Fostering the Acceptance, Use, and Management of Nutrient-Reducing Septic System Technologies in Upstate New York

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Owasco Lake, Photo courtesy of Bill Hecht

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I. Introduction

Blue-green algal blooms, fueled by warm weather and an excess of nutrients (phosphorus and nitrogen) in freshwater bodies (lakes, rivers, and streams), have been tied to serious environmental and human impacts such as fish kills, beach closures, contaminated drinking water, and pet deaths. Managing excessive nutrient loading from nonpoint source pollution such as stormwater and fertilizer runoff, atmospheric deposition, soil erosion, and septic systems is imperative in controlling blue-green algal blooms.

Although there has been significant progress in the acceptance, use, and management of nitrogen-reducing septic systems, the current state of phosphorus removal septic systems in the US is in its infancy, with only a few technologies that are currently commercially available. Coastal Wastewater Solutions, LLC was contracted by The Nature Conservancy to provide a review of the current state of phosphorus removal in septic systems and provide recommendations of technologies that could potentially be evaluated in a future phosphorus-reducing septic system demonstration program to assist in the advancement of these initiatives.

II. The Importance of Dual Nutrient Management (Nitrogen and Phosphorus)

Historically, excessive phosphorus loading has been attributed to blue-green algae blooms (cyanobacteria) in fresh waterbodies. The toxin microcystin is the most common and serious toxin produced by cyanobacteria. According to New York State Department of Health, exposure to high levels of these toxins can cause stomach sicknesses such as diarrhea, nausea, or vomiting in addition to skin and respiratory irritation in humans. Consuming water containing microcystin has also been tied to the deaths of pets, wildlife, and livestock (Falconer and Humpage, 2005).

Although phosphorus may be the limiting nutrient when it comes to the formation of blue-green algae blooms, recent studies have shown that cyanobacteria in some algal blooms are so rich in phosphorus that nitrate is fueling excessive toxicity and enhancing the life span of these blooms. This data is causing scientists to stress the importance of managing both nitrogen and phosphorus loading to significantly impaired fresh waterbodies that are plagued by frequent blue-green algae blooms.

III. Phosphorus Removal in Conventional Septic Systems

Phosphorus removal in a conventional septic system begins inside the septic tank where phosphorus may be contained and trapped in the sludge that settles to the bottom of the septic tank and in the scum that floats to the top of the tank. It is estimated that this represents an approximately six percent (6 %) reduction of phosphorus in the effluent that is ultimately dispersed to the leaching structure. The amount of phosphorus leaving a conventional septic tank tends to range from 9 – 16 mg/L (Loomis and Kalen, 2014; Richards et al. 2016). Therefore, most of the removal of phosphorus in conventional septic systems occurs through adsorption and precipitation reactions which occur in the soils beneath the leaching structure.

Adsorption involves the binding of phosphorus to soil minerals such as iron, calcium, manganese, and aluminum. The ability of phosphorus adsorption in the soil is limited and can reach a fixed capacity. This capacity can be expanded by utilizing larger leaching footprints and distributing effluent higher in the soil profile where more of these minerals occur and where more soil organic matter is present. However, adsorption is not a permanent solution to removing phosphorus from wastewater as phosphorus can eventually be desorbed and leach through the soils into ground and surface waters.

Precipitation of phosphorus in the soil occurs when phosphorus reacts with the soil minerals mentioned above. However, during precipitation, this reaction causes the formation of a separate and solid mineral, the formation of a three-dimensional solid-phase arrangement of molecules from the solution phase. Precipitation is a more sustainable process if sufficient minerals are present in the soil. In addition, there needs to be adequate vertical and horizontal separation distances between impervious soils, seasonal high groundwater table, and surface waters. Septic regulations are designed to assure these processes occur, as it is within these unsaturated soils where precipitation occurs and where insoluble phosphorus and soil mineral complexes can form, thereby removing P from septic effluent (Amador and Loomis, 2018). In situations where adequate separation is not possible, it becomes more likely that phosphorus will not adsorb or precipitate and will remain in solution or be released back into the soil by the process of mineralization.

Based on these processes, many soil treatment areas can adequately manage phosphorus movement. The shallower the soil treatment area placement, then the more effective the P treatment potential, as P removal decreases with soil depth. However, in areas near water bodies, such as in the Owasco Lake Watershed, advanced phosphorus management methods may be necessary to successfully limit phosphorus loading from conventional septic systems.

Key Facts about Phosphorus and Soil

- When soil treatment areas (soil absorption fields) are kept shallow, the vegetative cover root system can penetrate and take up some of the phosphorus and nitrogen through biological processes and result in the formation of plant top growth during the growing season.
- P can be removed by the microbial community living in the soil treatment area by uptake and microbial biomass accumulation. This P can be released when organisms die and P is released through the mineralization process. This released P can be adsorbed by soil or leach to the water table.
- Soils low in aluminum and iron oxides typically remove only a small fraction of the P introduced from onsite wastewater.
- The calcium content of sand is the best predictor of P removal. However, in order for calcium to remove P the soil solution needs to be fairly alkaline.
- Utilizing pressurized shallow drainfields (PSDs) in silty and loamy soils containing naturally occurring Fe and Al oxides can remove over 90% of P inputs.
- Soils high in clay and silt content have been shown to remove 90% of phosphorus at a depth of 100 cm
- Sandy and gravelly soils move wastewater quickly but have limited iron, aluminum, and manganese soil particle coatings useful in P adsorption and precipitation.
- Using advanced treatment technologies and maximizing travel time through the soil -(through either using time dosing or flow modulation) a clean-water septic system is the best way to ensure maximum N and P removal.
- The amount of phosphorus leaving a conventional septic tank tends to range from 9 – 16 mg/L. Currently, phosphorus-treating septic systems are expected to reach phosphorus concentrations of 1 mg/L or less. This represents the removal of approximately 90 % of phosphorus from the waste stream.

IV. Treatment Processes to Remove Phosphorus from Wastewater

The state of phosphorus removal septic system technologies in the United States is in its infancy. However, it is more common in municipal wastewater treatment facilities. The phosphorus treatment processes can be broken down into two main categories: (1) Chemical Treatment; and (2) Enhanced Biological Phosphorus Removal (EBPR). Phosphorus removing Septic Systems either utilize one of these processes or a hybrid approach of the two.

Phosphorus Removal through Chemical Treatment

There are two common types of chemical methods to manage and remove phosphorus in wastewater: (1) Precipitation; and (2) Adsorption.

Precipitation typically consists of metal salts reacting with soluble phosphate in wastewater, producing a solid precipitate which then settles into the sludge either through chemical dosing or ion exchange processes.

The following metal salts are often used in this treatment process:

- Aluminum sulfate (alum)
- Sodium aluminate
- Ferric chloride
- Ferric sulfate
- Ferrous chloride

Chemical dosing is not seen as a feasible solution in small-scale residential uses due to the need for ongoing operational and maintenance needs. Chemical dosing typically increases the amount of sludge by 40% in a conventional configuration and 20% when following an anaerobic treatment process.

Ion exchange is another type of chemical precipitation process that is more suited for onsite septic systems. Ion exchange processes can be used to remove phosphorus by utilizing electrodes that release ferric ions that react with the phosphate ions in the wastewater. This process also produces solid precipitate which produces additional sludge. This process can be used following a nitrogen-removing septic system, making it a suitable hybrid process to treat for both nitrogen and phosphorus in septic systems.

Another chemical process that can be applied to small-scale septic systems is the use of absorptive media. Typically this media contains either calcium or iron and similar to chemical dosing, the soluble phosphate reacts with the iron or calcium in the filtration media. Current research indicates this could be an effective method to control total phosphorus (TP) below 1 mg/L. However, there are concerns regarding wastewater pH and unknown longevity of the media, both concerns would need to be further evaluated.

Phosphorus Removal through Enhanced Biological Phosphorus Removal (EBPR)

The EBPR process uses an activated sludge process (aerobic process) to facilitate the growth of phosphorus-accumulating organisms (PAOs). PAOs reproduce under aerobic conditions, where they consume phosphates. Solids that accumulate in the aerobic chamber are recirculated back to the septic (anoxic) compartment where the PAOs can consume volatile fatty acids, creating energy and preparing the PAOs for another EBPR cycle.

A limitation with EBPR in septic tanks is that there is a high concentration of organic nitrogen in household wastewater, and during the aerobic process, nitrifying bacteria are more common and can often outcompete PAOs as the prevailing bacteria, thereby limiting the desired production of a robust and necessary population of PAOs. PAOs are also more reliant on pH than nitrifying bacteria, making this process difficult to achieve in onsite septic systems.

V. Potential Technologies for Demonstration in Cayuga County

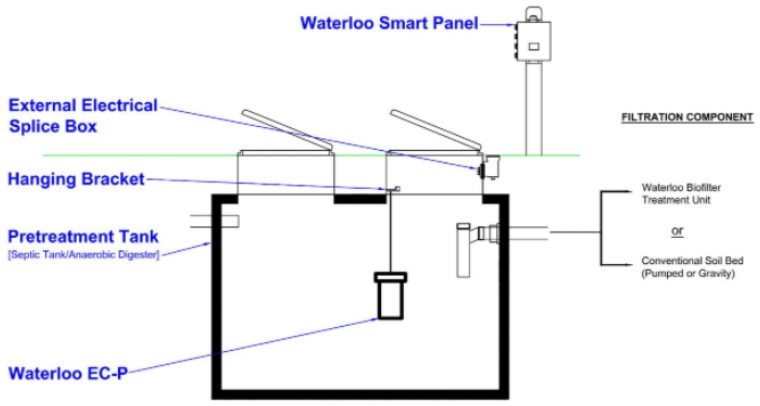
Commercially Available Technologies

Based upon the phosphorus treatment processes outlined above, Coastal Wastewater Solutions has completed a review of existing and emerging phosphorus removal septic system technologies and has identified the systems below as warranting further evaluation through a potential demonstration project in Cayuga County. The information provided for each of these technologies was obtained from the manufacturer either through email, conversation, or taken from their website. All systems included below are reportedly capable of reducing TP to less than 1 mg/L. The technology cost estimates listed are approximate and are subject to change with supply chain issues and specific material costs.

1. Waterloo EC-P™ by Waterloo Bio-Filter

Waterloo Biofilter Systems Inc. is a Canadian-owned and operated company that develops, designs, manufactures, and maintains advanced onsite wastewater treatment systems. They developed the Waterloo Bio-Filter which is a packed bed media filter technology that has NSF 40 (BOD and TSS removal) and 245 (nitrogen removal) certifications depending on the configuration.

Waterloo has recently developed the EC-P patent-pending technology for phosphorus removal from onsite wastewater. The EC-P system utilizes an ion exchange process to remove phosphorus. In this process, natural iron electrodes are installed in the septic tank, or in a small chamber immediately thereafter, and a small current is applied to the electrodes. The iron emitted from the electrodes is dissolved into the wastewater where it reacts with phosphorus to form highly stable and insoluble iron-phosphate minerals. The Waterloo EC-P effluent is then passed through a filtration component, such as a Waterloo Biofilter treatment unit or conventional leach field or sand filter, where the iron-phosphate minerals precipitate out preventing phosphorus from reaching the natural environment. Waterloo estimates approximately 99% phosphorus removal from the EC-P and has 15 - 20 units installed (or in the process of being installed) in Manitoba, Ontario, and Barnstable County, Massachusetts. The cost of the EC-P is estimated to be $4,500 and is recommended to be installed following pretreatment.



2. CRX-II by FujiClean

FujiClean is a Japanese-owned and operated company that develops, designs, manufactures, and maintains advanced onsite wastewater treatment systems. Although relatively new to the United States, FujiClean is the world's largest manufacturer of P reducing Septic Systems with over 2 million systems installed and operated worldwide. The Fujiclean CEN (nitrogen reduction model) is the most popular system on Long Island with over 1,200 systems installed or pending installation.

The Fuji Clean CRX-II system integrates iron electrolysis into its standard denitrification treatment process to simultaneously maximize the reduction of both nitrogen and phosphorus nutrients as well as BOD and TSS. Treatment is accomplished in a continuous flow process through a 3-chambered tank sized according to hydraulic flow and organic strength. The entire process is driven by air flowing from one small linear diaphragm blower positioned external to the treatment tank. The CRX series is new to the United States and participation in a Cayuga County Demonstration Program would represent one of the first combined modular nitrogen and phosphorus removal septic systems installed in the US. The material cost is estimated to be around $18,000.

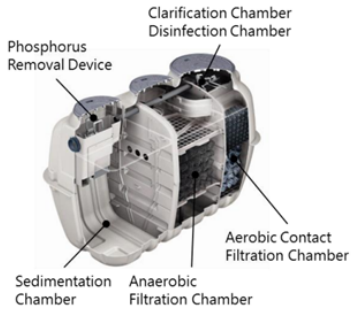


Fig. 1 Structure of CRX Ⅱ model

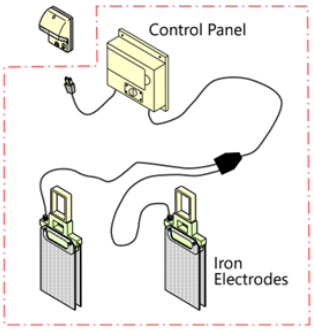


Fig. 2 Phosphorus removal device

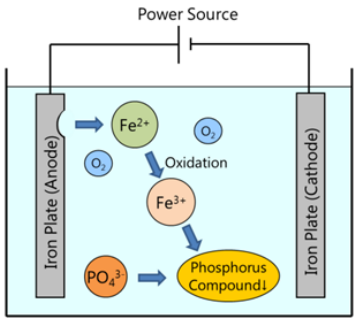
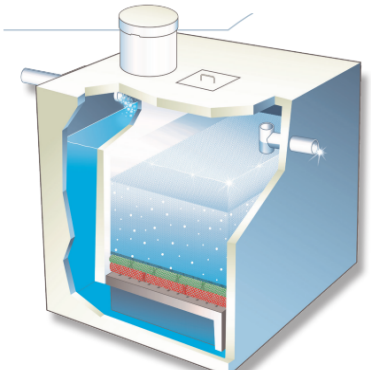


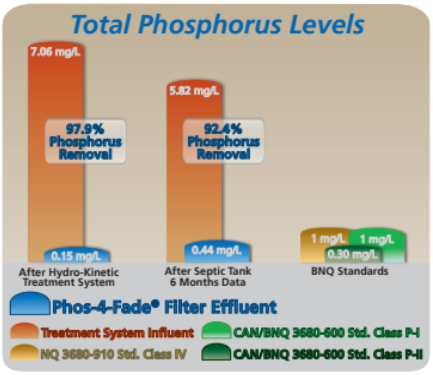
Fig. 3 Process of phosphorus removal

3. Phos-4-Fade™ by Norweco

Norwalk Wastewater Equipment Company (Norweco) is a manufacturer of water and wastewater treatment products, systems, and chemicals. Norweco's residential product line includes the Singulair system which is certified to NSF Standard 40, the Singulair TNT which is certified to NSF Standard 245, and the Hydro-Kinetic system which is certified to NSF Standards 40 & 245.

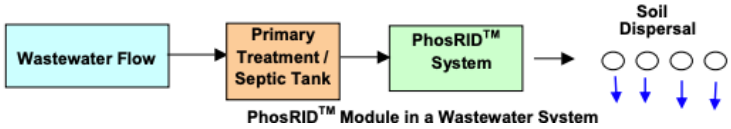
The Phos-4-Fade phosphorus removal filter is a patented, non-mechanical component that employs proprietary adsorptive media to reduce total phosphorus in the effluent. Flow enters the inlet chamber of the Phos-4- Fade filter where it then moves downward and passes into the media chamber through an array of transfer ports. Media support channels direct flow beneath the media where evenly spaced apertures provide uniform dispersal of the flow. Progressively sized layers of primary filtration media further distribute the flow to the adsorptive media layer. As the flow passes through the adsorptive media, final polishing takes place as phosphorus adheres to the porous media surfaces. There are approximately 300 Phos-4-Fade systems installed throughout the Northeast US and Canada. The cost of the Phos-4-Fade system materials is estimated to be $21,000 and is recommended to be installed following pretreatment but may also be installed following a conventional septic tank. The Phos-4-Fade technology is not commercially available in Cayuga County at this time, though Norweco is currently working to establish a local distributor to make this technology available.



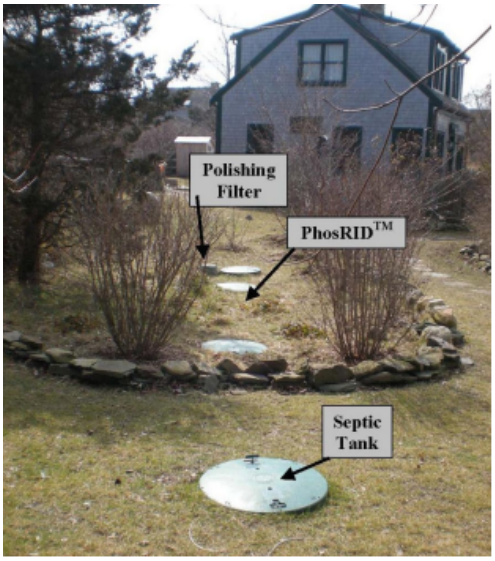


4. PhosRID by Lombardo Associates

The PhosRID systems utilizes a passive upflow filter with reductive iron dissolution media to reduce total phosphorus. The filter can follow either an advanced treatment system or a standard conventional septic system. Wastewater effluent flows from the septic tank into the PhosRID upflow filter and the final treated effluent is then conveyed to the leaching field for final treatment and dispersal.



PhosRID™ Module in a Wastewater System

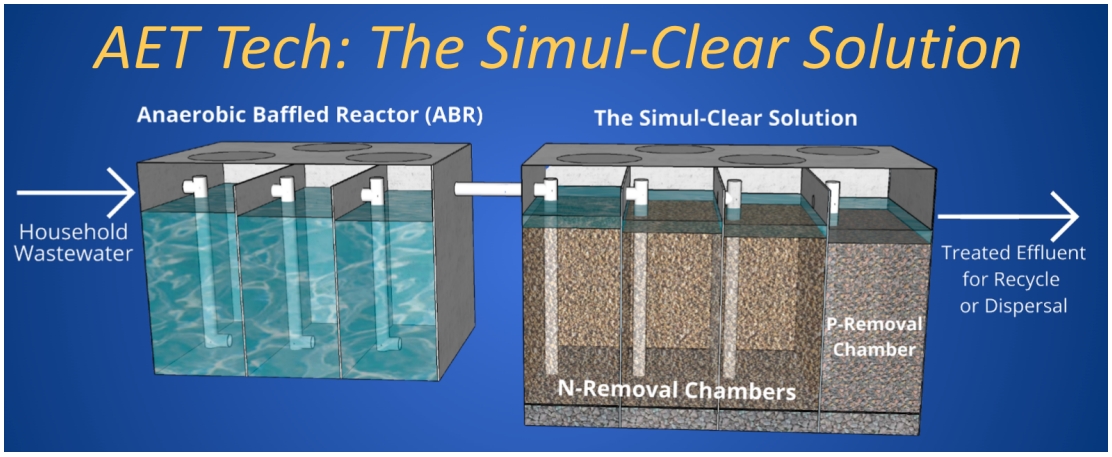


Technologies Showing Promise but are Not Commercially Available

1. The Simu-Clear Solution by AET Tech.

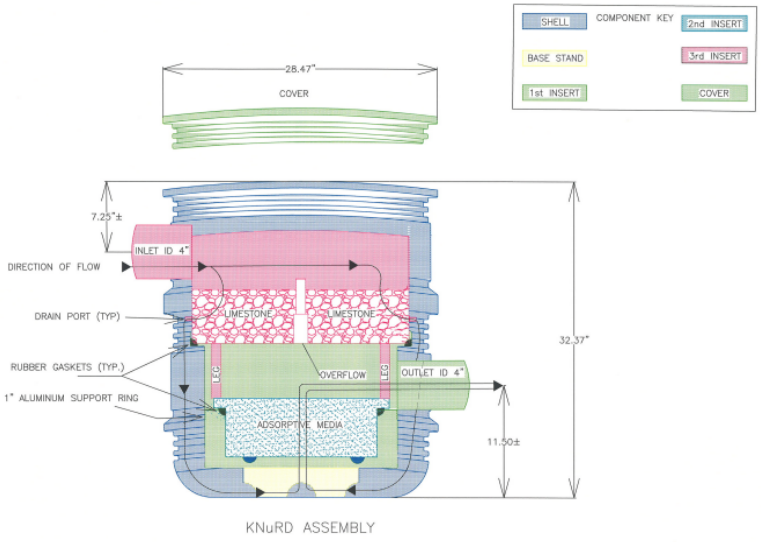
The Simul-Clear Solution is a new technology created for the complete removal of Nitrogen and Phosphorus from onsite wastewater. In Simul-Clear, The New-Clear Solution for nitrogen removal is followed by a post-filter containing reactive media that retains phosphorus by adsorption. The post-filter is housed in a polypropylene tank with a small 44-ft3 footprint and is designed to retain greater than 90% of wastewater phosphorus for at least 3 years.

The Simul-Clear Solution employs two reactive media platforms for phosphorus removal: surfactant modified zeolite (SZ) and activated alumina (AA). Phosphorus filter design will employ one or a combination of SZ/AA media as determined by site and wastewater characteristics, opportunities for nutrient recycling, and spent media management options. SZ and AA media are both commercially available with reliable suppliers and supply chains. The Simul-Clear design provides for ready replacement of phosphorus media with the starting or alternative media formulations, or with new phosphorus retention media that may emerge. The unit cost is estimated to be around $15,000 which includes the nitrogen and phosphorus removal tanks and media. The Simu-Clear Solution technology is currently under research and development by the manufacturer not commercially available in Cayuga County at this time.



2. <u>The KNuRD Phosphorus Removal Filter by Knight Treatment Systems, Inc.</u>

The KNuRD phosphorus removal filter is designed as an upflow polishing filter intended to follow an ATU or other type of pretreatment. The filter contains reactive media that retains phosphorus by adsorption. The filter may be housed in a small polypropylene or fiberglass basin and, depending upon loading. The phosphorus filter is non-mechanical, operationally passive, and requires no energy.



KNuRD ASSEMBLY

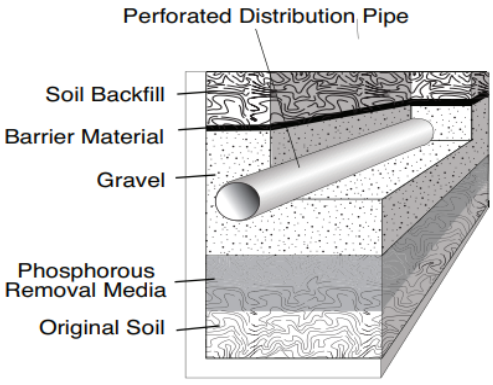
The KNuRD unit cost is estimated to be around $5,000 for a standard 4-bedroom home configuration. The KNuRD phosphorus filter is <u>currently under research and development by the manufacturer and</u> not commercially available in Cayuga County at this time.

Although the above-mentioned technologies show promise, once P removal is required in sensitive watersheds and market demands increase, commercial availability could possibly occur.

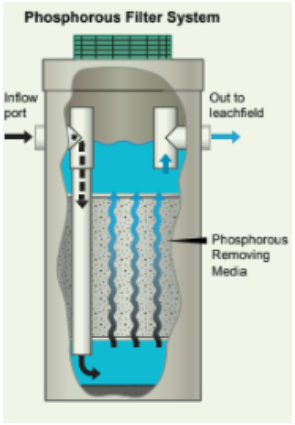
VI. Phosphorus Removal from Augmented Systems

Several media, both proprietary and non-proprietary have been suggested for use in drainfield trenches to capture phosphorus. An approved leachfield configuration would be proposed to be augmented with a phosphorus removal medium, typically added at the leachfield bottom where the excavation meets native soil. A suitable medium must have a high capacity to immobilize phosphorus and sufficient permeability. Since it will eventually need to be replaced it should have as long a lifespan as possible or be designed in a way where the media could routinely be inspected, maintained, and replaced as needed.

An alternate design configuration could utilize this media in a separate tank as an upflow polishing filter prior to the distribution box similar to several of the proprietary units discussed above. This would make the media more accessible for inspection, sampling, and replacement and is the recommended approach for new technologies until there is a statistically significant dataset on the feasibility and longevity of such media.



National Environmental Services Center, Pipeline Newsletter Vol 24, No. 1, 2013



Sample up flow filter configuration (TNC)

There are several companies that manufacture material that could be implemented in a passive up flow filter configuration. Additional research, development, and piloting is needed before a commercially available phosphorus-removing onsite wastewater filter can be commercially available. However, this technology could a feasible solution if manufacturers could develop a passive and low maintenance up flow filter that would last 3 years and costs less than $5,000 to install. Costal Wastewater Solutions, LLC has been in contact with the following companies that manufacturer phosphorus-removing media:

1. Abtech Industries – Smart Sponge

Contact Information:

Michael Creeden, East Coast Regional Manager
Abtech Industries
mcreeden@abtechindustries.com
(602) 418-2200
www.abtechindustries.com

2. MetaMateria – PO4 Sponge

Contact Information:

Dr. Richard Schorr, CEO
jrschorr@metamateria.com
MetaMateria, PO4 Sponge
614-340-1690 (x102)
614-599-0939 (mobile)
870 Kaderly Drive Columbus, OH 43228
http://www.metamateria.com/
PowerPoint on PO4 Sponge

VII. Maintenance Requirements for Nutrient Removing Septic Systems

The New York State Department of Health (NYDOH) requires that local health departments or their designee develop a management program to regulate the approval and management of Enhanced Treatment Units (ETUs). NYSDOH asks that the management program evaluate and consider the following aspects of septic system management:

- Define program goals and requirements.
- Educate engineers, contractors, and the public on IA OWTS and Codes
- Oversee site evaluation, design, construction, and maintenance.
- Provide system tracking, maintenance verification and record-keeping.
- Confirm the availability of service providers for approved technologies to assure adequate authority, enforcement, and compliance incentives.

Routine maintenance is key to the longevity and function of all septic systems. Systems with P reducing technology are no different and must be maintained in accordance with manufacturer requirements to meet their intended performance goals.

Typically, the billing for the first few years of maintenance is included in the cost of system materials. This is usually done to ensure that the system is maintained during the initial system warranty period.

After this initial period, the property owner is responsible for paying between $200 - 400 per year for a service agreement that covers two non-emergency maintenance visits per year in which the service provider typically provides the following services:

- Measure scum and sludge levels in system tank(s) and recommend pumping as needed.
- Check floats, controls, and alarms.
- Measure and adjust recirculation rates, depending on the technology.
- Measure and adjust the airflow through the system, depending on the technology.
- Check system electrical panel box for damage/wetness.
- Clean all submerged pumps.
- Change the air filter in aerators and blowers.
- Check and clean treatment media surfaces as needed.
- Check the pump system and flush out any pressurized drainfield piping components that may exist.

VIII. Operating Costs of Advanced Treatment Systems

In addition to routine maintenance, there are operational costs such as electricity and repair/replacement costs for these septic systems. The estimates below are based on actual Long Island prices and represent costs and requirements for nitrogen-reducing septic systems. Due to the limited dataset of phosphorus-removing septic systems in the United States, and the potential for additional sludge accumulation and pumping from phosphorus systems, the costs will need to be refined with actual data obtained through the demonstration program.

Approximate Repair and Replacement Costs*

Item	Cost	Life Expectancy
Routine Pumping	$200 - 300.00	approx. every 5 years
Blower / Aerator Replacement	$450.00	10 years
Blower / Aerator Rebuild	$150.00	10 years
Float Replacement	$100.00	5 - 10 years
Recirculation Pump Replacement	$700.00	10 years

** It is important to note that the complete replacement of a control panel is very rare and usually associated with lightning strikes or power surges. The typical control panel cost is $1,200 if it needs to be replaced. Costs are based on information provided by manufacturers participating in the NYS Septic System Replacement Program on Long Island and may vary for the Finger Lakes Region.*

Components of each Technology (includes N and P components)

Technology	Blower or Aerator	Floats	Recirculation Pump	Control Panel	Media Needs to be replaced
Waterloo EC-P™ & Waterloo Bio-Filter	✗	✓	✓	✓	✗
FujiClean CRX-II	✓	✓	✗	✓	✗
Phos-4-Fade™ by Norweco	✗	✗	✗	✗	✓
PhosRID by Lombardo Associates	✗	✗	✗	✗	✓
Norweco Hydrokinetic NSF 245 System	✓	✓	✓	✓	✗
Simul-Clear Solution by AET Tech	✗	✗	✗	✗	✓
KNuRD Filter by Knight Treatment Systems	✗	✗	✗	✗	✓

IX. Summary Recommendations and Next Steps

A holistic approach is currently needed to address the nutrient pollution affecting waterbodies in Cayuga County and this approach should include the evaluation of both advanced nitrogen and phosphorus removal from onsite wastewater sources. Although this approach is needed now, the current state of phosphorus removal septic systems in the US is in its infancy, with only a few technologies that are currently commercially available. However, there are many technologies that are being developed and tested but there is currently no standardized evaluation processes or performance standards for phosphorus-removing septic systems in the US. However, recent DEC investment into the New York State Center for Clean Water Technology (NYS CCWT) can help to expedite the R&D and piloting of technologies.

It is also important to note that New York is not alone in the need for phosphorus removing septic systems, and there is an opportunity to build on and partner with other jurisdictions on their research and demonstration efforts. Specifically, the Massachusetts Alternative Septic System Test Center (MASSTC) on Cape Cod is currently researching and piloting commercially available phosphorus-removing technologies. In order to streamline the state of phosphorus removal systems locally, it may be beneficial for Cayuga County and CCWT to partner with MASSTC to pilot technologies that are proving successful in Massachusetts locally in Cayuga County. In addition, the County could issue a Request for Expression of Interest to solicit manufacturer participation in a phosphorus-removing septic system demonstration program.

REFERENCES CITED

Amador. J. A. and G. W. Loomis. 2018. Soil-based Wastewater Treatment. Soil Science Society of America, Madison, WI. 368pp

Falconer, I.R. and A.R. Humpage. 2005. Health risk assessment of cyanobacterial (blue-green algal) toxins in drinking water. Int. J. Environ. Res. Public Health2:43-50. doi:10.3390/ijerph2005010043

Loomis, G. and D. Kalen. 2014. Characterization of septic tank effluent from coastal residences. Proceedings of the Soil Science Society of America Onsite Wastewater Conference. Albuquerque, NM. p. 279-290.

Richards, S., P.J.A. Withers, E. Paterson, C.W. McRoberts, and M. Stutter. 2016. Temporal variability in domestic point source discharges and their associated impact on receiving waters. Sci. Total Environ. 571: 1275-1283. doi:10.1016/j.scitotenv.2016.07.166.