UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the Use of Solar Aquatic Wastewater Treatment in The new UBC Farm Center Building:

A Triple Bottom Line Assessment

Chamith Liyanage

Wajih Al-Qutub

Ian Dusome

Sina Motalebi

Hsuan Wei Fu

University of British Columbia

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Prepared by:

Chamith Liyanage
Wajih Al-Qutub
Ian Dusome
Sina Motalebi
Hsuan Wei Fu

Abstract

The UBC farm is moving forward with the design and construction of a new farm center building and as a world leader in sustainable agriculture, this building should reflect those ideals. The goal is for the building is to represent a living lab, fully integrated into the farms primary food production, while also setting a precedent for smart design and providing educational opportunities. In order to achieve these goals, every aspect of the buildings design must be carefully considered to ensure a fully integrated and sustainable system. A very important part of this system, especially in an agricultural setting, is the water usage. The Farm would like to employ an onsite wastewater treatment facility that captures rainwater, greywater and blackwater, treats it in an environmentally friendly method, and produces a high quality resource for agricultural use. This report provides a triple bottom line assessment on a solar aquatic style wastewater treatment facility, as one possible option to be considered by the farm.

The triple bottom line assessment takes ecological, economic and social aspects into consideration in order to make recommendations. It combines primary research from discussions with ECO-TEK President Kim Rink, with secondary sources such as papers and journals. The important ecological aspects to be considered primarily involve the quality of the water produced by a solar aquatic system (SAS) treatment facility and its suitability in providing a safe and healthy resource for use on the farm. The economical investigation examines the cost feasibility and potential financial benefits of installing and operating a SAS. The social aspect looks into any benefits a SAS would have on the Farm and general UBC communities.

It was found that the water produced from a SAS was consistently of high quality and can meet drinking water quality standards without further treatment. This would be more than enough for irrigation or other farm uses, however in order to be used as drinking water

government regulation requires further treatment with chlorine. Also the SAS can be tailored to specifically target water quality issues such as heavy metal contamination or high endocrine disrupting compound (EDC) levels. Installing a SAS would also be a financially viable option for the UBC farm as it uses simple materials and is easy to install and maintain. It is also modular and reliable allowing for the system to be modified in the future with possible demand changes. A SAS is an attractive way of dealing with an unattractive waste product, while also meeting the goal of creating an educational living lab space. It fits well into the farm community, complying with many, if not all, of the farms core ideals and therefore, it would be a good choice for use in the new farm center building.

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Glossary

Alum: Both a specific chemical compound and a class of chemical compounds.

Biodiversity: A measure of the health of ecosystems. Biodiversity is in part a function of climate.

Bioponic: A system that encapsulates both hydroponics and aquaponics in an organic environment.

Bio solid: Nutrient-rich, human-like materials that result from the treatment of liquid waste.

Black water: Wastewater containing fecal matter and urine.

Chlorination: The process of adding the element chlorine to water as a method of water purification to make it fit for human consumption as drinking water.

ECO-TEK: It is an environmental leader in the design and construction of solar aquatic systems to treat sewage and wastewater through purely biological means.

Gravity Clarifier: A tank used to remove solids by gravity.

Greywater: Wastewater generated from domestic activities such as laundry, dishwashing, and bathing which can be recycled on-site.

Hydroponics: Method of growing plants using mineral nutrients solutions, in water, without soil.

Hyperaccumulator: Organisms that absorb take larger-than-normal amounts of contaminants.

Pathogen: Infectious agent, a microbe or microorganism such as a virus, bacterium, prion, or fungus that cause disease in its animal or plant host.

Polymer: Large molecules composed of repeating structural units.

Potable water: Water pure enough to be consumed.

Struvite: Magnesium ammonium phosphate. It is a phosphate mineral.

Sustainability: Capable of being continued with minimal long term effect on the environment.

List of Abbreviations

BOD - Biochemical oxygen demand

CIRS – Centre for Interactive Research on Sustainability

EDC - Endocrine-Disrupting Compounds

GVRD - Greater Vancouver Regional District

L – Liters

M – Million

mg – Milligrams

MSR - Municipal Sewage Regulation

PCB – Polychlorinated Biphenyl

pH – Potential Hydrogen

SAS – Solar Aquatic System

Sq. Ft – Square feet

SUB – Student Union Building

TSS - Total suspended solids

UBC – University of British Columbia

UV – Ultraviolet

1.0 Introduction

The UBC farm is a global leader in sustainable and organic agriculture practices, focusing heavily on food production in such a way that cooperates with the environment, minimizes impact and values all potential resources. The new farm center, currently being designed for construction beginning in the summer of 2013, should coincide with these values. The aim is for the building to represent the farms core ideals in the form of a fully integrated living lab, providing a net positive operation along with educational opportunities for not only UBC students but also the Vancouver and sustainable agriculture communities. This report looks into one possible option for a wastewater treatment facility that could be integrated with the building's operation, a necessary aspect in order to meet the goals set forth by the farm. This facility would collect rainwater, greywater and blackwater produced in the building and surrounding area, for onsite treatment. After treatment the effluent water would provide a valuable resource for agricultural and educational uses such as irrigation, hydroponics and aquaponics. A solar aquatic system (SAS) of wastewater treatment was chosen to be the main focus of this investigation.

This report begins by examining the details of how such a system would work at a building scale and in an agricultural setting. Current wastewater treatment methods employed by other areas of UBC are also briefly discussed to provide contrast to an alternative such as a SAS. The report will then proceed with a triple bottom line investigation, taking into account ecological, economical and social considerations before making a final recommendation.

2.0 Background Details

Before moving on to the triple bottom line assessment it is important to review some background information including a brief description of the steps involved in a SAS and a quick look into current methods of wastewater treatment currently employed at UBC. The details in regarding to these two background subjects are in the following sections:

2.1 Solar Aquatic Process

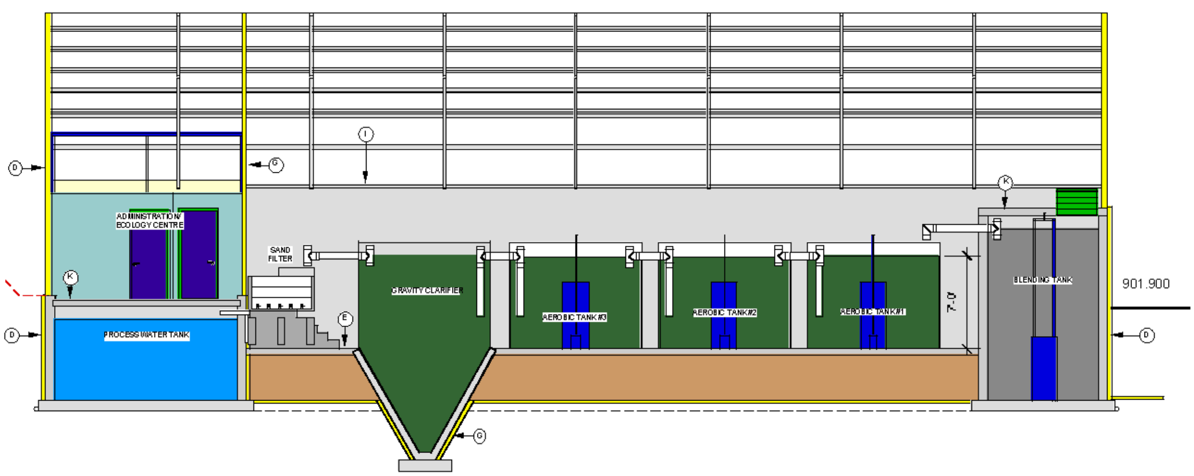

Figure 1: Solar Aquatic System (EcoTek, 2012)

To begin with it is important to give a brief overview of a SAS and the steps involved in this process. Figure 1 shows an example of a building scale solar aquatic system similar to the one installed in the CIRS and similar to what would potentially be used in the new farm center. Although the process can vary with size and implementation, the general idea involved is, that biologically active organisms are used to treat the water without the need for chemicals and without producing large quantities of sludge. (Todd, 1992)

As shown in the diagram, most systems start out by utilizing a blending tank to buffer against any day-to-day variation in the incoming wastewater stream. (Teal & Peterson, 1993) The water then proceeds into large translucent plastic or glass tanks. These tanks are aerated to keep any solids from settling and contain a large variety of microorganisms including bacteria, protoctists and fungi. On the surface of these tanks a variety of marsh plants such as water hyacinths or duckweed, for example, are supported. (Todd, 1992)(EcoTek, 2012) The combination of microorganisms and plants effectively treat the water and remove pollutants. After a series of these tanks the water empties into a conical gravity clarifier that allows for any solids to settle out and be recirculated back into the blending tank at the start of the system. A small amount of water may also be recirculated to help restock the microorganisms in the more harsh initial stages. (Todd, 1992) In the figure shown the systems ends with a sand and UV filter before finally emptying into a storage tank. This is the simplest implementation of a solar aquatic system and even though it is fully effective for small-scale operation many other systems include further stages to polish the water quality. These stages most often represent a more complete ecosystem including zooplankton, phytoplankton, fish, turtles, snails and freshwater clams for example, as well plants grown hydroponically on the surface. These plants are not limited to marsh types and can include virtually any plant that is suitable for growth via hydroponics. (Todd, 1992)

There are many options to be considered when implementing a solar aquatic system besides the basic volume and spacing requirements. Different plant species may be more effective at removing certain contaminants, such as heavy metals, from the wastewater stream.

(Todd, 1992) Because the water is being collected from both building waste and rainwater runoff, it may be useful to have a diverse selection of plant and animal life to ensure the best water quality possible.

2.2 Current Wastewater Treatment at UBC

Lions Gate Wastewater Treatment Plant, located on leased land that is being returned to the Squamish Nation, provides primary treatment to wastewater from approximately 17400 residents of the District of West Vancouver the City of North Vancouver, the District of North Vancouver and Electoral Area A, which includes the University of British Columbia. The Lions Gate Wastewater Treatment Plant holds seven times more capacity as it was opened in 1961. In 2006, the government of British Columbia gave the plant the certificate allowing the plant to release Biological Oxygen Demand of 130 mg/L, Total suspended solids of 130 mg/L and Maximum daily discharge of 318,000 m^3/day. So far the number of the times exceeding permit has remained 0. (Metro Vancouver, 2012)

Figure 2: Lions Gate Wastewater Treatment Plant

The Lions Gate Wastewater Treatment Plant is a Primary or Mechanical Wastewater Treatment Plant. A Primary Plant physically separates the suspended solids and can remove 30 to 40 percent of total suspended solids and 50 percent of biological oxygen demand which is only half as effective as the Secondary or Biological Wastewater Treatment Plants. A Secondary Plant use bacteria to consume organic matter and can remove up to 90 percent of suspended solids and biological oxygen demand.(Metro Vancouver, 2012)

In January 2012, a project definition of building a secondary treatment plant on the North Shore had begun. The structure will ensure the wastewater continue to be managed safely, affordably and effectively. New federal and provincial standards require all primary level treatment plants to be upgraded to secondary treatment. To meet these requirements, Metro Vancouver will build the new secondary treatment plant at a site approximately two kilometers east of the existing Lions Gate Wastewater Treatment Plant. The wastewater treatment plant will be upgraded to secondary level treatment by 2020. (Metro Vancouver, 2012)

3.0 Ecological Aspect

The environmental impacts of a SAS wastewater treatment facility in comparison with more traditional methods are obviously important to consider. In order to coincide with UBC's reputation of sustainability it is desirable to treat water on site with minimal, if any chemical treatment. A SAS achieves this by mimicking the natural processes of water treatment found in marshlands. However the quality of the water needs to be suitable for use in organic agriculture and ideally for human consumption. Environmental factors and water quality are discussed in the sections as follows:

3.1 Impacts of Wastewater Treatment on the Environment

In order to protect the earth from the problems it is facing, such as deforestation, erosion, water shortages and water pollution, there needs to be actions taken. One of the biggest steps engaged would be to restore water, whereas water can be considered as the foundation of life on earth. Different procedures can be taken for saving water on our planet. Examples include water reclamation from wastewater, industrial wastewater treatment and reuse, urban stormwater treatment and reuse. One of the procedures practiced on UBC campus is the usage of wastewater as resources. In this method, valuable nutrients are recovered from wastewater and then used to propagate and fertilize biodiversity. Following this we can restore land with biodiversity and composted biosolids. In figure 3, a variety of wastewater types are being observed and tested for later usage.

Figure 3: Wastewater Sample Comparison

This method has many positive impacts on the environment. This procedure converts toxic ammonia to reusable nitrate nutrients. It also removes or breaks apart contaminant chemicals, placing clean water back into the environment. Another advantage is that chemicals are not required to produce high quality water output. No chlorine, alums or polymers are required by the process, however government regulation may make them necessary for human use. Most pathogens are destroyed naturally, and the ultra-filters and ultraviolet light used completes the disinfection. (EcoTek, 2012)

3.2 Solar Aquatic Water Treatment Quality

One of the most important factors for deciding upon the type of wastewater treatment facility to be utilized in the new farm center building was the quality of water output. The UBC farm prides itself with being a world leader in organic, sustainable farming practices and as such it places the utmost importance on the health of the land along with the plants and animals it sustains. To keep with these ideals, any water output from the new farm center building needs to be of the highest quality and suitable for use in an organic agriculture setting. It has been demonstrated by early pilot projects exploring the viability of SAS that class 1 drinking water can be obtained using this method. (Teal & Peterson, 1993)

TABLE 1

A comparison of septage constituents (in mg/L) from four Massachusetts towns with EPA design standards[a]

Constituent	EPA standard	Yarmouth mean	Yarmouth (SE)	Orleans mean	Orleans (SE)	Wayland mean	Wayland (SE)	Harwich mean	Harwich (SE)
BOD_5	7000	2090	(154)	2650	(91)	1100	(61)	1410	(73)
TSS	15,000	4290	(378)	5180	(139)	3580	(289)	4960	(257)
TN	700	325	(18)	NA		233	(20)	224	(12)
TDP	250	36.6	(4)	NA		48.2	(NA)	45.7	(1.8)
NH_4		131	(NA)	NA		110	(NA)	52.5	(2.4)

[a] BOD_5, five-day biological oxygen demand; TSS, total suspended solids; TN, total nitrogen; TDP, total dissolved phosphates; NA, not available. Harwich data are from the entire pilot operating period.

TABLE 2

Influent and effluent values (in mg/L) for SAS Harwich septage treatment plant[a]

Constituent	Influent mean	Influent (SE)	Effluent mean	Effluent (SE)	Line C effluent mean	Line C effluent (SE)
TSS	5780	(990)	19.8	(1.23)	21.0	(1.03)
BOD_5	1740	(362)	6.74	(0.68)	8.6	(0.62)
TN	187	(17.9)	9.62	(0.44)	5.98	(0.32)
Organic N	153	(17.4)	4.54	(0.21)	4.44	(0.23)
NH_4	32.7	(2.56)	0.34	(0.06)	0.31	(0.03)
NO_3	0.9	(0.08)	4.74	(0.49)	1.17	(0.15)
TP	43.0	(3.5)	6.52	(0.32)	5.98	(0.32)
Ortho-P	14.8	(1.1)	4.96	(0.34)	3.32	(0.23)

[a] Values were analyzed by a certified lab from weekly samples taken during the steady-state period, Oct. 1991 through March 1992. TSS, total suspended solids; BOD_5, five-day biochemical oxygen demand; TN, total nitrogen; TP, total phosphate; Ortho-P, ortho phosphates. Line C data are obtained from the line with enlarged marshes.

Table 1: Wastewater Sample Quality Comparison (Teal & Peterson, 1993)

The technology has developed as the standards have changed allowing systems such as the one currently established in the CIRS building to consistently meet the standards required for drinking water. TSS, BOD, phosphorus, nitrogen and fecal coliform levels are all reduced to levels below the required standards and the utilization of UV and sand filters also helps to ensure that all harmful pathogens are removed. (Teal & Peterson, 1993)(Todd, 1992)(EcoTek, 2012) This being said the water quality output by a SAS is more than adequate for use as irrigation. A major benefit of this type of technology is that the plant life used to treat the water can be tailored to meet specific water quality issues. Some marsh plants are known as hyperaccumulators and are especially effective at removing heavy metals from water. (Todd,

1992) SAS style systems have also been demonstrated to be more effective at removing Endocrine-Disrupting Compounds or EDC's than traditional wastewater treatment methods. EDCs mimic estrogen and have been linked to a large variety of health problems in both humans and animals. (Kumar, Chiranjeevi, Mohanakrishna & Mohan, 2011) The process utilized in a SAS mimics the method of waste water treatment found in nature, producing higher quality, safer and healthier water than most traditional methods of waste water treatment and so it seems it would be a good choice for the UBC farm.

4.0 Economic Analysis

The SAS is economically viable to be constructed in the new UBC Farm centre. The costs from construction, operation, and maintenance are lower when compared to conventional treatment methods. The material used to construct the system from the greenhouse to the constructed wetlands is reliable and expandable. Moreover, the SAS brings decentralization, which also contributes to the cost reduction in many ways. These three important features are thoroughly discussed in the subsections below as follows:

4.1 Cost Implications

UBC proposed a 15-20 million dollar budget on the total cost of renovation for the new UBC Farm centre, which includes the construction of the wastewater treatment facility (Rushmere 2012). However, the specific budget plan for the wastewater treatment itself is not specified. The cost of the SAS is less than conventional systems and it produces reclaimed water that could be sold for revenue (EcoTek 2012). This means that we can assume the wastewater treatment facility expenses are much lower than 20 million dollars.

While doing this investigation our group strictly considered the utmost sustainability on the cost of the SAS. The type of treatment facility must be appropriate and within budget limits. Past research has shown that copying innovative technology without considering the site specifications and budget plans leads to permanent system shutdowns (Volkman 2003).

The area available proposed by UBC for the "living lab space" is $52m^2$ so the treatment facility should take up to 20 – 30 m^2 (Rushmere 2012). Since this area is relatively low compared to other treatment facilities at UBC`s, such as constructed wetlands, therefore the implementation of the SAS is perfectly acceptable. EcoTek needs about 1 – $2m^2$ of area for the greenhouse portion for every $1m^3$ of wastewater produced per day (EcoTek 2012). In Cynthia, Alberta EcoTek has implemented a SAS for a 2000 sq.ft wastewater treatment facility. The capital cost in construction for this system was $1.4 M and the operating monthly costs were about $1167 per month (Chang, Haines, Rittemann, & Trieu, 2011). Based on these data from previous research our team was able to calculate the following:

INDICATORS	COSTS AND COMMENTS
UBC Farm centre capital construction costs for the wastewater treatment facility (Chang et al., 2011)	Assuming linearity for a 2000 sq.ft(~$186m^2$) it is $1.4M. So for the $30m^2$ new UBC farm centre it would cost $226,000 for capital construction costs.
Monthly operating costs	The cost for operations would be $1/$m^3$. Assuming the UBC Farm centre generates $100m^3$ it would be $35,000 per annum (Rink, 2012). So the monthly operating costs would be $2917 per month.
Human Resources	$100 per person for 1 year (Rink, 2012).
Operational Revenue from potential sale of by-products (Chang et al., 2011)	This is very high in SAS since it generates reclaimed water, composted biomass, and a variety of aquatic and hydroponic plants such as duckweed (Chang et al., 2011).

Table 2: Economic Analysis

4.2 Decentralization

Currently, 85% of wastewater is treated by the GVRD (Greater Vancouver Regional District) and UBC pays \$0.40 for the treatment, which sums up to \$2 million dollars per annum (Binns, D'Souza, & Lam, 2011).

The dependence of purchasing potable water from Metro-Vancouver to utilize in wastewater treatment processes is part of a centralized mechanism. The aim of UBC is "to achieve a net positive water system" (Binns et al., 2011) which is implicitly stated in the general mass balance equation given below:

$$0 = \text{Influent} - \text{Effluent} - \text{Waste} - \text{Accumulation} - \text{Removal}$$

(Kavanagh, 2007)

Centralization means that wastewater coming from flushing toilets, including human excreta, will be combined with potable water. This creates a large flow of pathogenic wastewater flowing around the whole region, which is centralized to one pipeline (Volkman, 2003). Centralized systems, in today's world, are being considered unsustainable due to major concerns over human health issues (Volkman, 2003).

•	**Contamination of water downstream, causing public health hazards if treatment has a low efficiency.**
•	**Loss of nutrient resources (N, P, K, and S) and trace nutrients in domestic waste**
•	**Loss of opportunity to maintain the fertility of the soil through wastewater reuse. This leads to the need to purchase inorganic fossil fertilizer.**
•	**Results in contaminated sludge not suitable as fertilizer for agriculture.**

Table 3: Negative effects of centralized systems.
Retrieved from *Sustainable Wastewater Treatment and Reuse in Urban Areas of the Developing World (Volkman, 2003)*

The SAS system provides an excellent method for decentralization, which "reduces pumping and piping costs and installation timelines" (EcoTek, 2012). If the wastewater treatment system is broken down into smaller individual segments of treatment, the system can be more flexible to sudden changes such as weather conditions (Volkmann, 2003). Therefore, the new UBC Farm centre would benefit a decentralized system such as the Solar Aquatics System by EcoTek.

4.3 Modular and Reliable

The components used to build the SAS are "easy to assemble" and "lightweight". This makes it easier to upgrade the current SAS to satisfy any wastewater flow treatment within budget limits (EcoTek, 2012). For example, an additional aeration tank could be installed easily if there is a sudden increase in wastewater flow. Furthermore a SAS is constructed with simple building material and does not require a specifically skilled workforce. A large aspect of maintenance includes tending to the plants live that thrives in the conditions created by this system and therefore training a agriculture student to oversee system maintenance would be very reasonable.

Figure 4: Multiple Aeration Tanks which can be installed easily. (*EcoTek, 2012)*

To disinfect the treated wastewater from pathogenic germs, UV Filtration is used by the SAS. Although chlorination is not necessary to disinfect the treated wastewater, the municipal government imposes that chlorination treatment must be used (Rink, 2012). Moreover, chlorination relatively has low costs compared to other options but it also introduces "toxic by-products such as PCB's" (Grant, Hill, Holbrook, Lymburner, McTavish, & Sundby, 2002). The benefits of having a UV Filter in the SAS are that it doesn't require a specific pH value or temperature constraint (Grant et al., 2002). The SAS provides industrial quality UV Filters that can withstand peak flows and operate for many years without malfunctioning.

Figure 5: The UV Filter at CIRS Building *(EcoTek Slides, 2012).*

5.0 Social Impact

After a thorough investigation on implementing a SAS at the new UBC Farm center, our group concluded that there are several social impacts that affect the neighboring community and UBC as a whole. The treatment facility will include the following factors; it is attractive and odor free, it serves valuable educational purposes to visitors, and it decreases unemployment in the UBC community.

5.1 Attractive Greenhouse System

The SAS is mostly contained in a greenhouse where the solar tanks and aquatic plants are maintained around a temperature of 20 degrees Celsius (Rink, 2012). These plants, from the aeration tanks and constructed wetlands, provide a natural view to the public eye. The greenhouse is mostly composed of glass, which embeds the wastewater treatment facility as part of the natural environment itself. The figure below is the SAS implemented in Cynthia, Alberta in 2009. It shows how the facility acts as part of the environment to treat the wastewater.

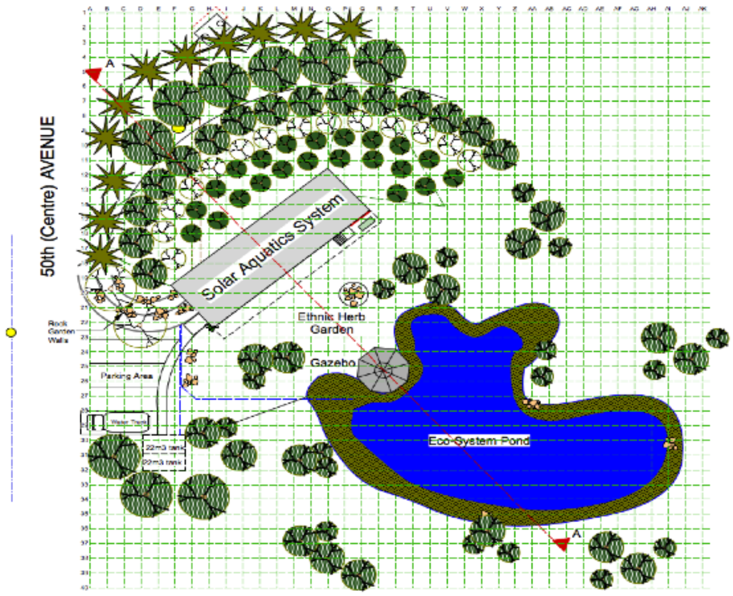

Figure 6: Landscape plan for the Cynthia, Alberta SAS (EcoTek Slides, 2012)

Moreover, the SAS operates on an odor free process. This is mainly due to the greenhouse portion of the system that consists of aeration tanks with dissolved oxygen levels (DO levels) (Grant et al., 2002). Everything in the SAS is composed of natural indicators. For example, if an odor occurs then the facility operator can point out that the system may be overloaded (Grant et al., 2002). Fish and plant growth also serve as a strong indicator of how well the system is operating. In general if life is flourishing in a particular aspect of the system it can be assumed that they are removing the nutrients they need and in doing so performing their required task (Todd, 1992)

5.2 Pedagogical Services

The SAS provides a valuable academic tool used by student and faculty to research more about ecological engineering in the solar aquatics field (Binns et al., 2011). The structure in the SAS provides catwalks, such as the bioponic catwalk, for guided tours shown in the figure below.

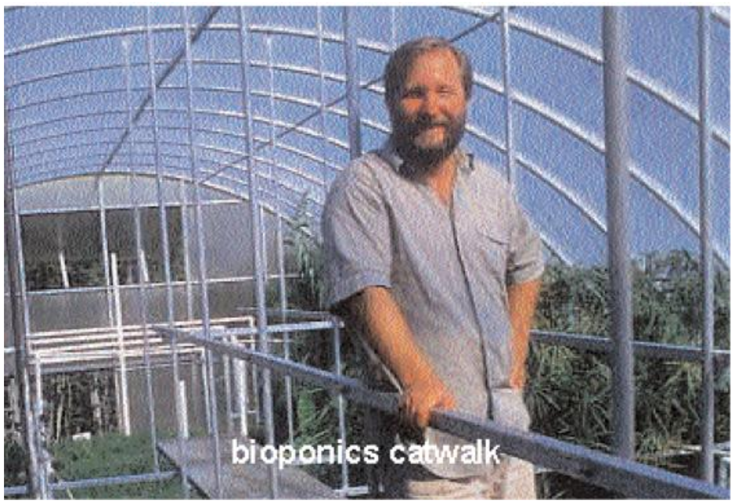

Figure 7: Bioponics catwalk used for guided tours *(EcoTek, 2012)*

5.3 Job Opportunities

Maintenance, construction and operational functions of the SAS could generate several jobs in the UBC community. Also, the management and sales of by-products generated by the SAS can provide UBC Students with several employment opportunities (Binns et al., 2011). These by-products include reclaimed water, which could be potentially sold to the GVRD if not used onsite, and many more such as struvite recovery from wastewater used for fertilization purposes. There is also the potential for selling tropical plants or fruits and vegetables grown hydroponically in final stages of the system.

5.4 Improve Regulations

The Municipal Sewage Regulation (MSR) provides the standard requirement for the discharge of waste and sewage water to comply with the Waste Management Act. The code is to monitor the treatment and use of reclaimed water. (Code of Practice for the Use of Reclaimed Water, 2001)

The reclaimed water can be used on the following:

1. Irrigation
2. Chemical Spraying
3. Fire Fighting
4. Toilet and Urinal Flushing
5. Ponds and Decorative Uses
6. Stream Augmentation
7. Habitat Restoration and Enhancement
8. Commercial Vehicle
9. Driveway and Street Washing
10. Snow and Ice Making
11. Dust Suppression and Soil Compaction
12. Industrial Uses

One of the MSR code is that chlorine must be added to wastewater to remove any possible bacterial, viral or parasitic infections to the water. The addition of chlorine conflicts with UBC farm's organic produce. The construction of the wastewater treatment facility aims to demonstrate with the use of proper treatment, chemicals would not be required for removing biological infections. (Municipal Sewage Regulation, 2010) Therefore, improve the current regulation for wastewater treatment.

Although the most of current treatment plants provide drinkable water, the usage of treated water as a drinking resource was made illegal by government regulations.

6.0 Conclusion

Through our research for a triple-bottom line assessment of the wastewater treatment facility at the new UBC Farm centre, our group was able to conclude that the solar aquatics facility would be the perfect choice. Environmentally, the facility would have a slim to none impact on the surroundings and not disrupt the inhabitants. Economically, the SAS is the best option since it provides revenue. Socially, having this facility here at the new UBC Farm centre will provide a strong public image of sustainability and nurture the community with employment. From the research that we acquired writing this report, our group strongly recommends that UBC considers implementing another Solar Aquatics System at the new UBC Farm center.

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Appendix

Notes from meeting Kim Rink, the Solar Aquatics System (SAS) President

A meeting was set on March 13th, 2012 at the CIRS building with Mr. Kim Rink, the president of ECO-TEK.

In that meeting, we were fortunate to have a look inside the SAS and understand the mechanism and functionality of this kind of wastewater treatment. Mr Rink started explaining the process by showing us how each separate vessel works and its purpose. The following subsections were explained by Mr. Rink:

Biodigestion from the plants:

Depending on water consumption, a specified number of tanks will be put in place to serve as a reserve for wastewater. These tanks consist of plants with large roots that act as an excellent habitat for bacteria with temperatures of approximately 20 degrees celsius. In order for clean water (reusable) to be acquired, bacteria and other micro-organisms simply break down waste products in the water. Besides contributing to the bio-digestion, plants provide a suitable environment for microorganisms.

Economic Features:
The cost for operations on the Solar Aquatics System is about $1/m^3. So for about 100 cubic metre system it would be around $35,000 per annum. And for human resources of the system it would be about a $100/year per head.

Social Aspects:
Although the process requires no use of chlorine for disinfection purposes, Mr. Rink explained that the government suggests the use of chlorination. Therefore besides UV disinfection, chlorination is also used.