City of Guelph
Guelph Residential Greywater Field Test Draft Final Report

Appendix D

Preliminary Lifecycle Assessment (PLCA)

Final Report

June 29, 2012

Preliminary Lifecycle Assessment (PLCA)

As in most urban areas in the developed world, the wastewater stream produced by Guelph is sent to a centralized treatment facility. Once there, the wastewater undergoes biological, chemical, and electrically intense (largely process blowers, pumps, and motors) processes to treat the wastewater before returning it to the environment (Speed River). Approximately one third of Guelph's electrical usage is for operating the treatment equipment at the WWTP (CEP, 2007). Water conservation can thus dramatically reduce a city's electrical use. Further research into the lifecycle of GWRS is needed to determine the impact greywater reuse would have on water and energy conservation on a city-wide scale. It is expected that a decrease in the wastewater treatment plant (WWTP) influent flow would cause a decrease in electrical consumption; however, it is less known what other impacts would occur in terms of biological treatment processes and chemical usage. It is also expected that water conservation would reduce electrical and chemical usage at the water treatment plant (WTP). Refer to **Error! eference source not found.** for more information.

Goal and Scope of PLCA

The main goal of the PLCA was to determine the environmental performance of greywater reuse systems technologies (GWRS #1) compared to the baseline: treating wastewater solely at the wastewater treatment plant (business as usual)(see **Error! Reference source not found.** and REF _Ref312488729 \h * MERGEFORMAT **Error! Reference source not found.**). This will ultimately aid in determining the sustainability and the appropriateness of the GWRS as a water conservation method for Guelph. The environmental performance was analyzed with the following impact categories; water use, climate change (greenhouse gas emissions, GHG), electricity, and resource use (treatment chemical use). A consequential PLCA was conducted on a greywater reuse system.

The results from this PLCA can provide insight on how to further improve GWRS in terms of environmental performance, as well as to better inform Guelph in policy and decision making regarding its water resource management strategies. It is critical that water and energy conservation be examined for the impact categories as they are two main areas that Guelph wishes to improve upon as detailed in their Community Energy Plan and Water Supply Master Plan (CEP, 2007)(WSMP, 2006). The human health issues and the possibility of pathogen presence is one impact category that is excluded. This process is still not well understood and requires further research to acquire more reliable data.

Functional Unit

The function of the GWRS is to treat and reuse a portion of domestic wastewater at the home. The functional unit is the volume of wastewater treated in a household per day. The reference flow would be the following:

- Regular household (no GWRS) – 164L/day (Site 3 data used) treated at WTP (including extraction) and the WWTP; and,
- GWR household – 31L/day of wastewater treated at home and 133L/day of water treated at WTP and WWTP. The water demand, 164L/day, is still being met but some treatment is being avoided at the WTP and WWTP (31+133L/day).

System Boundaries and Process Flowchart

The boundaries for this LCA involve different phases of both the WWTP and the GWRS found within the Guelph homes.

- The baseline treatment system is the Guelph wastewater treatment plant. Solely the operation of the WWTP will be examined with its construction, maintenance, disposal phases not being included.
- The cradle to grave life cycle impacts of the treatment chemicals will need to be accounted for as they play a critical role in the water treatment process.
- This assessment will be based on GWRS being piloted in Guelph; the key stages analyzed are the product's assembly and operation, with system disposal and transportation being excluded.
- Filter usage and yearly inspections were excluded for the GWRS boundary.
- The effects of GWRS on the WWTP microbiological treatment processes and cleaning/repairs were excluded from the WWTP boundary.

In general, phases were not included in the boundaries that were thought to be beyond the scope of this assessment, which was to focus on the actual treatment processes occurring at the WWTP along with the GWRS in the homes. Two process flowcharts were created to illustrate both the WWTP (the baseline system) as well as the GWRS's being examined (see **Error! eference source not found.** and **Error! Reference source not found.**).

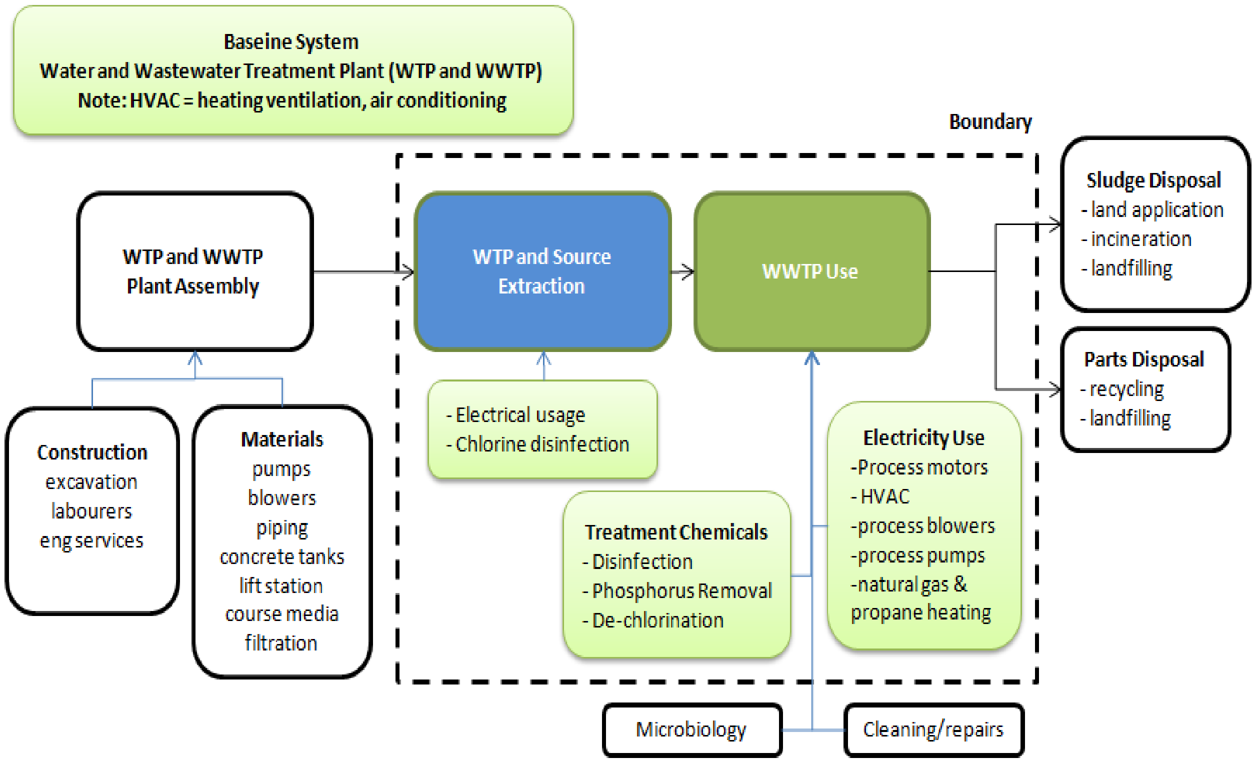

Figure 1: Process Diagram of Baseline System (Memon, et al., 2007)(WWTP, 2006).

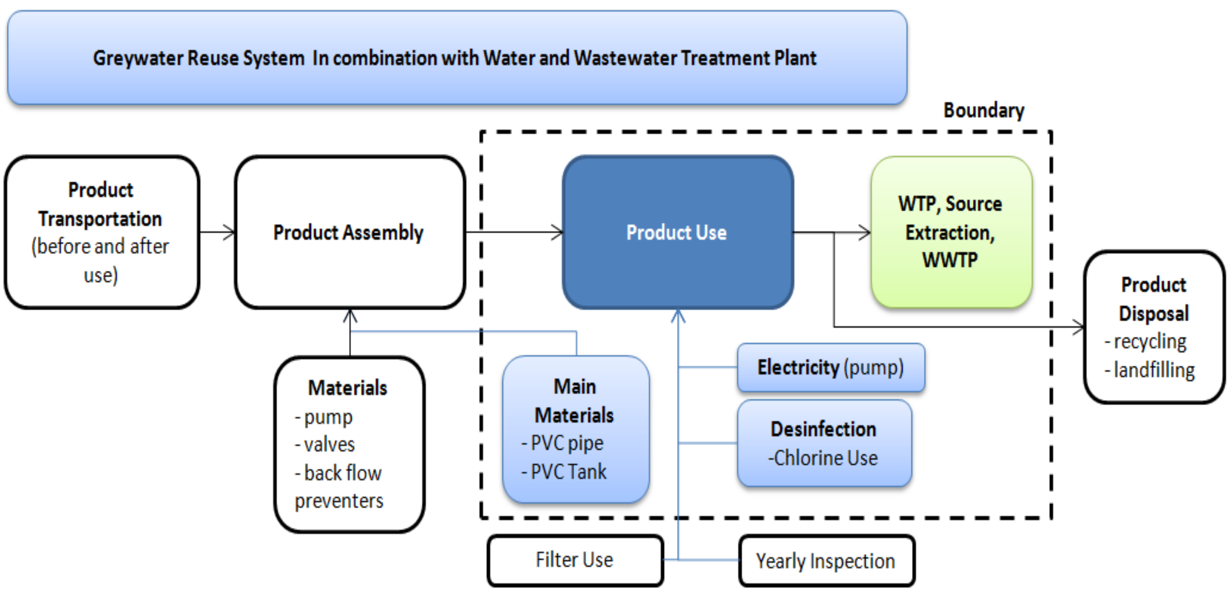

Figure 2: Process diagram of the GWRS in conjunction with the Water and Wastewater Treatment Plants (Memon, et al., 2007)(WWTP, 2006).

Assumptions and Limitations

Some simplifications of the systems and assumptions were necessary to perform this LCA, and they include the following;

- Wastewater reduction is assumed to cause a linearly proportional decrease in chemical usage at the WWTP, and effects of reduction on infrastructure maintenance were ignored.
- As the quantity of organic matter is not changing with the implementation of the GWRS, the required biological treatment at the WWTP is assumed to remain the same. The sludge disposal is also assumed to be unaffected and thus is excluded from the system boundary for the same reason (quantity of organic matter output is constant).
- Quality of water produced was assumed to be equal between the two GWRS's; however, in reality the water quality varies depending on the treatment system and the users.
- The PVC piping and storage tank are only considered for the product assembly phase of the GWRS and not the disposal or transportation. The piping would be different depending on the home that the system is installed in.
- The chemicals used at the Guelph WWTP are ferrous sulfate, sodium bisulfate, sodium hypochlorite, and calcium hypochlorite. Due to limitations in data availability the chemicals that were considered at the WWTP were chlorine, alum, ferrous & ferric. For the WTP only chlorine was considered with polymers being excluded (Maas, 2009).

Impacts Categories and Impact Assessment Method

To evaluate the environmental performance of two types of GWRS's relative to the WWTP and their appropriateness as a water conservation method, several impact categories were considered. They include the following:

- Water use – the reduction in domestic water usage that the GWRS achieve.
- Electricity Use – the net change in electricity usage due to the use of GWRS.
- Climate change – what is the net change in GHG emissions due to the implementation of the GWRS. This considers emissions from electrical and chemical usage.

PLCA Calculations

Table 1: Preliminary Life Cycle Analysis Calculation Tables

Baseline Emissions (Business as usual) Treating 164 L/day for Site 3		
Description	**Value**	**Units**
Water Treatment		
Electricity use	0.01788	kg CO2eq/ home/day
Chlorine Use	0.000279	kg CO2eq/ home/day
Wastewater Treatment		
Electricity use	0.0204	kg CO2eq/ home/day
Alum/chlorine/ferric chloride use	0.00156	kg CO2eq/ home/day
Totals	**0.0401**	**kg CO2eq/ home/day**

Emissions Balance From the Use of a GWRS Site 3 - GWRS #1		
Additional Green House Gases From GWRS (31 L/day being treated at home)		
Description	**Value**	**Units**
The System Components		
Piping (20m)	0.048	kg CO2eq/home
Tank HDPE (41kg)	80.36	kg CO2eq/home
Total	**80.408**	**kg CO2eq/home**
System Operation		
Additional Electricity Use	0.00944	kg CO2eq/ home/day
Sodium hypochlorite	0.000167	kg CO2eq/ home/day
Total	**0.00961**	**kg CO2eq/ home/day**
Avoided Inputs From Using GWRS (31 L/day of treatment avoided)		
Water Treatment		
Electricity reductions	0.00339	kg CO2eq/ home/day
Chlorine reduction	5.3E-05	kg CO2eq/ home/day
Wastewater Treatment		
Electricity reductions	0.000529	kg CO2eq/ home/day
Alum/chlorine/ferric chloride reduction	0.000148	kg CO2eq/ home/day
Total	**0.00412**	**kg CO2eq/ home/day**
Summary		
Emissions Net Increase	0.00549	kg CO2eq/ home/day
GWRS operation Emissions	0.0456	kg CO2eq/ home/day
Baseline Operation	0.0401	kg CO2eq/ home/day
Increase in	12	%

operation emissions		

PLCA Results

Using a GWRS will reduce emissions (avoid inputs) at the WTP and WWTP. However, the additional emissions associated with the use of a GWRS would far exceed any reductions. Thus, overall a GWRS would result in a net increase in emissions corresponding to 0.0055 $kgCO_2eq$/home/day or 12% (considering only electrical and chemical factors). When considering the emissions associated with the production of a 41kg (150L) high density polyethylene (HDPE) tank they are significant at 80.4 $kgCO_2eq$/unit. The HDPE tank is the predominant source of emissions, thus it is advisable that a different material be used for the tank (i.e. recycled materials).

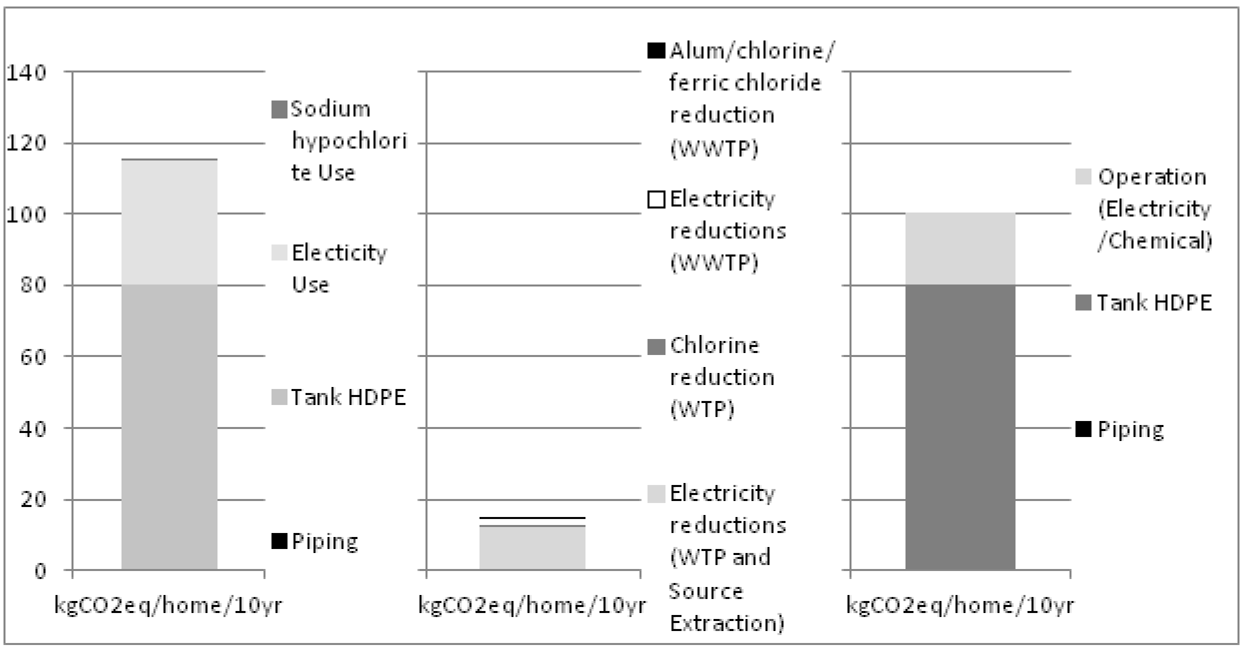

Figure 3: Site 3 (GWRS#1) - Emissions (Left), Avoided Inputs (Middle), Net Emissions Increase (Right)

During the operation of a GWRS the emissions related to the electrical usage is far more significant than those from chemical usage. Maas (2009) also confirmed that the energy used to manufacture the chemicals used in water treatment is relatively insignificant. It is therefore, advisable that the GWRS use more energy efficient methods to pump greywater. Gravity-fed systems are possible if used shower water is stored above the greywater fed toilet. For example, if a shower is on second floor of a house and a greywater fed toilet is on the first floor, used shower water could be stored above the toilet.

Using a GWRS produces more GHG emissions than the business as usual model. This is largely attributed to the emissions from the manufacturing of a GWRS, and because these systems use electricity and chemicals less efficiently. The electrical intensity was measured at sites 1, 3, and 5 to be 3.7, 1.3, and 1.85 kWh/m^3 respectively. This is higher compared to wells, water treatment, and wastewater treatment plants which consume approximately equivalent amounts of energy per m^3 of water produced, around 0.5 kWh/m^3 (Maas, 2009).

This preliminary investigation suggests that GWRS appear to be less sustainable than the conventional centralized treatment approach. However, conserving water does have environmental benefits that were not considered in this calculation. By using a GWRS and through water conservation, water is left in the natural water cycle providing important environmental benefits and services. A more detailed and rigorous life cycle assessment is needed to better understand the environmental impacts of GWRS compared with conventional water and wastewater management approaches.