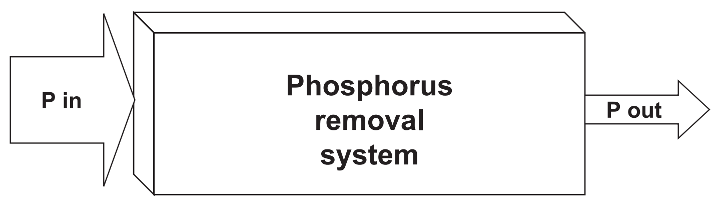
Onsite Wastewater Treatment Systems Technology Fact Sheet 8

Enhanced Nutrient Removal—Phosphorus

Description

There are a large number of processes that can reduce nitrogen and a few that can reduce phosphorus. Most of these phosphorus removal processes are additions to other pretreatment processes that enhance the overall removal of phosphorus (figure 1). The degree of nutrient removal, the cost, and the O/M difficulty of these combinations quickly reduce the number of systems that are likely to be implemented for onsite nutrient removal. The removal of phosphorus is of concern where effluents may enter surface waters via direct surface discharge or subsurface flow through fractured bedrock, and in soils where little phosphorus exchange would take place (see chapter 3). Phosphorus is a key element in the eutrophication of natural or impounded freshwater bodies and some estuarine waters.

Figure 1. Phosphorus removal



Few phosphorus removal processes are well developed for onsite wastewater systems application. Those that have been successfully applied generally fall into the categories of chemical, physical, and biological systems. The controlled addition of chemicals such as aluminum, iron, and calcium compounds with subsequent flocculation and sedimentation has had only limited success because of inadequate operation and maintenance of mechanical equipment problems and excessive sludge production. Physical and chemical processes such as ion exchange and precipitation of phosphates have been tried, but with limited success. Most notable successes have come with special filter materials that are naturally high in their concentration of the above chemicals, but their service lives are finite. Studies of high-iron sands and high-aluminum muds indicate that 50 to 95 percent of the phosphorus can be removed. However, the life of these systems has yet to be determined, after which the filter media will have to be removed and replaced. Use of supplemental iron powder mixed with natural sands is also being researched. All calcareous sands and other sands with high concentrations of these three elements will exhibit high phosphorus removal rates for some finite periods. Typical calcium-containing U.S. sands will essentially exhaust their capacity in 3 to 6 months, after which they will remove only particulate-based organic phosphorus or about 10 to 20 percent of the phosphorus contained in the wastewater.

One other practical way to minimize phosphorus discharges to the environment is the use of low-phosphate or phosphate-free detergents, which can reduce the wastewater P concentration from 7 to 8 mg/L to 5 to 6 mg/L. In terms of P movement from the SWIS to nearby waters, such a change could add 30 to 40 percent to the site's service life in attenuating or containing P from movement away from the SWIS. Of all the options, this may be the simplest, but concerns over public acceptance of these detergents as cleaning agents persist.

The only other known P-removal approach is the use of biological treatment systems. All aerobic treatment systems described in other fact sheets have the natural ability to remove 10 to 20 percent of the influent phosphorus, which is connected to the organic form in the biological reactors and wasted with excess sludge. Certain processes such as the sequencing batch reactor (SBR) can improve on this removal by proper sequencing of aeration periods. Other aerobic biological units can similarly upgrade their phosphorus removal performance by the addition of anaerobic steps up to an effluent limit of 1 to 2 mg P/L, but the data to support the onsite applications of these upgrade technologies are lacking.

Typical application

Phosphorus is rarely designed to be removed in onsite pretreatment because most soils have the innate ability to adsorb the nutrient for many years before it begins to migrate to nearby ground or surface waters. However, as onsite system sites age, there is the potential for serious environmental degradation, as witnessed by the thousands of inland lakes where older, onsite development is increasingly being cited as the primary reason for lake eutrophication.

Therefore, the most likely P-reduction systems that will be applied are iron-rich intermittent sand filter (ISF) media, sequencing batch reactors (SBR), and phosphate-free detergents. Other systems will surely be developed, especially upgraded aerobic treatment systems, but these three systems are most representative of current phosphorus reduction programs.

Design assumptions

For special filter media, the design assumptions would be the same as those for an intermittent sand filter (ISF) with adjustment to the hydraulic and phosphorus areal rates because they might differ from conventional systems. Hydraulic loadings for one successful study are essentially 3 cm/day, and the TP loading is 0.16g/m^2/day. The major unknown is the life of the special P-adsorption media. Most high-calcium sands become saturated in a few months, but one specific case has reported 2.5 years. Generally, these sands are not cost-effective. High-iron sands and crushed bricks are being studied and show longer durations of P-removal effectiveness, but definitive service lives are as yet unknown. The use of "red mud" and iron oxide powder mixed with sands and placed below the infiltrative surface in the SWIS has been successful, but the life of such media and the difficulty of replacement make these concepts less attractive unless the former is in the range of 20 years. Red mud (a bauxite mining by-product) must constitute at least 30 percent of the total volume of the filter bed. In a SWIS, the material must be mixed with the natural soil to a depth of 1 foot (0.3 m) below the infiltrative surface to attain high P-removal efficiency. Specific depths of mixed soils and loading rates have not been clearly delineated.

SBRs are capable of phosphorus removals greater than the typical CFSGAS, which can range from 20 to 40 percent. This is best accomplished by the "true" SBR (IF), but also by continuous feed (CF) SBRs if designed to do so. The IF type must not aerate during the fill stage in order to remove greater amounts of TP. The CF type must have a no-aeration section immediately following the recycle point to accomplish similar goals. Such designs are capable of reaching effluent TP in the range of 1.0 mg/L. The only onsite CF test available did not employ this sequence and removed only about 30 percent of the TP. Sludge wasting requirements are severe and limit the performance of this alternative.

Because carbon-to-phosphorus ratios in septic tank effluent are generally favorable (typically, 150 mg/L BOD to 7mg/L TP), the anoxic/anaerobic first stages (combined with appropriate organic loading rates and HRTs, as noted in the SBR fact sheet) can result in significant TP removal. Typically, this mode of SBR operation should also remove most of the nitrogen. All the phosphorus removal options require noncorrosive materials of construction, appropriate alarms and sensing systems, and regular management by semiskilled staff.

Performance

The systems described above, in concert with low- or non-phosphate detergent use, are capable of removing phosphorus to an effluent value of 1 to 2 mg/L with proper maintenance. Subsequent travel through the soil's vadose zone would further enhance TP concentrations to very low ambient values. Direct discharge (after disinfection) would meet most surface discharge requirements.

Phosphorus removal should be provided in sensitive surface water areas if direct surface discharging systems are used, or if SWISs are located in noncalcareous, low-iron or low-aluminum soils in close proximity to or directly influencing sensitive surface waters.

Management needs

The use of low- or non-phosphate detergents would generally be a regional responsibility. Management of a high-iron or a high-aluminum filter would be similar to that required for ISFs. Flows and dosing rates should be checked on each O/M visit, along with annual recalibration of dosing pumps and monitoring of TP in the effluent. At least two visits per year are suggested to manage these systems (or 8 hours per year).

The SBR option is exactly the same as in the SBR fact sheet or three to four visits per year by semiskilled personnel (6 to 12 hours), with electrical usage of 3 to 10 kWh/day. The SBR will produce an additional 0.6 to 1.0 lb TSS/lb BOD removed, over and above the solids captured in the septic tank.

Risk management issues

The two treatment systems described above are relatively unaffected by wide flow variations. The SBR can be seriously impaired by the toxic shocks but not the enhanced ISF. Both should be safe from extremely cold climates if properly insulated, but the SBR will suffer reduced biochemical efficiency in such extremes. Power outages will affect the SBR, producing odors and poor efficiency for some time after power restoration. The enhanced filter will also be interrupted because of dosing pump failure, but it should not experience odors or subsequent impairment.

Costs

Enhanced TP-removal filters will have cost characteristics similar to conventional ISFs except in the initial and subsequent replacement of the enhanced media. Such a system may have an initial media cost increment of at least 1.2 and possibly 2.0 or larger, and an annual additional O/M cost related to more frequent media replacement. For example, a 5-year life would mean that a substantial replacement charge would be incurred every 5 years, equating to several hundred dollars per year in O/M cost over and above the normal O/M cost of $250 to $400 per year. The capital cost would vary between $5,000 and $11,000.

The SBR would exhibit similar capital ($9,000 to $12,000 per year) and O/M ($650 to $800 per year) costs as provided in Technology Fact Sheet 3.

References

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