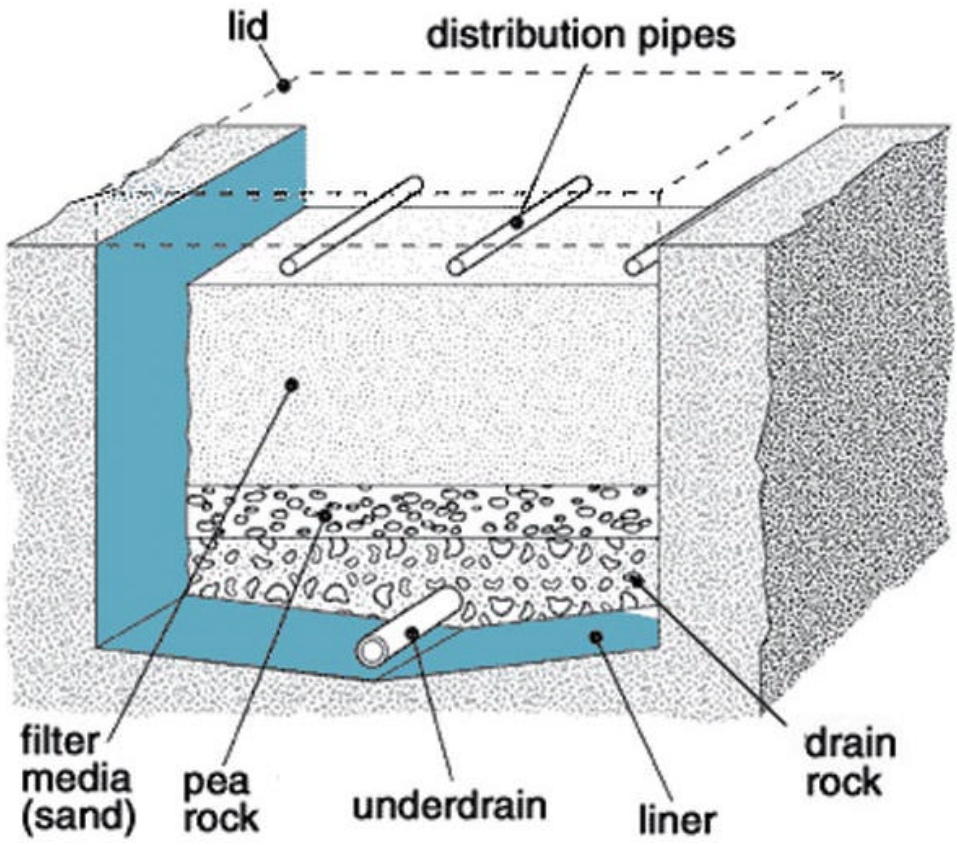
National Decentralized Water Resources Capacity Development Project

Executive Summary



Micro-Scale Evaluation of Phosphorus Management: Alternative Wastewater Systems Evaluation

Submitted by Stone Environmental, Inc.
Montpelier, Vermont

June 2005

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National Decentralized Water Resources Capacity Development Project (NDWRCDP) Research Project

Final Report, **June 2005**

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EXECUTIVE SUMMARY

Understanding and reducing sources of phosphorus pollution in the landscape includes evaluating and minimizing the phosphorus contribution from onsite systems to surface waters. Many phosphorus-management methods have been developed and tested for use in decentralized wastewater treatment. This project gathered information about the application, performance, cost-effectiveness, and other factors associated with each method.

A range of phosphorus-management approaches was investigated:

- **Source reduction.** Source reduction prevents phosphorus from entering wastewater streams by reducing or eliminating its use in domestic products and by reducing the amount of kitchen waste in wastewater. Source reduction results in wastewater that contains little more phosphorus than that from urine and feces.

- **Source diversion.** Two-thirds or more of the phosphorus in domestic wastewater is contained in the blackwater, and about two-thirds of the phosphorus in the blackwater is in the urine. Therefore, roughly 50% of the phosphorus generated in the home is in the urine. Collecting urine and/or feces separately, with no water or very small amounts of flush water, makes it possible to transport them cost-effectively for treatment in a less-sensitive environment or to recycle them to agriculture.

- **Precipitation in the septic tank.** If septic tank sludge is a significant sink for phosphorus, perhaps the removal potential in septic tanks could be improved.

- **Post-septic tank treatment.** A wide range of phosphorus-removal methods applied to septic tank effluent was investigated, including small-scale chemical precipitation, sequencing batch reactors, packed-bed filters, constructed wetlands, and other biotic methods.

- **Design of the soil absorption system (SAS).** Phosphorus uptake can be enhanced in the trenches or beds themselves and in the soil underneath.

- **Biotic sequestration.** Biotic sequestration spans both post-septic tank treatment and the soil absorption system. A separate investigation was made of biotic sequestration methods using other organisms than the microbial communities that naturally arise in activated sludge or attached growth secondary treatment.

Method

Representative methods in the categories identified above were identified through literature searches, conversations with practitioners, and consultation with the National Decentralized Water Resources Capacity Development Project (NDWRCDP). The most important criteria for evaluating the methods were identified as:

- Proven track record
- Phosphorus-management capability
- Cost
- System robustness
- Phosphorus-recycling capability
- Maintenance requirements
- Familiarity to the user

The seven criteria were weighted, with the highest weights awarded to cost, phosphorus-management capability, and proven track record. Each of the methods evaluated was individually scored on a scale of one to five for each of the seven criteria on this list, with five being the best. The weighted average of the scores for all criteria was then calculated for each phosphorus-management method, with 5.8 being the highest possible weighted average. The scoring was conducted transparently, with a mixture of objective measures and professional judgement. Objective measures were used for phosphorus-management capability, cost, and maintenance. All the methods were ranked according to their weighted average scores to determine the most promising phosphorus-management methods overall.

Results

Twenty-three phosphorus-management methods were evaluated (see Table 3-1). All methods were initially ranked by their overall weighted average scores. Of all the criteria used, the least amount of data was found about phosphorus-recycling capability. To anchor the evaluations more firmly in available data, the phosphorus-recycling capability was excluded from the weighted average score. The most promising phosphorus-management methods are listed in Table ES-1.

A sensitivity analysis was performed by removing each of the evaluation criteria in turn from the average score. All of the additional methods that made it into the top ten when various criteria were excluded from consideration ranked just below the top ten listed in Table ES-1; thus, the ranking is reasonably robust.

Methods that use the soil absorption system comprise five of the top ten methods. All three source-reduction strategies are among the most promising methods for phosphorus management, showing that a method does not have to eliminate large amounts of phosphorus from the waste stream to be a top scorer if it excels with respect to other criteria. Microflush toilets enable diversion of around 75% of the phosphorus in domestic wastewater to holding tanks, from which

it may be treated in municipal plants or recycled in agriculture. Although lightweight aggregates were the only post-septic tank medium to rank among the most promising methods, two other methods—basic oxygen furnace (BOF) slag and PhosRid™ —show excellent potential.

Table ES-1
Most Promising Phosphorus-Management Methods Ranked by Weighted Average Score (excluding phosphorus recycling capability)

Rank	Method	Weighted Average Score Excluding P Recycling Capability
1	Comprehensive site assessment	5.3
2	Design of long, narrow trenches	5.3
3	Limestone as SAS medium	5.1
4	Phosphorus-free laundry detergent	4.9
5	Phosphorus-free dishwasher detergent	4.9
6	Shallow SAS	4.8
7	Eliminate garbage disposal	4.7
8	Lightweight aggregates	4.6
9	Microflush toilet	4.6
10	Tire chips as SAS medium	4.5

Contribution to Knowledge Base

This project collects and reviews representative portions of state-of-the-art phosphorus-management methods for decentralized wastewater systems. The approach documents the potential for phosphorus removal, reduction, and recycling, from before the beginning of the pipe (use low-phosphate detergents) to after the end of the pipe (site the soil absorption system where phosphorus uptake capability in the soil is highest). Costs of each method and benefits other than phosphorus management are also documented. Each approach to phosphorus management, from source reduction to soil absorption system design, was represented among the most promising methods, except for precipitation in the septic tank and biotic sequestration.

Source diversion methods that close the nutrient loop by recycling phosphorus from urine or blackwater to agriculture have been researched and tested in Europe in the last decade. By documenting performance of methods that use “waste” phosphorus as a resource, this project helps broaden the national discussion of phosphorus-management strategies for decentralized systems.

The research and demonstration needs documented in this project provide guidance for further developing phosphorus-management methods and demonstrating their feasibility.

Implications for Application

The method summaries presented in the report and the detailed information presented in the evaluation forms for individual methods may be useful to anyone who wants to learn more about phosphorus management in small systems, and particularly to community decision makers and members of the public who want to learn more about specific phosphorus-management methods. Watershed planners, regulators, management entities, and others can use the method summaries and ranking tables to understand the pros and cons of implementing different phosphorus-management strategies within their jurisdictions. The methods for improving soil absorption system design may be of particular interest to regulators in charge of writing rules and technical standards for onsite system design and installation.

With the exception of the source reduction strategies and some of the soil absorption system design methods, nearly all of these methods require some form of maintenance or management in order to successfully manage phosphorus in the long term. This finding has important implications for watershed managers, regulators, and management entities interested in managing phosphorus from decentralized wastewater systems.

Research and Demonstration Needs

Based on the results of this project, ten areas for research and demonstration are recognized, and the top five include:

- Demonstrate microflush toilets in terrestrial applications. (In the US, microflush toilets have been used almost exclusively on boats and ships.)
- Identify general properties of a sorbent that make it useful for phosphorus removal
- Demonstrate packed-bed filter media
- Continue developing nanoparticle selective resins
- Develop a vulnerability index for phosphorus breakthrough in soil absorption systems

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