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A Case Study in Designing for High Strength Wastewater: Using A Holistic Approach

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Introduction

A new truck stop located in East-Central Ontario consisting of a high-traffic gas station, variety store and coffee & doughnut shop required an on-site wastewater treatment system. The daily design sewage flow for this system was 20,000 L/day, which required an engineered design and MOE approvals. In order to meet stringent effluent criteria for nitrates and meet reasonable use guidelines, Dobri Engineering Ltd. was hired to propose an innovative design.

Due to the difficult nature of the wastewater, and the high quality of effluent required, a holistic approach was used in the design and operation of this system, which can be broken down into the following steps:

1) **Design Elements**- Specifying the correct tank sizes for retention time; Using balance tanks to store peak flows; Incorporating various re-circulation loops in the system process.
2) **Wastewater Characterization**- Compiling historical data from similar sites; Anticipating the strength of sewage and impacts on the wastewater treatment system performance based on analytical data including: cBOD, TSS, TKN, pH and alkalinity.
3) **Usage of the facility**- Understanding company policies for kitchen practices and cleaning procedures; Investigating the potential of modifying company policies to benefit wastewater treatment
4) **O+M Requirements**- Assessing system performance (mechanical components, dosing rates, biological and chemical characteristics of wastewater); Frequency

for regular grease trap and septic tank pump-outs; Using Bio-Augmentation as a valuable tool for remediation, optimization and system start-up.

Where the sewage strength is domestic and cleaning habits and kitchen practices can be controlled (using safe-for-septic practices), on-site wastewater treatment systems are inherently simple to operate and maintain, and a good design can usually be accomplished by taking steps 1 & 2 of the holistic approach and paying little attention to or even overlooking steps 3 & 4. However, in situations where sewage entering the septic system is harsh, a full holistic approach (Steps 1-4) is required to formulate a successful design. This paper is a case study of how the holistic approach was taken to design an on-site treatment system for a truck stop, consisting of a gas station and coffee shop, which produces difficult-to-treat sewage. The success of this design is also discussed through historical performance data of the treatment system.

Steps 1 & 2: Design Elements & Wastewater Characterization

Since the facility was a commercial type, it was known that the treatment system would have to be oversized. Based on historical data for the coffee shop, BOD and TKN loadings were expected to be in the range of 1500-2000 mg/L and 40-200 mg/L, respectively *(Dobri Engineering Ltd., 2004)*. Additionally, the flow produced by the facility would be inconsistent, with hydraulic peaks occurring during the busy hours (breakfast and lunch). Based on the number of seats + staff at the facility and an additional restaurant at the truck stop, the daily design sewage flow was sized to accommodate 30,000 L/day of high strength wastewater.

General design guidelines for a commercial facility were provided by Waterloo Biofilter. The preliminary design, shown in Figure 1, consisted of septic tanks with 3-day retention time, effluent filters, balance tank, Waterloo Biofilter SC-40 treatment unit, disposal tank, proprietary denitrification unit and leaching bed. The design also incorporated alternating duplex pumping systems for longer pump life and a back-up, in case of pump failure. A large balance tank was used to store the peak flows allowing the Waterloo

Biofilter to be evenly dosed throughout a 24-hour period using a cycle timer, as depicted in Figure 2.

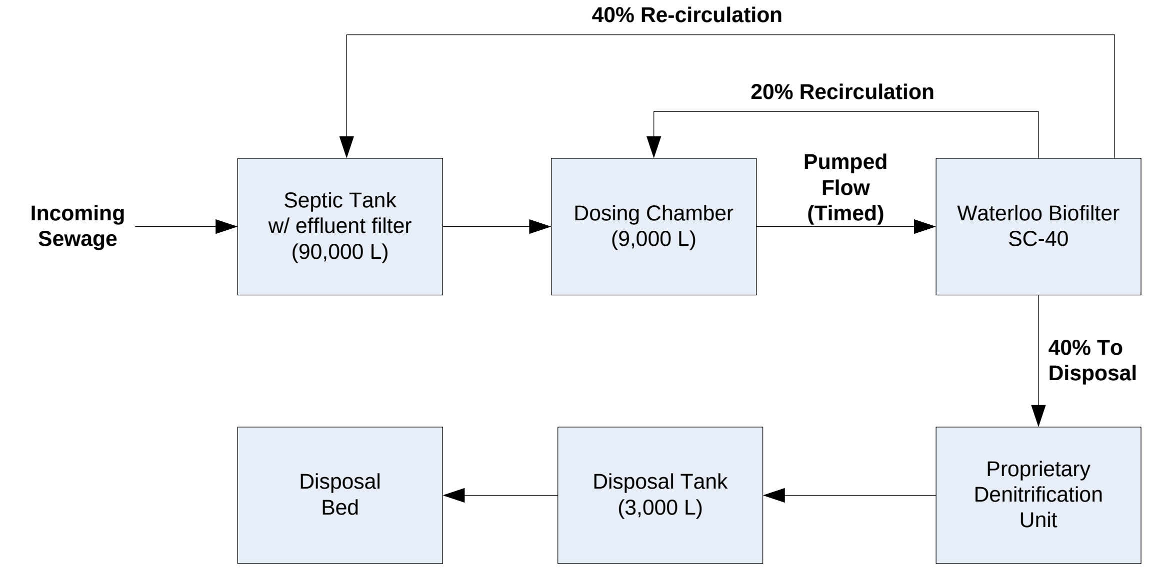

Figure 1 – Preliminary Design of WBS treatment system to treat 30,000 L/d from a coffee shop and gas station with a restaurant.

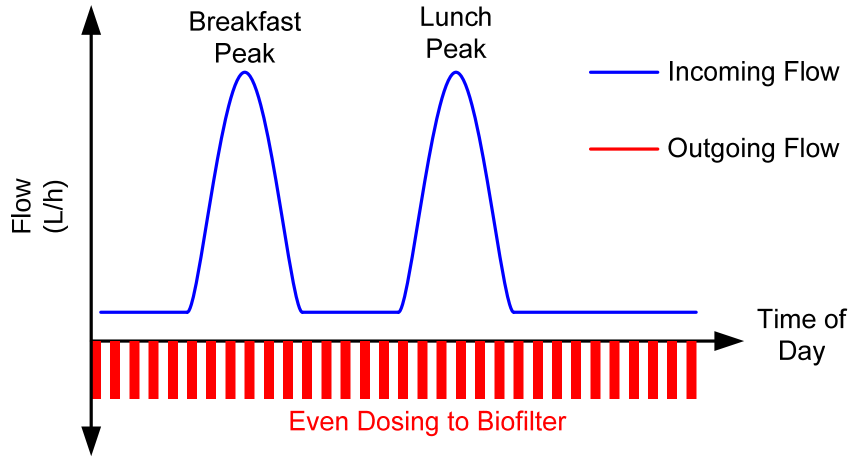

Figure 2 – Incoming flow is stored in balance tank. Outgoing flow is modulated using a cycle timer to allow for even dosing to the Waterloo Biofilter.

After the initial design was submitted, difficulties encountered using the proprietary denitrification unit historically were discussed, prompting Dobri Engineering to rethink their design approach.

Step 3: Usage of the facility

When an on-site system is designed, a site visit is an essential requirement. One of the key components of the site visit is to map the site layout (topography, property boundaries, etc.), so that a system can be properly designed and placed on the site. This is very important because every site is different, and there are occasional design challenges that one cannot see without making a visit.

Investigating the '**Usage of the facility'** is an equally essential component of the site visit, because it helps identify the practices and what kind of waste will ultimately enter the septic system. This also allows a chance to understand the cleaning and disposal needs of the client, and allows for recommendations to help make treatment easier.

The cleaning habits and kitchen practices of commercial facilities can differ significantly from domestic practices, and in fact can differ significantly from commercial facility to commercial facility. Restaurants are especially difficult because health and safety is paramount in the operations. Most restaurants adhere to strict cleaning procedures to meet health requirements, which if not met, can mean that the business is forced to shut down.

After investigating the **'Usage of the facility'**, by observing cleaning procedures and kitchen habits, the following challenges were found:

1) **Food waste and food preparation materials entering septic system** - Glazing, granulated sugar, soups, coffee and other food scraps and other solid wastes were being put down the sink. These materials are difficult to degrade, cause higher BOD & TKN loadings onto the treatment system, and create conditions that adversely effect the microbial populations responsible for treating the wastewater.

2) **Chemical cleaners entering septic system –** Harsh chemical disinfectants are used to clean surfaces and are used frequently throughout the day. This problem

is also exasperated by the fact that the quantity of chemical used was far more than what was required to effectively clean the surface.

3) **Fats, oil and grease –** FOG is a typical problem for most restaurants as they are slow to degrade and tend to accumulate and form a thick scum layer in the septic tank. FOG accumulation decreases the effective retention time of the septic tank which impacts the capacity to settle solids and to provide adequate fermentation. FOG can also degrade and produce fatty acids, which lower the pH of the wastewater, causing treatment problems (slows metabolic activity) in biological systems.

Once the above challenges were identified, recommendations were made to alleviate the negative impact they were having on the septic system.

The recommendations made include:

1) Diverting as much (or all) food and food preparation materials to the garbage rather than down the sink. Divert liquid food (coffee, soup) to separate storage system (i.e. holding tank not connected to septic system) and dispose off-site.
2) Cleaning Habits-
    a) Implement steam cleaning technology and minimize the need to use chemicals. This would require training staff, or hiring staff dedicated to cleaning only.
    b) Clean surfaces with soap and water only. Spray disinfectant on surface and wipe off with towel for residual effect, and dispose towel in garbage.
3) Install exterior grease traps and incorporate regular pump-out schedule.

Figure 3 shows the ‘sources’ (coffee, soups, disinfectants, etc.) and the recommendations made to lessen their impacts on the treatment system (isolated storage tanks, garbage, septic tank, grease trap, etc.).

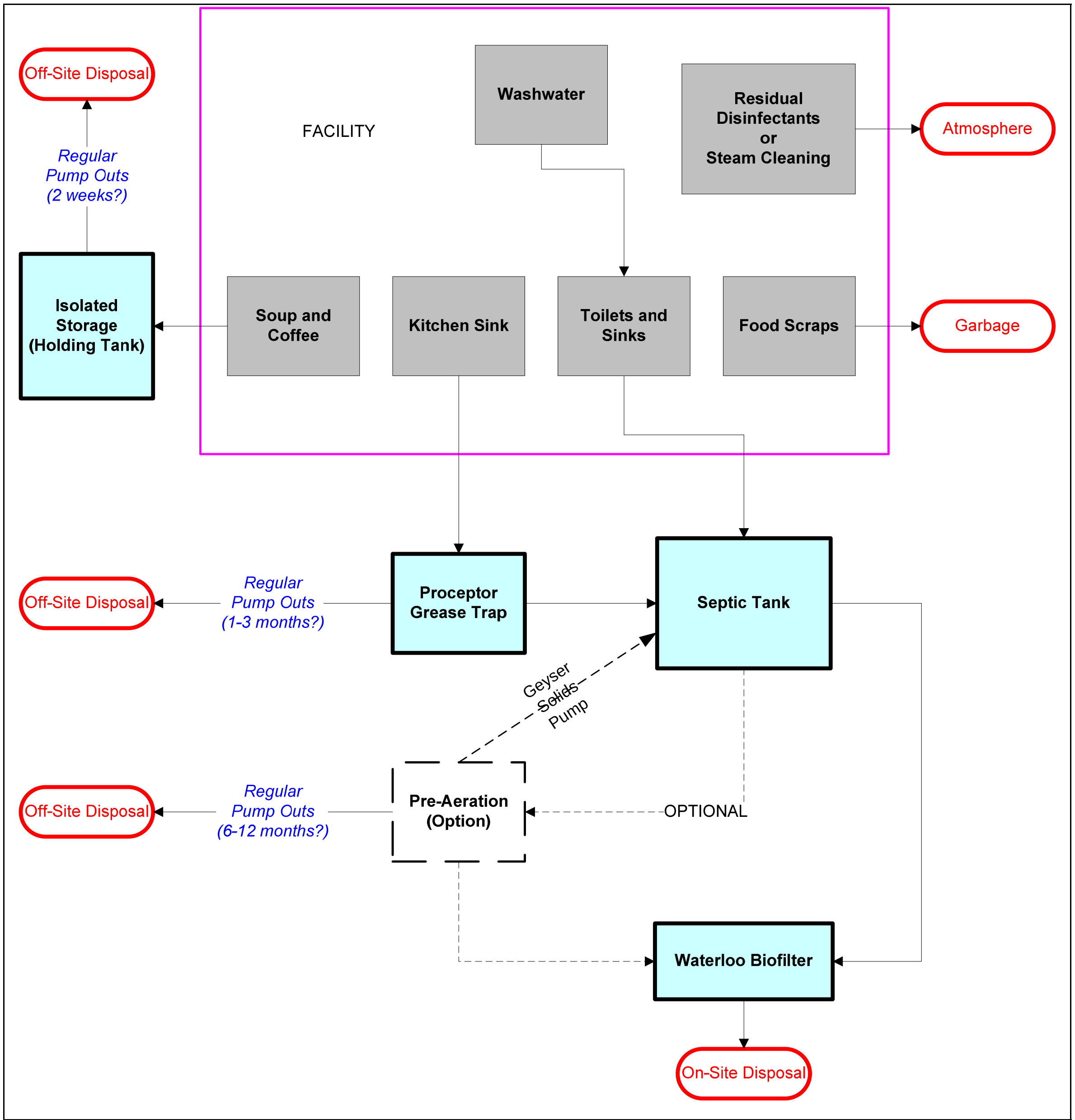

Figure 3 – Flow Diagram illustrating the recommendations for the operations of the facility.

The goal of these recommendations was to minimize the impacts of the 'non-domestic' cleaning and kitchen practices on the treatment system, by attempting to change procedures within the facility and to incorporate additional design elements (grease traps, regular septic and grease pump-outs, and aeration system).

Recommendations to change kitchen and cleaning practices are much easier to implement and are readily accepted at facilities with highly trained staff such as high-end golf courses *(Jowett et al., 2001).* However, corporate policies for maintaining high levels of health and safety at this national coffee chain are strict and must be adhered to for safety. Recommendations of changes must be within their corporate policy framework and show that health & safety standards are not affected.

The purpose of this exercise was to further investigate the nature of the facility, and how policies and procedures affect the treatment system. The wastewater treatment system does not start at the inlet pipe to the septic tank, but starts inside the facility. Although the recommendations would have been effective in decreasing the strength of the sewage, it is not possible to implement all of them, in particular changing cleaning and kitchen practices.

After completing Step 3, Dobri Engineering gained better insight into the usage of the facility which prompted a review and amendment to the design. The design flow was downsized to 20,000 L/day after the owner decided not to proceed with a restaurant. The final design, shown in Figure 4, incorporates new additions such as a grease trap, aeration tank with aerobic sludge return and an Aquamend Denitrification unit. Although the design flow had decreased, the size of the Waterloo Biofilter remained the same to provide more treatment medium to treat the high strength wastewater.

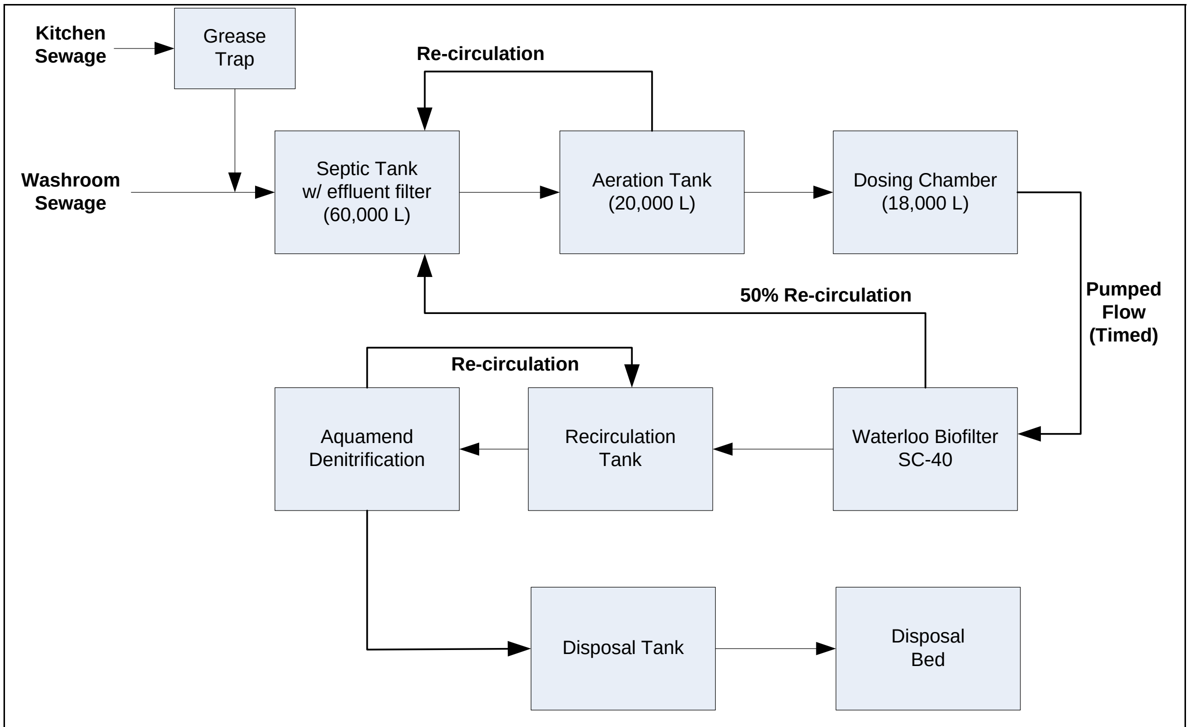

Figure 4 – Final Design after investigating the usage of the facility to treat 20,000 L/d from a coffee shop and gas station. Design flow was decreased after owner decided not to proceed with building a restaurant.

Steps 4: O+M Requirements

The treatment system was installed in the Fall of 2004 and start-up commenced in the Winter of 2005. Start-up was slow, and there were no signs of nitrification, which was expected because of cold temperatures *(Metcalf and Eddy, 2003)*. It was anticipated that the treatment performance would improve with time and with warmer temperatures, but even after 6 months, the system continued to perform poorly. The effluent produced by the Waterloo Biofilter was brown and very cloudy and had a noticeable food odour, and Waterloo Biofilter Systems was asked to assess the situation and troubleshoot.

Analysis of System

After conducting a site visit, it was apparent that the system was not treating properly and a professional operator had not been engaged. Several system adjustments were made to help optimize system performance, but treatment had not improved by the next site visit a few weeks later. The results were surprising considering that the treatment system was oversized and incorporated upgrades (aeration, grease traps). Samples of septic tank effluent, aeration effluent and Biofilter effluent were taken and under normal circumstances, the effluent gets progressively clearer. However, there was no visible difference between the three samples and the food odour emanating from all three samples. These findings showed the system was ineffective in treating the wastewater to the required level, and implied that: 1) naturally occurring microbes residing in the system were not resilient enough to survive the harsh chemical usage, and 2) the system would require more attentive operations and maintenance.

Understanding the impacts on Biological Treatment

As shown in Figure 6a, biological treatment of wastewater can be simplified by classifying it into a three-step process: 1) BOD removal, 2) Nitrification ($NH_{3,4}$-N → $NO_{2,3}$-N), and 3) Denitrification (NO_3-N → N_2). For maximum TN removal, BOD must be treated (Level 1), before optimal nitrification can occur (Level 2). Nitrification must occur to produce nitrate, which can then be recirculated to an anoxic zone (septic tank) to be denitrified (Level 3).

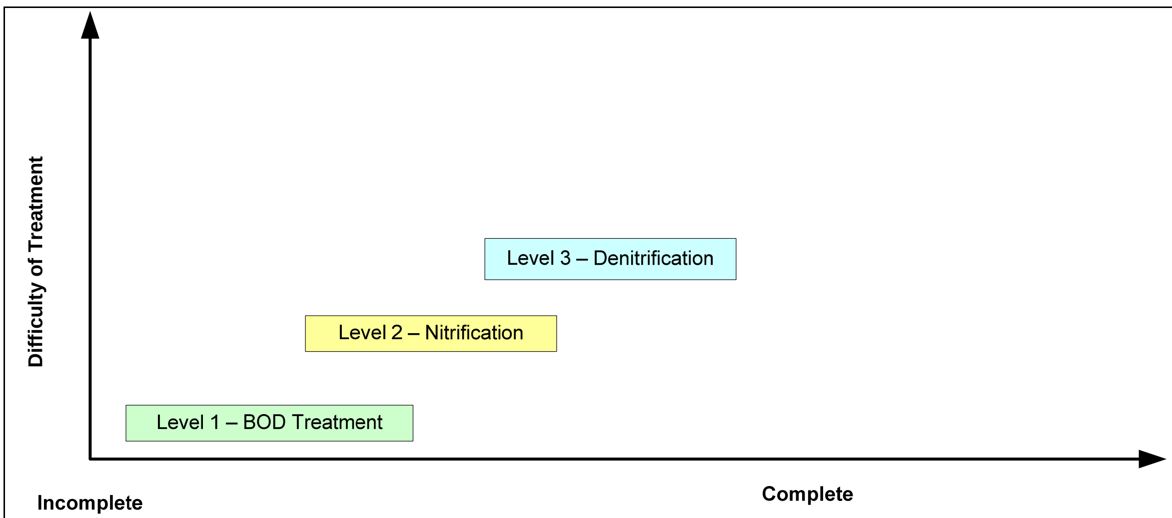

Figure 6a – Levels of treatment required for 'complete treatment'

The effects of the kitchen and cleaning practices are illustrated in Figure 6b. Disinfectants and harsh chemicals inhibit and even kill microbial populations, thereby making treatment more difficult as illustrated by the shift of treatment up the scale of difficulty (Y-axis). Kitchen practices which require disposing large amounts of coffee and soups cause the BOD and TKN loads to increase as illustrated by the extension of each level (X-axis), requiring 'extra' treatment to achieve completion.

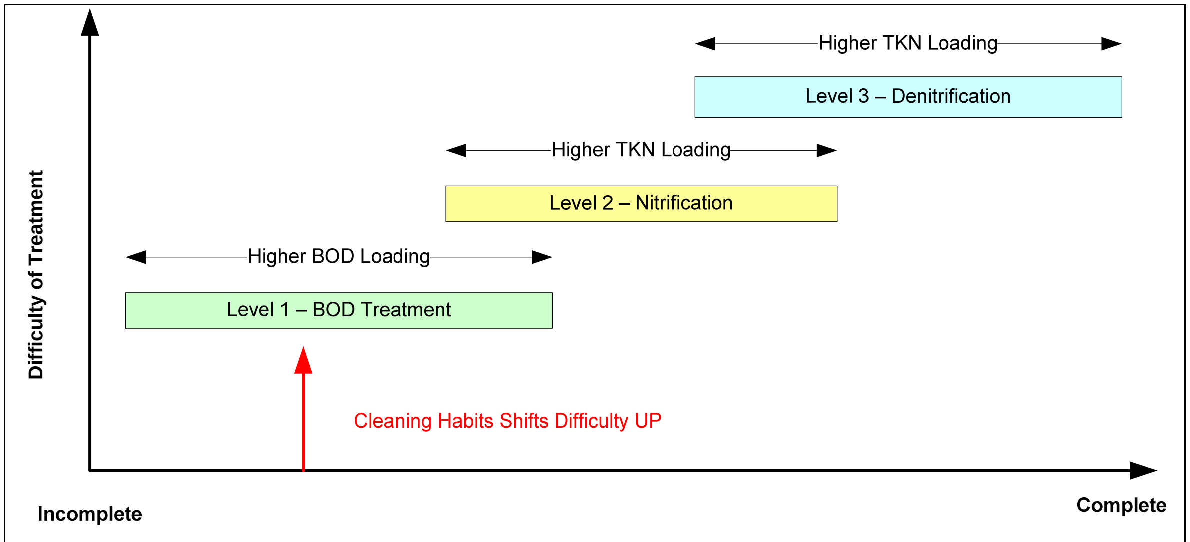

Figure 6b – Effects of kitchen practices and cleaning habits on the levels of treatment required for 'complete treatment'

O+M Solutions

The proposed solution to help treatment consisted of:

1) Decreasing the BOD and TKN load into the system, and
2) Bio-augmenting the treatment system with a more resilient and efficient microbial population (using proprietary bacteria).

Decreasing BOD and TKN Loading

The role of grease traps is to remove FOG and solids by settling solids and allowing FOG to float to the top. This allows a "less potent" clear zone to flow through into the treatment system. However, as the solids and FOG accumulate, retention time in the grease trap decreases, allowing for short-circuiting to occur and releasing compounds that increase BOD and TKN loading.

Decreasing the BOD and TKN loading into the treatment system was accomplished by mandating pump-outs of interior and exterior grease traps. The interior grease trap was to be pumped out on a monthly basis and the exterior grease trap to be pumped out on bi-monthly basis. This frequency was necessary to decrease the likeliness of short-circuiting.

Bio-Augmentation – Using Proprietary Bacteria

For years most on-site wastewater professionals have been discouraging people from using bacterial additives and enzymes for remedial and start-up purposes. Although inoculation was successfully used in landfill leachate treatment, Waterloo Biofilter Systems had no noticeable success using commercially available bacterial additives.

Another argument was that enzymes mask the problem by emulsifying slow-to-degrade compounds such as FOG. The emulsified FOG will eventually wash out to the leach field where it can clog the soil. The role of enzymes is to “cut up” complex molecules into simpler molecules, so that microbes can use them as a food source. Microbes naturally secrete enzymes to do this job, and the amount of enzyme is regulated by the microbe’s food requirement. The problem with introducing enzymes into a treatment system is that they only take care of the up-front problem by liquefying the slow-to-degrade compounds. However, if there is insufficient microbiology to treat the waste, these compounds remain in solution and short-circuit into the field.

The basis for choosing an appropriate bacterial additive for bio-augmentation of this site was: 1) the constituents of the additive (selected bacteria only and not merely an enzyme), 2) the efficiency of the bacteria in degrading the difficult compounds in wastewater, such as FOG and 3) the survivability of the bacteria in harsh conditions. After researching available bacterial additives on the market, a product was chosen based on these requirements.

Bio-augmentation was accomplished by seeding the treatment system manually for the first month. After the first month, the engineered bacteria was added using a chemical dosing pump on a continuous basis.

Biofilter Treatment Performance

After implementing the new operations program and bio-augmenting the treatment system, analytical results showed drastic improvements in Biofilter effluent quality as shown in Table 1.

	cBOD (mg/L)	**TSS (mg/L)**	**TKN (mg/L)**	**$NO_{2,3}$-N (mg/L)**
Before O+M Protocols & Bio-Augmentation				
Raw Sewage*	318	200	93	0.6
Waterloo Biofilter Effluent	148	75	78	0.6
% Removal:	*54%*	*62.5%*	*Nitrification Efficiency = 0.76%*	
After O+M Protocols & Bio-Augmentation				
Raw Sewage	236	74	46	0.03
Waterloo Biofilter Effluent	6	6.8	5.5	21.5
% Removal:	*97%*	*91%*	*Nitrification Efficiency = 79%*	

Table 1 – Treatment Data Summary Table

*Raw sewage numbers are actually a mixed value of Biofilter Effluent + Aeration Effluent + Raw sewage entering into the septic tank. Actual raw sewage is much higher than the numbers reported here.

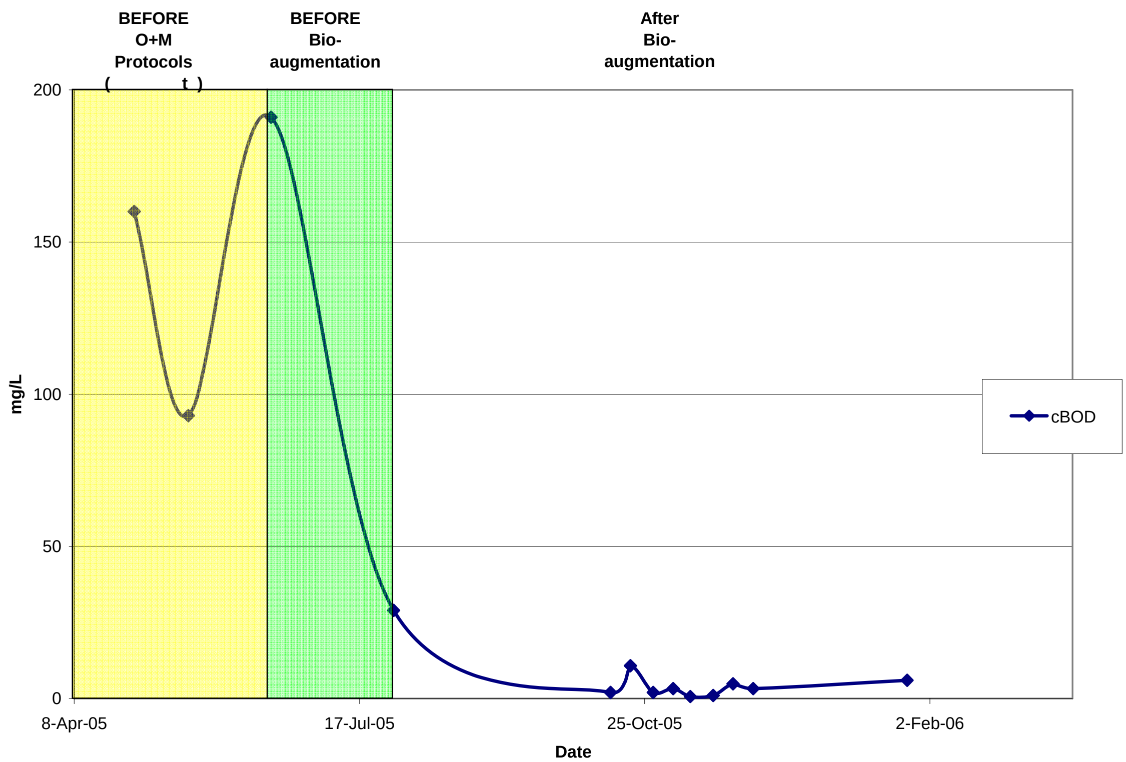

Figure 9 –Biofilter Effluent Performance Graph for cBOD

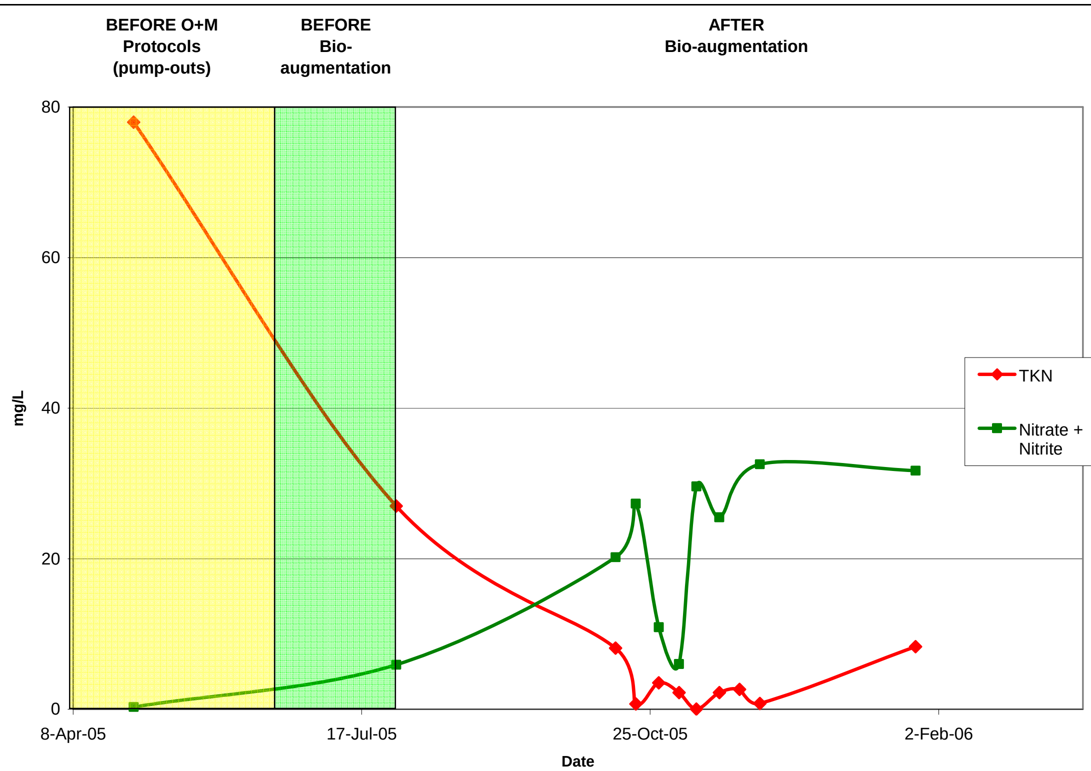

Figure 10 –Biofilter Effluent Performance Graph for Nitrogen

As shown in Figures 9 & 10, Biofilter effluent improved dramatically for cBOD and nitrification starting to take place. Visual inspections show that the effluent was clear and odourless, with a slight yellowish tinge, most likely due to the presence of colour causing compounds such as lignins and tannins (*Jowett et al., 2001*).

Conclusions

This case study shows how a poorly performing system was improved by adding proprietary bacteria and incorporating better O+M practices. After these steps were taken, the system responded quickly with excellent BOD removal and showed a dramatic improvement in nitrification efficiency. This shows that a holistic approach is essential in designing an on-site wastewater treatment system, especially for difficult wastewaters. The approach is essential because it allows the designer to identify the elements within the commercial facility that can be very problematic to treatment and provide necessary safeguards to provide a sound design.

Design elements (step 1) and wastewater characterization (step 2) are minimum requirements typically incorporated into all system designs. Unfortunately, ‘Usage of Facility’ (step 3) is typically overlooked and O+M requirements (step 4) are usually unknown until the system is in operation. This case study shows how a holistic approach can be used to effectively design analyze and operate a treatment system to treat difficult wastewaters, and also showcases how regular scheduled pump-outs and bio-augmentation can be used to help maintain a consistent high level of performance.

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