ONTARIO'S GREEN SCHOOLS PILOT INITIATIVE

– Year One Sewage Treatment Results

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INTRODUCTION

The Green Schools Pilot Initiative (GSPI) is a joint program of the Ministry of Research & Innovation and the Ministry of Education *(www.edu.gov.on.ca/eng/parents/greenSchools.html)* that seeks to identify, demonstrate and test innovative green technologies developed in Ontario using a well-known reference customer – Ontario schools. Part of the effort is to reduce the environmental footprint of the schools' infrastructure, including on-site sewage treatment systems.

Through the initiative, the Ministry of Education (EDU) has provided over $20 million in funding for school boards to purchase and demonstrate innovative green technologies in over 150 schools across Ontario, with 23 different Ontario-based companies. For information on GSPI, please contact: David Ogilvie, Technology Programs, Ministry of Economic Development and Innovation (*www.Ontario.ca/innovation*) at 416-326-9628 or Fiona Menzies, Elementary-Secondary Business & Finance Division, Ministry of Education at 416-212-4444.

GREEN SCHOOLS SEWAGE TREATMENT

The district school boards of Upper Grand and Algoma submitted joint proposals with Waterloo Biofilter Systems Inc. (WBS) to replace existing sewage systems that were underperforming or too costly to operate. After a multi-phase selection process in 2009, WBS was asked to demonstrate high-level sewage treatment, nutrient removal, wastewater reuse, safe disposal means, and energy and operating cost savings at three Ontario schools.

The schools chosen for the pilot initiative were monitored over a period of five months to establish baseline performance benchmarks of energy consumption, noise levels, and nuisance odours. Historical data was available to establish benchmarks for effluent quality compliance, disposal success, and operational costs. Two schools had subsurface disposal nitrate removal objectives, and the third had surface discharge after chlorination, as established with Ministry of Environment (MOE). Engineering design and MOE approvals were completed in late spring of 2010, with the old systems being dismantled and new systems installed during the school's two-month summer holiday.

This article describes the system designs and analytical results of the first year and a half of operation, compares the data against the established benchmarks, and notes the positive environmental impacts and economic benefits. It concludes that these new technologies help meet MOE discharge requirements, while saving substantially on operation and energy costs for Ontario schools.

CENTRAL ALGOMA SECONDARY SCHOOL (CASS)

Baseline system – CASS

The CASS facility *(http://cass.adsb.on.ca/)* has a capacity of 834 students with cafeteria and was serviced by a 1970-era activated sludge-extended aeration plant designed to treat 132,000 L/d. After chlorination, the baseline plant effluent was discharged directly to Walker Creek that in turn outlets to Lake Huron. Phosphorus removal by alum addition was installed in 2007. Energy consumption was measured at ~3500 kWh per month. The baseline plant had no MOE Certificate of Approval (CofA) effluent limits but produced effluent averages of 18 mg/L cBOD and 37 mg/L TSS (medians of 3 and 19 mg/L respectively) between 2007 and 2009.

In 2008 the MOE and operator identified several physical plant deficiencies as well as health and safety concerns. To address these issues several alternative approaches including plant refurbishment and plant replacement were considered. Ultimately, a Waterloo Biofilter system was proposed to replace the plant due to its established track record of treating sewage in the cold Canadian climate, as well as its experience in surface discharge, nutrient removal and reuse, and low energy use.

Green School Design – CASS

The CASS Green School system consists of four 50,000 L septic tanks in series, 100,000 L of flow-balancing tankage, Waterloo Biofilter absorbent aerobic filters housed in three SC-40 shipping container treatment units, one 25,000-L final effluent dosing tank, and a shallow area bed disposal field. Two SC-40 treatment units are each rated at 40,000 L/day; the third is rated at 20,000 L/day and houses a 14-m^2 controls and operator room. Surface discharge for the new plant would have been uneconomical due to stringent new effluent limits proposed by the MOE for phosphorus, nitrogen and *E. coli*. Instead, a shallow area bed disposal field was constructed on the native clay soils and, due to its reduced footprint, could be placed at a distance of 300 m

CASS	cBOD mg/L	TSS mg/L	$NH_{3,4}$-N mg/L	*E. coli* cfu/100mL
MOE objectives	10	10	-	-
Baseline system N = 31	3	19	-	-
Green School system N = 14	1.9	1.5	0.15	1050

Table 1. Effluent median values for CASS baseline and Green School systems compared to MOE objectives. Baseline data are from 2007 to 2009; Green School data are from October 2010 to December 2011.

CASS	Baseline system $/year	Green School system $/year	Percentage savings	Cost savings $/year
Energy cost	$5,163	$1,804	65%	$3,359
O&M cost	$20,933	$8,718	58%	$12,215
Total savings per year with CASS Green School system				$15,574

Table 2. Energy and operation-maintenance cost comparison for CASS baseline and Green School treatment systems.

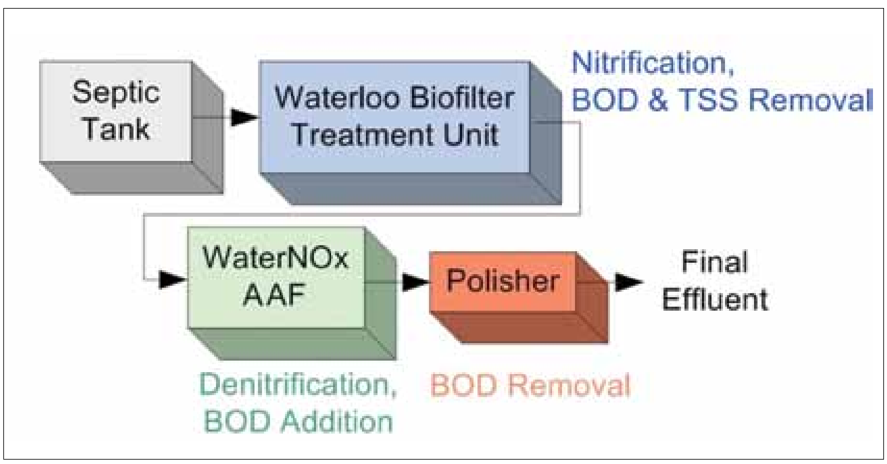

Figure 1. Process diagram of the Waterloo Biofilter nitrification-denitrification system installed at Erin DHS and Brisbane Green schools, including a Waterloo Biofilter to nitrify, a WaterNOx to denitrify, and a polisher to remove excess (biochemical oxygen demand) BOD added by the external carbon source. A shallow area bed with 250-mm sand barrier layer was installed at two facilities as disposal means.

from surface water, thereby eliminating phosphorus removal and disinfection from the design.

Analytical results – CASS

The CASS Green School plant was commissioned in September 2010 and sampled monthly beginning on October 19, 2010. From commissioning, the sewage was healthy and easily treated by absorbent filtration. The Waterloo Biofilter effluent discharged to the Shallow Area Bed was within MOE compliance objectives of 10 mg/L for cBOD and TSS within one month of start-up (Table 1). After a two-month start-up period (December 2010), 60% of total nitrogen (TN) was removed before disposal, and 73% TN during the actual school term when flows are highest. Median values of E. coli were reduced from 124,000 cfu/100mL in septic tank effluent to 1050 cfu/100mL after filtration and to 20 cfu/100mL below the 250 mm shallow area bed sand layer.

Green School energy and operational Costs – CASS

The Waterloo Biofilter plant consumed ~1220 kWh of electrical power per month compared with ~3500 kWh for the baseline system, a reduction of 65% (Table 2). This lower power consumption is largely due to a design of passive anaerobic digestion followed by passive aerobic filtration, with small effluent pumps replacing the energy-intensive air compressors of the baseline plant. Simpler maintenance requirements and fewer moving parts lowered operations and maintenance (O&M) costs by almost 60%, for a total savings of ~$15,600 per year in running costs, and with MOE compliance achieved since start-up.

ERIN DISTRICT HIGH SCHOOL (DHS) MULTI-USE FACILITY

Baseline system – Erin DHS

Erin DHS *(www.ugdsb.on.ca/edhs/)* serves over 600 students and staff, several offices, a nursery school, a library and an arena, and was serviced by a 160,000 L/d extended aeration package sewage plant installed in 2000. The baseline system included a denitrification tank with methanol addition, followed by a single-pass, back-washable sand filter and subsurface disposal in a leaching bed. Final effluent quality of the baseline plant had been very good (Table 3), however between 2005 and 2008 the plant was routinely out of compliance for nitrate, TKN and ammonia. In 2008 the MOE ordered that the plant demonstrate compliance with these effluent limits.

Because of past prohibitive energy consumption and operational costs (see Table 4 – with major capital improvement costs over 10 years not included in the Table), and the additional capital required to bring the system into compliance, the system was abandoned and replaced by a *Waterloo Biofilter* nitrification-denitrification system.

Green School design – Erin DHS

The Erin DHS Green School system consists of three 40,000-L septic tanks, 40,000 L of flow-balancing tankage, three Waterloo Biofilter SC-40s shipping container treatment units, and a demonstration-only, periodically operated

Erin DHS	cBOD mg/L	TSS mg/L	TAN mg/L	TKN mg/L	Nitrate-N mg/L
MOE objectives	10	10	2/3	3/4	3.6
Baseline system N = 118	2	3	0.1	1.0	4.2
Green School system N = 38	4	3	0.3	1.6	7.3

Table 3. Effluent median values for Erin DHS baseline and Green School systems compared to MOE objectives. Baseline data are from January 2005 to June 2010; Green School data are from September 2010 to December 2011.

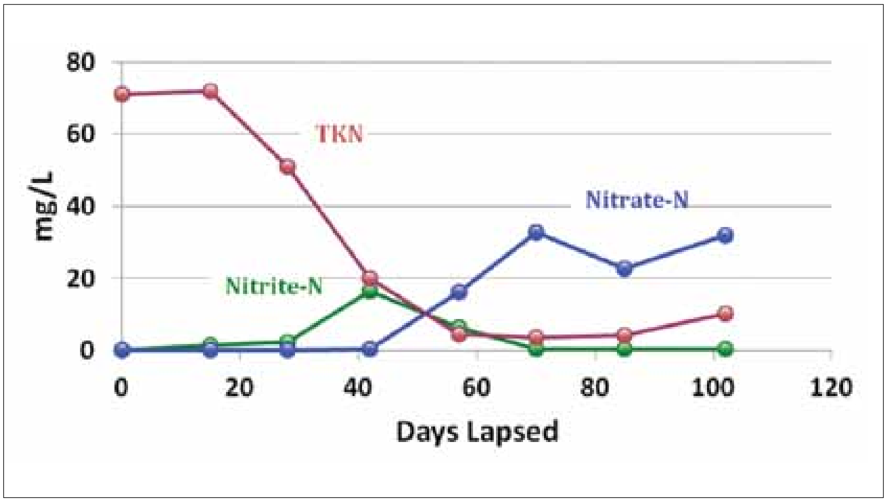

Figure 2. Thorough nitrification in the Waterloo Biofi*lter* was established 60-70 days after start-up following transitory appearance of nitrite, with ~50% TN removal at this time. Cold sewage after Day 100 inhibited nitrification. The Brisbane Green School plant followed a similar pattern for the nitrogen species.

wastewater reuse system (UV disinfection after final effluent). The existing leaching bed disposal field was reused at the site. One SC-40 treatment unit rated at 40,000 L/day houses the Waterloo Biofilter, one SC-40 houses a WaterNOx nitrogen removal system with carbon addition (*Jowett et al., 2009*). The third SC-40 houses a Waterloo polisher to remove excess carbon for final discharge (Figure 1), as well as a 14-m^2 controls and operator room where carbon addition and UV disinfection are located. Performance tracking at Erin DHS and Brisbane schools was more extensive than at CASS due to the nitrate, TAN and TKN requirements and the demonstration reuse system.

Analytical results – Erin DHS

The Green School plant was commissioned in September 2010 and was sampled twice-monthly beginning in late September. The standard cBOD and TSS parameters were within the <10 mg/L objectives within three months (Table 3), but nitrogen was another issue.

Cold temperatures, potential solvent use, and low alkalinity, etc. impede nitrification, and these factors affected Erin DHS and Brisbane schools. At start-up, nitrite (NO_2-N) is produced first in the Biofilter from ammonium and then converted to nitrate (NO_3-N), which then can be de-nitrified to nitrogen gas in the anoxic environment of the WaterNOx. Figure 2 shows the conversion of ammonium to nitrite and then to nitrate in the Waterloo Biofilter unit over a number of months. Alkalinity mirrors TKN in the effluent as it decreased from 400 – 500 mg/L at start-up to 100 – 200 mg/L after 60 – 70 days as it was consumed by conversion of TKN to nitrite and nitrate. Cold temperatures were characteristic of the Erin DHS and Brisbane sewage with winter values of 4 – 6°C, as evidenced by the rise in TKN after three months.

Operational issues overcome in starting up the WaterNOx at Erin DHS and Brisbane were relative recirculation rates for de-nitrification and alkalinity levels, carbon dosing before thorough nitrification, and maintaining an anoxic environment. These issues were resolved in the period from October – November and the systems were fully operational by the end of December 2010. Figure 3 shows the final effluent at Erin DHS in compliance for cBOD & TSS (10 mg/L) within three months. The anomalies at Days 30, 240 and 480 are due to over-dosing of carbon in the WaterNOx, and the natural anomaly at Day 75 – 110 is due to onset of thorough nitrification and denitrification. Brisbane shows a similar trend for cBOD & TSS.

Energy and operational costs – Erin DHS

The Erin DHS baseline suspended-growth extended-aeration plant was operated at 25% of its total capacity and consumed ~8900 kWh electrical power per month mainly due to large air compressors. In comparison, the Green School system consumed ~1460 kWh per month, a reduction of 84% (Table 4). A 70% reduction in O&M costs was attained due to simpler maintenance requirements, fewer moving parts and lower chemical addition and storage costs. An overall savings of ~$38,700 per year is realized in running costs at Erin DHS (Table 4) with MOE compliance achieved for all parameters within two to seven months.

Noise pollution – Erin DHS

Decibel level readings were taken at various distances from the respective plants at Erin DHS (Table 5). The baseline aeration system used large, high capacity air compressors that were audible more than 30 m from the compressor building (doors closed). Noise readings around the Green School *Waterloo* system were at background levels within 3 – 8 m from the plant, while for the baseline aeration system levels were still twice the background at this distance.

Nuisance odours – Erin DHS

For the baseline system, a teacher in the nearest portable to the system had often detected foul odours at a 100-m distance;

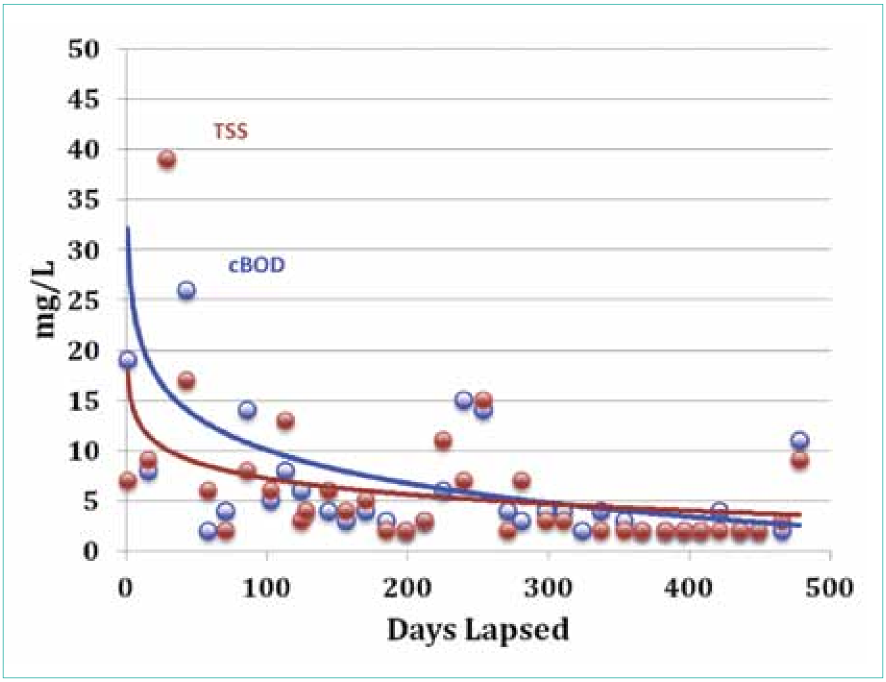

Figure 3. Final polisher effluent at Erin DHS Green School before subsurface discharge was within the 10 mg/L compliance for cBOD & TSS after three months. Performance improves steadily to < 5 mg/L with two to three upsets due to excessive organic carbon loading on the WaterNOx unit.

Erin DHS	Baseline system $/year	Green School system $/year	Percentage savings	Cost savings $/year
Energy cost	$10,748	$1,775	84%	$8,973
O&M cost	$42,516	$12,770	70%	$29,746
Total savings per year with EDHS Green Schools System				$38,719

Table 4. Energy and operation-maintenance cost comparison for Erin DHS baseline and Green School treatment systems.

Horizontal distance from sewage plant (m)	Baseline (dB)	Green School (dB)
<1	91	55
3	79	43
8	69	40
15	63	-
30	55	-

Table 5. Noise pollution levels for Erin DHS baseline and Green School treatment systems (~40 dB is background value).

whereas, once the Green Schools system was installed, the same teacher detected no foul odours even with the plant positioned at 40 m away from the portable.

BRISBANE ELEMENTARY SCHOOL

Baseline system – Brisbane

Brisbane public school (*www.ugdsb.on.ca/brisbane/*) has a capacity of 416 students and was serviced by a 14,100- L/day suspended-growth extended-aeration package plant installed in 2003. Despite strict nitrogen effluent limits, the baseline system had no de-nitrification component prior to disposal in shallow buried trenches. Final effluent quality at the baseline plant had been very poor, being consistently out of compliance with the MOE effluent limits (Table 6). In 2008, the MOE ordered that the plant be brought back into compliance with the CofA. Being concerned with the past performance of the baseline system the decision was made to replace it instead of attempt to remedy it.

Green School design – Brisbane

The Brisbane Green School system consists of one 39,000-L septic tank, one 13,000-L flow-balancing tank, one modified Waterloo Biofilter SC-40 shipping container treatment unit, a demonstration-only, intermittently operated wastewater reuse system (UV after final effluent), and a shallow area bed disposal means. The SC-40 container at Brisbane makes efficient use of space by housing components with multiple uses in different compartments – a Waterloo Biofilter rated at 13,000 L/day, a WaterNOx nitrogen removal system, a Waterloo polisher, as well as a control room with all control panels, chemical dosing equipment, and UV disinfection unit and operator's table.

Analytical results – Brisbane

The Green School system was commissioned in September 2010 and was sampled twice-monthly beginning in late September. The standard cBOD and TSS parameters were within the 10-mg/L objectives within two months (Table 6, Figure 4), but, again, a longer time period was required for full nitrogen removal, achieving compliance after five months.

Brisbane	cBOD mg/L	TSS mg/L	TAN mg/L	TKN mg/L	Nitrate-N mg/L
MOE objectives	10	10	2	4	4
Baseline system N = 23	18	38	20.0	32.4	6.8
Green School system N = 36	6	7	0.3	1.6	4.9

Table 6. Effluent median values for baseline and Green School treatment systems compared to MOE objectives. Baseline school data from March 2005 to June 2010; Green School data from September 2010 to December 2011.

Cold sewage and solvent use are the main suspected inhibitors to nitrogen removal at this site. A final effluent quality spike in nitrogen species was seen in January and coincided with a similar spike seen at Erin DHS, possibly due to cleaning over the holidays. Like Erin DHS, conversion of TKN first to nitrite and then to nitrate was evident in the analytical results.

Energy and operational costs – Brisbane

The Brisbane baseline package plant consumed ~1100 kWh electrical power per month compared to the Green Schools consumption of ~241 kWh, a reduction of 78% of energy costs (Table 7). Operational and maintenance costs were reduced by 46% for an overall reduction in running costs of ~$5,400 per year.

NITROGEN SPECIES AT ERIN DHS AND BRISBANE

WaterNOx performance – Brisbane

The Brisbane WaterNOx started to remove nitrate after Day 55 (Figure 5) to a total nitrogen level of <4 mg/L by Day 100 in the final effluent. Denitrification continued to follow this level of treatment except for periodic inhibitory events that impeded nitrification at both Brisbane and Erin DHS schools. These inhibitory anomalies are considered real but the cause is not always known. They have no effect on pH or cBOD, COD or TSS. Known causes include cold temperatures, holiday or end-of-term cleaning, lack of carbon dosing, sudden increases in influent sewage strength, and chemicals used in HVAC maintenance. The anomaly at the close of school at Day 270 affected TKN and nitrate only, and coincides with a tripling of strength of sewage in TKN and TP.

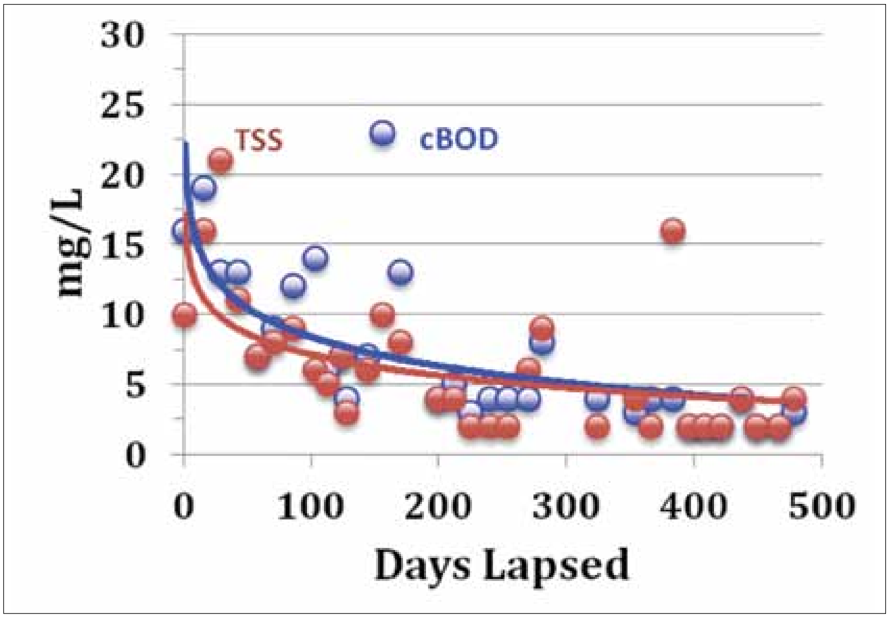

Figure 4. Biofilter effluent at Brisbane before subsurface discharge was in compliance for cBOD & TSS (10 mg/L) after two months, with a consistent improvement to < 5 mg/L.

Brisbane	Baseline system $/year	Green School System $/year	Percentage savings	Cost savings $/year
Energy cost	$1,337	$293	78%	$1,044
O&M cost	$10,536	$5,702	46%	$4,834
Total savings per year with Brisbane Green School system				$5,878

Table 7. Energy and operation-maintenance cost comparison for Brisbane baseline and Green School treatment systems.

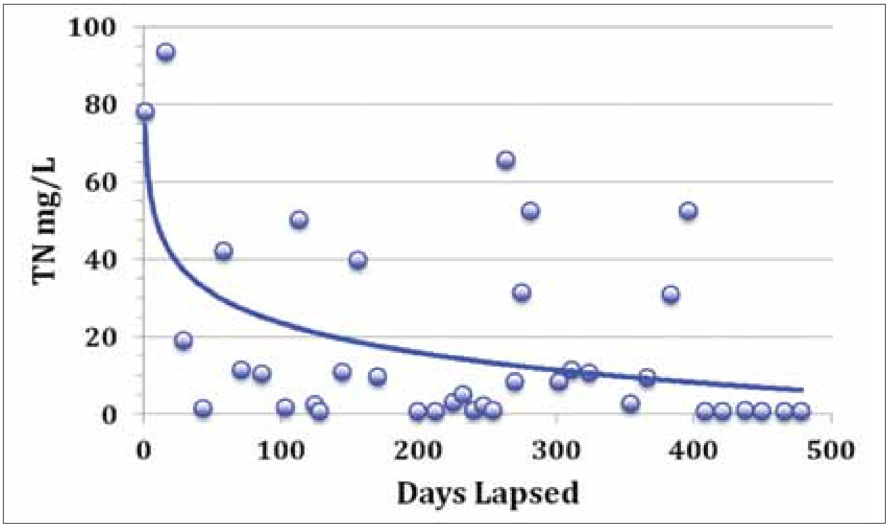

Figure 5. WaterNOx effluent at Brisbane showing thorough removal of total nitrogen (TKN + NO_3-N + NO_2-N) with periodic anomalies due to insufficient carbon, holiday cleaning, and HVAC maintenance procedures.

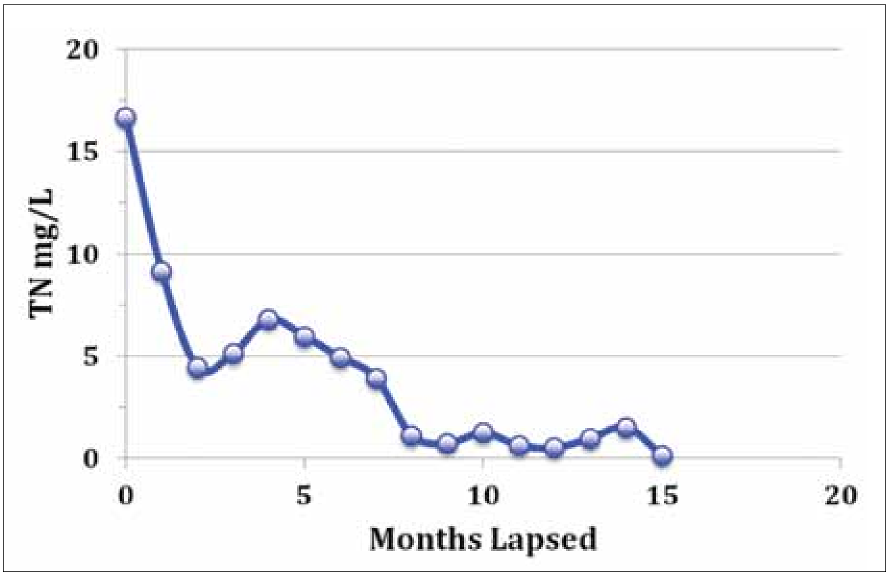

Figure 6. Calculation of total nitrogen concentration at Erin DHS Green School property boundary per MOE D-5-4 procedure. Certificate of Approval limit of 2.7 mg/L TN at the boundary was met after seven months operation during the first winter.

Property boundary concentration – Erin DHS

The ultimate reason to remove nitrogen from sewage is to ensure that the groundwater resources of neighbouring properties is not contaminated by nitrate. The allowable nitrate concentration at the property boundary is first assumed (2.7 mg/L at Erin DHS) and then a concentration is calculated for the plant effluent (3.6 mg/L at Erin DHS) based on the design hydraulic flow and infiltrative dilution over a year. The periodic poisoning of sewage causes nitrate anomalies in the plant effluent, but it is the mass of nitrogen that is of primary importance in protecting groundwater resources.

E. COLI REMOVAL AT ERIN DHS and BRISBANE

Although not a compliance parameter, *E. coli* is of interest to the Green Schools program and was included in the analyses. Figure 5 shows the evolution of *E. coli* in the polisher effluent from 1,000 – 10,000 cfu/100mL in the first months to a geometric mean value less than 200 cfu/100mL after two months at both schools. The Waterloo Biofilter and WaterNOx effluents show similar trends with higher values.

WASTEWATER REUSE AT ERIN DHS AND BRISBANE

The Erin DHS and Brisbane Green School systems include a UV disinfection unit after the polisher to produce a final effluent suitable for non-potable reuse in toilet flushing or irrigation. Wastewater reuse at these sites is demonstration only – UV units are operated for 20 minutes each month before a sample is collected. Both Erin DHS and Brisbane Green School systems produced a final effluent suitable for reuse after four months of operation, with final effluent values of <10 mg/L cBOD and TSS, and <5 cfu/100mL *E. coli*.

SHALLOW AREA BED DISPOSAL

The subsurface disposal trenches used in the Brisbane baseline system were not evenly distributing effluent, increasing the likelihood of surface breakout. The trenches were replaced by a shallow area bed disposal means using a fine sand barrier layer, with a pan lysimeter installed to collect final effluent as it enters the natural environment. The arithmetic average concentrations of contaminants beneath the sand layer are *E. coli* = 3 cfu/100mL (N = 6), cBOD = 2.8 mg/L (N = 5), and NO_3-N = 2.1 mg/L (N = 4). Chloride values of final effluent and shallow area bed are both 420 mg/L indicating that contaminant removal by the sand layer is due to biological filtration and not dilution.

CONCLUSIONS

The first year and a half of the Green Schools Pilot Initiative demonstrating high-quality sewage treatment with low energy inputs has been successful at the three schools involved. The substantial cost savings are estimated at $15,600, $38,700 and $5,900 per year at CASS, Erin DHS and Brisbane schoolss respectively.

Effluent criteria for standard parameters of cBOD and TSS are met within two to three months of start-up, with thorough nitrogen removal after three to four months. Periodic operational and natural events inhibit nitrification but microbial recovery after the events has been quick. Removal of all sewage parameters including *E. coli* is thorough before subsurface disposal, and the shallow area bed sand barrier layer is removing the remainder to non-detectable levels before the natural environment. There are no nuisance noises or odours.

The Green School systems incorporating wastewater reuse add-ons produced a final effluent suitable for reuse in toilet flushing or irrigation within four months of start-up.

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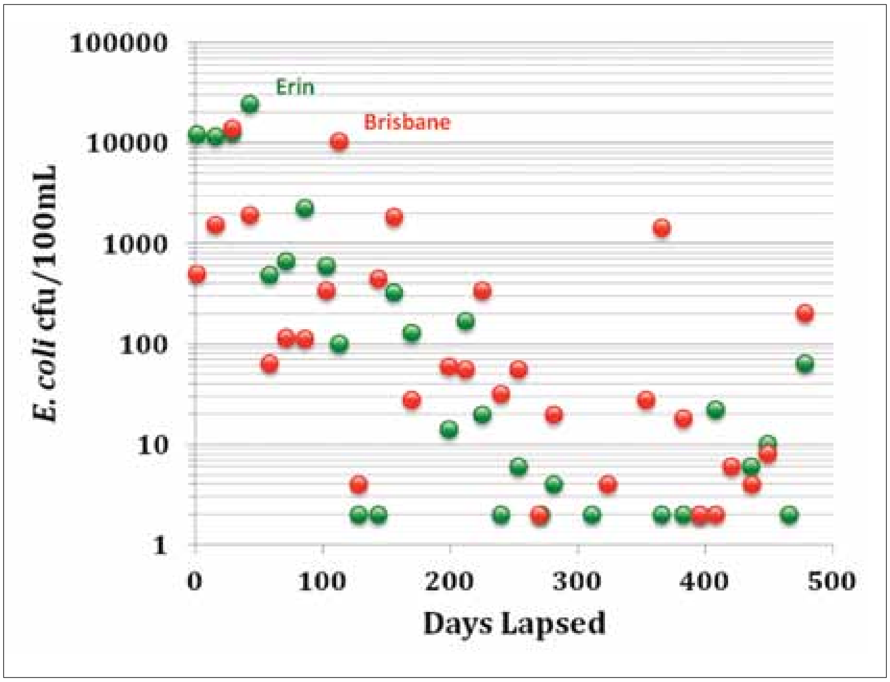

Table 7. *E. coli* values decrease with time in the polisher at Erin DHS and Brisbane schools and average less than 200 cfu/100mL after four months.