New York State Water Resources Institute

Annual Technical Report

FY 1999

Introduction

Research Program

The New York State Water Resources Institute's (NYSWRI) FY1999 activity under the Federal Water Resources Research Act consisted largely of six research projects funded during FY1997, FY1998, and FY1999. The FY1997 and FY1998 projects (two in each year) had been funded in northeast regional competitions and the FY1999 projects were funded within a New York competition.

The FY1997 and FY1998 projects had eclectic themes due to their derivation from competitions covering the diverse Northeast US that allowed many possible topics. The four projects covered *Cryptosporidium* oocyst survival in the environment, low-streamflow statistics, remediation of solvent-contaminated aquifers, and leaching of heavy metals from sludge-amended soils. Principals completed three of the four regional projects during the FY1999 reporting period, and one principal will complete theirs in the FY2000 period.

One of the FY1997 regional projects finished early; its work did not overlap into FY1999. Its progress report in NY's FY1998 report is its final report. This FY1999 report refers back to the project's synopsis in the FY1998 report.

The FY1999 projects resulted from an in-NY competition whose topic focus reflected NYS WRI's long-term priority on nonpoint source pollutant management. The projects study *Cryptosporidium* oocyst settling with applications in stormwater treatment, and fine-detailed *Cryptosporidium* oocyst transport modeling. Both FY1999 projects will again be reported upon during the FY2000 period since their schedules overlap two fiscal years.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	The Development of a Regionalized Approach to Estimate Low Streamflow Frequency at Ungauged River Sites in the Northeastern United States
Project Number	NY97-C-02
Start Date	08/01/1997
End Date	08/31/1999
Research Category	Climate and Hydrologic Processes

Focus Category #1	Water Quality
Focus Category #2	Water Supply
Focus Category #3	Management and Planning
Lead Institution	Cornell University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Charles Kroll	Assistant Professor	State University of New York	01
Jeffrey McDonnell	Professor	State University of New York	02

Problem and Research Objectives

This project finished early. See NY's FY1998 report for the final synopsis.

Methodology

Principal Findings and Significance

Descriptors

Water Quality Management, Water Use Efficiency, Decision Models, Pollution Control, Aquatic Protection, Baseflow, Rivers, Optimization, Stochastic Hydrology

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	*Cryptosporidium parvum*: fate of oocysts in soil
Project Number	NY97-C-03
Start Date	10/01/1997
End Date	08/31/1999
Research Category	Biological Sciences
Focus Category #1	Ecology
Focus Category #2	Non Point Pollution
Focus Category #3	Water Quality
Lead Institution	Cornell University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Dwight D. Bowman	Associate Professor	Cornell University	01
William C. Ghiorse	Professor	Cornell University	02
Michael B. Jenkins	Research Associate	Cornell University	03

Problem and Research Objectives

Cryptosporidium parvum is the highest priority contaminant in New York's Source Water Assessment Program (NYS DOH, 1999), reflecting the potential vulnerability of many public water supply systems and potentially severe consequences from infection of humans with weakened immune systems. There remain substantial uncertainties about the relative significance of sources of these organisms in watersheds and the environmental mobility and survival of oocysts. This uncertainty leaves watershed management programs with a weak basis for investing protection resources. Some may overprotect, causing extra costs to wastewater system owners and hardship to rural farm industries. Some may under protect and leave their populations at risk to waterborne disease outbreaks. This research project focuses on the basic soil microbiology survival behavior of the oocyst stage of *Cryptosporidium parvum*, especially in soil and sediment. This is an area that has received little or no attention, although it is probably of the utmost importance in understanding how this transport stage moves through the environment. Our broader research goals are basically two-fold and are directed at providing information on the survival and transport of the oocyst of *C. parvum*. First, we are physically and chemically characterizing oocysts and the protective oocyst wall relative to their survivability in the field laboratory experiments to test individual environmental factors. Second, we are characterizing the survival and transport of oocysts in the environment under close-to-natural conditions, in special sentinel chambers. Thus, relative to our overall plan, this proposal project deals specifically with the highly circumscribed area of survivability of oocysts under different environmental conditions.

Methodology

This project encompasses both laboratory and field portions. The project will run for two years and will consist of parallel projects being run with samples in the laboratory and with samples from the field. There are three specific objectives to the work we will perform. 1. We will determine the survival of oocysts in soils maintained at -4ºC, 10ºC, 20ºC, and 30ºC, with pH being equal to 5, 7, or 8 and with soil water potentials of 0.33 bars (water holding capacity), -5 bars, and -20 bars. There will be six different soils used: sandy loam, clay loam, and silt loam, with two different organic matter contents for each. 2. We will examine how oocysts survive on a farm within the New York Watershed (the David Post Farm in Delaware Co., NY). This farm is one where we have already performed preliminary work with the sentinel system. We will distribute sentinel chambers around the farm and examine the viability of oocysts over the next 12 months. We will also record soil temperature, pH, moisture content (to be calibrated to a soil moisture curve for soil water potential determinations), and ammonia for each site where samples are placed. To validate further the relation between oocyst survival kinetics and the soil parameters maintained in the laboratory, field sites on the Post Farm will be were identified whose soils are were characterized (by soil scientists from the Natural Resources Conservation Service). These will be were a Barbour soil which is well drained and has an organic matter content of 2.7, and an Onteora soil which is was poorly drained and has had an organic matter content of 7.2%. Oocyst survival in these soils will be compared to the results of the laboratory experiments. 3. We will mapped the survival of the oocysts in the field relative to the observed data collected at the field sampling sites. This will produced a two dimensional map of the surface of the farm that will allow us to look for correlation's between changes in oocyst viability and various soil characteristics. The results of this analysis will served as preliminary work for our planned future experiments dealing with oocyst transport where the number of samples will be performed at a much greater density on an expanded sampling grid. We expect to produce the following data relative to oocysts in the environment: laboratory data showing how well oocysts survive in soils of different types when under different environmentally feasible conditions; nomographs for oocyst survivability under different conditions; field data that can then be used to determine if the laboratory data is representative of what occurs under field situations and the opportunity to determine whether the devised nomographs have any real-world application; and a surface map on a farm of oocyst survival relative to measured soil characters that will allow us to examine whether there is any relationship between these characters and the survival of oocysts.

Principal Findings and Significance

Progress report:

Our work has identified a method that determines the survival of oocysts in soil conditions using a sentinel chamber system. This system allows us the ability of examining the persistence of oocysts in the soil environment and the determination of the effects of various environmental conditions. Using this method of examination, we have shown that oocysts in both soil and in manure piles persist much less than would be expected based on work under more reductionistic, bench-top systems where the soil/manure interactions are ignored. Using this system we have shown major effects due to soil water potential and temperature. Results of Aan experiment where we have looked at the long-term survivability of oocysts in the soil on a farm site are currently in the process of being analyzed demonstrated the feasibility of the sentinel approach and showed clear effects of temperature especially freeze-thaw events on oocyst survival in soil. We plan to map the soil survivability over the farmyard. We are also in the process of examining the effects of repeated freeze-thaw cycles on oocysts in soil. We are currently moving into the These results will allow us to study of the transport of oocysts where we will begin to examine in depth how they move about within farms on the watershed.

Descriptors

Cryptosporidium, Pathogens, Public Health, Water Quality Control, Soil Microbiology, Surface Drainage, Land Use, Pollutants, Ecosystems, Dairy Waste Management, Animal Waste, Agriculture, Contaminant Transport

Articles in Refereed Scientific Journals

Brush, C. F., W. C. Ghiorse, L. J. Anguish, J.-Y. Parlange and H. G. Grimes, 1999, Transport of *Cryptosporidium parvum* oocysts through saturated columns, J. Environ. Qual., 28, 809-815. Jenkins, M. B., M. J. Walker, D. D. Bowman, L. C. Anthony, and W. C. Ghiorse, 1999, Use of a sentinel system for field measurements of Cryptosporidium parvum oocyst inactivation in soil and animal waste, Appl. Environ. Microbiol., 65, 1998-2005. Brush, C. F., M. F. Walter, L J. Anguish, and W. C. Ghiorse, 1998, Influence of pretreatment and experimental conditions on electrophoretic mobility and hydrophobicity of Cryptosporidium parvum oocysts, Appl. Environ. Microbiol., 64, 4439-4445. Jenkins M. B. , D. D. Bowman, and W. C. Ghiorse, 1998, Inactivation of *Cryptosporidium parvum* oocysts by ammonia, Applied and Environmental Microbiology, 64, 784-788. Barr, S. C., D. D. Bowman, M. F. Frongillo, and S. L. Joseph, 1998, Efficacy of a drug combination, praziquantel, pyrantel pamoate, and febantel against giardiasis in dogs, American Journal of Veterinary Research, 59, 1134-1136. Jenkins M. B., M. J. Walker, D. D. Bowman, L. C. Anthony, and W. C. Ghiorse, 1999, Use of a sentinel system for field measurements of Cryptosporidium parvum oocyst inactivation in soil and animal waste, Applied and Environmental Microbiology, 65, 1998-2005.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Bowman, D. D., M. B. Jenkins, and W. C. Ghiorse, 1997, Excystation of *Cryptosporidium parvum* sporozoites requires oocyst pretreatment with hydrogen ion and is maximized in the presence of bile salts, 7th International Coccidiosis Conference, Oxford, UK, Abstract No. 106. Jenkins, M. B., D. D. Bowman, M. J. Walker, and W. C. Ghiorse, 1997, Use of sentinel *Cryptosporidium parvum* oocysts to measure effects of passive manure storage on oocyst inactivation, 7th International Coccidiosis Conference, Oxford, UK, Abstract No. 107. Jenkins, M. B., P. L. McDonough, D. D. Bowman, L. C. Anthony, S. C. Kachlany, and W. C. Ghiorse, 1997, Fatty Acid and lipid composition of the oocyst of *Cryptosporidium parvum*. American Society of Tropical Medicine and Hygiene, Orlando, FL, Abstract No. 469. Anthony, L. C., D. D. Bowman, M. B. Jenkins, B. S. Eaglesham, S. C. Kachlany, and W. C. Ghiorse, 1998, Chemical Composition and ultrastructure of the oocyst walls of wildtype *Cryptosporidium parvum*, ASM Annual Meeting, Atlanta, GA Jenkins, M. B., M. J. Walker, D. D. Bowman, and W. C. Ghiorse, 1998, Use of sentinel *Cryptosporidium parvum* oocysts for field measurements of oocyst inactivation kinetics in surface soil. ASM Annual Meeting, Atlanta, GA. Werre, S. R., D. D. Bowman, H. O. Mohammed, M. B. Jenkins, F. W. Quimby, K. M. Horton, and J. P. Dubey, (date not cited), Transmission to guinea pigs of very low doses of *Toxoplasma gondii* oocysts in drinking water, Americal Society of Protozoologists, Raleigh, NC. Kato, S., D. D. Bowman, and M. B. Jenkins, 1999, The effects of the pretreatment with hydrogen and potassium ion and bile salts on the

excystation of *Cryptosporidium parvum* sporozoites, American Association of Veterinary Parasitologists, New Orleans, LA. Jenkins, M. B., D. D. Bowman, E. A. Fogarty, S. R. Werre, S. Kato, and W. C. Ghiorse, 1999, Inactivation of *Cryptosporidium parvum* oocysts in three soil types at various temperatures and water potentials, American Society of Tropical Medicine and Hygiene, Washington, DC. Jenkins, M. B., D. D. Bowman, and W. C. Ghiorse, 1999, Inactivation of *Cryptosporidium parvum* Oocysts in Three Soil Types at Various Temperatures and Water Potentials. Northeast Section of the American Society of Agronomy and Soil Science Society of America, Guelph, Canada.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Preferential flow and organic enhancement of metals transport to groundwater from land-applied biosolids in the northeastern U. S.
Project Number	NY98-C-05
Start Date	10/01/1998
End Date	08/31/2001
Research Category	Ground-water Flow and Transport
Focus Category #1	Solute Transport
Focus Category #2	Toxic Substances
Focus Category #3	Models
Lead Institution	Cornell University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Tammo S. Steenhuis	Professor	Cornell University	01
Murray B. McBride	Professor	Cornell University	02

Problem and Research Objectives

Application of municipal wastewater sludges (biosolids) to land is being widely promoted as a cost-effective management practice. Agricultural land, forest land, and land reclamation sites are increasingly being used for land application. In addition to beneficial components such as organic matter and

nutrients, sludges also contain trace metals (such as Cd, Cu, Hg, Ni, Pb and Zn) which in groundwater or agricultural products present human and/or animal toxicity risk. Current USEPA regulations governing sludge application assume little or no mobility of sludge-applied metals to groundwater. Many field studies are unable to account for a substantial fraction of sludge-applied trace metals when the receiving soil is examined several years after application. Losses from the soil profile via leaching is a potential mechanism for the apparent losses. Relatively few studies report water quality data, and results can be complicated by instrumental detection limits and by the potential for sampler interactions.

Our overall research objective is to obtain a better understanding of the potential risks to water quality posed by land application of sludges, and to contribute to the base of knowledge needed to define land application practices that are protective of water quality in the Northeast. The specific goal of the grant was to study metal movement though the vadose zone with undisturbed laboratory soil cores, field observation and modeling.

Methodology

Laboratory field and modeling studies were carried out to study the metal movement in the soil. Because each of these studies had a separate methodology, it is listed with each study description in the section "Principal Findings and Significance"

Principal Findings and Significance

The studies carried out with partial support of this grant are listed according to the objectives as: laboratory, field and modeling:

The effect of sludge processing (digested dewatered, pelletized, alkaline-stabilized, composted, and incinerated), soil type, and initial soil pH on trace metal mobility was examined using undisturbed soil columns by Richards et al. (2000). Soils tested were Hudson silt loam (Glossaquic Hapludalf) and Arkport fine sandy loam (Lamellic Hapludalf), at initial pH levels of 5 and 7. Sludges were applied during four accelerated cropping cycles (215 t/ha cumulative application for dewatered sludge; equivalent rates for other sludges), followed by four post-application cycles. Also examined (with no sludge applications) were Hudson soil columns from a field site that received a heavy loading of sludge in 1978. Romaine (*Lactuca sativa*) and oats (*Avena sativa*) were planted in alternate cycles, with oats later replaced by red clover (*Trifolium pratense*). Soil columns were watered with synthetic acid rainwater, and percolates were analyzed for trace metals (ICP spectroscopy), electrical conductivity and pH.

Percolate metal concentrations varied with sludge and soil treatments. Composted sludge and ash had the lowest overall metal mobilities. Dewatered and pelletized sludge had notable leaching of Ni, Cd and Zn in Arkport soils, especially at low pH. Alkaline-stabilized sludge had the widest range of percolate metals (relatively insensitive to soils) including Cu, Ni, B and Mo. Old site column percolate concentrations showed good agreement with previous field data. Little leaching of P was observed in all cases. Cumulative percolate metal losses for all treatments were low relative to total applied metals. Leachate and soil pH were substantially depressed in dewatered and pelletized sludge soil columns and increased for alkaline-stabilized and ash treatments.

Field studies: Two different papers were published examining the metal movement under field conditions.

The study by Richards et al. (1998) was undertaken to determine the present distribution and mobility of sludge-applied metals at an old land application site. Trace metals concentrations were determined for soils (using 4M HNO3 extracts), soil leachates (collected with passive wick lysimeters over a 2.5-year period), and plant tissue from a held site which received a heavy loading of wastewater sludge in 1978 and an adjacent control plot. Blue dye was used to indicate preferential percolate flowpaths in the sludge plot soil for sampling and comparison with bulk soil metals concentrations. After nearly 20 years, metals in the sludge plot leachate were found at significantly greater concentrations than in the control plot, exceeding drinking water standards for Cd, Ni, Zn, and B. Annual metals fluxes were only a fraction of the current soil metal contents, and do not account for the apparent substantial past metals losses determined in a related study. Elevated Cd, Cu, and Ni levels were found in grass growing on the sludge plot. Despite heavy loadings, fine soil texture (silty clay loam) and evidence of past and ongoing metals leaching, examination of the bulk subsoil indicated no statistically significant increases in metals concentrations (even in a calcareous subsoil horizon with elevated pH) when comparing pooled sludge plot soil profiles with controls. Sampling of dyed preferential flow paths in the sludge plot detected only slight increases in several metals. Preferential flow and metal complexation with soluble organics apparently allow leaching without easily detectable readsorption in the subsoil. The lack of significant metal deposition in subsoil may not be reliable evidence for immobility of sludge-applied metals.

McBride et al. (1999) examined leachate samples from the same site by using a more sensitive method (ICP-MS), which revealed elevated concentrations of Cu, Zn, Sr, Rb, Mo, Cd, As, Cr, Ni, Sb, W, Ag, Hg,and Sn compared with a nearby control site. Enhanced leaching of some elements from this near-neutral, fine-textured (silty clay loam) soil could be explained by exchange of soil-bound elements by components of the added sludge. For most of the heavy metals, however, increased leaching was a response to the high metal loadings in the soil, probably facilitated by higher dissolved organic matter in the leachate. Laboratory determined distribution coefficients, K-D, for the metals in newly prepared sludge/soil mixtures were lower than K-D values of the field-aged sludge-treated soil, suggesting that metal mobility may have been substantially higher shortly after sludge application than many years later. Cumulative losses of certain trace elements from the topsoil have been estimated relative to Cr, a comparatively immobile element. These suggest that relative long-term losses range from 20 to 80%, with the order being: Sr, Mo, Sb > Ni, Cd, Cu > Zn, Ag. Generally, those elements with the smallest K-D values (most soluble) measured recently in the soil had the largest loss estimates. However, present leaching loss rates are too low to explain the estimated relative losses of several of these elements from the topsoil over the 15 or more years since sludge application.

Model development: Steenhuis et al. (1999) examined the first-order model used by the USEPA for predicting losses from the zone of incorporation as part of the risk assessment that undergirded the development of Part 503 regulations. We found that when empirical adsorption partition coefficients from the site are used as model inputs, the EPA model for the incorporation zone is similar to that derived from preferential flow theory and simulates well the loss of metal from the surface soil layer at an orchard site where sludge was applied 15 years earlier. The EPA model and the preferential flow model were clearly different for the remaining part of the unsaturated soil below the incorporation zone.

Descriptors

Contaminant transport, sludge, biosolids, heavy metals, leaching, phosphorus, surfactants, nonylphenols, pollutants, preferential flow, facilitated transport groundwater, water quality, modeling

Articles in Refereed Scientific Journals

McBride M. B., B. K. Richards, T. S. Steenhuis, G. Spiers, 1999, Long-term leaching of trace elements in a heavily sludge-amended silty clay loam soil, SOIL SCIENCE 164(9), 613-623. Richards B. K., T. S. Steenhuis, J. H. Peverly, M. B. McBride, 1998, Metal mobility at an old, heavily loaded sludge application site, ENVIRON POLLUT, 99(3), 365-377. Richards B. K., T. S. Steenhuis, J. H. Peverly, M. B. McBride, 2000, Effect of sludge processing mode, soil texture and soil ph on metal mobility in undisturbed soil columns under accelerated loading, ENVIRON POLLUT, 109(2), 327-346. Steenhuis T. S., M. B. McBride, B. K. Richards, E. Harrison, 1999, Trace metal retention in the incorporation zone of land-applied sludge, ENVIRON SCI TECHNOL, 33(8), 1171-1174.

Book Chapters

Dissertations

Richards, B. K., 1999, Trace metal mobility from land applied sludge products, Ph.D. dissertation, Cornell University, Ithaca, NY. Welt, S. B., 1999, Colloidal transport of heavy metals via preferential flow paths, MS thesis, Cornell University, Ithaca, NY.

Water Resources Research Institute Reports

Conference Proceedings

Heilig, A., T. S. Steenhuis, M. B. McBride, B. K. Richards, E. Z. Harrison, and P. Dickson, 1999, Reducing the Risk of Adverse Environmental Impacts from Northeast Dairy Farms (Poster), ASA-CSSA-SSSA Annual Meetings, Salt Lake City, UT, October 31 - November 4, 1999. Welt, S., B. K. Richards, M. B. McBride, and T. S. Steenhuis, 1999, Colloidal Transport of Heavy Metals via Preferential Flow (Poster), ASA-CSSA-SSSA Annual Meetings, Salt Lake City, UT, October 31 - November 4, 1999.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Developing comprehensive criteria for dehalorespiratory bioremediation of chlorinated ethenes in a contaminated aquifer
Project Number	NY98-C-04
Start Date	10/01/1998
End Date	06/30/2000
Research Category	Water Quality
Focus Category #1	Ecology
Focus Category	Toxic Substances

#2	Toxic Substances
Focus Category #3	Groundwater
Lead Institution	Cornell University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Eugene L. Madsen	Assistant Professor	Cornell University	01

Problem and Research Objectives

Industrial operations in past decades led to significant groundwater pollution with chlorinated solvents (especially trichloroethene, TCE). This family of solvents (which includes perchloroethene, PCE) is among the most widespread groundwater contaminants, regionally and nationally. Conventional pump-and-treat cleanup technology, designed to keep a corporation in Niagara Falls (Textron Inc.) in environmental regulatory compliance, constitutes a major financial liability. But more importantly, TCE-impacted groundwaters threaten human and ecosystem health throughout the Northeastern US and current treatment technologies constitute a significant drain on the financial resources of municipalities and private enterprises. Dehalorespiration by naturally-occurring groundwater microorganisms has the potential to supplement or replace pump-and-treat technology at some of these sites. The goal of this project is to implement a series of laboratory and field procedures (stable isotopic analyses of key carbon pools in the contamination site, analysis of site samples, physiological assays examining competing biodegradation pathways) that document the variety of processes that influence the effectiveness of naturally-occurring microorganisms in detoxifying chlorinated ethenes in groundwater. A key goal of this investigation is identifying the site geochemical component (the physiological electron donor) that derives and sustains reductive dechlorination.

Methodology

Procedures involved iterative progression from field to the laboratory and back again. We gather site groundwater samples from wells inside and outside the contaminant plume and analyze them chemically and microbiologically. Aseptically gathered groundwaters are brought back to the laboratory where they are used for physiological assays aimed at identifying the degree to which the naturally occurring microbial community has adapted to various potential electron donors (e.g., H2, yeast extract, hexadecane native to the aquifer formation). We also use laboratory incubations of groundwater and rock samples from the field site to assess the impact of competing physiological regimes (electron accepting processes that include methanogenesis, sulfate reduction, iron reduction, manganese reduction, nitrate reduction) on dehalorespiration. These incubations include microcosms that document the potential of groundwater microorganisms to metabolize vinyl chloride (the most toxic of chlorinated ethenes daughter products) under iron-reducing and other conditions. We have discovered that pulverized aquifer material added to laboratory microcosms accelerates reductive dechlorination of TCE. We are using GC/MS analysis to attempt to identify petroleum compounds in the rock that may drive the dehalorespiratory process in situ. In addition, recently-developed molecular biological procedures for characterizing the identity of the microbial community (by sequencing the 16S rRNA

genes) are being employed. Furthermore, we are using stable isotopic analyses of the inorganic and organic carbon pools in the contaminated field study site to trace the sources and fates of carbon transformation processes. Characteristics signature in 13C to 12C ratios will allow in situ electron sources and sinks to be identified. Overall the procedures are designed to create a diverse, comprehensive chemical, microbiological, and physiological understanding of the interactions between site geochemistry and microbial detoxification processes.

Principal Findings and Significance

GC/MS analyses have detected straight chain (C16-C25) aliphatic hydrocarbons in the aquifer rock. Furthermore, these were depleted in the microcosms after accelerated reductive dechlorination. Thus, the native microbial comm8unity may be adapted to utilize rock-borne hydrocarbons as electron donors and TCE as the electron acceptor during microbial growth. Analysis of the hydrocarbons in field-derived rock cores also shows a depletion of these compounds at the fracture faces where microbial activity and hydraulic flow are likely to be the greatest. Stable isotopic analysis of 13C/12C ratios of the dissolved inorganic carbon (DIC) in site groundwater shows a value (delta 13C = -14.8) that is intermediate between the native dolomite rock (delta 13C = -0.61) and the rock derived petroleum hydrocarbons (delta 13C= -26.8). These data are also consistent with the hypothesis that the petroleum hydrocarbons are being oxidized in situ and contributing to the DIC pool [If not, the (delta 13C value of DIC would match that of the dolomite]. Both molecular analysis of the microbial community and anaerobic incubations assessing the response of the community to potential electron donors are in progress. Overall, the study is contributing knowledge of geochemical and microbiological factors that may sustain intrinsic bioremediation at this and other contaminated sites.

Descriptors

Bioremediation, TCE, reductive dechlorination, dehalorespiration, stable isotopes.

Articles in Refereed Scientific Journals

Yager, R. M., S. E. Bilotta, C. L. Mann, and E. L. Madsen, 1997, Metabolic adaptation and In situ attenuation of chlorinated ethenes by naturally-occurring microorganisms in a fractured dolomite aquifer near Niagara Falls, NY, Environ. Sci. Technol., 31, 3138-3147.

Book Chapters

Dissertations

Plummer, S. M., 1999, In Situ biodegradation: Involvement of aliphatic hydrocarbons in the dechlorination of trichloroethylene, MS Thesis, Cornell University, Ithaca, NY.

Water Resources Research Institute Reports

Conference Proceedings

Madsen, E. L., 2000, Natural attenuation of chlorinated ethene-contaminated waters: Field experience and monitoring protocols from an American perspective, Proceedings of the 9th European Congress on Biotechnology, 11-15 July 1999 Brussels, Belgium. E. L. Madsen, R. M. Yager, and S. M. Plummer, 2000, Petroleum hydrocarbons native to a fractured aquifer may serve as electron donors for in situ

reductive dechlorination of trichloroethenes contamination, Abst. Amer. Soc. Microbiol. Annu. Meet., Los Angeles, CA.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Settling Characteristics of As-Deposited *Cryptosporidium* Oocysts
Project Number	B-06
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	Treatment
Focus Category #3	Agriculture
Lead Institution	Rensselaer Polytechnic Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Simeon J. Komisar	Assistant Professor	Rensselaer Polytechnic Institute	01

Problem and Research Objectives

Understanding the transport and fate of *Cryptosporidium* in the environment is especially critical to the prote and treated sources with the potential for large protozoan inputs from their watersheds. Watershed Best Man been designed to mitigate the inputs of farm-generated pollutants to surface and ground water. Many of these solids from farm runoff, relying on sedimentation as a removal mechanism. Although the effectiveness of BM nutrients has been documented (*e.g*. NYSDEC, 1992; Edwards *et al*., 1996; Meals *et al*., 1996), to our know the effectiveness of agricultural BMP's for the removal of *Cryptosporidium*. The use of BMP's in NYS wate potential inputs of *Cryptosporidium* oocysts to reservoirs may or may not be effective. **Understanding the s *Cryptosporidium* oocysts in the environment, then, is critical to the rational design of BMP's that rely *Cryptosporidium*. In addition, oocyst settling is a key parameter in modeling and predicting the fate of The rate at which *Cryptosporidium* oocysts settle is an important element in our efforts to understand and in NYS reservoirs.**

This study is examining the settling velocity of oocysts under controlled laboratory conditions, using oocysts possible, unaltered from the form in which they occur in the environment. By using freshly obtained oocyst-in experiments, we hope to overcome the experimental bias of previous investigations by other researchers into study will contribute to our understanding of the associations of oocysts with larger particles in fecal matter a significantly impact the sedimentation of oocysts from the water column. Our objectives in conducting this in

1. to determine the settling velocity distribution for oocysts, as deposited in infected fecal material, when column of quiescent water with known constituents;
2. to examine the effect of the experimentally-determined settling velocity distribution on the fate of *Cryp* by models for reservoirs and for sedimentation basins designed to treat agricultural runoff.

Knowledge of the distribution of settling velocities of *Cryptosporidium* oocysts, then, will provide a mo assessment, regulation and monitoring as well as design of BMP's to enhance oocyst removal.

Methodology

The settling column apparatus

Sedimentation rates for *Cryptosporidium* oocysts in fecal material are being measured in a settling column co vertically into a polyvinyl chloride (PVC) and metal gate valve (overall dimensions for the column: 10 cm insi high). The depth of the settling column is 115 cm when the gate valve is closed. The bottom of the PVC valv PVC base. Glass side ports (10 mm I.D. x 35 mm long) have been affixed to the glass column at 8 levels on t been placed at each of the levels - 3, 6, 9, 15, 30, 45, 75 and 105 cm from the top surface of water in the colu cm below the top of the glass column). A rubber stopper into which a 14-gauge canula is inserted so that the into the column plugs each side port. The canula is attached to two syringes by way of a 3-way stopcock. Th mounted on a pneumatically damped vibration-free table and wrapped with tubing through which 26^{o}C water insulation encases the entire apparatus to aid thermal stability.

The test procedure

At the start of an experiment, 4 g of fecal material containing *Cryptosporidium* oocysts was mixed into appro (DI) water. Oocyst-infected fecal material had been obtained from a 20-day-old female Holstein calf by Excel The material was not fluid, and the calf appeared healthy. The suspension was gently stirred enough to break were collected from this suspension for analysis of initial *Cryptosporidium* oocyst concentration and particle fecal material used in these initial tests was based on the concentration of oocysts in the feces. A large enough needed to create detectable numbers of oocysts in the small volumes sampled from the column. However, too oocyst enumeration. The degree of mixing used was intended to create a suspension of primary fecal particles oocyst-particle associations.

The suspension was then poured all at once into the top of the column. The gate valve at the start of an exper suspension filled the entire column. After filling the column, a Styrofoam plug covered with fiberglass insulati column to prevent evaporation and provide insulation. A temperature meter probe had been inserted through temperature of the column.

After an initial period (0.5 or 1 hr), the gate valve was closed, and samples were withdrawn from selected por microcentrifuge tubes, and stored on ice or refrigerated until analysis. The procedure for sample withdrawal v 0.5 ml was slowly drawn into a waste syringe to clear the canula of residual sample; 2) at each port at selecte and 1.5 ml of the column contents were slowly drawn into a clean plastic disposable syringe; 3) syringes cont unscrewed from the stopcocks, and their contents were ejected into the microcentrifuge tubes; 4) fresh syring stopcocks. Sampling always proceeded from the top of the column to the bottom, and ports were sampled in procedure was repeated at 24 hour intervals after the start of the experiment (the gate valve remained closed

After an early experiment revealed little, if any, settling of oocysts in the column, fluorescent latex microsphe diameters were added as markers to the fecal suspension. 5.75 μm microspheres from Polysciences, Inc., and

Beckman Coulter were added to produce concentrations in the settling column of 1600, 840, and 500 micros spheres were reported by their manufacturers to have a density of 1.05 g/cm^3.

At the end of the experiment, the column contents were drained from a port located at the 105-cm level. The port, but above the closed gate valve, were drained and collected separately. This fraction presumably contai to the bottom between the time the gate valve was closed and the end of the experiment. The contents of the were also collected separately. The numbers of *Cryptosporidium* oocysts in each of these three fractions were determine a mass balance for the oocysts in the column.

Sample analysis

Particle size analysis. Particle size analysis was performed within 6 hours of sample collection to avoid chang agglomeration or degradation. Particle size analysis was also conducted on the sample before oocyst enumera requires vortexing the sample, which might impact particle sizes. Particle sizes were analyzed using a Beckma Multisizer operates by a volume displacement method. As a particle in a thin stream of electrolyte passes by i the resistance between those electrodes. This change produces a voltage pulse, the magnitude of which is pro Assuming the particle is spherical, the volume detected can be converted to an equivalent diameter. Consider meaning of this equivalent diameter, if the particles of interest are not spherical.

Microcentrifuge tubes containing samples were gently inverted for 1 minute to evenly distribute the sample th subsample was then pipetted using a cut-off pipette tip to avoid excluding larger particles from the subsample 50 ml of the electrolyte (Beckman Coulter Isoton), and slowly stirred by a glass paddle during the measureme suspension was analyzed for number of particles in the 2 – 60 μm range, and 2 x 2000 μl of suspension was a range of 5.6 – 168 μm (different sized apertures must be used on this instrument depending on the size of par particle size distributions can be overlapped to produce a continuous distribution for the sample). The output particles in the sample that fall within selected size ranges. These numbers can be converted to concentrations and electrolyte are used. Using this information, the concentrations of selected particle sizes were tracked wit

*Oocyst enumeration***.** After vortexing the sample for 1 minute, 100 μl of the sample taken at a port (or taken pipetted using a cut-off pipette tip to avoid exclusion of larger particles from the subsample. This subsample Whatman Nucleopore membrane filter, pore size 0.8 μm. The sample on the filter was then incubated for 40 100 μl of Aqua-Glo fluorescent monoclonal antibody for *Cryptosporidium parvum* diluted 1:20 with AusFlow sodium pyrophosphate, 500 μl 0.05% w/v Tween 80 solution, 500 μl 0.05% w/v sodium azide, and 5 g BSA to pH 8 with HCl and filtered through 0.2 μm filter). At the end of the incubation period, the filter was rinsed FlowBuffer (same as AusFlow® mAbBuffer without the BSA albumin added), then placed on 5 μl of AusFlo glycerol, 2.4 ml DI water with 100 mg/ml DABCO, 4.8 ml 1 M TRIS buffer, 0.5 ml formalin, and 0.5 ml 5 M M HCl) on a glass microscope slide. Slides were examined for oocysts at 400x magnification using a Nikon e 480/30 nm excitation wavelength and 535/40 nm emission wavelength, oocysts were identified as bright appl spherical objects, 3 – 6 μm in diameter and with brightly highlighted perimeters. When latex microspheres we 5.75 μm spheres were observed using the same wavelengths used for oocysts (microspheres were easily disce spheres were observed using an excitation wavelength of 510 – 560 nm and emission wavelength of 590 nm, examined under brightfield. Oocysts and microspheres were enumerated for the entire 100 μl subsample.

Subsamples from the contents of the base of the column (composed of the initial suspension plus the particles before the gate valve was closed) were also stained and placed on microscope slides. Oocysts in these sample many seemed to be associated with the larger particles in the sample (*i.e.* were observed to be touching or res

Additional analyses. Conductivity of the initial suspension of fecal material in water was also measured. In fu

fecal material, and dissolved organic carbon (DOC), pH, and total suspended solids (TSS) in the initial fecal s
will also be determined for the 3 fractions of the column contents at the end of each experiment to provide an
distribution and of potential losses of mass in the system.

Principal Findings and Significance

Progress Report

Importance of thermal isolation of the settling column

A preliminary settling experiment employing 5.75, 10 and 20 μm latex microspheres in water was carried out
vibration-free table, but without the water jacket and insulation described above. In this type of settling exper
are completely mixed, and particles do not accumulate at the lowest measured point in the system, one would
particles (*i.e*. a level in the column above which no particles having the same settling velocity are found and b
their initial concentration) move down the column at the particles' characteristic settling velocity. While the c
microspheres decreased in the upper section of the column relative to the lower section, this decrease did not
microspheres, and no distinct front was observed for any of the microsphere sizes. However, the concentratio
the depth of the column decreased through time for all sized microspheres in this experiment.

The absence of a distinct settling front in the preliminary experiment suggested that thermal currents might be
column. Ela and Leckie (2000) have documented the importance of thermal isolation of settling systems in cr
conditions. A temperature probe in the column during the preliminary experiment described above revealed th
much as 7.5^{o}C during the course of the experiment. Even when the column was jacketed with a 1 inch layer o
temperature changed 1^{o}C in 24 hours. Newman *et al*. (1990) note that a temperature difference between a ve
settling column will create a turnover of fluid in the column. For a column with a 7 cm diameter and 50 cm he
difference, this turnover will have a period of about 250 seconds. The consequent mixing is enough to mainta
of particles. The turnover rate will increase as a function of an increased temperature gradient, but will decrea
radius and length of the column. Based on this information and the results of our preliminary experiments, we
to improve its thermal stability. After wrapping the column in tubing through which water was pumped at a c
by a circulating water bath) and in fiberglass insulation material, the temperature in the column was observed
precision of the temperature probe, ± 0.1^{o}C) for the duration of the succeeding experiments.

Preliminary results of settling tests

To date, three settling tests have been performed in the settling column during which vibration and temperatu
first test was performed with the three sizes of latex microspheres in 25^{o}C DI water, the second test with 5-m
material in 25^{o}C DI water, and the third test with latex microspheres and the same fecal material (now 9 days
second and third tests, the number concentrations of oocysts at the sampled depths in the column were not sig
another for a given sample time (one-way repeated measures analysis of variance test, $p > 0.05$). This was als
microspheres in the first and third tests. In other words, despite improved thermal stability in the column, the
statistically uniformly mixed throughout the experiment.

Although the particles in the columns remained mixed, the concentrations of oocysts and microspheres averag
observed to, in general, decrease with time. A mass balance performed on oocysts and microspheres in the co
revealed that the numbers of oocysts and spheres were enriched in the bottom portions of the column. Appro
of oocysts, 92% of 5.75 μm spheres, 84% of 10 μm spheres, and 98% of the 20 μm spheres were recovered
column. This would indicate that the disappearance of oocysts and microspheres from the upper water colum
and not to other losses from the system (*e.g*. sticking to walls, containers, etc.).

Newman *et al*. (1990) present a model for determining settling velocities for particles in a water column in wl maintain a uniform particle concentration throughout the column, but not so great as to cause resuspension o assumes that there is a plane above the bed at the bottom of the water column above which particles are not a part of the suspended load. If a particle settles through this plane, it is out of the system and cannot be resusp will be deposited at the bottom at a per unit area rate equal to their settling velocity (v) times their number co concentration of particles having the same settling velocity in the column, then, should be first order and follc

$$\frac{n(t)}{n(o)} = e^{\frac{-vt}{H}} \quad (1)$$

where $n(t)$ is the number concentration of particles with time (t), n(o) is the initial number concentration, and According to this model, the slope of a plot of $\ln\left[n(t)/n(o)\right]$ versus (t/H) should equal the settling velocity Results for the three tests were plotted in this manner and are presented in Figures 1 – 3. Since no significant oocysts at different depths and numbers of microspheres at different depths were seen in these tests, the conc sample time were averaged and used as $n(t)$ to create these figures. The settling velocities obtained from thes settling velocities predicted by Stokes' Law, are summarized in Table 1.

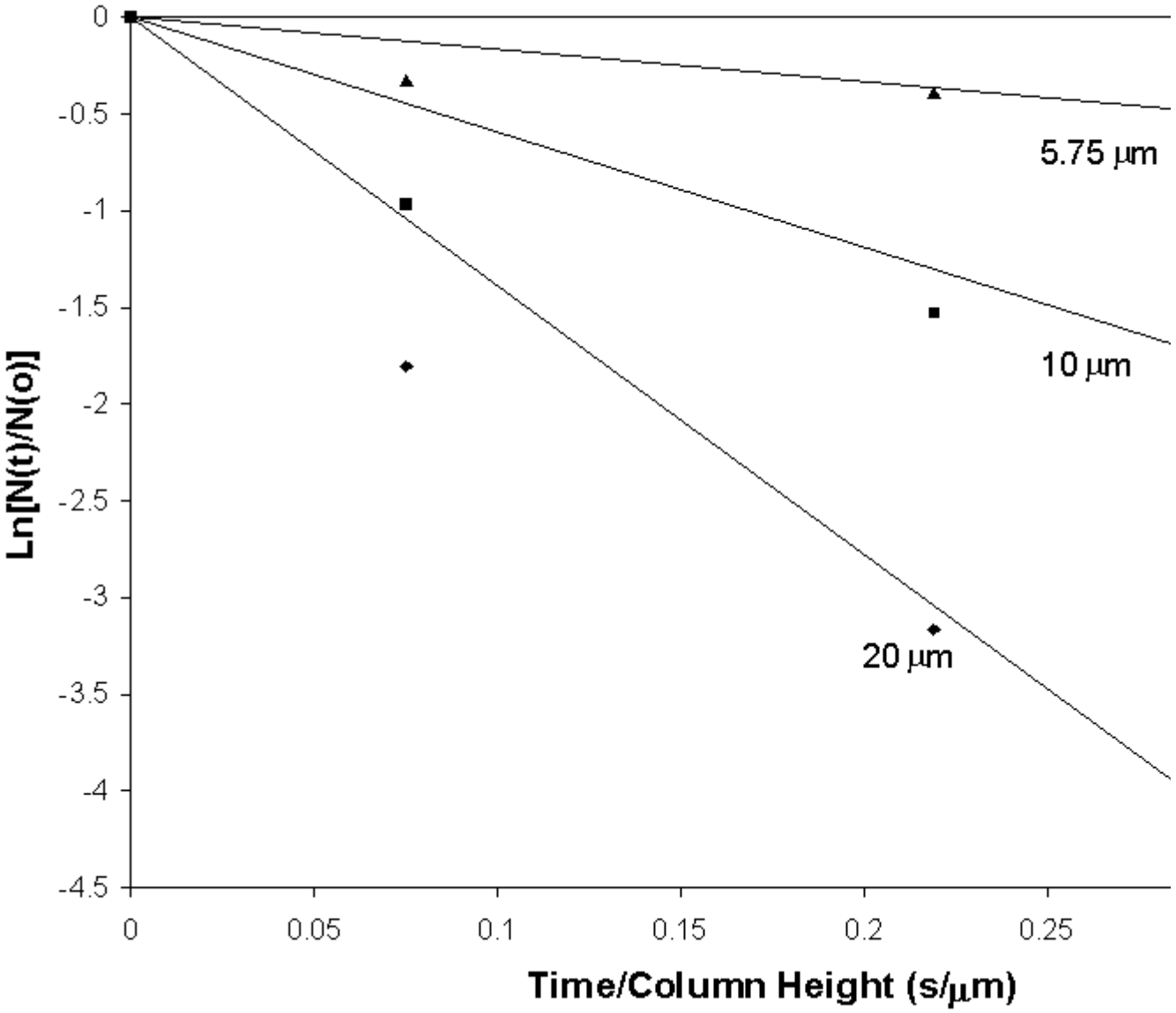
Table 1. Settling velocities (v) for *Cryptosporidium* oocysts and 5.75, 10 and 20 µm latex microspheres deriv settling columns.

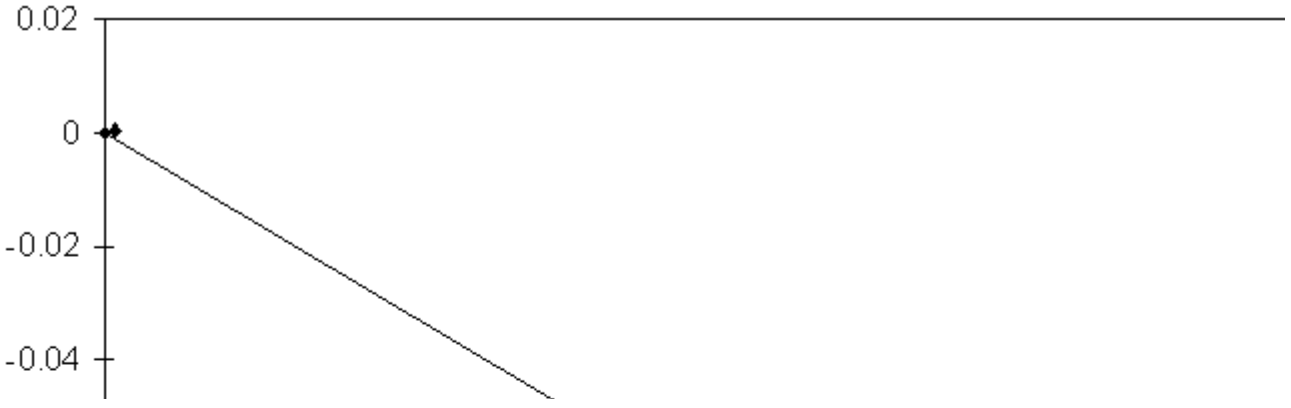
	$V_{Oocysts}$ (mm/s)			$V_{Microspheres}$ (mm/s)								
Test (duration)	$v_{Oocysts}$	R^2	*p*-value	$v_{5.75}$ µm	R^2	*p*-value	v_{10} µm	R^2	*p*-value	v_{20} µm	R^2	*p*-value
Test 1 (94h)	-	-	-	1.7	0.60	>0.10	6.0	0.72	>0.10	14	0.92	<0.05
Test 2 (72h)	0.66	0.68	<0.10	-	-	-	-	-	-	-	-	-
Test 3 (144h)	0.63	0.56	>0.10	1.3	0.95	<0.05	4.3	0.91	<0.05	11	0.89	<0.05
Theoretical[a]	0.77 (0.41 – 1.07)			1.1						13		
25ºC	0.79 (0.42 – 1.1)			1.1			3.2			13		
26ºC							3.3					

[a] Theoretical Stokes' settling velocity assuming density of microspheres =1.05 g/cm^3. Theoretical Stokes' velocity for oocysts ba density (p) and diameter (d) by Medema *et al*. (1998) (p=1.045g/cm^3, d=4.9µm). Lowest velocity calculated using mean measur (p=1.029 g/cm^3, d=4.6µm), and highest velocity calculated using mean p and d plus one standard deviation (p=1.062 g/cm^3, d= Test 1 and 2, and 26ºC for Test 3.

Note that although settling velocities in Table 1 have been derived from the linear regression lines fit to the se

relationships represented by the regression lines fit to the data for the 5.75 and 10 μm spheres in Test 1 and f
statistically significant at the $p = 0.10$ level.





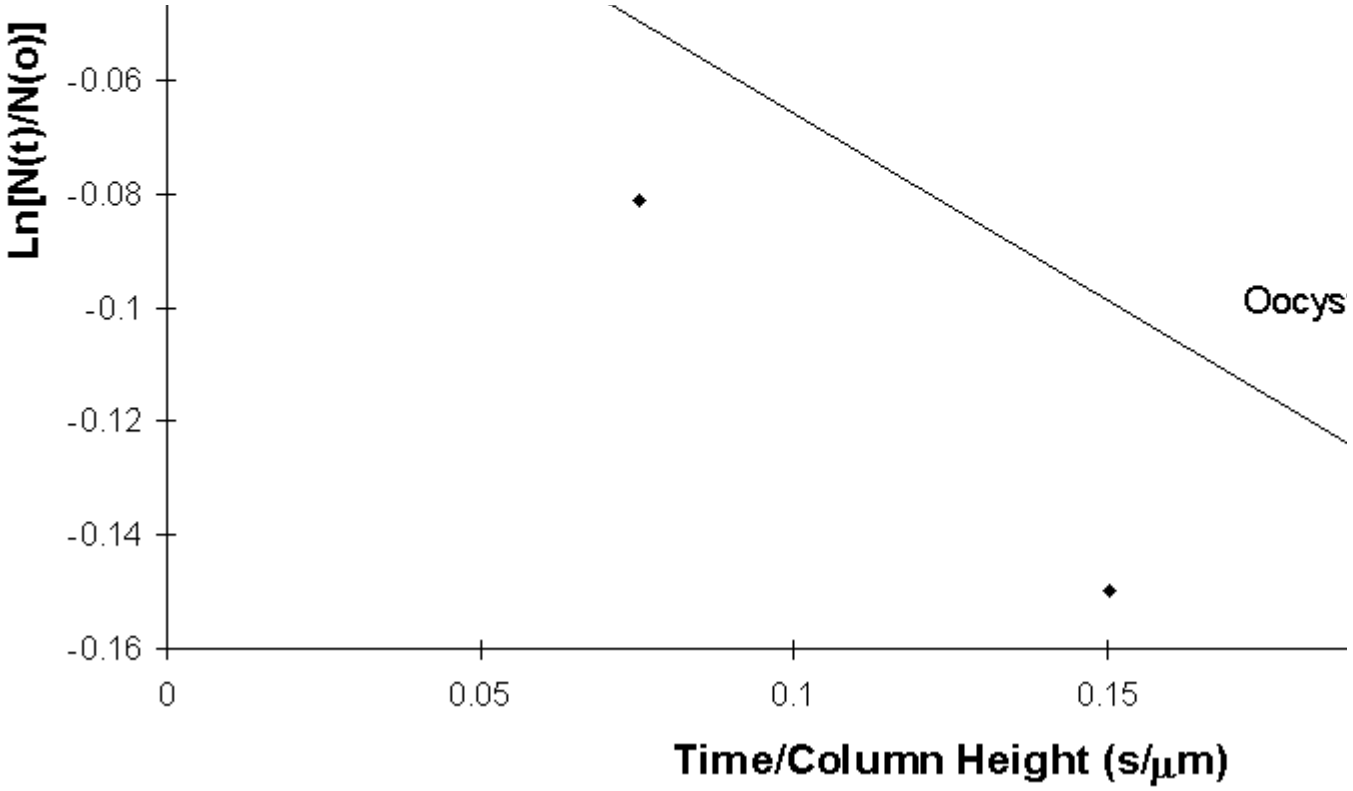
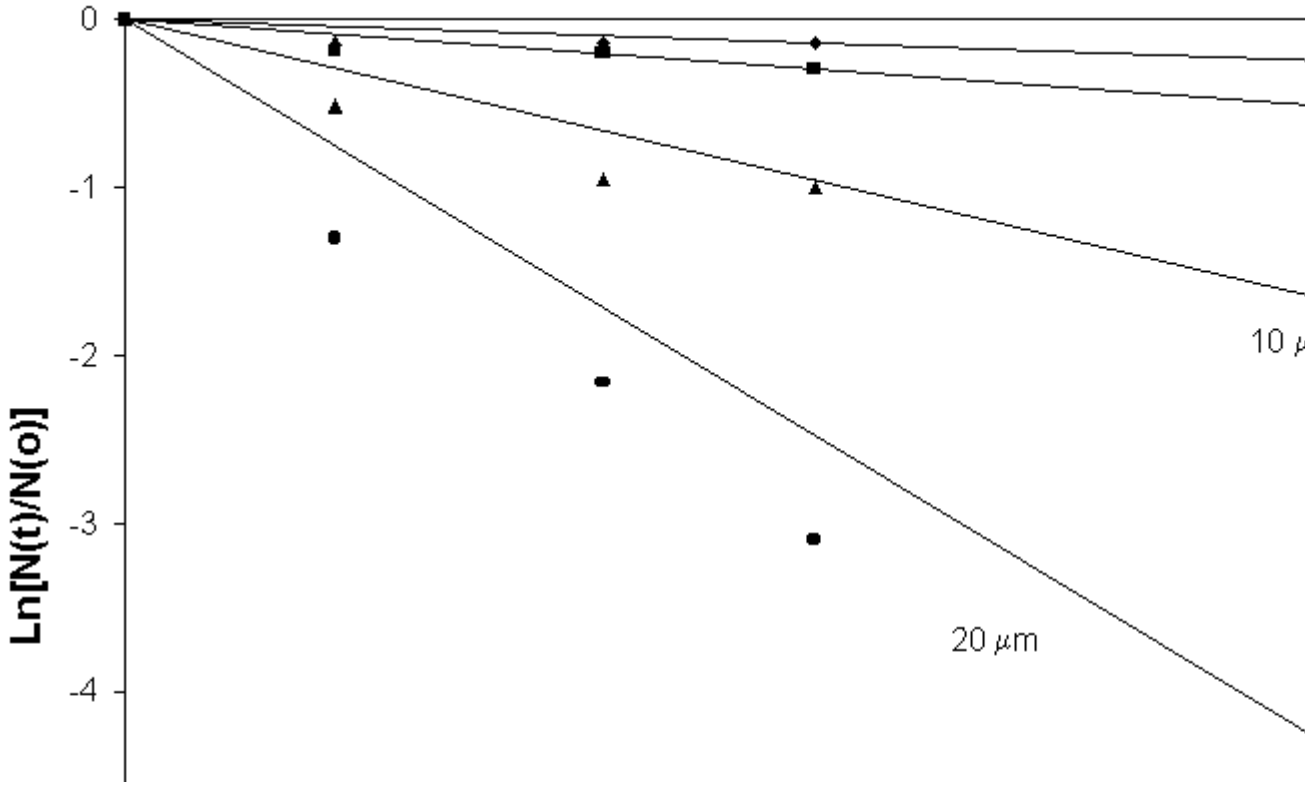


Figure 1.
Fraction of number concentration of latex microspheres remaining in water column in Test 1 vs. time/column

Figure 2. Fraction of number concentration of *Cryptosporidium* oocysts remaining in water column in Test 2



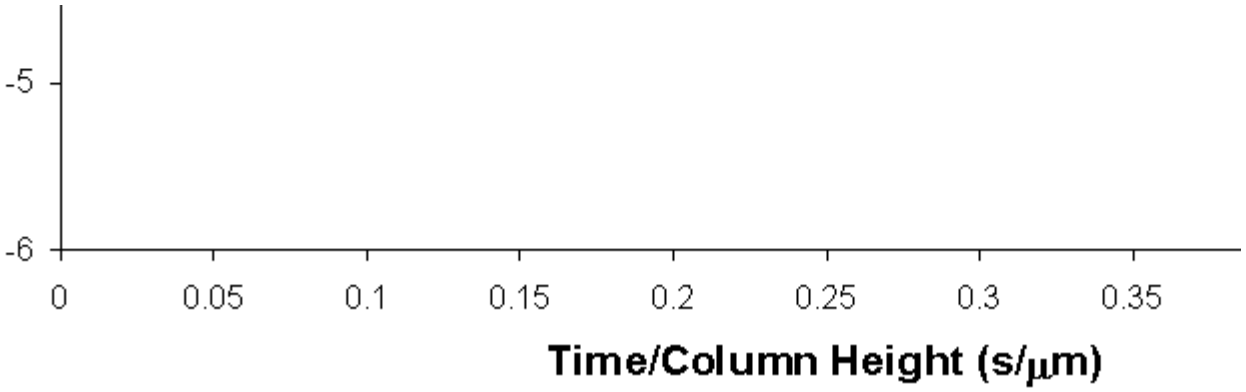


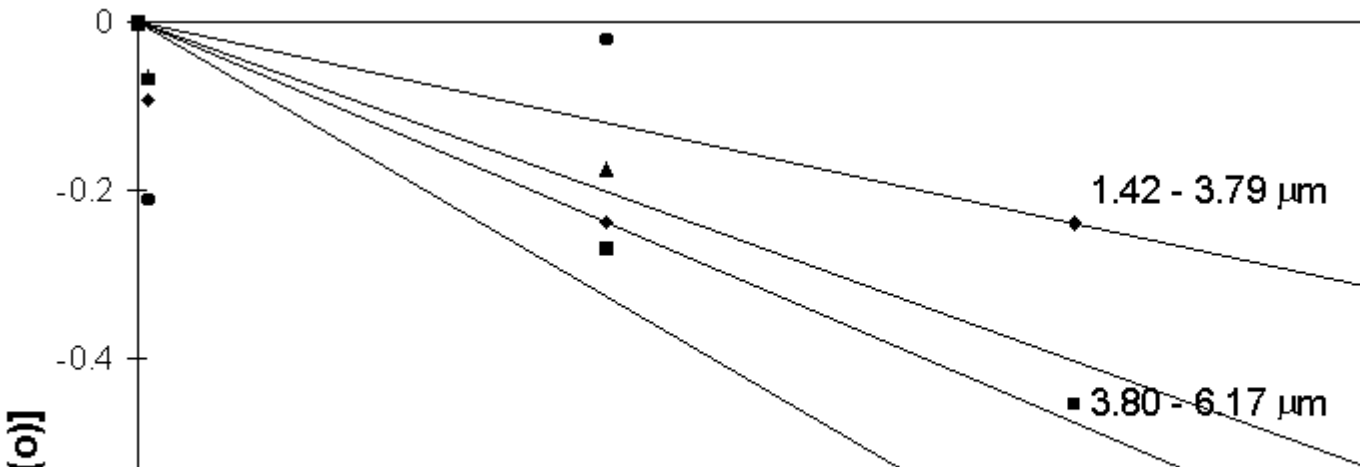
Figure 3. Fraction of number concentration of latex microspheres and oocysts remaining in water column in

An interesting result of the tests conducted to date is that while the latex microspheres in our settling apparat theory, *Cryptosporidium* oocysts settled more slowly than predicted for a sphere having the characteristic de In future tests, 4 μm spheres will be added to the fecal suspensions to examine whether latex microspheres th settle faster than predicted in our system.

Medema *et al*. (1998) also measured a slower than predicted settling velocity for oocysts in their work (initia This settling velocity is nearly half of what we have observed in our tests. Medema *et al*.'s use of purified oo solution may account for some of the difference between our respective results.

Particle Size Analysis

Particle size analysis was performed on samples from the second test. Technical problems with the Multisizer particle size analysis for the third test. In order to compare settling rates of particles from the fecal material in rates of the latex microspheres and oocysts, particles in the samples from the column were grouped accordin within the ranges 1.425 - 3.799 μm, 3.800 - 6.174 μm, 6.175 - 8.549 μm, and 8.550 - 10.92 μm were averag for each sample time. *Cryptosporidium* oocysts measured by Medema *et al*. (1998) were found to range from μm). One would expect, then, that particles in the 3.800 - 6.174 μm range (assuming a spherical shape and si settling velocities close to that observed for oocysts in the test apparatus. As had been done with the microsp - 3, the natural log of the fraction of particles of a given nominal diameter remaining in suspension at a given (Figure 4). The settling velocities derived from the regression lines fit to these data, and the associated statist



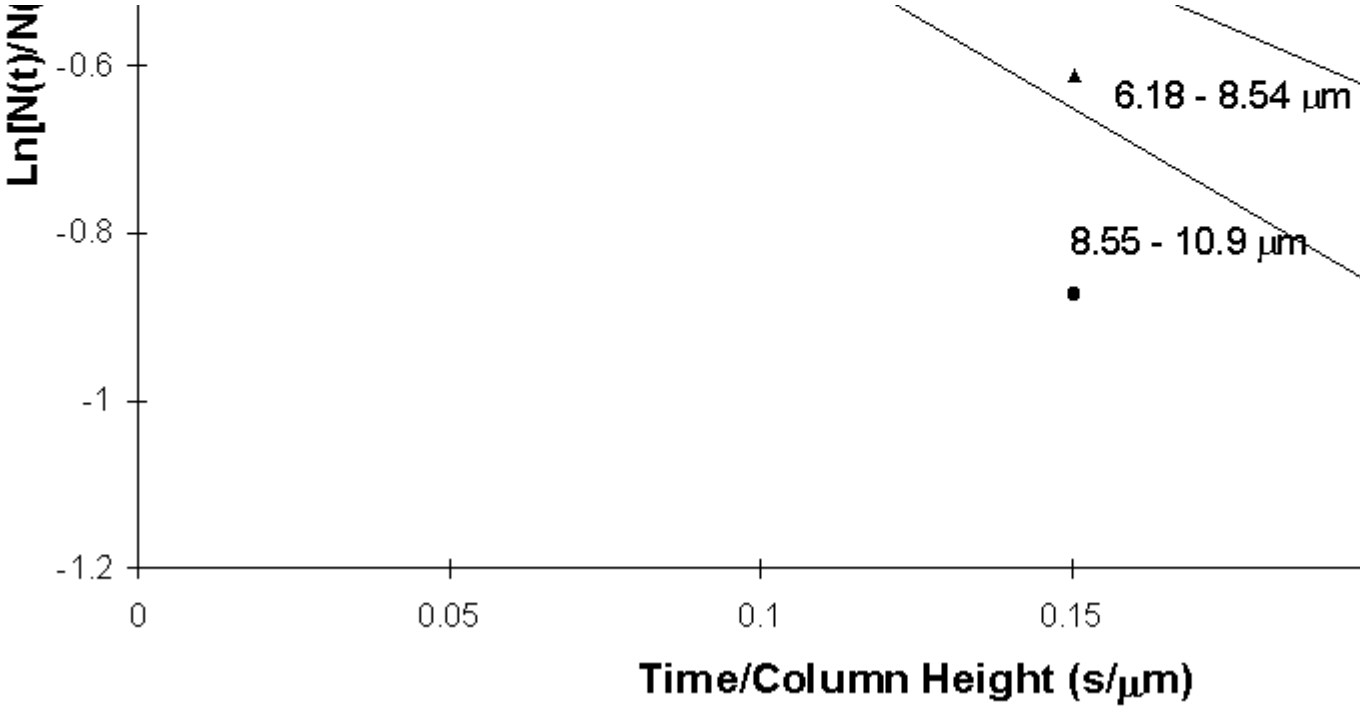


Figure 4. Fraction of number concentration of particles within various size ranges remaining in water column

Table 2. Derived and theoretical settling velocities (*v)* for particles in a suspension of *Cryptosporidium*-infect

Size Range (mm)	**1.425-3.799**	**3.800-6.174**	**6.175-8.549**	**8.550-10.92**
***v* (mm/s)**	0.93	2.2	2.8	4.0
R^2	0.1668	0.9230	0.8861	0.8107
***p* - value**	>0.10	<0.01	<0.05	<0.05
Theoretical *v* [a]	0.10-0.73	0.73-1.93	1.93-3.69	3.69-6.02

[a] Theoretical Stokes' settling velocity assuming density of particles =1.08 g/cm^3 and water temperature = 25^{o}C.

Theoretical settling velocities for the fecal particles are presented in Table 2 for comparison. In calculating th
was assumed and a density was selected (1.08 g/cm^3) so that the resultant velocities more or less bracketed t
when these particles are observed under the microscope, they are not characteristically spherical. Many of the
and have a variety of shapes, while the smaller particles appear floc-like. Li and Logan (1997) have observed
particle (*e.g*. a floc) act to reduce hydrodynamic drag on the particle. Consequently, an aggregate particle wil
with an equivalent diameter. Moreover, the fecal particles probably represent a range of densities. Given this,
settling velocities for the particle size groups as averages that incorporate the variations in shape, porosity, ar
Comparison of the derived settling velocities for the fecal particles to the settling velocity exhibited by the oo

useful, however. For example, detection of particles even smaller than oocysts (as measured by a volume disp basin effluent may indicate that conditions in the basin are inadequate for oocyst to settle out of the water col particle sizes, particle settling velocity, and oocyst settling velocity in various suspensions will be examined in

Microscope analysis of association of oocysts with fecal particles

Several tests were conducted in which a suspension of *Cryptosporidium* oocyst-infected fecal material was al minutes before separating the settled portion from the overlying water. Subsamples from the settled portion v Aqua-Glo. Oocysts on the filters were enumerated, noting how many were apparently resting on or touching projected areas approximately $>1x10^4$ μm^2) on the filter. The percent of oocysts in the samples that were res particles in the samples ranged from 0 - 17.3% (mean = 5.4 ± 3.8%, n = 26). The larger particles in 3 subsam sized using a calibrated micrometer. If the oocysts in a subsample are assumed to be uniformly distributed ov the probability of observing a given number of oocysts or fewer on the area occupied by the larger particles i using:

$$P_{n\le k}(A) = \sum_{k=0}^{k} e^{-\alpha A} \cdot \frac{\alpha A}{k!}^{k} \quad (2)$$

where k is the number of oocysts observed to be associated with larger particles in the sample, A is the projec particles in the sample, and α is the expected number of oocysts/unit area of the sample on the filter (assumin on the filter). For the 3 slides examined, there was a >98% probability that, by chance, one would have obser than was counted resting on the larger particles. This result indicates that the oocysts in these samples were n the larger particles in the samples.

Future Work

In future work, we intend to:

- verify our initial results using side-by-side duplicate columns and adding 4 μm microspheres to test sus
- examine the effect of ionic strength of the fluid medium on settling velocity
- examine the effect of fecal maturation on oocyst settling velocity
- examine the settling behavior of as-deposited oocysts and other particles in suspensions characteristic o animal feedlot or pasture).

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Descriptors

Cryptosporidium, Pathogens, Settling Velocity, Animal Waste, Dairy Waste Management, Contaminant Tran

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Estimating the Risk of Water Contamination by *Cryptosporidium parvum* oocysts and other colloidal pollutants
Project Number	B-07
Start Date	10/01/1999
End Date	09/30/2000
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	Non Point Pollution
Focus Category #3	Solute Transport
Lead Institution	Cornell University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Carlo D. Montemagno	Assistant Professor	Cornell University	01

Problem and Research Objectives

Many municipalities world-wide provide their citizens with finished drinking water whose source is surface waters. Recent outbreaks of cryptosporidiosis (a gastrointestinal disease caused by oocysts of *Cryptosporidium parvum*) raise grave concerns about the quality of raw surface waters, and watershed management of the risk of contamination by pathogens.

Cryptosporidium parvum is a protozoan pathogen that is found in high concentrations in animal feces. High intensity agriculture such as cattle feedlots and land application of sewage and manure may be the source of these pathogens in drinking water. The transmissive form of *C. parvum*, its oocysts, may not be eliminated by filtration and standard disinfection methods. *C. parvum* oocysts thus challenge the long-standing engineering approaches to public health risks from water supply contamination, and little is known about the transport of the oocysts in natural systems.

Our primary objective is to develop an accurate method for the quantitative determination of the effect of watershed management practices on the risk of human health caused by the transport of *C. parvum* oocysts into municipal water supplies. This goal will be achieved through development and verification of an integrated model of the transport of *C. parvum* oocysts in environment. While the study considers *C. parvum*, our strategy can be applied to any pathogenic microorganisms or colloidal particles that share the specifics and transport of *C. parvum* on the soil surface.

Methodology

The project consists of two major components: a modeling and an experimental study. The modeling study identifies the key measurements necessary to fully describe the processes. The experimental study will provide the data necessary to verify and drive the model in practical applications.

The model has the following features:

1. ability to predict low probability events
2. temporal and spatial distribution of pathogenic microorganisms in runoff
3. pathogenic microorganism partitioning in soil, sediments, and the aqueous phase
4. sensitivity analysis of microorganism yield with respect to land management and environmental factors

To verify the model, we will

- carry out plot experiments with various vegetation, slope and soil types. Experimental plot studies will be designed and built to simulate field conditions
- analyze the microorganism partitioning in water, soil, and sediments of varying sizes
- employ immunofluorescence assay (IFA) to estimate microorganism concentrations in water, soil and sediments, and dye permeability assay to carry out viability analysis

Principal Findings and Significance

Progress report:

The theoretical part of the project has been completed. We have developed a new approach to modeling microorganism transport and interactions on the soil surface and in overland flow. We have simultaneously employed and established a correspondence between stochastic (microscopic) and deterministic descriptions of the process. The deterministic approach describes the flow of concentrations and leads to the macroscopic evaluation of surface water contamination. The process dynamics on the microscopic scale describe the flow of probabilities and provide a more basic understanding of the mechanisms underlying the transport and interactions of microbial organisms in the environment.

Our model has the capability of employing any erosion model that provides the sediment load and particle size distribution in runoff. We have incorporated the output of the Water Erosion Prediction Project (WEPP) into our calculations. Computer simulations were run for two contrasting soils supplying results consistent with the theory.

Ongoing research:

We are in the process of setting up experiments that will provide an empirical evaluation of the magnitude and character of transported loads of oocysts from controlled plots. These data will be used to verify the predictions of the microorganism transport model. Plot studies and the subsequent analysis of oocysts for partitioning in soil, sediments and water will provide parameters that will be used as an input to different modules of the transport model.

The sensitivity and risk assessment analyses will be conducted at the same time with experimental studies.

Descriptors

Cryptosporidium parvum, pathogens, colloidal particles, stochastic modeling, deterministic modeling, contaminant transport, sensitivity, risk assessment.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Yeghiazarian, L. and C. D. Montemagno, Estimating the risk of water contamination by Cryptosporidium parvum oocysts, XIII International Conference on Computational Methods in Water Resources, Calgary, Alberta, Canada, 2000 (to appear). Yeghiazarian, L. and C. D. Montemagno, Stochastic model of microorganism transport from non-point sources of pollution. EOS-Transactions,

American Geophysical Union, Abstract H22D-03, 1998. Yeghiazarian, L. and C. D. Montemagno, Estimating the risk of water contamination by Cryptosporidium parvum oocysts, EOS-Transactions, American Geophysical Union, Abstract S152, 1998.

Other Publications

Invited Presentations Yeghiazarian, L. and C. D. Montemagno, Estimating the risk of water contamination by *Cryptosporidium parvum* oocysts, International Riverbank Filtration Conference, Louisville, KY, November 1999.

Information Transfer Program

(Note: Base funding for this activity comes from the New York State College of Agriculture and Life Sciences, including Cornell Cooperative Extension. This section describes NYS WRI's general information transfer approach.)

As in most previous years, the Institute gave priority to information transfer activities during the Federal FY1999 period, supported primarily by Cornell University. The transfer process works in both directions: scientific information is disseminated to government agencies, professionals, and the general public and the needs and opinions of these individuals and organizations strongly influence the content and form of most NYS WRI activities.

Subject matter and problems:

Some of the issues NYS WRI staff and cooperating faculty have addressed through education and training activities during recent years are:

- protecting watersheds and well catchments of water supplies;
- managing the impact of new land development on water quality;
- protecting groundwater and surface water from pesticides;
- assessing nonpoint source impacts on lakes, streams, and groundwater;
- assessing urban water demand;
- managing agricultural manure for nutrient and pathogen control.

Most of these issues are identified through the constant interaction of NYS WRI staff with the public, business, and governmental entities.

Target audiences and related strategies:

NYS WRI considers everyone in New York to be potential members of one of its audiences. NYS WRI staff and cooperating faculty normally pursue the following activities with the following groupings of people:

- local government staff: technical assistance projects;
- agricultural industry: technical assistance projects for agricultural chemical companies;
- water supply industry: technical and educational assistance projects related to source water quality protection;
- County Extension staff: periodic Statewide training courses including teleconferences; regional training activities; telephone consultation;

- County Soil and Water Conservation District staff: Statewide and regional training activities, collaborative demonstration projects, new program development;
- private citizens concerned about their own or local water problems: telephone advice and referral; development of general leaflets and bulletins about water and contaminants.

Cooperators:

Some NYS WRI staff (including the Director) have appointments with Cornell Cooperative Extension and participate in Extension activities on a statewide and regional basis. WRI's sponsored projects generally involve the appropriate County Extension Association if they have any interest in the issue.

Besides Cooperative Extension entities in counties, some of NYS WRI's recent, more frequent partners in information transfer activities include:

- County Soil and Water Conservation Districts;
- New York City Watershed Agricultural Council, Inc.;
- New York City Department of Environmental Protection;
- Within the New York City watershed program, Cornell's Department of Soil, Crop, and Atmospheric Sciences (agricultural nutrient assessment and management), Department of Agricultural Management and Resource Economics (local government, farm business management), Department of Agricultural and Biological Engineering (hydrology and farm nutrient and pathogen transport), Section of Microbiology (farm pathogen viability and analysis), Department of Animal Science (nutrient and pathogen management through dairy nutrition and health), Department of Veterinary Clinical Sciences (pathogen risk assessment); Veterinary Diagnostic Laboratory (pathogens and animal health), Department of Rural Sociology (rural community watershed management);
- Upper Susquehanna Coalition (Conservation Districts and other county entities in thirteen counties in New York and Pennsylvania);
- NYS Dept. of Environmental Conservation (NYS DEC) and NYS Department of Health (NYS DOH) program development activities.

Since early 1997, NYS WRI has been participating in an Environmental Community Assistance Consortium, whose current academic members are units from Cornell University, Syracuse University, the State University of New York at Buffalo, the State University of New York at Stony Brook, and the Rensselaer Polytechnic Institute. The Consortium specializes in technical and educational assistance to local government. Its first official project assisted Genesee County, NY, in constructing a water supply infrastructure plan.

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	9	1	0	0	10
Masters	0	2	0	0	2
Ph.D.	4	2	0	0	6

Post-Doc.	0	0	0	0	0
Total	13	5	0	0	18

Awards & Achievements

A focal area dominating NYS WRI's activity since the early 1990's has been the development of programs based on watersheds. Most effort since 1992 has been devoted in the New York City Watershed. NYS WRI has been acting as an intermediary between New York City and elements of the agribusiness sector and wider community in the watersheds as they strive to develop alternatives to the "police power" approach, alternatives that retain more local sovereignty. The most mature component program operates under the banner of "Whole Farm Planning" (WFP). This program has been carrying out Phase II of a long-term, $35M program since 1994. The program has attracted national attention due to its unusual blend of balanced environmental and economic goals, local farmer governance, a promising voluntary participation rate, multilevel governmental cooperation, diverse scientific input, and significant funding transfer between the water supplier and farmers. During the Federal FY1999 period, NYS WRI continued to develop a new work area: phosphorus management in the Cannonsville Reservoir basin (West Branch of the Delaware River). The Cannonsville Reservoir is somewhat eutrophic. New York City has imposed strict controls on additional wastewater phosphorus discharges in its basin, a policy that the watershed communities feel is hampering economic development. The area is economically disadvantaged relative to the rest of the state, making economic restrictions especially troubling.

Prior to FY1999, NYS WRI has assisted Delaware County in obtaining over $800,000 of State and Federal seed funding (Federal Water Resources Development Act, Federal Safe Drinking Water Act) to develop its own scientifically credible local program that will reduce phosphorus loadings to the reservoir without unduly constraining economic development. An additional $1M of scientific support funds are likely to be allocated during calendar 2000, to further enhance local efforts in water quality modeling and monitoring. Cooperating municipalities will receive over $1M in grants to implement small-scale stormwater treatment systems for existing development. These new systems will be monitored to quantify phosphorus removal so that loading reductions here can offset additional phosphorus loads from expanded wastewater treatment plants. $270,000 has been acquired (some within the $800,000 in prior years) to demonstrate techniques to balance phosphorus budgets on farms via feed management. The locally-owned and operated phosphorus management program promises to inspire efforts elsewhere in New York and elsewhere in the US as did the continuing watershed agricultural program.

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications