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# Waste Water Treatment in New Hampshire: Analysis of Nitrogen Treatment in the Great Bay Community

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**Problem Description**

The majority of the wastewater treatment plants that are currently in operation today were constructed in the United States during the 1970s and 1980s when the Clean Water Act (CWA) was implemented. A large sum of federal money was available and executed in order to satisfy the requirements of the CWA. The equipment is now over 30 years old and reaching the end of its useful life. It needs to be replaced in pursuance of meeting the needs of additional challenges due to external factors such as advancements in technology, population growth and stricter permit requirements. An increase in capacity is needed and to counterbalance these factors, significant efforts will be focused on the design of wastewater treatment plants and developments will be conducted to improving and discovering new methods to treat wastewater. There will be fewer completely new treatment plants under construction as this is the least cost effective option and opposes the demand of the public.

**Introduction**

In order to provide citizens with clean, high quality water, the US Environmental Protection Agency (EPA) regulates the drinking water quality in public water systems and sets maximum concentration levels for water chemicals and pollutants. However, the public's health is not the only concern. All of the nation's waters need to be protected as well, including rivers, streams, estuaries, oceans and groundwater. In order to ensure this, the Clean Water Act (CWA) was created in 1972 as a result of an amendment to the Federal Water Pollution Control Act of 1948. The CWA was passed by Congress to protect all "waters of the United States."

Waste water collected from municipalities must ultimately either be returned to waters, land, or be reused. Reusing waste water is an environmentally-conscious and viable option. To satisfy the proposed conditions of the CWA, waste water needs to be properly treated. In the interest of successfully accomplishing the goals of the act, the EPA facilitates surveys and obtains data on the numbers and types of wastewater treatment plants used and needed. The results are shown in a needs assessment survey which indicates the number and types of facilities needed in the future.

The current treatment system that is widely used in the United States is deteriorating. As advancements in technology are made and the country continues to employ more sustainable practices, waste water treatment needs to also look toward the future. Instead of rebuilding the same system, new and innovative methods need to be developed to meet the current and future ideology. To achieve this goal, technology, economics, the environment and people are all categories that must be considered. The greatest challenge that a waste water treatment plant in a community face is that it must be robust and reliable while also being cost effective and properly meeting the price demand of the public.

**POTWs**

Publicly owned treatment works (POTWs) are the most commonly used practice to treat wastewater due to their large capacity and high reliability. POTWs are owned and operated by local government agencies and are designed to treat domestic sewage. POTWs collect wastewater from homes, commercial buildings, and industrial facilities and transport it to the treatment plant. Prior to treatment at the facility, the EPA requires pretreatment of wastewater because it solves two problems that can occur very easily. These are interference, when a discharge inhibits the treatment process and the second is pass-through, which is when a discharge of an untreated pollutant flows into the receiving water. If the wastewater is pretreated before arriving at the treatment facility, the chance of interference or pass-through is less likely to occur. After the pretreatment, the removal of harmful organisms and other contaminants from the sewage is fulfilled through primary, secondary and tertiatry treatment methods. Lastly, the POTW is composed of discharge pipes which are used to safely discharge the treated water into the receiving stream.

**Nitrogen**

One of the greatest issues that treated wastewater faces is releasing water with high levels of nitrogen into discharge streams. Although the EPA has declared that an acceptable range of total nitrogen is 2 mg/L to 6 mg/L and has permit limits and monitoring limits in place, it is recommended that treatment plants introduce technology to remove greater levels of nitrogen (US Environmental Protection Agency). Biological nutrient removal (BNR) is used for the removal of nitrogen. BNR is popular among operations because it uses fewer chemicals to treat water than other chemical treatment methods, reduces the production of waste solids, and has lower energy consumption (Tchobanoglous). Some wastewater treatment plants are able to remove more nitrogen from their water than others depending on their equipment and the method used to treat wastewater. Enhanced treatment systems enable some wastewater plants to produce discharges that contain less nitrogen than plants using conventional treatment methods. While upgrading wastewater treatment plants is expensive for municipalities, there are existing technologies that are available to reduce nitrogen levels from wastewater. These strategies are being pursued throughout the country and research has been conducted in New Hampshire to test the effectiveness of one advancement that is being actively pursued.

**Environmental and Health Effects**

Nitrogen is the most ample element in the air we breathe and can get into water through sewage effluent. It poses a hazard to the environment and to the health of humans. Nitrogen levels need to be controlled because high levels of nitrogen cause algae to grow at an increasing rate. These significant increases in algae cause harm to the water quality, food resources and habitats. High levels of nitrogen also decreases the oxygen that fish and other aquatic life need to survive. The severe reduction or potential elimination of oxygen in the water leads to illnesses in fish and the death of fish as well. The algae destroys current habitats by blocking sunlight and exhausting the water of oxygen.

In regards to human health, people may get sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water. Infants are especially susceptible to the danger of excessive nitrogen because their stomachs are not yet able to prevent bacteria from growing and. Similarly to the negative impact nitrogen has on fish, high levels of nitrogen can oxidize hemoglobin and lack the human body from carrying oxygen. In infants, this may cause brain damage or even death by suffocation.

**New technology**

**Permeable Reactive Barriers**

Nitrogen is a prevalent chemical in water and may be toxic when present in drinking water. Treatment tanks are often too small in most wastewater plants to eliminate nitrogen. As improved microbiological techniques are developed, it will be possible to enhance the sterilization process of water and to specifically improve nitrogen elimination. The New Hampshire Water Resources Research Center has conducted a project on two technology sites in Strafford and Rockingham counties to advance nitrogen elimination. This is made possible by providing additional equipment to treatment tanks such as hollow fiber membranes. These retain nitrifying bacteria and feed oxygen to it which allows de-nitrification and nitrification to simultaneously take place (Kelley and Truslow). This technology is a viable solution to the presence of nitrogen because it would completely eliminate the chemical and provides a faster treatment process. It solves environmental concerns as well because the fiber membranes can replace carbon sources that are currently used for treating wastewater such as methanol. The expense of completely new treatment plants can be avoided because the fiber membranes can be installed into existing wastewater treatment systems (Kelley and Truslow).

**Challenge**

The challenge that the existing treatment facilities experience is how to include new technologies while maintaining the price demand of the public. Municipal treatment plants need to be reliable and meet established performance criteria and EPA regulations consistently over extended periods of time. POTWs are most common because they are reliable, durable and funded with local moneys. However, the need to conserve energy and resources is still prevalent. Operation and maintenance costs need to be minimized in order for the price of the reusable water to remain in harmony with the demand of the public. Some of the new and innovative treatment methods require the use of large amounts of electricity, specifically used for aeration that is desirable for biological treatment (Tchobanoglous). Typically, about one-half of the entire plant electricity usage is for aeration. In the design of waste water treatment plants, power use can be minimized by selecting energy-efficient equipment and designing facilities to recover energy for in-plant use.

During the next 20-30 years, the electricity requirements for wastewater treatment are expected to increase by an additional 30-40%. Currently, about 30% of the operating cost of a wastewater treatment plant is budgeted for energy use. It is imperative that wastewater treatment complies with future trends and employs sustainable practices. Since there are nationwide concerns about the sufficiency of fuel supplies, the cost of energy consumption should be reduced and the design and operation of wastewater treatment plants must be focused on improving the efficiency of electric energy use and decreasing the cost of treatment (Tchobanoglous).

Stricter water quality requirements have been placed onto municipalities as an increasing number of lakes, rivers, and streams are being classified by the EPA as impaired. Nitrogen removal is one of the key issues that the Great Bay coalition faces. The challenge for these three communities is to meet the nitrogen limit by choosing a nitrogen removal process that improves the existing infrastructure while remaining economically affordable.

**Dover**

The city of Dover, NH is home to a wastewater treatment plant that is more than 20 years old. Its mission and purpose is to efficiently treat wastewater and bio-solids generated by Dover residents and businesses. It is a part of the Great Bay Coalition along with two other communities, Portsmouth and Rochester. Nitrogen pollution is an important issue affecting the ecosystem of the Great Bay. Dover recently disagreed with a draft permit sent by the EPA in 2013 which set a standard of limiting nitrogen to 3 milligrams per liter. Dover did not accept this because not only is it a significant and costly reduction compared to the current nitrogen levels, but there was insufficient data provided by the state Department of Environmental Services used as evidence to suggest that high nitrogen levels are what caused the destruction of the eelgrass population and oyster beds in the Great Bay. Researchers have estimated that 25 percent of the nitrogen reaching the estuary comes from the wastewater treatment plants while the remainder is estimated to come from nonpoint sources such as septic systems and fertilizers (dover.nh.gov).

Nonetheless, Dover is in agreement that nitrogen levels need to be reduced and it has been performing annual upgrades to the twenty year old plant. The city has committed $9 million from its budget towards upgrades for the facility. Rather than supporting the standard that the EPA has proposed, it supports a less costly approach that still addresses nitrogen reduction in Great Bay. This plan, the Adaptive Management Plan (AMP) limits the nitrogen level to 8 milligrams per liter.

**Comparison**

A program was completed in 2007 in the Chesapeake Bay to study and restore it after identifying nitrogen pollution as an important issue affecting the ecosystem of the Bay. The Chesapeake Bay Cost Study was completed and used actual cost data, engineering information, and statistical information to estimate costs in the Chesapeake Bay watershed. Costs were estimated for four levels of treatment and were based on 2000 dollars and projected 2010 flows. The four scenarios used are described as follows.

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Nitrogen amount | POTWs with operating or planned nutrient removal technology: TN = 8 mg/L | TN = 8 mg/L | TN = 5 mg/L | TN = 3 mg/L |
| Technology used | Existing technologies | Extended aeration processes and denitrification zones | Additional aeration, a secondary anoxic zone, methanol addition, and additional clarification tankage | Deep bed denitrification filters |

The cost estimations differed for each scenario since they require the use of different technologies. For the first scenario, no incremental costs were required for most facilities, because it is based on current technologies in use. However, additional operating costs were required for some facilities since it used projected flows of 2010 levels. For the second scenario, Operation and maintenance costs increased and included costs of alum and sludge disposal. For the third scenario, cost estimates were completed for four plant sizes: 0.1 MGD, 1.0 MGD, 10 MGD, and 30 MGD. Based on these estimations, capital costs for the nitrogen reduction range from $0.41 to $2.41 per gallon of design flow.

| Annual Average Flow | | | | |
|---|---|---|---|---|
| Cost Type | 0.1 MGD | 1.0 MGD | 10 MGD | 30 MGD |
| Capital Cost | $241,000 | $1,112,000 | $4,927,000 | $12,383,000 |
| O&M | $7,046 | $29,218 | $157,469 | $293,938 |

Source: CBP (2002)
Costs were estimated assuming that TN is reduced from 8 mg/L to 5mg/L using a secondary anoxic reactor and increased clarification.

For the last scenario, the estimated costs of reducing nitrogen levels to 3mg/L are displayed.

| Cost Type | 0.1 MGD | 1.0 MGD | 10 MGD | 30 MGD |
|---|---|---|---|---|
| Capital | $312,000 | $1,268,000 | $9,620,000 | $26,520,000 |
| O & M | $22,993 | $69,925 | $311,634 | $841,120 |

Source: CBP (2002)
Costs were estimated assuming that TN is reduced using deep bed denitrification filters. Facilities are assumed not have filtration and pumping stations before scenario 4 upgrades are installed.

In comparison to the Chesapeake Bay, cost estimations have been prepared for the Great Bay communities including Dover, Rochester and Portsmouth. These estimations were completed in 2011 and are based on 2010 flow rates. There were three different scenarios of nitrogen levels analyzed.

| Cost Type | Nitrogen level | Dover | Rochester | Portsmouth |
|---|---|---|---|---|
| Capital | 8 mg/L | $10,500,000 | $7,450,000 | $15,000,000 |
| | 5 mg/L | $25,000,000 | $11,250,000 | $16,900,000 |
| | 3 mg/L | $30,000,000 | $21,550,000 | $34,900,000 |
| O & M | 8 mg/L | $400,000 | $4,500,000 | $900,000 |
| | 5 mg/L | $600,000 | $4,800,000 | $980,000 |
| | 3 mg/L | $800,000 | $5,700,000 | $1,028,000 |

**Data Conclusions**

Reducing the nitrogen levels to 3 mg/L is a very expensive proposition. The Great Bay communities operate on a short-run basis in order to avoid the extensive increase in costs. They are all currently implementing upgrades to their treatment facilities but do not have current plans to utilize new innovations that will improve nitrogen elimination, such as the permeable reactive barriers.

**Funding Options**

For many municipalities, the standards set by the EPA are beyond their technological feasibility and economic means. Funding the improvements that need to be made to the treatment plants in order to meet the standards is a challenge experienced by many. Although many are currently focused on functioning in the short-run, constant improvements will need to be made to meet the fluctuating standards of the EPA.

Combining and consolidating public water systems is an interesting proposal as it would decrease the cost per household to treat wastewater and would make it easier for the municipalities to meet the regulatory standards. A New Hampshire Water Infrastructure Survey was completed by Joyce Massicotte, John Halstead and Sarah Pillsbury in 2011 to gather stakeholder opinions on different funding options to meet the projected water infrastructure investment.  It was found that a majority of New Hampshire stakeholders (70% or 42 out of 60) are in agreement that small community public water systems should be combined to make it easier for them to meet regulatory requirements and industry standards. This data shows significant evidence to support the claim that municipalities should work together to develop water system projects on a larger scale instead of only working to improve their own community needs.

The EPA, federal agencies and state government programs all offer funding for communities through multiple grant programs.

**Conclusion**

Municipalities across the nation are faced with the challenge of improving the technology used in their wastewater treatment plants. Many of the facilities were built in the 1970s and are now reaching the end of their useful life. Nitrogen pollution is a contributing issue that affects the quality of water. Many of the current facilities in operation do not have the necessary updates to allow them to discharge water with the amount of acceptable nitrogen according to the standard set by the EPA.

Dover is one example of a community that has access to potential advanced technology but does not have the funds for the improvement to their water infrastructure treatment system. The increased usage of water due to population growth and new EPA standards contribute to the challenges experienced by municipalities to fund their systems.

Sources

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