Full-Scale Demonstration of a Ballasted Treatment System for Capacity Expansion

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The Kemptville (Ont.) Water Pollution Control Plant (WPCP) is a conventional activated sludge (CAS) facility, with a rated average day flow (ADF) capacity of 1.2 mil gal per day (mgd). A recent environmental assessment has concluded that continued growth in the service area will require a plant capacity expansion of approximately two times the current design. The site, however, has limited space, and a conventional plant expansion would require acquisition of additional land. For this reason, the sewer authority decided to evaluate the use of the innovative BioMag™ treatment process as an alternative to influent equalization and expansion of the CAS process. The treatment system, which is a ballasted activated sludge process, was identified due to its small footprint requirements, capability to treat high peak flows, and ease of retrofitting into the existing CAS process.

The goal of the project was to confirm the feasibility of converting the WPCP to the new treatment system. The objectives of the program included confirming design parameters for the new process, including operating mixed liquor suspended solids (MLSS) concentration, peak clarifier solids loading, and surface overflow rates, as well as performance in terms of effluent quality, chemical and energy use, and ballast recovery.

The project was conducted with assistance from the Ontario Ministry of the Environment under the Showcasing Water Innovation grant program. The pilot system and associated equipment, materials, and services for the demonstration were contributed by the developer of the treatment process, Evoqua Water Technologies.

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Existing Kemptville Water Pollution Control Plant

The WPCP is a conventional activated sludge wastewater treatment plant with tertiary filtration. The treatment processes include: screening, grit removal, primary clarification, aeration, secondary clarification, flocculation, filtration, and ultraviolet (UV) disinfection. Sludge management is provided by waste activated sludge (WAS) cothickening in the primary clarifiers and digestion of the cothickened sludge in a two-stage anaerobic digestion process. A general process flow schematic of the liquid treatment train at the WPCP is shown in Figure 1.

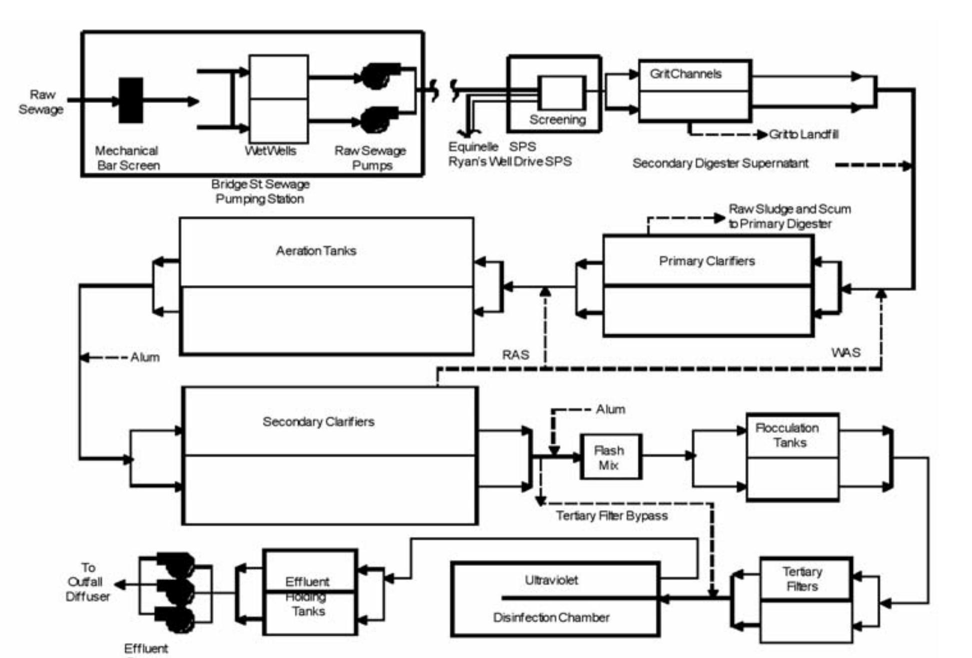

Figure 1. Kempteville Process Flow Schematic

Innovative Treatment Process

The treatment process is a ballasted activated sludge system that incorporates the addition of magnetite into the activated sludge process to ballast the biological floc and increase its specific gravity, resulting in improved secondary sludge settling efficiency. This also allows the system to carry a higher level of MLSS, thereby providing additional treatment capacity.

The process focuses specifically on the secondary treatment components of the activated sludge facility. A typical process flow schematic is shown in Figure 2. Return activated sludge (RAS) is combined with recovered magnetite and virgin magnetite in a ballast mix tank. The ballasted RAS then flows to the aeration tank where biological treatment occurs, and then to the secondary clarifier. The settled sludge is then returned back to the biological process as RAS, and WAS is sent to a ballast recovery system prior to sludge handling and disposal. The magnetite recovery system incorporates a shear mill to dislodge and allow extraction and recovery of the magnetite on a rotating magnetic drum.

The increased specific gravity and settleability of the magnetite-impregnated solids allows the secondary clarifiers to be operated at higher hydraulic and solids loading rates, while maintaining and improving effluent water quality. This also allows the biological reactors to be run at elevated MLSS levels, similar to membrane bioreactor (MBR) processes, and enables additional biological plant capacity.

Full-Scale Demonstration Methodology

A demonstration program was undertaken that involved temporary full-scale integration of the treatment process at the WPCP during a three-month period. This was accomplished by removing one secondary treatment train from operation, adding magnetite (ballast) to the on-line treatment train, and temporarily installing a magnetite recovery system housed in a trailer. A process flow diagram of the full-scale demonstration is presented in Figure 3.

The demonstration system was operated at projected future operating conditions to confirm the design parameters associated with biological treatment. Secondary clarifier stress testing was also conducted to confirm clarifier performance and peak flow capacity.

Results

Long-Term Testing

Long-term testing began on July 15, 2013, and the demonstration period ended on Sept. 30, 2013. The treatment system operated at an average MLSS concentration (without magnetite) of 6,945 mg/L. With magnetite, the total MLSS concentration was 20,036 mg/L.

The average sludge volume index (SVI) values reached a steady state value of approximately 50 mL/g by the end of the demonstration period, indicating a very well settling sludge. The SVI values were calculated based on the MLSS concentration without magnetite so that it could be compared to the SVI of other activated sludge facilities.

Over the study period, the average rate of magnetite recovery from the WAS was approximately 95 percent. Magnetite remaining in the WAS accounted for approximately 9 percent of the average WAS mass flow rate.

Secondary Clarifier Stress Testing

Clarifier stress testing took place over two days. In order to provide added flow for stress testing, two pumps were used to recirculate secondary effluent from the tertiary flocculation tanks, which were located downstream of the test secondary clarifier to the head of the on-line aeration tank to simulate peak flows. Samples of mixed liquor, secondary effluent, and tertiary effluent were collected throughout testing. Sludge blanket levels were also monitored throughout testing.

During Day 1 testing, flows were increased incrementally at one-hour intervals to attempt to reach the hydraulic capacity of the clarifier and a maximum influent flow rate of approximately 2 mgd was reached. During Day 2 testing, a target flow value of approximately 2.64 mgd was chosen and was held over a three-hour period.

A summary of the secondary clarifier operating conditions and secondary effluent quality during the two days of stress testing are presented in Table 1. It should be noted that the solids loading rate (SLR) values were calculated based on the solids loading from the MLSS without magnetite so that they could be compared to typical SLR values for nitrifying CAS facilities.

It was determined that the existing secondary clarifier can be operated at sustained surface overload rate (SOR) and SLR values of 945 gal per day per sq ft (gpd/sf) and 67 lb/da/sf, respectively, and peak SOR and SLR values of

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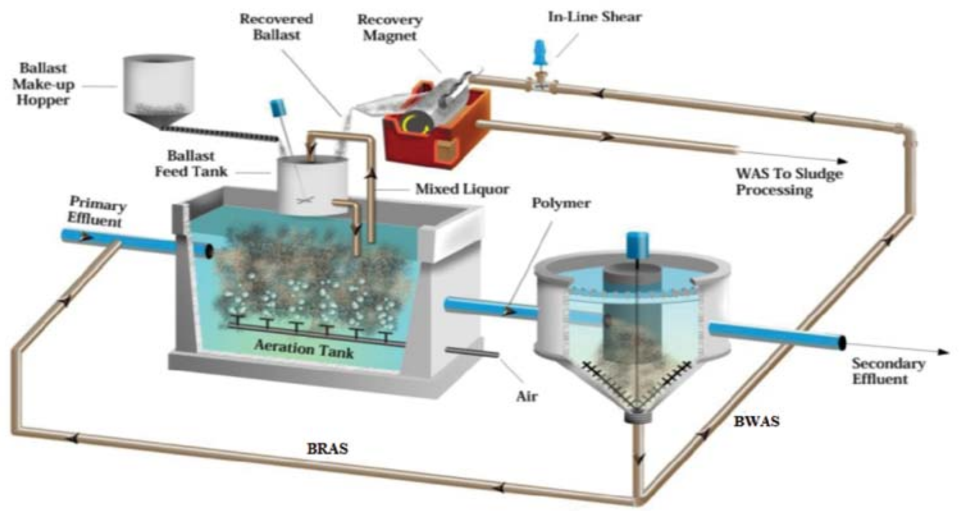

Figure 2. Typical BioMagTM Treatment System

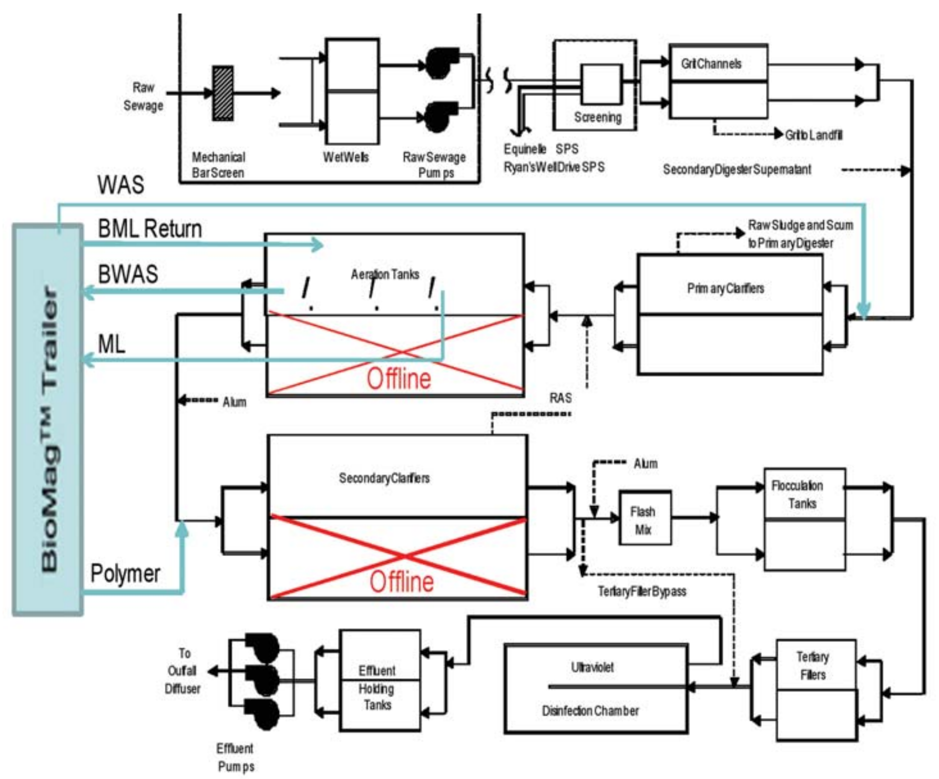

Figure 3. Full-Scale Integration of the Treatment Process

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1369 gpd/sf and 98 lb/da/sf, respectively, while maintaining the required secondary effluent quality.

At an operating MLSS of 7,000 mg/L, the existing secondary clarifiers at the WPCP are estimated to have an equivalent peak-hour flow process capacity of 5.9 mgd, or approximately twice the existing peak rated capacity of 3 mgd.

Conclusions

The results of the full-scale demonstration confirmed that conversion of the existing CAS process at the WPCP to a BioMag™ treatment system is a feasible option to provide additional wastewater servicing capacity within the existing biological and clarification tankage and without the need for additional land acquisition.

Based on the results of long-term testing, the treatment process was capable of meeting the target secondary effluent performance targets of 10 mg/L, 10 mg/L, and 0.3 mg/L for carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), and total phosphorus (TP), respectively. The ballasted mixed liquor exhibited excellent settleability, with an average SVI value of 50 mL/g. Secondary clarifier stress testing results indicate that the treatment process can maintain secondary effluent quality, even at high flows.

The results of this full-scale demonstration indicate that the treatment technology is a viable treatment option that can be easily integrated into existing activated sludge processes to provide additional treatment capacity, including peak flow treatment capacity, in a small footprint, while maintaining effluent quality.

Table 1. Secondary Clarifier Stress Testing: Select Operating Conditions and Effluent Quality

Day of Testing	Maximum SOR (gpd/sf)	Maximum SLR (lb/da/sf))	Secondary Effluent TSS (mg/L) (1)	Secondary Effluent TP (mg/L) (1)
Day 1	945	67	5.4 (9.0)	0.14 (0.21)
Day 2	1369	98	12 (19)	0.17 (0.22)
Target Conditions	≥ 883	57-80	10	0.3

Notes:
SLR – solids loading rate
SOR – surface overflow rate
1. Secondary effluent values presented are average values over the duration of the stress test and, in parentheses, the maximum reported discreet sample value.