Using Enhanced Primary Clarification to Reduce Energy Use in Wastewater Treatment

by Celine Cua

The purpose of wastewater treatment is to remove contaminants from wastewater to protect human health and natural ecosystems. Conventional wastewater treatment usually includes both primary and secondary treatment. In primary treatment, heavy particles are separated from the water by letting it settle by gravity. In secondary treatment, microorganisms are utilized to degrade organic matter. Additionally, the biological treatment can be modified to remove nutrients like nitrogen and phosphorus. Wastewater treatment is an energy intensive process. Approximately 60% of the energy is used for aeration in the biological system because oxygen is needed for microorganisms to degrade the waste quickly and efficiently. Thus, aeration is a good target when looking to reduce energy use in wastewater treatment.

Enhanced Primary Clarification (EPC) is the addition of chemicals to enhance particle aggregation and settling in primary treatment. Based on preliminary studies, EPC is very efficient in removing phosphorus and decreases the amount of organic matter entering the biological system. With less organic matter, biological oxygen demand decreases. However, EPC does not improve the removal of nitrogen, mostly in the form of ammonia, during primary treatment. Typically, ammonia is removed via nitrification-denitrification, which requires a large amount of oxygen for nitrification and readily biodegradable organic matter in anoxic environment for denitrification. In low dissolved oxygen (DO) conditions, nitrogen may be removed via nitrite (instead of nitrate) through nitritation-denitritation. This process requires 25% less oxygen and 40% less carbon. Thus, nitrogen can be removed via less energy-intensive pathways and for a lower cost.

This study aims to assess the feasibility of EPC in reducing aeration requirements, determine its effect on biological nutrient removal and evaluate the overall system performance under low DO conditions. We hypothesize that with less organic matter to be removed biologically, less air and thus, less energy will be needed to achieve the same treatment. Our second hypothesis is that if EPC lowers carbon and oxygen inputs to the biological system, nitrogen removal will not be significantly compromised because if nitritation-denitritation can be achieved, less carbon and oxygen will be needed for the same removal.

To test the hypothesis, wastewater from the Mines Park Residential Area was pumped into two parallel primary treatment systems - the conventional primary clarifier, and the EPC system consisting of a rapid-mix tank, flocculation tank and a clarifier. Ferric chloride is dosed at the rapid-mix tank while the polymer is added in the flocculation tank. The primary effluents were collected into their respective storage drums because the bioreactor for secondary treatment is a sequencing batch reactor, so it only accepts inflows at the start of each treatment cycle. Each treatment cycle consist of a Fill period, alternating anoxic and aerobic periods, a settling period and a decant period. Samples of the influent, primary treatment effluent and after each stage of the biological treatment were collected for multiple cycles, composited, and analyzed for various parameters like total suspended solids, chemical oxygen demand (COD), ammonia, nitrites, nitrates, and phosphorus.

The first three weeks of the summer involved building and setting up the primary treatment system. Our research team built tanks, installed mixers, connected pipes and tubes, and calibrated numerous pumps. Calculations were made to determine the volume of the tanks and feed reservoirs. After the whole system was put together, we ran it with tap water and tracers to make sure that the hydraulics are working. A preliminary jar test was also conducted to determine the removal of suspended solids, alkalinity, chemical oxygen demand, phosphorus and ammonia in primary treatment at various doses (20, 40 and 60 mg/L) of ferric chloride. For all jars receiving ferric chloride, removal was at least 80% for phosphorus while ammonia levels were essentially unchanged.

The next three weeks involved doing literature reviews, calculations and modeling to predict treatment efficiency and optimize the system. The biological treatment cycle was based on Morrison Wastewater Treatment Plant. Using preliminary data, microbial stoichiometry and kinetic parameters from textbooks and literature, we conducted a computer simulation of the biological treatment process. Using the simulation results, the dose of ferric chloride was lowered from 40 to 20 mg/L and the treatment cycle was shortened from 4.8 hours to 3 hours.

The last three weeks were spent working on the biological system. Initially, the sludge from the membrane bioreactor (MBR) in Mines Park was used as the seed sludge. However, the sludge did not settle well. Preliminary chemical analysis also showed that denitrification was minimal, probably because the MBR selected against denitrifiers in order to retain adequate amounts of nitrate for tailored water irrigation. Thus, additional seed sludge was obtained from Plum Creek WWTP. Sensors for dissolved oxygen and total solids were also calibrated. DO was the main control parameter, but because sophisticated control of the blowers was not available, the airflow had to be set for each system individually based on the time needed for DO to climb from 0 to 0.8 mg/L. After the electronic controls for the bioreactor had been set up and running for several days, sampling and analysis proceeded.

Total COD removal was approximately the same but for the EPC train, a larger proportion of COD was removed in primary treatment. For phosphorus, removal was 80% during primary treatment for EPC, but negligible for CPC. However, phosphorus concentrations dropped to <<1 mg/L PO_4 for both systems at the end of the biological treatment. Enhanced biological phosphorus removal (EBPR) occurred because the seed sludge came from a WWTP that practices EBPR. Low DO did not significantly affect ammonia removal. Complete nitrification, rather than just nitritation, occurred for both systems. However, ammonia oxidation was slightly lower for EPC system, and final NH_3-N concentrations were three times higher than that of the conventional system. Effluent nitrate levels were at the borders of the permit level as denitrification was limited by readily biodegradable carbon supply. Overall, final effluent quality was similar for both conventional (CPC) and EPC systems, but the ***EPC system achieved it using 1/3 the airflow.***

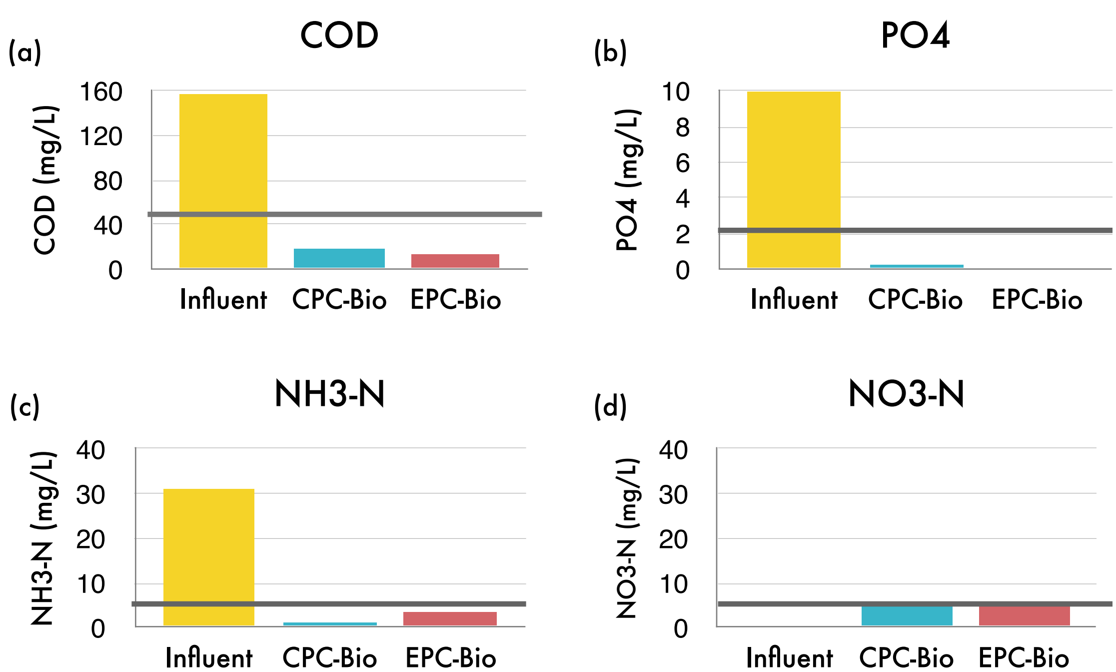

Figure 1: COD (a), Reactive P (b), NH_3-N (c) and NO_3-N (d) of the influent and final effluents of both systems. Black horizontal lines represent typical permit limits.