as-needed basis to all the piles. In experiment one, the piles comprised of mainly litter received more water initially because of their peanut-shell basis. Food residuals had much higher water content. The piles with mainly food residuals needed to be drained at first because of the high moisture content. In experiments two and three, moisture initially was much less of an issue because the raw materials were more balanced. Water was added when either pile temperatures decreased over a couple days, or the piles were not wet to the touch when turned. Moisture is also an important factor in the storage and handling of the composted product. If below 35% moisture, the product is dry and dusty, but above 50%, it tends to be wet and clumpy (Epstein 385).

Aeration serves several purposes in the composting process. Microbial resiration requires oxygen. Drying of wet substrates within the compost is accomplished through air movement. Excess heat generated by microbial respiration is removed by the airflow (Hug 261). Aeration can be indirectly measured by odor and temperature. A sulfur-odor-like pile can indicate anaerobic conditions, as can low temperatures.

The pH of the composting system effects microbial degradation greatly. Under both highly acidic and highly basic conditions, the majority of microorganisms begin to die. This is because of the change in ionization state of various protein components. When the physical structure of the protein changes, there is a loss in enzyme activity, inhibiting the microbes' ability to degrade the material (Haug 253). Although pH can range from about 4 to 10, the ideal pH is around 6.5. Normally there is a drop in pH initially due to the formation of organic acids, but it rises again as the composting process continues. Usually this is a function of the gradual temperature decrease at the end of the active composting phase (Epstein 48).

Other tests were run on the final composted product. These measurements are used to determine the quality of the finished product as a soil amendment or potting media. One of the most important parameters measured is the total exchangeable cation capacity. It is a measure of the particle's ability to sorb or retain cations on its surface

(Epstein 116). Many cations are important to plant growth and the exchange capacity provides for retention of those nutrients so that they will be available o the plants (Epstein 363). The cation exchange capacity of compost is higher than that of soils and clays because of the large amount of organic matter. Using compost with a high CEC as a soil amendment will make nutrients more available to plants.

Another parameter used in the analysis of finished compost is that of available carbon. The Walkley-Black method of organic matter determination was used for all finished compost. The measure of available organic carbon is a more direct measurement of the compost's quality as a soil amendment than the measure of total carbon (Epstein 107). Soluble salt concentrations for the finished composts were determined. If salt concentration is too high, the compost may be phyto-toxic (Epstein 390). Metal and other element concentrations were also measured for manganese, zinc, copper, iron, magnesium, calcium, potassium, and phosphorus. The EPA has set standards for maximum metal concentrations in soils. Although all composting operations much meet the standards, they are most important when composting municipal solids wastes and dehydrated sludges.

In some areas, pathogen testing is required if time-temperature requirements for pathogen removal are not met (Epstein 214). The state of Delaware has no regulations specific to composted products. The EPA has set guidelines based on compost raw material and final product use. They generally apply to sewage sludge and domestic solid waste where pathogen sources include discarded diapers and domestic animal waste (Haug 162, Epstein 219).

Maturity and stability of compost are indicators of complete degradation of organic matter. Because of the short term of these experiments, the compost was not allowed to cure completely and these parameters were not determined. Stability is the stage in decomposition of organic matter where there is no detectable change over a short period of time. Here, biological activity has slowed dramatically. Maturity indicates a lack of phyto-toxic organic acids present in the finished compost (Epstein 109). An indicator of stability would be lack of carbon dioxide evolution. This signals an end of microbial respiration (Epstein 20). An indicator of maturity is the lack on ammonia in a cured pile. All the nitrogen is in the nitrate-nitrite form (Epstein 115). Maturity and stability are required before compost is to be applied to soil or used as a potting media to ensure that the microbes cannot compete with plants for nutrients and oxygen. This state requires time, sometimes between three and nine months, depending on the success of the active composting stage.

Regulations for compost products are highly regional. Many regulations that are in place a based on a “no-net” increase philosophy that background concentrations of metals and contaminants don’t increase (Epstein 480).

Accuracy of Analyses

Due to the high level of heterogeneity associated with composting, the analytical accuracy of the measurements is sometimes questionable. Because many tests only need a small amount of sample, a representative sample may not be completely attainable. This can be seen particularly in the comparing the metals concentrations between the initial and final data in experiments two and three. Metals such as zinc, copper, and iron theoretically shouldn't change concentration dramatically between the start and finish of the active composting phase.

Before sending the composting samples to the laboratory to be tested, they were dried in the hood. This sometimes took several days. Then the samples were mixed in a blender and put in bags and stored in the freezer.

Discussion

Curing

A major problem in all the experiments was the lack of a curing phase. Curing is the phase when a lower level of biological activity occurs. In the earlier, thermophillic, phase, organics such as carbohydrates, sugars, proteins and fats were decomposed. In the curing phase, more complex organic compounds such as hemicellulose, cellulose, and lignin are degraded (Epstein 79-80). This stage is very important, specifically if the compost will be directly in contact with plants. Unstable compost or fresh organic matter incorporated into soil lower the oxygen content of the soil. The microbes fight with the plants for air.

Curing also allows for complete nitrogen conversion. The ammonia in the raw materials is converted mostly to the organic form by the microbes, while some is left as nitrate. The nitrate concentration in the finished product must be monitored to ensure that the right amount is applied to land. If excess nitrate is applied, it is likely to leech into groundwater or runoff into surface waters (Epstein 367).

Odor Management

Another problem with the experiment, particularly experiments one and three is that of odor management. In both these experiments, much of the odor produced was due to anaerobic conditions that developed within the piles. The high moisture content of several of the piles led to water-logger pore spaces, allowing for the development of anaerobic microorganisms. Turning these piles more often could have alleviated this. Adding more carbon substrate to the ammonia-emitting piles would have helped to lessen the emission of nitrogen. The microbes were carbon-limited and couldn't degrade as much nitrogen as a result. Larger piles would have helped hold in odors. Most of the odors were emitted at the surface of the compost piles. Although, odors would still be let off when piles were turned, they would more effectively dissipate. There could be more control over the release of odors, such as time of day or day of week the piles were turned.

All composting operations will have odor management problems to deal with at some point because all living systems excrete odorous molecules on a nearly continual basis. Even if a raw composting material is non odorous, such as yard trimmings, the biochemical metabolic pathways are inevitably so (Haug 546). Many strategies, both low and high technology, have been designed to deal with odor problems.

A general class of odor management techniques is that of absorption. This is where one or more soluble components of a gas mixture are dissolved into a scrubbing liquid or solution followed by chemical reactions with other compounds in the liquid phase (Haug 569). Examples of absorption devices are misting towers, packed bed scrubbers, and condensation/cooling towers (Haug 570-7).

Another process is adsorption. This refers to contacting the odorous gas with a particulate phase, chosen to selectively take up and store odorous species. An example of adsorption is activated carbon complex (Haug 579).

A more high technology odor management process is that of thermal oxidation. The odorous gas is oxidized at very high temperatures, around 800^0C, for less than a second (Haug 582).

At the opposite end of the technological scale is the odor management practice of masking or neutralization. This is the process of overpowering and unpleasant odor with another (Haug 594). A composting facility in Sacramento, California successfully overcame public criticism of odors by setting up a misting system around the perimeter of the facility that sprayed fine droplets of neutralizing agents (Feinbaum 46-9). Although normally only successful at odor reduction on the short term, when combined with sound compost management practices, neutralization is a viable short-term odor solution.

Applications of Compost

As well as serving as a soil amendment, stable finished compost product has many other applications. Compost may be used in residential, horticulture, bioremediation, biofiltration, and land reclamation markets.

Stabilized compost serves two purposes when as a soil amendment: structure and energy (Haug 25). The compost reduces the bulk weight of the soil, thereby increasing the porosity. This allows for improved aeration within the soil. The organic matter binds with soil particles to promote better root growth and allow for more efficient utilization of water and nutrients (Epstein 347). The compost also increases the organic content of the soil, increasing the energy available for the growth of new plants.

Many composting operations bag finished compost for sale on a small-scale. Regulations are set by state as to the quality of sold composts. Delaware currently has no laws regulating compost quality.

High-quality compost, as defined previously by several parameters, could also be sold to greenhouses and nurseries for use in horticulture (Epstein 389). Compost can be an acceptable substitute for peat moss. The sod and turf grass production industries are another potential compost markets because every layer of product produced removes an entire layer of topsoil (Epstein 398).

The bacteria, fungi, and other microorganisms growing in compost have been found to degrade persistent xenobiotic organic compounds (Epstein 171). Composts have aided in in-situ remediation of pesticide-contaminated soils (Epstein 181). Biofiltration of liquid-phase contaminants in storm waters has been accomplished using stabilized composts (Epstein 383).

Large-Scale Application of Poultry Litter and Food Residuals Composting

The goal of this study was to determine the efficacy of composting mixtures of poultry litter and food residuals. Ultimately, this would be applied on a large-scale and include all organics from the municipal solid waste stream. These objectives are highly reasonable and have been implemented in several areas of the United States and Canada employing different composting techniques with various levels of technology.

A community in Nova Scotia combines residential and institutional food residuals and yard trimmings with livestock manure using the windrow composting method (Cline 34-5). The community saves money it would have spent on tipping fees to landfills.

A high-technology municipal solid waste composting facility in Edmonton, Alberta has achieved more than 50% landfill diversion. Organics are rolled in mixing drums for 24 hours after reaching the site and then mixed with dewatered biosolids, screened to remove large particles, and then aerated for 28 days (Goldstein 26-9).

The majority of the large-scale composting operations the United States are commercial or institutional related (Goldstein, Block, Oshins 48-53). There are several reasons for the lack of widespread agricultural and municipal solid waste composting. The first is the cost associated with transporting the raw materials and finished products. Another problem is the high variability of raw materials associated with this type of composting. This applies to seasonal fluctuations in quantity of raw materials and also fluctuations in material characteristics. Another obstacle associated with large-scale composting is the variation of regulations among the states.

Delaware would benefit from the addition of a municipal solid waste composting facility. A good odor management plan would need to be designed. The strong agricultural and commercial presences in the state produce plenty of raw materials. Also, Delaware's size is one of its advantages because there would be fewer issues associated with transportation.

Conclusion

Based on the experiments performed in this project, mixtures of poultry manure and food residuals make an acceptable raw material for large-scale composting. Stabilized compost makes an acceptable soil amendment for use in agriculture and could potentially be used in other industries.

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Basic Information

Title:	Ectomycorrhizal Mantles as Indicators of Historic Hydric Soils
Project Number:	G-11
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Wetlands, Hydrology, Groundwater
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Anna Palermo

Publication

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Ectomycorrhizal Mantles as Indicators of Historic Hydric Soils

(abstract)
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Wetlands are protected by Section 404 of the Clean Water Act. The U.S. Army Corps of Engineers developed a Wetland Delineation Manual to provide technical guidelines and methods for the identification and delineation of wetlands. The manual endorses a three criteria approach for wetland determinations: the presence of a hydrophytic plant community, hydric soil and wetland hydrology. For the majority of fresh water wetlands on the DelMarVa Coastal Plain, wetland hydrology is only evident for a part of the growing season. Therefore, many wetlands have been destroyed because of inaccurate characterizations.

Typical indicators of wetland hydrology such as drift lines and blackened leaves require inundation which does not occur in many wetlands. One potential hydrology indicator is the presence of ectomycorrhizae, a symbiosis between fungi and plant roots, in which fungal hyphae surround a root tip forming a visible 'mantle'. Ectomycorrhizae start forming early in the growing season, when the water table is close to or at the soil surface, and remain there for most of the growing season. The vertical distribution of the visible 'mantle' within the soil profile should provide valuable information regarding previous heights of the water table.

Anna Palermo, a senior majoring in Environmental Soil Science, worked with a team of scientists, including her advisor, Dr. Bruce Vasilas, Jeff Thompson from the Maryland Department of the Environment and Lenore Vasilas from the Natural Resources Conservation Service, to evaluate the potential of ectomycorrhizae as a hydrology indicator. She received training in plant identification, plant community assessment, soil morphology descriptions and the interpretation of hydrologic conditions based on soil morphology.

There were three objectives of the research project. The first objective was to determine if a correlation could be made between the presence of ectomycorrhizal fungal mantles (ECM mantles) and other wetland indicators, such as water table depths and hydric soil indicators. If so, the next objective was to determine whether or not the presence or absence of these ECM mantles could aid in wetland delineation (by being consistently present or absent along the edge of a wetland). Finally, the third objective was aimed at determining the feasibility of using the ECM mantles as indicators of hydrology to aid in the identification of historic hydric soils. Historic hydric soils occur when artificial drainage changes the hydrology of a site, so that it is no longer an official functioning wetland.

Four locations representative of seasonally saturated naturally forested systems were selected. At each location, three sites were delineated to include an upland with non-hydric soil, a wetland with undrained hydric soil and a site with drained hydric soil. Monitoring well data was collected to show water table fluctuation throughout the year. Results to date show that ECM mantles were found less than 5 cm deep at all sites, but only found greater than 5 cm deep at the upland site and the drained site (never greater than 5 cm depth at the wetland site).

Although the research is still ongoing, the data collected so far indicates that new hydrology indicators are needed if accurate delineations are to be completed. Since in most cases wetland delineators will not have the time to set up monitoring wells and wait for hydrology data, a reliable method is needed to distinguish wetlands from drained wetlands. More sensitive than plants to hydrology conditions, ectomycorrhizae have the potential to be a living hydrology indicator whose presence or absence within certain ranges could be used to help make a decision about a wetland. At the conclusion of the project, a protocol will be developed so wetland scientists can test this indicator for themselves.

Basic Information

Title:	The Impact of Alum on Pathogen Survival in Poultry Litter
Project Number:	G-12
Start Date:	6/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Agriculture
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Jeff Fuhrmann

Publication

The Impact of Alum on Pathogen Survival in Poultry Litter

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Most poultry litter is currently applied to agricultural lands, a practice that is under scrutiny by both federal and state lawmakers, due to concerns regarding nutrient contamination of surface and groundwaters from the poultry litter. Aluminum sulfate (Alum) is used to control ammonia emissions from poultry houses, thereby improving air quality. It also has been shown by USDA's Agricultural Research Service that alum reduces levels of phosphorous available for runoff to waterways. Yet, despite a growing interest and increased use in alum as a poultry litter amendment, its effect on pathogens and other microorganisms is virtually unknown.

The purpose of this project is to evaluate the effects of high rates of alum application on the survival of bacterial pathogens in broiler litter. Research demonstrating that alum negatively affects pathogen survival would increase justification for its use to meet poultry health and marketability objectives as well as human health and environmental protection concerns. However, if research shows that pathogen survival is enhanced through the use of alum, the wide-spread adoption of alum application to litter should clearly be avoided. (Research is still ongoing)

Information Transfer Program

Basic Information

Title:	A Spatial Analysis of the Distributional Effects of Water Quantity Management
Start Date:	6/1/2000
End Date:	2/28/2001
Descriptors:	Water Use Management and Conservation
Lead Institute:	Water Resources Center
Principal Investigators:	Robert Ehemann

Publication

Twenty-five copies of the FREC Research Report entitled, A Spatial Analysis of the Distributional Effects of Water Quantity Management, were disseminated to stakeholders and policy makers in Delaware. As a result, contacts at the Delaware Water Resources Agency have invited Mr. Ehemann and Dr. Duke to present their results at a statewide conference in October 2001. Within the field of natural resource economics, this project generated scholarly contributions. Indeed, to our best knowledge, this is the first economic study to integrate water-quantity pricing and GIS. The results are proving to be policy relevant. The research report is generating interest among water policy specialists in Delaware. The full impact of the research will be realized later this year when the results are presented to State administration officials and others at an October conference.

Basic Information

Title:	Delaware Water Resources Center Student Research Conference
Start Date:	2/9/2001
End Date:	2/9/2001
Descriptors:	Undergraduate Interns and Graduate Fellows presented their DWRC funded projects
Lead Institute:	Water Resources Center
Principal Investigators:	

Publication

On February 9, 2001, the graduate fellows and undergraduate student interns who had been funded over the past year by the Delaware Water Resources Center (DWRC) presented the results of their research. Conference participants included representatives from academia, non-profit organizations, the agricultural community, environmental management and water resource agencies. The DWRC Advisory Panel held a planning meeting after the conference. Three graduate fellows and nine undergraduate interns were funded, through their faculty advisors, with the fiscal year 2000 DWRC grant to work on water resource related research projects.

Basic Information

Title:	Development of the University of Delaware Experimental Watershed Project
Start Date:	6/1/2000
End Date:	2/28/2001
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Jennifer Campagnini

Publication

Information Transfer Activities of the Experimental Watershed Project: Presentation entitled, "Development of the University of Delaware Experimental Watershed Project", Proceedings of the American Geophysical Union, Spring Conference, Boston, MA, June 1, 2001. In addition, a web site is being developed that will describe the results of the project. The project report is posted at www.udel.edu/ipa

Basic Information

Title:	Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation"
Start Date:	1/2/2000
End Date:	2/28/2001
Descriptors:	
Lead Institute:	Water Resources Center
Principal Investigators:	Stefan Hunger

Publication

Hunger, S. and D.L. Sparks, "Reactions of Phosphate at the Gibbsite-Water Interface: A Molecular Scale Study", Annual Meetings of the Soil Science Society of America, Minneapolis, MN, 2000, p. 222.

Basic Information

Title:	Biodiversity of the atrazine chlorohydrolase (atzA) gene in soil microbial communities as a function of triazine treatment history
Start Date:	6/1/2000
End Date:	2/28/2001
Descriptors:	Microbial degradation of atrazine
Lead Institute:	Water Resources Center
Principal Investigators:	Melissa Weitz

Publication

The results of the research entitled, “Biodiversity of the Atrazine Chlorohydrolase (*atz*A) Gene in Soil Microbial Communities as a Function of Triazine Treatment History” was presented at the USDA W-82 multi state committee meeting at U.C. Berkeley Jan. 2001.

USGS Summer Intern Program

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	9	0	0	0
Masters	0	4	0	0	0
Ph.D.	0	4	0	0	0
Post-Doc.	0	0	0	0	0
Total	0	17	0	0	0

Notable Awards and Achievements

None

Publications from Prior Projects