Large-Scale Watershed Restoration Partnerships

Annual Report

New York City Watersheds Study

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I. Partnership Overview

The New York City (NYC) water supply system provides more than 1.4 billion gallons of high quality drinking water daily to approximately 8 million city residents and 1 million residents of southeastern New York. The NYC Department of Environmental Protection (DEP) and New York State Department of Environmental Conservation (DEC) operate and maintain the entire NYC water supply system, which draws water from 19 reservoirs and three controlled lakes from the 1,969 square-mile total watershed. Agricultural and forested lands, most of which is privately owned, collectively constitute more than 90% of the Catskill/Delaware watersheds.

The DEP is working with farmers and forest landowners to maintain a traditional open-space landscape that creates rural economic opportunities while protecting the water supply. The DEP works with local partnership programs administered by two nonprofit organizations, the Watershed Agricultural Council (WAC) and the Catskill Watershed Corporation (CWC). The WAC implements voluntary pollution prevention programs based on open-space protection; the largest program, the Watershed Agricultural Program, protects both water quality and the economic viability of farming as a preferred watershed land use. The aim of WAC is to improve the short- and long-term economic viability of forest landownerships and the forest products industry in ways compatible with protecting water quality and sustaining the forests.

Although the quality of NYC drinking water is high, 10 of the 19 reservoirs are classified as eutrophic by Carlson's (1977) trophic state assessment methodology.[1] In 9 reservoirs, all in the Croton District, phosphorus load reductions are due to wastewater treatment plant (WWTP) upgrades and upstream compliance.[2]

It was reported nationally that 40% of rivers in the NYC watershed are unhealthy as a result of nutrient enrichment; 50% of surveyed lakes and reservoirs and 57% of surveyed estuaries are similarly affected. Methods historically used to remove phosphorus from wastewater treatment plants include adding chemicals, phosphate-accumulating organisms (PAOs), or light-expanded clay aggregates. The NYC Watersheds Study focuses on removing phosphorus from water.

The Forest Products Laboratory (FPL) has an ongoing research program in the use of lignocellulosic fibers to remove dissolved ions from water; removing these pollutants is typically the most difficult and expensive part of water filtration. The natural sorption capacity of lignocellulosic fibers varies, depending on the type of material. FPL researchers have determined that modifying the surface of the lignocellulosic fiber can substantially increase its sorption capacity.

The latest area of research is the development of filters from non-lignocellulosic media that can be used in combination with lignocellulosic fibers, which cannot be used in certain situations. Non-lignocellulosic media can increase the capacity of filters made from lignocellulosic fibers.

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[1] A trophic state index (TSI) of greater than 50 indicates eutrophic conditions. The TSI is based on measurements of chlorophyll II a (CHLA), total phosphorus (TP), and Secchi depth (ZSD).

[2] *Nonpoint Source Implementation of the Phase II Total Maximum Daily Loads* (TMDLs). 2001. Prepared by NYC Department of Environmental Protection and New York State Department of Environmental Conservation.

Mesoporous media, acid mine discharge precipitant, and slags constitute the main area of study. These media can be incorporated to the lignocellulosic fibers.

Efforts toward improving utilization of the wood resource and developing new products and the environmental industry would strengthen local industry, enhance the profitability of forests as a beneficial low-density use of land, and help maintain the overall health and long-term sustainability of the forests.

The DEP has a number of regulatory and non-regulatory nonpoint-source pollution control programs. The Filtration Avoidance Determination (FAD) program involves the development and implementation of many nonpoint source pollution control programs. FAD also imposes strict reporting requirements to monitor the DEP's progress in implementing its programs and to evaluate whether NYC continues to meet the conditions for avoidance. However, as the water quality of NYC watersheds degrades, filtration avoidance might not be feasible. One solution, massive filtration, poses a danger to the watersheds and would cost from $6 to $8 billion.

A small-scale filtration system such as our design will cost only a fraction of the cost of a larger system. The small units will be installed to prevent known point sources of pollution, rather than to attempt to filter the watersheds as a whole. Moreover, most money will stay within the watershed areas.

Also, physical, and biological techniques for modifying lignocellulosic fibers are being studied. FPL has been engaged in the development of filters, the wooden/plastic filtration system, and monitoring technology.

II. Partnership Goals

Phase II TMDLs are based on attaining a phosphorus value of 15 μg/L for the seven source water reservoirs (Kensico, West Branch, Rondout, Ashoka, New Croton, Cross River, and Croton Falls) and attaining the NY State phosphorus guidance value of 20 μg/L for the remaining upstream reservoirs. Nine of the 19 reservoirs currently exceed the Phase II TMDL and require phosphorus reductions. In general, Croton watershed, which is east of the Hudson River and close to NYC, needs more phosphorus reduction than do reservoirs west of the Hudson. The nonpoint source reductions for the 9 reservoirs in question are Amawalk (122 kg/yr), Croton Falls (885 kg/yr), Cross River (57 kg/yr), Diverting (983 kg/yr), East Branch (993 kg/yr), Middle Branch (204 kg/yr), Muscoot (2,058 kg/yr), New Croton (1,356 kg/yr), and Titicus (140 kg/yr). Total nonpoint source reduction for these reservoirs is 6,798 kg/yr.

The goals of this team in 2001 and 2002 were removal of phosphates from dairy farms. The long-range goal is to develop a technology based on using modified wood fibers to absorb pollutants from surface water runoff. Specific objectives are as follows:

1. To evaluate a range of wood fibers, including locally available fibers, through physical, chemical, and biological modification processes to increase their capacity to absorb phosphates/nutrients.
2. To design a filtration system so that the effectiveness of lignocellulosic filtration can be proven and adopted by DEP/DEC to reduce non-point source reduction and ultimately prevent eutrophication.

3. To install and monitor demonstration filtration systems.
4. To conduct life-cycle assessment of economic feasibility of using wood fiber filters.
5. To prepare a technology implementation plan for all NYC watersheds.

The immediate goal is to establish phosphorus load and reduction based on dairy operations. About 350 dairy farms are in the Catskill/Delaware watershed. Our team is studying how much phosphorus reduction can be achieved by application of our system. Demonstration/simulation research has indicated that total phosphorus load and reduction can be calculated, and it is our goal to establish a model for the best management practice for a dairy operation.

III. Accomplishments

A. Actions

Most of 2002 was spent in improving the filtration media and system. According to the opinion of several agencies, most pollution in the watersheds is farm related and caused by *Cryptosporidium* bacteria (a seasonal problem) and phosphates. Thus, our main focus was the removal of phosphates. Generally accepted sources of phosphate pollution are fertilizers, agricultural wastes, municipal and industrial byproducts, and plant residues. The two basic sources of pollution in agricultural wastes are animal manure and milkhouse waste. The process of collecting and spreading animal manure is not easy to monitor or apply to our technology, but it is not impossible. The most effective way of addressing filtration was to study milkhouse waste. In 2001, two systems were installed at the Delaware County (see Figure 1) and some data were collected. In 2002, the systems were redesigned and replaced.

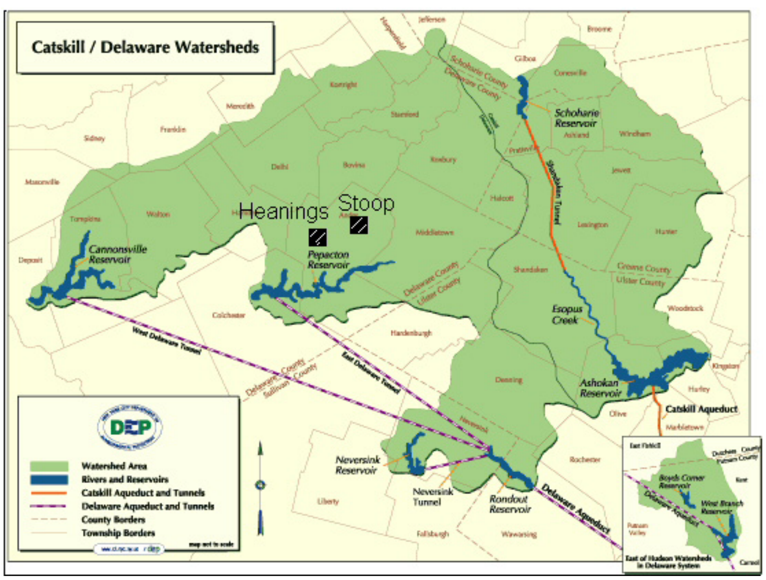

Figure 1. Catskill/Delaware watersheds.

1. Lignocellulosic filters

The raw material of filter media is Juniper (*Juniperus monosperma)* small-diameter and underutilized (SDU) lignocellulosic material. Adding a value to a SDU material is a good example of producing a value-added product in the forestry industry, and it also can impede forest fire by removing fire loading. Juniper was selected as a raw material through screening test for heavy metal removal. Juniper trees were shredded to small chips, refined, and chemically modified. Resultant fibers or pulp was made into a Rando mat using 10% HC–105 binder. Mat density was 0.109 to 0.131 g/cm^3 and thickness was about 1.3 cm. The hydraulic conductivity was 6.4 by 10^{-4} cm/s. Mats were cut into 61- by 61-cm pieces, fitted into stainless steel frames, and installed into filtration boxes.

The juniper mats were treated with several forms of metal oxide (ferric, ferrous or aluminum oxide, etc.), which is widely used for removal of anion from water.[3,4] Those mats containing individual and mixed metal oxides were tested in the laboratory and the results were acceptable. In the next experiment, we studied acid mine drainages (AMDs) because AMDs are already in solution and this stable solution can be injected into lignocellulosic mats to make a high capacity anion-exchanger. Three AMD solutions were analyzed for chemical composition and the salts of these solutions were simultaneously tested for anion-exchange capacity. Test results showed that the ratio between iron and aluminum seems to govern anion-exchange capacity. The AMD results indicate that the exact ratio between iron and aluminum needs to be further defined.

The iron-containing lignocellulosic filter media were used at the NYC watersheds to remove phosphates. Before use, the modified filter media were washed with clean water to remove soluble components from the filter media and then dried (MLFM01).

The other modification was impregnation of aluminum oxide into the original lignocellulosic filter media at FPL (MLFM02).

2. FPL non-lignocellulosic filtration media

The isotherm experiment of phosphorus removal was performed on slags (potential phosphorous-removing substrates, from E. C. Levy Co.) and various clays and chemicals, such as iron, zinc, aluminum, and calcium (development of synergetic composite materials for adsorption of phosphates). The mesoporus media were further studied because these media offer a high surface area (about 1,000 m^2/g), very regular pore arrangement, and narrow pore size distribution. The drawback of these media is their high cost. However, the study of mesoporous materials gave us basic knowledge of chemical modification because of their well-defined surface structure. We learned that inorganic impurities such as zinc, iron, calcium, or aluminum are needed in lignocellulosic and other potential media to enhance phosphate reduction, but the amount needed and their synergistic relationships have not been determined. We are hoping to learn the exact ratio of impurities from the study of mesoporous media. The ultimate goal is to mimic the chemical property of mesoporous medium starting with inexpensive materials such as

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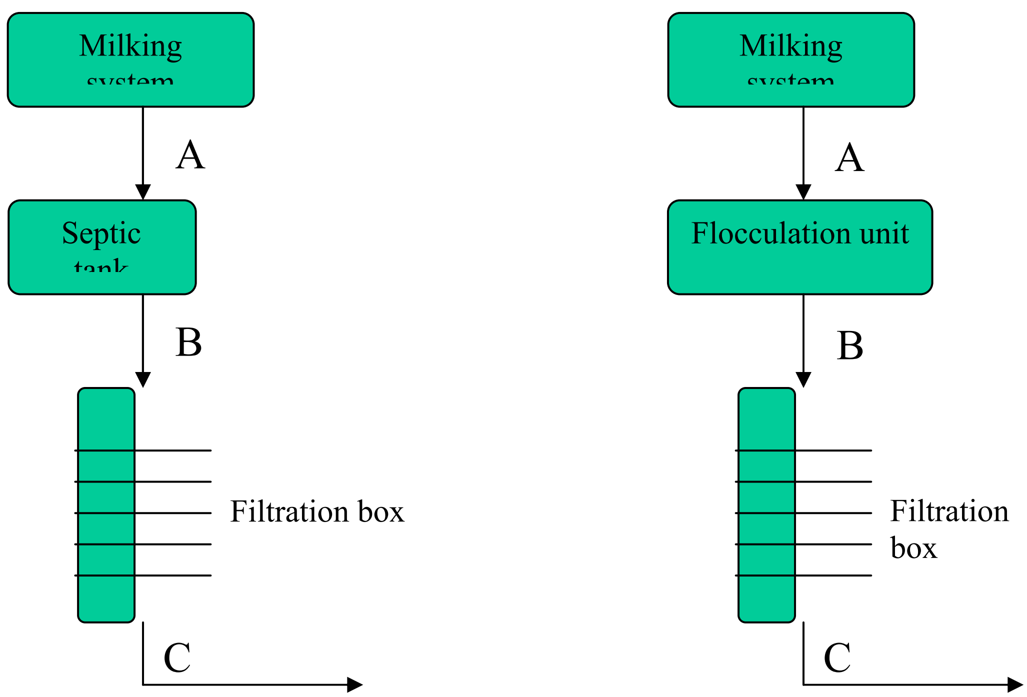
[3] Akay, G., Keskinler, B., Cakich, A., and Danis, U. (1998. Phosphate removal from water by red mud using crossflow microfiltration. *Water Res.*, *32*, 717–726.

[4] Ayoub, G. M., Koopman, B., and Pandya, N. (2001) Iron and aluminum hydroxy (oxide) coated filter media for low- concentration phosphorus removal. *Water Environ. Res.*, 73, 478–485.

lignocellulosics and applying this principle to increase the capacity of the lignocellulosics. The highest rate of phosphorus absorption developed in the laboratory is 24.6 mg/g.

3. Filtration system at Catskill sites

Schematic diagrams for the filtration systems installed at two farms are shown in Figure 2. The farms have a similar milking and cleaning process, which implies that the source of phosphorus is analogous. However, the filtration processes of the farms are conceptually different. At the Stoop farm, the septic tank was installed between the cleaning unit and the filtration box to settle down the particles in wastewater coming into the filtration box. At the Heanings farm, in place of a septic tank, a flocculation unit was installed before the filtration box to reduce the phosphorus content in water drained outside. At both farms, wastewater passing through the filtration box is drained into the farming area. The filtration box was designed at FPL and built by Empire Fibreglass Products, Inc. using fiberglass. This filtration box is the 3rd generation in terms of material. The disadvantages of the first filtration box, which was made of plywood, were heavy weight and distortion of the box by contact with water. The second filtration box, made from plastics, was light but weak. The third filtration box was made of fiberglass. The box has 13 slots where the filter frames are fitted and 10 lignocellulosic filter mats. Figure 3 shows the filtration boxes at both farms.



(a) Stoop farm

(b) Heaning farm

Figure 2. Schematic diagrams for filtration system at farms

(a)

(b)

Figure 3. Filtration boxes and filter frames: (a) Filtration box at Stoop farm; (b) filtration box at Heaning farm.

4. Filter performance at Catskill sites

The isotherms and the kinetics of phosphorus adsorption for MLFM01 and MLFM02 were conducted in batch tests (Figure 4). The isotherms were fitted to the Langmuir isotherm model and the kinetics to a pseudo 2nd kinetic model. In the isotherm tests, the Q_{max} (maximum adsorbate loading onto adsorbent) values of MLFM01 and MLFM02 were 2.18 and 1.32 mg/g, respectively. These results indicate that the sorption capacity for phosphorus of the iron-containing filter medium is slightly higher than that of the aluminum-containing filter medium. In the kinetic experiments, these media had almost identical sorption capacity, around 1.9 mg/g. However, the kinetic behavior of these filter media is totally different. For MLFL01, the kinetic of phosphorus adsorption is relatively fast.

Phosphorus adsorption reaches equilibrium within 2 h. However, phosphorus adsorption of MLFL02 is very slow; equilibrium is barely achieved after 24 h. Such different kinetics of two filter media can affect the results at field sites even though their sorption capacity is similar. However, since this sorption capacity is similar to that of natural inorganic products that have been used for phosphorus removal, the modified lignocellulosic filter media are comparable with other inorganic filter media.[3,5,6] The P-sorption capacities of diverse filters reported in the literature are listed in Table 1.

In the field test, samples were taken at points A, B, and C in whole filtration system (Figure 2). Point A corresponds to the water sample drained from the milking. At points B and C, the sample going into filtration system and the sample coming from the filtration system are collected, respectively.

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[5] Baker, M. J., David, W. B. and Carol, J. P. (1998) Laboratory development of permeable reactive mixtures for the removal of phosphorus in from onsite wastewater disposal system. *Environ. Sci. Technol.* 32(5), 2308–2316.

[6] Brady, N. C. and Weil, R. R. (1999) The Nature and Properties of Soils, 12th ed., Prentice–Hall. Inc.

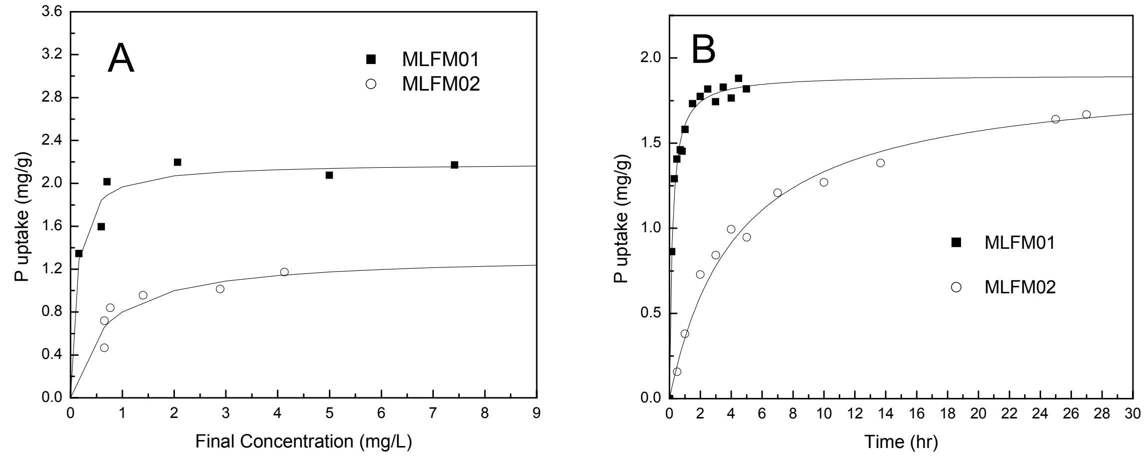

Figure 4. Phosphorus adsorption for MLFM01 and MLFM02: (A) isotherm test, (B) kinetic test.

Table 1. Phosphorus sorption capacity of various filter media

Sorbent	Type	Q_{max} (mg/g)	Source
Kandiustalf	Kaolinite, iron oxides	0.394	Brady et al. (1990)
Matapeake	Chlorite, kaolinite, iron oxides	0.465	Brady et al. (1990)
Tropohumults	Iron and aluminum oxides, kaolinite	2.060	Brady et al. (1990)
Iron and aluminum oxide coated sand	Iron and aluminum oxides	0.011–0.033	Ayoub et al. (2001)
Iron and aluminum oxide coated olivine	Iron and aluminum oxides	0.015–0.035	Ayoub et al. (2001)
Goethite	Iron oxides	1.3[a]	Baker et al. (1998)
AA300G	γ aluminum oxides	2.0[a]	Baker et al. (1998)
C-70	α aluminum oxides	1.0[a]	Baker et al. (1998)

[a] Calculation based on results reported in the literature.

Tables 2 and 3 show the performance of each filter medium. Filter mats containing iron components (MLFM01) were installed at the Heaning farm and filter mats containing aluminum components (MLFM02) at the Stoop farm. Water samples were collected twice a day for 3 days at points B and C because the milking system is cleaned twice a day. On the whole, the filtration system with filter media removes phosphorus whereas the other installed filtration units, such as the septic tank and flocculation unit, apparently do not remove phosphorus. Phosphorus concentrations at point B were almost the same as those at point A, which indicates that the septic tank or flocculation unit between points A and spot B has no effect on the removal of phosphorus from wastewater. The septic tank installed at the Stoop farm seems to have little effective on the removal of inorganic phosphorus. However, the filter media installed in the filtration boxes were efficient in removing phosphorus. At the Stoop farm, MLFL02 removed 41.51% of inlet phosphorus at 59.19 ppm of inlet phosphorus concentration on average, whereas the average removal efficiency of MLFL01 at the Heaning farm was 28.79% at 68.30 ppm of inlet phosphorus concentration.

Table 2. Phosphorus analysis of water samples taken from Stoop farm

Sampling time		Concentration of total phosphorus			Removal efficiency (%)
		Inlet (ppm)	Outlet (ppm)	Delta	
Day 1	a.m.	57.55	34.89	22.65	39.36
	p.m.	57.57	19.87	37.70	65.48
Day 2	a.m.	56.41	31.41	24.99	44.30
	p.m.	59.76	44.02	15.74	26.33
Day 3	a.m.	64.68	42.94	21.73	33.60
Average value		59.19	34.62	24.57	41.51

Table 3. Phosphorus analysis of water samples taken from Heaning farm

Sampling time		Concentration of total phosphorus			Removal Efficiency (%)
		Inlet (ppm)	Outlet (ppm)	Delta	
Day 1	a.m.	62.46	36.27	26.19	41.93
	p.m.	55.32	29.03	26.29	47.52
Day 2	a.m.	65.55	62.54	3.01	4.59
	p.m.	52.37	43.35	9.02	17.22
Day 3	a.m.	105.8	71.98	33.82	31.96
Average value		68.30	48.63	19.66	28.79

B. Environmental Outcomes

1. Biological/physical outcomes

The main goal for 2002 was remediation of phosphate from milkhouse waste. Phosphate detergents are used to clean milking apparatus, and milkhouse wastewater is discharged to watersheds. A common phosphate detergent contains 0.33% or 0.36% phosphorus. However, measured phosphate content can be as high as 9%. Some farms are equipped with a milkhouse wastewater treatment system or systems. This system can be efficient in removing phosphorus; as high as 98% efficiency has been claimed. In addition, the sludge can be used as a soil amendment. However, such a system is time consuming and requires operating funds.

A maximum of about 20 g phosphate from detergent can be discharged in milkhouse waste from an average dairy farm. The next source of phosphate is milk; 8 oz milk contains 247 mg phosphate. In tests of milkhouse wastes, phosphate levels varied from 70 to 100 ppm per 60 gallons discharge [1 gallon = 3.8 L]. In the 350 farms in Catskill/Delaware County, about 4,000 kg/year phosphorus can be traced to milkhouse waste.

Our filtration system can reduce about 30% to 40% of milkhouse-generated phosphorus. The annual rate of phosphorus reduction is expected to be about 1,400 kg/yr, which is 20% of the non-point source pollution from the entire Croton area (6,798 kg/yr). Wastewater treatment plants reduce phosphorus from point sources of pollution. Our filtration system technically reduces phosphorus from non-point sources.

2. Socioeconomic outcomes

The NYC Watersheds Study will affect two or possibly three communities: NYC residents and people living within the watershed areas that supply water to NYC. Support from those within the outlying watershed areas depends on developing a plan mutually beneficial to them and NYC residents. The use of locally grown wood fibers for filtration could provide a new market for forest products. Our study is targeted to utilize low-grade forest products and forest wastes. At present, five New York manufacturing facilities process wood chips and roundwood directly into paper and paperboard. Another facility produces a type of hardboard while processing wood into chips. Although some out-of-state companies utilize sawmill residues and low-grade materials, the closure of a major wood pulping operation in Pennsylvania has meant the loss of a very important market for up to 70,000 tons of wood chips generated annually from lumber production in the Catskill region. There is a growing need to create a more diverse market for new products that can be manufactured economically and efficiently from sawmill residues and other low-grade material.

The entire process of producing filter derived from forest products—fiber selection, fiber processing, chemical modification, mat formation, field tests, and generation of data—will be oriented toward involving the forest products industry in watershed management research.

Our technology will be more cost effective than treating the raw water supply. Application of this innovative technology may be used as a best management practice in watershed management. If our filtration technique proves is accepted by the DEP and DEC, 100% of raw water supply can be filtered using some 30,000 filtration units in the region at a cost of about $60 million, assuming $1,000 per system and another $1,000 for installation and operating expenses for 5 years. This figure is considerably lower than the $6 to $8 billion needed to install a membrane filtration system, and most monies will be returned to the region. Installation and 5-year operation of a filtration system that could serve about 350 dairy farms in the study region is estimated to cost under $1 million. This system would remove approximately 80% of phosphate discharge from milkhouse waste.

Another potential beneficiary could be people of AMD sites. Wayne National Forest is situated in Ohio, and their waste fiber mats can be sold as a commodity to the Catskill area. For now the shipping cost might a burden to the cost of fiber, but the filtration wastes can be shipped to New York for profit and the disposal problem avoided. At present, the quality of Wayne National Forest AMD is not the best; the sulfur level is too high and the aluminum level needs to be higher. We found another site near the Wayne National Forest where AMD composition was much better. The best match would be two neighboring communities, where waste from one could serve as a commodity for the other.

C. Project Growth

Since 1999, several changes have been made to increase the effectiveness of our operation. Two engineering colleges had been involved, but only one university has been retained because of its proximity to the work. Bray Engineering was added as a partner for work in the Catskill/Delaware area. Activity in the Delaware County Soil and Water Conservation District has increased. We expect to involve new communities as our research becomes more visible.

D. Products

Two manuscripts were published[7] and one manuscript was submitted for publication.[8] The fiber selection process, refining process, formation of mats, test procedures for filter capacity, and design of filtration box were accomplished. In the past 2 years, the system has been tested in the Wayne National Forest, the Monroe Street detention pond (Madison, WI), and Lake Stewart (Mount Horeb, WI); new fiberglass boxes were installed in New York and Middleton, Wisconsin.

The team is in the process of simulating the flow vs. the system design. The aim is to simulate the flow numerically and provide information on flow inside the system. The numerical model is based on solving the Reynolds–Averaged Navier–Stokes Equation (RANSE), taking into account the free surface via volume of fluid (VOF) method. We are using a commercial program, STAR–CD, that implements such methods. We will be able to obtain vital information about the flow and size of the filtration system without actually building the system. To date, the predicted flow agrees with the current flow of about 30 gallon/min using an 8- by 4- by 2-ft (2.4- by 1.2- by 0.6-m) filtration box with 12 parallel filters. Plywood, plastic, and fiberglass were assessed as building materials for filtration boxes. Physical strength, degradability, and cost were the main evaluation criteria.

E. Features

The NYC Watershed team at FPL designed a method for using pinyon juniper for filter material. This underutilized species has been effective in removing heavy metals from AMD and subsequently removing phosphates. Our dual goals are to remove water pollution and conserve natural resources.

IV. Challenges and Changes

The socioeconomic dynamics in the Catskill area and NYC is delicate. As is true of most city people in the United States, most NYC residents do not know where their water comes from. There are pros and cons to the three materials (plywood, plastic, and fiberglass) tested as building materials for filtration boxes. The challenge is the design criteria for the box. We are trying to keep the price per box under $1,000, and we may be able to reduce this cost by half.

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[7] Han, J. S. 1999. Stormwater filtration of toxic heavy metal ions using lignocellulosic materials: selection process, fiberization, chemical modification and mat formation. Proceedings of 2nd Interregional Conference on Environ-Water 99, Lausanne, Switzerland. Han, J. S., Park, J. K., and Min, S. H. 2000. Removal of toxic heavy metal ions in runoffs by modified alfalfa and juniper. In Proceedings of 1st World Congress of International Water Association, 3¥7.

[8] Min, S.H., Han, J. S., Shin. E.W. and Park, J.K. Improvement of cadmium ion removal by base treatment of juniper fiber. Submitted for publication in Water Research.

The next challenge is selecting experimental sites. Installation of a filtration box requires an approximately 10- by 5-ft (3- by 1.5-m) piece of land as well as accessibility to the area. Installation of the filtration system requires logistics. A good partnership is essential.

We learned that establishing experimental sites east of the Hudson River–Croton watershed is difficult and we eventually abandoned this possibility. In searching for sites west of the Hudson River, we found that the DEP is very cautious about issuing permits to researchers. In the interest of time, we decided to limit our search to one good experimental site.

Our original plan was remediation of all four categories of water pollution: (1) oil/grease, (2) toxic heavy metals, (3) pesticides/herbicides, and (4) phosphates/nutrients. Our partners suggested that we limit our scope to two pollutants, phosphates and the pathogen *Cryptosporidium*. Because we are not equipped to handle pathogens and the problem with *Cryptosporidium* is seasonal, we decided to focus on phosphates, for which our designated site is suitable for study.

Preliminary investigations indicate that modified wood fibers are potentially effective as sorbents for removing ions and soluble materials from waste streams. Nonetheless, successful demonstration of this technology within the project area will depend to a great extent on the following:

Knowledge of wood chemistry: The design of high capacity and efficient wood fiber filters requires a thorough understanding of the chemistry of cellulose, lignin, and extractives.

Logistics: The research team is represented by people in the Midwest and Northeast regions of the United States.

Identification of demonstration sites: Sites must be located where pollutants are present and the water flow rate can be controlled. An ideal site would be immediately downstream from a wet detention pond.

Regulatory structure: An understanding of the many layers of governmental structure within the project area is necessary to ensure cooperation and assistance for installing and monitoring demonstration sites.

Weather: Storm water flows vary widely, depending on weather conditions and storms. The adverse impact of intensive runoff needs to be considered in filtration system design and location of demonstration sites.

Problems could occur if the demonstration filtration systems are not properly designed and installed; for example, excessive rate of water flow through the filtration box, erosion around the exterior of the box, and leaking of the box. We anticipate that all of these problems can be remedied. Risks can be minimized through careful attention to design parameters for constructing the filtration boxes. Applying a sealant to all joints after installation can prevent leaking.

Successful demonstration of the wood fiber filtration technology does not necessarily imply that this technology can be applied throughout the NYC watersheds. Application will depend on many factors, which are difficult to access accurately at this time. Important factors are legislation to mandate high water quality and funding for installation and maintenance.

The nature of the problem may be difficult to handle politically. Water pollution is caused by small amounts of polluted runoff from many acres of land, owned by different entities and people. We assume that if the public is aware of a low-cost technology for improving water quality, there may be political support to install filtration systems where appropriate. We also assume that improved water quality will benefit the environment as a whole and particularly the biological communities that depend on lakes and rivers. It is essential that local organizations participate in decisions on the siting, operation, and maintenance of the demonstration projects. Local officials will be asked to help monitor the condition of the demonstration project periodically and to inform the project team if there are any signs of problems.

Despite these challenges, the NYC Watershed Study promises to be very beneficial. The concept of storm water filtration is in the embryonic stage, and the application of wood fibers for storm water remediation is versatile. The wood fiber resource is locally available, inexpensive, recyclable, and sustainable.

V. Future Actions and Opportunities

The NYC Watershed team is planning to estimate phosphate loads from farm animals in both dairy and beef farms in 2003. In 2004, we expect to study fertilizers since a better assessment of phosphate pollution will be available. By 2004, we hope to have a good understanding of heavy metal treatment. To date, our method of treating fiber mats at the AMD and reusing them at farms has been well received.

Another possibility of applying lignocellulosic filtration is two-stage filtration. This concept has arisen from the application of ill-designed but highly effective media or the application of highly effective media that produce deleterious side effects. We found a medium that can remove phosphates very effectively but discharges a trace of iron metals. Since lignocellulosic filters can remove iron, we can use this medium and simultaneously remove the discharge. Many ion-exchange resins will discharge sulfur after removing phosphates.

Life-cycle assessment of the filtration boxes will be conducted in the final year of this study (2004). In addition to providing information on the efficacy of the filtration technology, life-cycle assessment will allow us to estimate how much the technology will cost.

Lignocellulosic mats can also be used as filtration media for soil erosion control, generally called geo-textile media. This area is represents a great opportunity. Because of climatic changes, most deserts are expanding at an alarming rate and prevention of desertification has become an international issue. Remediation of desertification using lignocellulosic mats is being discussed between FPL and researchers in China.

VI. Partnership Budget and Costs

The NYC Watersheds Study is a unique research program. Involvement with our partners is rather limited compared with that of other large-scale watershed restoration groups. In our case, the partner’s contribution to the project usually takes the form of technical assistance. We received $10,000 from Northeastern Area State and Private Forestry (Marcus Phelps). Additional funds may be obtained from the Watershed Agricultural Council in 2002 (Brian Fisher/Victor Brunette) if funds from Large-Scale Watershed Restoration Partnerships are not available.

Expenditures, New York City Watersheds Study 2002		
Chemical analysis	205.49	
Shipping	1,090.07	
Equipment	18,329.70	
Chemicals	735.48	
Data processing	2,653.33	
Supplies	13,557.08	
Travel	4,695.80	
Salary	86,733.27	
Total	**128,000.20**	
LSWR, deposit		115,000.00
State and Private Forestry, deposit		5,000.00
Carryover		5,146.00
Total		**125,146.00**
Balance	**-2,854.20**	

Partnership Contacts

Public partners

- **USDA Forest Service Northeastern Area State and Private Forestry—**Albert Todd (410-267-5705), Chesapeake Bay Program Liaison, Annapolis, MD; Marcus Phelps (973-702-7266), Sussex, NJ. Todd and Phelps will serve as the bridge between the New York area EPA, the U.S. Geologic Survey, and various Federal and local organizations.
- **USDA Forest Service, Wayne National Forest, Ohio**—Mike Baines (740-753-0200), Mike Nicklow (740-753-0555), Pam Stachler (740-753-0556). About 300 AMD sites are in the Wayne National Forest. These sites will be an important factor in removal of phosphates.
- **Delaware County Soil and Water Conservation District—**This organization has the highest level of participation in the project. Brian Danforth (607-865-7161), our primary contact and technical collaborator, has been involved in all aspects of work in the Catskill area. This organization works very closely with the Watershed Agricultural Council.
- **EPA—**Links will be established with EPA during the field-testing stage (Phase II), with direct participation in Phase III. Results from Phase II will provide the basis for research proposals.
- **U.S. Geological Survey—**David Owens and Peter Murdock. Owens, a hydraulic engineer, will provide practical advice. Owens previously worked with Han on a detention pond in Madison, WI.

- **NYC Watershed Agricultural Council (WAC), Watershed Forestry Program—**Victor Brunette (replaced Brian Fisher) will coordinate project activities among governmental agencies. He will also help assess economic benefits of using local timber resources as raw material for fiber filters, with emphasis on species with low economic value.
- **NYC Department of Environmental Protection (DEP)—**Regulatory authority for compliance with water quality standards; responsible for implementing 15-year program to protect surface water quality within the project area. John Schwartz (Kinston, NY) is our main contact. Our main contact in Valhalla is Jean Marc Roche.

Academic partners

- **University of Wisconsin–Madison—**James Park, professor of civil and environmental engineering, will work on wastewater treatment with an emphasis on phosphorus removal. Jim works with more than a dozen PhD students who can provide GIS maps and instant information about phosphates. FPL is providing the basic concepts in utilization of fiber, and the students are responsible for implementation.
- **Ècole Polytechnique Federale de Lausanne—**Oliver Jolliet, professor, economic costs and environmental impact of remediation technology. Jolliet will conduct life cycle assessment in 2003.

Private partners

- **Catskill Watershed Corporation (CWC) and WAC—**The CWC facilitates development within the watersheds by issuing permits for remedial measures to reduce pollution in new and existing development. It serves 8 counties and 25 townships in the Catskill Mountains. CWC and WAC will be instrumental in siting the demonstration projects and coordinating communication with landowners and regulatory agencies. Ken Heavey, CWC engineer in the Catskill area, will be the primary contact for filtration sites. Justin Perry, WAC forester, will be the primary forester for utilization of local wood species and processing and fabrication of forest products into the filtration system.
- **Mat, Inc. and Odbek, Inc.—**These companies have been cooperating with FPL for several years in developing nonwoven fiber mats using modified wood fibers. Mat, Inc. is bigger and more experienced in refining and mat formation than is Odbek. Mat has its own refiner and can produce a 152-cm Rando mat. Odbek can produce a 61-cm mat, and Odbek owners are familiar with design, fabrication, and marketing. We anticipate establishing a licensing agreement with Mat or Odbeck for fiber mat production and marketing. We may also explore local production of mats in the greater New York area.
- **Bray Engineering—**Dr. Walter Bray is a professional engineer who works in the Catskill area. His company has been maintaining our filtration system and his engineers have taken samples. The partnership between Bray Engineering and FPL was formalized in 2001. Bray Engineering hires local people and promotes the filtration system. We hope to establish more sites in the Catskills next spring and to save money by letting Bray install the system. One problem Bray is trying to resolve is running the system during the winter. So far, the system has had to be closed during the winter because the water freezes. The company is a potential candidate for technology transfer.
- **Stoop and Heanning Farms—**These dairy farms are our most important private partners. The water filtration systems are located on their lands.

Summary

The past 3 years of the New York City Watersheds Study can be summarized as follows:

1) General NYC Watersheds operational principles and water pollution problems were learned. The main target pollutant is phosphorous. The source of pollutants consists of farms. Removal of phosphorous is accomplished by building wastewater treatment plants.

2) FPL installed two filtration systems at the Delaware County area farms. Our data indicate that about 4,000 kg/year phosphorous can be traced to milkhouse waste; at a 40% filtration rate, the discharge rate can be reduced to 2,600 kg/year.

3) Filtration boxes were built at the FPL using plywood, polypropylene, and fiberglass. Fiberglass was determined to be the best material for filtration boxes.

4) Filter frames were built using aluminum, plastics, and stainless steel. Because of the pH of the water, which is usually low, we learned that stainless steel frames should be used. The same logic should be applied to screens.

5) Lignocellulosic filter—Only juniper was used in this experiment. Juniper was refined, chemically modified (base treatment), made into a Rando mat, exposed at the Wayne National Forest AMD site, and installed at the Delaware County sites. Some locally grown trees (red maple, eastern hemlock, and tulip poplar) were tested, but most locally grown trees have high contents of phosphorous. In view of this, as well as the costs associated with debarking and transportation, we concluded that juniper is the best candidate in terms of chemical composition and cost. Juniper has a soft and thin bark, which can be refined with the woody material. Juniper also has an agreeable odor. Thus, mats exposed for a long time in polluted water do not have a foul odor.

Future Plans

- Chemical modification based on pressure treatment will be tested on juniper mats. Slags, mesoporous, or AMDP will be incorporated into lignocellulosic mats by injection or by adding them into the middle layer of the mat.
- Hydraulic simulation of filtration boxes will be updated and results will be compared with actual flow, with the help of Prof. Choi.
- To date, we've had to dismantle the filtration boxes for the winter. Tim Bray is working on winterizing the boxes; his plan may be activated if FPL receives 2003 funds before winter weather sets in. Otherwise, winterizing will have to be postponed until next year.
- Another set of chemically modified juniper chips are to be made into mats.
- Filtration capacity needs to be estimated. Four sets of samples were taken in 2002 at approximately 2-month intervals and the filters are still holding. The capacity of the system at the Stoop farm was exceeded in September. We hope to know the effect of the septic tank in the coming months. The capacity of the filters will be measured by varying the number of filters.
- We will be exploring additional sites in 2003.

- It would be favorable to move test sites to east of the Hudson. However, without commitment of funds from the Washington Office, moving the sites would drain funds and staff power.