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Nitrogen-reduction treatment systems for long-term operations

A proper analysis of nitrogen-reduction systems is critical to finding the most effective treatment process for specific locations. Tristian Bounds of Orenco Systems illustrates how a nitrogen-reduction treatment system was evaluated for a recreational vehicle (RV) resort project in Deschutes County, Oregon, United States (US).

The need for nitrogen-reducing wastewater treatment systems has become more common in the past few decades due to various environmental concerns, including eutrophication, oxygen depletion, and toxicity to aquatic organisms in lakes and streams. The addition of nitrogen removal to any wastewater treatment plant – new or existing – typically increases the costs of the project significantly. When evaluating suitable technologies, it is critical to properly identify processes that can not only prove the best upfront capital value but also provide the most sustainable long-term functionality.

Decentralized management systems are recognized as the next step for sustainable wastewater infrastructure in our society. Various decentralized technologies offer a reliable, economical, and environmentally sensitive alternative for wastewater treatment, including nitrogen reduction and reuse.

Technology analysis

When selecting any wastewater treatment technology – including nitrogen-reduction systems – it's assumed that all technologies are sustainable, and, when operated correctly, will satisfy the ecological and social needs that they were initially designed to meet at a reasonable cost. Moving beyond the ecological and social debates, however, the mechanisms for measuring sustainability over the long term should be considered.

The principal mechanisms for biological removal of nitrogen are microbial assimilation and microbial nitrification-denitrification. Microorganisms assimilate ammonia nitrogen and incorporate it into cell mass, and it can be removed from wastewater by removing cells from the system. Relatively recent breakthroughs in technology development have enhanced this process to offer simultaneous reactions within the same chamber – reducing footprint and operational requirements.

Sustainability, in part, can be measured by the determination of life-cycle costs. Life-cycle cost analysis must be inclusive of all potential costs and measured over a time period that will accurately capture renewal and replacement costs for all of the systems' components.

Nitrogen-reduction systems, along with other wastewater treatment technologies, have three basic economic factors that are included in their life-cycle costs: capital costs, operation and maintenance (O&M), and repair and replacement (R&R).

- Capital costs should include direct, indirect, and risk costs. Direct costs such as construction materials, equipment, labor, and engineering are generally easy to determine. Indirect costs, though not always as obvious, should also be considered. For example, interest payments will be affected by the time it takes to complete construction and the amount of money borrowed. Additionally, indirect costs could include items like lost revenue, environmental monitoring, and construction-related complaints. Risk costs are those that accumulate due to unforeseen construction conditions. At a planning level, these potential costs are provided for by a standardized contingency percentage. At the time of construction, the actual costs are generally determined through contractor change orders. Rather than using a standardized contingency percentage, potential risk costs for each competing alternative should be determined and differentiated.

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- O&M refers to the annual costs of operating and maintaining selected design and technology, including maintenance equipment and labor. Year to year, O&M costs are highly variable. Additionally, O&M costs for similar systems can be greatly affected by the commitment to and intensity of regular preventative maintenance. At a planning and analysis level, O&M costs are often defined by using data from a comparable system. Unfortunately, this data is often selected without consideration of the age of the system or the level of preventative maintenance it has received. While the system is in good condition, the O&M costs will appear artificially low.

The membrane-aerated biofilm reactor (MABR) system is used for nitrogen removal. Image provided by Orenco Systems, Inc.

By using accurate analysis based on real data and true life cycles, it is possible to identify which technologies are the most sustainable over the long term for a given application. This not only provides financial benefits to utilities, property owners, developers, and end-users, but also contributes to the health of waterways and the environment.

- R&R is essentially a repeat of capital costs but projected out into the future. The desired life-cycle period necessary for proper analysis is determined by the longest lifespan of critical components for a selected technology. For example, if a critical component has an expected life of 40 years, R&R analysis should use 40 years as the basis for evaluation.

Generally, comparative life-cycle analysis is done by comparing Net Present Values (NPVs) for various options or technologies. Essentially, an NPV establishes the amount of money that is necessary today to pay the costs of a system over its lifespan.

Often, NPV analysis fails to assure sustainability over the long term. The goal of most projects is to make sure a facility works properly over a defined time period. In most cases, the defined period for an NPV is too short to actually provide a full comparative analysis. For example, a 20-year NPV analysis for a treatment system will not capture R&R costs that are ultimately necessary to sustain the system over its expected lifespan.

O&M costs are often understated relative to the operation and maintenance activities necessary to assure that typical goals and concerns are being addressed. Using O&M costs from systems that are not necessarily sustainable has become common-place, but this approach alone does not capture the data needed for accurate analysis.

Insufficient attention to O&M and R&R will generate escalating costs. The lack of regular O&M and R&R ultimately results in an urgent need to complete large-scale system repairs or system replacement, and the costs for large-scale system repairs are often unmanageable for users. Therefore, an "apples-to-apples" NPV analysis of any systems should be at least 50 years in length and could be as long as 100 years. Again, the length of the analysis should capture all R&R items.

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Selection process for RV resort project

In central Oregon, nitrogen contamination in the Deschutes River Basin led to the completion of an extensive report by Deschutes County that detailed the need for groundwater protection in the area. Onsite and decentralized wastewater systems are the primary types of treatment. During the study period, larger decentralized wastewater facilities without nitrogen-reduction systems were flagged as key projects requiring upgrades.

During the evaluation period for a large RV resort servicing more than 200 connections with 76,000 liters (20,000 gallons) per day of wastewater, it was determined that a detailed technology and economic analysis was necessary to identify the most sustainable alternative to replace the failing system. Many factors were key in the comparative analysis of technologies, none more critical than the Total Nitrogen (TN) limit of 10 milligrams per liter (mg/L) and the isolated location of the resort. Other key elements in the evaluation include the ease of operation, energy consumption, process complexity, and capital costs.

The nitrogen-removal processes evaluation included analysis of seven technologies: textile packed-bed filter, membrane-aerated biofilm reactor (MABR), simultaneous biological nutrient removal (BNR) activated sludge, sequencing bioreactor, pressurized membrane bioreactor, submerged membrane bioreactor, multi-stage activated sludge.

A capital cost analysis was completed with assistance from various equipment manufacturers and suppliers. This extensive analysis required comprehensive design work for all seven technologies. The design analysis included capital costs, O&M requirements, and long-term R&R cost analysis.

In order to compare capital costs of technologies, there was a need to determine which components in each system needed to remain the same throughout the comparison. The material specified for the enclosure and tankage was consistent throughout the analyses, which allowed for an accurate comparison of the individual technologies. It was also assumed that the building materials for the control shelter would remain consistent between technologies. With specific components of the design remaining constant, the equipment supplied by each manufacturer and estimated installation time were added for capital cost analysis. For additional comparison, a select few manufacturers were requested to provide quotes on full-package systems, which are typically installed within steel containers (often by recycling used shipping containers). It was, however, determined that steel containers were not optimal for the long-term sustainability of this project and quotes with steel containers were not included in the final comparison. After evaluating the capital costs for each treatment option, the range in up-front capital costs for all systems varied by as much a 18 percent.

The O&M comparison included the hours recommended by each manufacturer and the energy and chemical consumption of the treatment processes. The evaluation of O&M costs showed an annual variation of US$5,500 between the least intensive and most intensive operating requirements (approximately a 35-percent variation). Although O&M expenses appear to be of relatively low economic value compared to capital expenditures, the frequency of visits required each week for various technologies and the availability of trained service providers in the area played a vital role in the final selection of appropriate technologies for the project.

R&R costs were then evaluated as part of the long-term sustainability analysis. Overall, R&R costs varied little, with annual budgets differing by only $2,200 among the technologies evaluated. However, the importance of discussing R&R costs at the onset of a project cannot be emphasized enough. Providing the necessary information for owners to prepare setting aside funds to sustain the system is critical in the operation of any business.

At the end of the analysis, the final decision was most influenced by the capital and O&M costs, with a heavy emphasis on the availability of trained operators in this isolated area and their comfort level with the preferred technology. The technology selected based on these factors was the MABR system – due mainly to capital costs, performance reliability, and ease of operations.

Cost data is vital

There can be large differences in up-front and long-term costs between nitrogen-removal technologies. However, engineers and designers can make accurate comparisons between nitrogen-removal systems by gathering factual data about capital costs, O&M costs, and R&R costs. Additionally, the availability of trained operators may play a major role in the selection of a particular technology. Proper analysis of costs over a realistic life cycle for each system can help determine the best treatment option for any nitrogen-removal wastewater project.

Author's Note

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