WATER MANAGEMENT PLAN

Selection and Evaluation of Water and Wastewater Beneficial Practice Management Guide for the BC Mushroom Industry

March 2015

Prepared for:
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Growing Forward 2
A federal-provincial-territorial initiative

Golder Associates

British Columbia

Canada

Acknowledgement

This project was funded through *Growing Forward 2*, a federal-provincial-territorial initiative.

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Executive Summary

Golder Associates Ltd. (Golder) was retained by the BC Ministry of Agriculture (BCAGRI), Michael Schwalb, Waste Management Engineer, EIT, and Jennifer Curtis, Provincial Mushroom Industry Specialist, to identify and develop technically appropriate and cost effective Beneficial Management Practices (BMPs) for use on the mushroom farms in British Columbia. The following are the overall intended objectives of the BMPs:

- Reduce the water consumption related to farming activities;
- Optimize rainwater management; and
- Optimize wastewater management.

The BCAGRI chose nine farms located in the Abbotsford and Langley areas to participate in the BMP study. The project was carried out in a series of four stages as follows:

Stage I: initial farm meeting with the participation of the farm owners, Golder staff and BCAGRI, Michael Schwalb and Jennifer Curtis; with the intent of familiarizing the Golder staff with the farm water operation.

- Stage II: second site visit to the farm by Golder. The intent of this visit was to collect more information about the farm operation and to collect wastewater samples.
- Stage III: Identification of the generic BMPs.
- Stage IV: Report preparation and communication of the results.

All nine farms were visited by Golder during the discovering phase (Stage I), and seven of them were visited during stage II of the project. Wastewater samples were collected with the purpose to acquire an indication of the characteristics of the wastewater being generated and the effluent quality being achieved.

The information gathered during the site visits, along with data analyses and recommendation were used to prepare the water harvesting, dry-cleaning and wastewater treatment BMPs with input from Michael Schwalb and Jennifer Curtis.

Water Use Observations

The mushroom farms consume water for potable and non-potable applications. Non-potable applications include room wash-down between mushroom growing cycles, major room wash-down after crop termination, steaming of the rooms, cement slab washing and net washing.

During the site visits it was identified that most of the farms water consumption relates to washing down the growing rooms after crop termination. The wash-down operation to clear residual solids from the shelves and floor of the growing rooms is responsible for the majority of the water consumed by farm operations; requires an average of four hours of labour to complete, and generates wastewater that must be treated and disposed of at considerable cost.

In addition, some farmers reported boiler scaling issues. This is likely due to the fact that some farms use groundwater to feed the boiler for steaming operation, and the hard water results in significant scaling problems.

Rainwater Harvesting BMP

The rainwater harvesting BMP is proposed to take advantage of the wide roof catchment area available in the farms, to reduce costs associated with City water consumption for non-potable purposes and to prevent future water charges associated with groundwater consumption. Rainwater harvesting would also be beneficial as scaling prevention in the boilers. This BMP is innovative as there are no known mushroom farm operations that have implemented rainwater harvesting to supplement water supplies for farm water uses including cleaning growing rooms, exterior cement slabs and nets; or to feed the boiler.

Whenever possible, the use of existing piping systems should be maximized such that the capital costs related to implementing the rainwater system are minimized. The following sections discuss the components of a rainwater harvesting system and explain how to size a system.

Dry Clean BMP

The Dry Clean BMP refers to using a dry (no water use) vacuum process to remove solids from surfaces while decreasing the amount of water and labour required to clean the surfaces in the growing rooms. The use of an industrial vacuum with HEPA filtration is innovative as there are no known mushroom farm operations that have implemented this method to remove solids from the growing rooms.

The vacuum system could be implemented in either a centralized or decentralized mode. A centralized vacuum system is described as consisting of a centrally located stationary vacuum source, canister, HEPA filter and exhaust system that would be linked to the individual growing rooms through a vacuum line running through the building. A decentralized vacuum system is described as an industrial-grade mobile or portable vacuum complete with a large canister and HEPA filter. The centralized vacuum system is expected to be more expensive than the decentralized system, and potentially more problematic with respect to potential solids blockages in the vacuum line, and having a canister and HEPA filter that are located at a distance from the room being cleaned. On the other hand there is a potential for the mobile unit exhaust within the growing room to disturb and suspend solids into the air. These considerations lead to the concept of a hybrid system that combines the operational flexibility and portability of the mobile decentralized system with the remote exhaust advantage of the centralized system.

Information is provided on two industrial-grade mobile vacuum systems that have integral certified HEPA filters for use in the barns, as well as on an auto-scrubber system for consideration in cleaning the main corridor of the barns outside of the growing rooms, and a comparison of two manufacturer's products.

The application of a vacuum system as part of the growing room clean-up process is expect to reduce the amount of water consumed and wastewater generated by approximately 5 m^3 per growing room cleaning, and is expected to save in the order of $300 per year per growing room for those farms obtaining water from municipal services. In addition, the time required to clean up a growing room is expect to be reduced by 2 hours, with a labour saving of about $24 per growing room, or about $1250 per year per growing room per week. Finally the reduction in wastewater generated during the growing room cleanup, and the decreased contaminant loading is expected to result in significant costs savings for wastewater treatment. The approximate capital cost savings for reducing the wastewater generated during wash operations by 5 m^3/day of wastewater is about $25,000.

Wastewater Treatment BMP

Most of the farms participating in the BMP assessment program drain the barn wash water to septic tanks or ponds for solids removal, and then drain or pump the clarified effluent to some form of ground disposal system. While gravity separation of solids can work effectively, there is a significant operating cost for pumping the tanks out with a vacuum truck and disposing the contents. At least one farm has experienced the impact of not removing solids frequently enough, resulting in the solids being passed through to the disposal system, resulting in the failure of the system.

The water quality analyses shows the wash water also has a significant BOD concentration, representing soluble organic contaminants that can result in excess bacterial growth in the receiving environment. If that receiving environment is a ground disposal system, the bacteria feeding on the BOD in the septic tank effluent can clog the drain lines and cause the disposal system to fail. If the discharge is to a stream or other surface water body, the BOD is consumed by bacteria in the receiving body that require oxygen and can deplete the dissolved oxygen levels in the water body – affecting aquatic organisms.

While the natural environment will remove BOD, to avoid the impacts like those mentioned above, an extensive number of biological treatment technologies have been developed to mimic natural phenomena. These range from passive technologies which , are essentially enhanced natural treatment processes that require a large amount of land area (i.e., lagoons and wetlands) to highly sophisticated mechanical processes that are designed to accelerate the same biological processes that occur in nature and significantly reduce the land area requirements (e.g., membrane bioreactors). There is a trade-off between land area requirements and lack of operational flexibility and adaptability inherent to passive treatment technologies, and the high capital and operating cost and complexity of sophisticated mechanical treatment processes.

Taking into consideration the farm owners desire to have a treatment process that is simple to operate, and also recognizing that many farms do not have the land area available for a lagoon process, three technologies were selected for this BMP: 1) a constructed wetland; 2) an intermittent sand filter; and 3) a recirculating biofilter. The characteristics of each of these technologies are described, as well as the basic design principles and the advantages and disadvantages of their application to aid in selection for a specific farm. Because the farms have widely varying water use and growing room cleaning characteristics, additional water quality data is required to base a design on for a specific farm. The considerations for the wastewater treatment BMP are considered to be innovative as there are no known mushroom farm operations that have implemented any of the three wastewater treatment technologies described, in conjunction with fine-screening and, therefore, pilot testing is required.

Considering the relatively weak growing room wash-water wastewater strength, it is expected that the wetland, intermittent sand filter capital costs will be from $12 to $20 per gallon per day ($3000 to $5000/m^3/d) depending on local material costs, and the Orenco AdvanTex biofilter will be about $3,000/m^3/d.

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1.0 RAINWATER HARVESTING BMP

1.1 Background

Although with adequate treatment harvested rainwater can potentially be used as a source of water for potable purposes (drinking water), it is generally used for non-potable water applications for the following reasons:

1) generally water consumption for non-potable water applications greatly exceeds the need for potable water; and

2) the quality of water and level of treatment required for potable water applications are much greater than are required for non-potable water applications.

Because the amount of precipitation that can be collected from elevated surfaces, most often roofs, is typically limited and not available year round due to storage cost limitations, rainwater is most often used to supplement existing requirements. Further, because the stored rainwater has to be pumped to be used, it is usually applied to only one non-potable reuse application – with the "ideal" application being one that requires no or minimal treatment.

Mushroom farms have several non-potable water uses include: 1) growing room wash-downs after crop termination; 2) washing nets; 3) interior hallway washing; 4) washing down outdoor cement slab; and 5) feed water to the boilers. On average, 10 m^3 (2600 gallons) of water is consumed during a major growing room wash-down procedure (i.e., after crop termination) and 4 m^3 (1050 gallons) of water is consumed to wash the cement slab adjacent to the barn. It was not possible to quantify water consumption for net washing, interior hallway washing and boiler feed.

Of the five applications, the quality of the harvested rainwater would probably be of greatest importance for use in washing growing rooms due to the overriding concern for disease transmission. The collected rainwater has a potential to become contaminated as a result of bird and rodent feces on the roof surface, as well as dust and particulates from farm operations. On the other hand, there is much less concern for using rainwater to clean exterior pad surfaces and for boiler make-up water. Boiler water applications is expected to be the highest value and most sustainable use of the rainwater, as any microbial contamination that might occur would be negated by the elevated water temperatures, and the low alkalinity and pH of the rainwater would help to reduce boiler scaling problems, particularly if the farm currently uses groundwater for boiler use.

1.2 Water Consumption and Metering

Two of the critical key factors in determining the optimal amount of rainwater is: 1) determining how much water is required to meet the demand, and 2) determining the amount of precipitation that can be captured to supply the demand. While meteorological records are available to provide information regarding rainwater supply, it can be a challenge to obtain accurate or detailed information on water consumption characteristics for farm water uses. Farms that use well water do not have any water meter data to help estimate water use, whereas farms that use the municipal water supply have metering information. Only three of the nine farms in this study use municipal water for farm operations.

Considering the importance of managing and minimizing water use within the farm operations, and the low cost of installing water meters, the farms should consider strategically installing water meters for the major water uses. The data collected will be extremely useful in determining the cost effectiveness of future changes and expansion plans, and will also help the owners identify problem areas where there is excess water consumption that could be a significant operating cost. Suitable water meters with analog outputs can be purchased for less than $10 online through sites such as Aliexpress (http://www.aliexpress.com), but can also be purchased with a totalizer display for less than $100.

1.3 Water Availability

Monthly precipitation information assists in estimating the required amount of storage to prevent system overflow. The amount of water that can be captured for rainwater harvesting depends on the amount of total precipitation (i.e., all forms of precipitation including rain, snow, sleet and hail) per unit area, the catchment area (typically the rooftop area); and the storage volume available. Water storage is the primary cost affecting rainwater harvesting, and the determination of the storage volume involves both cost considerations as well as subjective qualitative considerations. The extreme variation in rainfall means that it is economically infeasible to store all of the precipitation that can be collected from a roof each year. Where a farm has to pay commercial water rates for a municipal water supply, the trade-off between the costs of storing rainwater and the cost of purchasing municipal water can be used to select an optimal storage volume. However, for farms obtaining water from groundwater sources, the costs of supplying the water are generally significantly lower than the costs for a municipal supply, making it more difficult to use lowest cost as the primary criteria to determine a storage volume. In such cases other factors such as the reduction in boiler scaling and costs of anti-scaling chemicals and remediation can be used to offset storage costs.

The following sub-sections describe how to calculate the catchment area to determine the amount of rainfall that can be captured (supply) and considerations for selecting the storage tank capacity.

1.3.1 Catchment Area

The amount of rainfall that can be potentially captured depends on the catchment area (area of the roof used to capture rainfall) and the precipitation. The catchment area refers to the “footprint” of the roof, or effective collection surface, in m^2, calculated as follows:

Catchment area (m^2) = horizontal length (m) x horizontal width (m) of the roof

Regardless of slope or layout, the amount of water that can be collected from a precipitation event is determined by the horizontal area covered by the roof (i.e., the area of ground covered by the roof). For a rectangular roof, this can be simply calculated as the horizontal length of the roof multiplied by the horizontal width.

1.3.2 Estimated Precipitation Volume

The amount of water that can be collected is estimated by obtaining historical total precipitation data from the nearest weather station to the farm, which can be found on the Canada Climate Normals website, and obtaining summary information for average monthly precipitation information. The potential volume of water that can be collected each month is estimated by multiplying the total precipitation for each month of the year by the Catchment Area, as follows:

Theoretical Precipitation Volume (L) = Total Precipitation (mm) x Catchment Area (m^2)

The water that is collected on the roof is subject to a number of water losses including evaporation, gutter and downspout leaks, first-flush diversions, sublimation (snow evaporating instead of melting), splashing and absorption by roof materials. It is common practice to reduce the estimated theoretical precipitation volume by 20 percent (i.e., multiply the theoretical precipitation volume by a factor of 0.8). The estimated precipitation volume is calculated as follows:

Estimated Precipitation Volume (L) = Total Precipitation (mm) x Catchment Area (m^2) x 0.8

1.3.3 Storage Tank Sizing and Make-Up Water

Because the water supply from precipitation is seasonally variable, the optimal objective is to balance the water storage to meet the more uniform farming demands throughout the year. Figure 1 illustrates the variation in total precipitation per month for the Langley/Abbotsford area. The red line illustrates the average precipitation for the year of about 128 mm per month. A horizontal roof area of 100 m^2 could collect a total of 123 m^3 per year (100 m2 x 128 mm/month x 12 months x 0.80), equivalent to 340 Litres per day.

The portions of the monthly precipitation chart that are above the line in Figure 1 represents the storage volume that would be required to equalize the collected precipitation, which is estimated at about 25 m^3 (6500 gallons), representing about 20 percent of the total annual precipitation or 2.5 months of storage.

To calculate the maximum storage volume it is important to properly quantify the water consumption. Consequently, it is recommended that farms consider installing flow meters to monitor specific consumptive uses including separately monitoring barn washing, pad washing, and steam generation.

As consumption information is limited for barn washing operations, and not available for pad or steam generation at this time, as a rough rule of thumb (noting the above calculation) it can be assumed that the optimal storage volume is equivalent to approximately three months of storage. Based on this assumption, the following calculation can be used to determine the storage tank capacity.

Storage Volume (m^3) = Estimated Annual Precipitation Volume (L/yr) / 4 / 1000 (L/m^3)

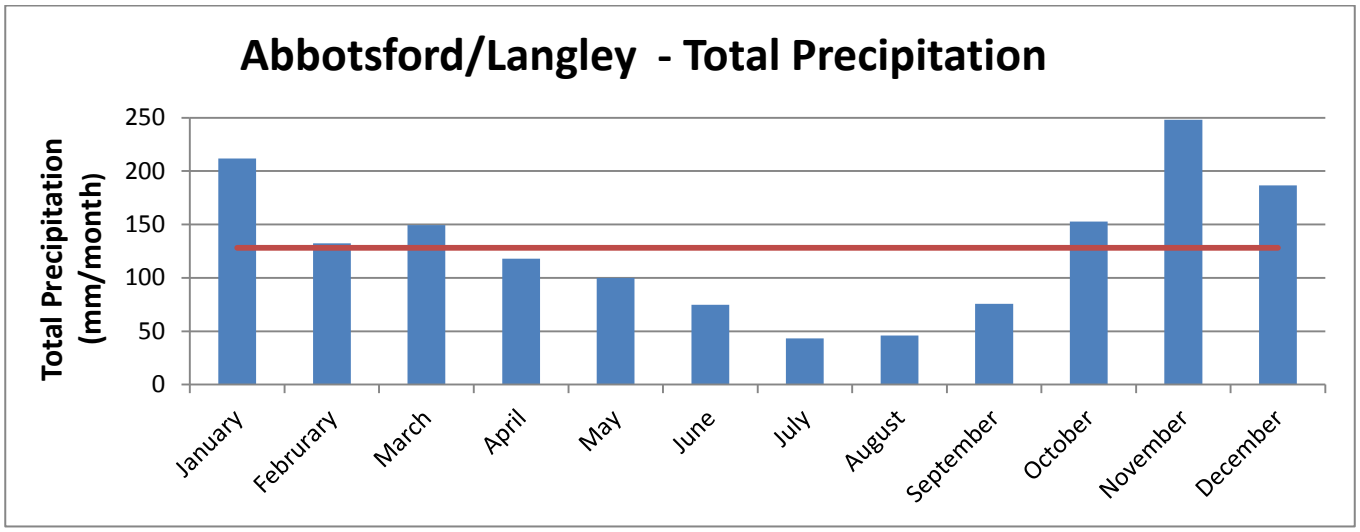


Figure 1: Total Monthly Precipitation for the Langley/Abbotsford Area

1.3.4 Components of the Rainwater Harvesting System

The primary components of a rainwater harvesting system for non-potable water applications include the following:

- roofing materials;
- gutters, gutter covers and downspouts;
- leaf screens and roof washers;
- first-flush diverters;
- storage tank (or Cisterns);
- pumps and pressure tanks;
- labelling to differentiate non-potable from potable water distribution pipe;
- filters; and
- backflow preventers to prevent cross connections between where the non-potable water distribution system.

It is recommended that an air gap be used to prevent cross connections in providing make-up water to the system.

While water treatment and disinfection are not expected to be required for non-potable water applications within the farms, the water may need to be filtered to remove particulates that could otherwise clog irrigation systems.

Capital costs can be minimized in a number of ways. For example, pipes required to transfer collected rainwater to storage can be passed through existing conduit and drainlines in the concrete. Also as storage costs are a significant component of the capital costs, it may be possible to locate salvaged tanks may be purchased at a lower cost than new storage vessels.

1.3.4.1 Roof Materials (Catchment Area)

It is important to select suitable roofing materials for the roof that will be used as catchment area for the rainwater harvesting system. Some roofing materials, such as galvanized roofs or asphalt may add contaminants to the harvested water. However, for non-potable applications the roofing material is generally not as an important factor as the materials that may be deposited on the roof (i.e., bird feces, leaves and branches). Table 1 shows contaminants that may leach from different roofing materials.

Table 1: Contaminants from Common Roofing Materials
(Canada Mortgage and Housing Corporation, 2013) - Modified

Roofing Materials	Potential Contaminants
Asbestos-cement	Asbestos Fibres
Terracotta Tiles	Coating materials, colour
Paints and Other Coatings	Lead, acrylic leachates, bitumen-based contaminants
Wood Shingles	Pesticides, pressure-treated wood, creosote
Metal Roofing	Zinc

1.3.4.2 Gutters, Gutter Covers and Downspouts

Like roofing materials, the materials used in gutters may affect the quality of water collected and maintenance. For example, copper and lead construction materials must be avoided if water will be used for irrigating edible plants.

Suitable construction materials for gutters, downspouts and additional wetted components associated with rainwater harvesting systems include: galvanized steel, coated aluminum, vinyl and PVC.

1.3.4.3 Roof Washers and Leaf Screens

Roof washers and leaf screens remove debris that may collect on the roof. Screens or strainers should be installed upstream of the storage tank to prevent debris from entering the water storage tank. Organic material, such as leaves, branches, and animal feces can biologically degrade within the storage tank and cause odours and other water quality problems. Consequently it is important to prevent these materials from entering the storage tank as well as routinely cleaning out the tank. Typically this is done using coarse screens.

PVC, galvanized steel and stainless steel are recommended construction materials for the screens. Nylon mesh can also be attached to the PVC pipe at the tank inflow. The following types of screens may be installed in the gutter: leaf guards; funnel-type downspout filters; strainer baskets; cylinder of rolled screen; and filter socks.

1.3.4.4 First-Flush Diverters

After a long dry period a considerable amount of debris, bird feces, and air-borne contaminants can accumulate on the roof of a building. Research has shown that the initial portion of the first intense rainfall event following a dry period typically washes off the majority of contaminants that have accumulated on the roof. Consequently, it is desirable to divert this initial contaminated “first flush” rainwater from entering the water storage tank and, by doing so, improve the overall water quality and reduce storage tank maintenance. This is particularly important for organic contaminants that can decompose in the storage tank and create colour and odour problems, and it is especially important for rainwater harvesting systems intended for potable water use.

As illustrated in Figure 2, first flush diverters are often simply a downspout or vertical pipe that the initial diverted water flows into. The pipe typically has a small drain opening at the bottom and once the pipe is full with the initial flush water, the remaining rainwater flows past the pipe and into the storage tank. The small opening at the bottom of the pipe allows it to drain between storm events, and a plug at the bottom allows the pipe to be manually flushed clear of debris. The key to using this approach is to size the vertical pipe to catch a specific proportion of the roof drainage, with the proportion being larger for larger catchment areas and increased potential for debris accumulation.

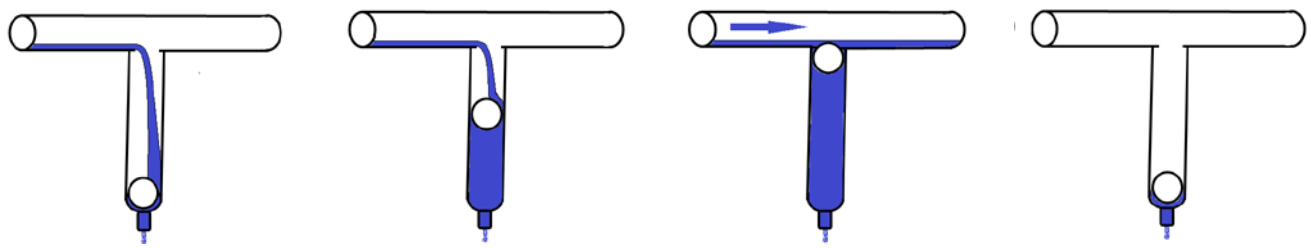


Figure 2: First Flush Diverter Operation Illustration

For a medium contaminant environment (e.g., areas with rough surfaces such as shingles and normal levels or organic material), it is recommended to divert the first 0.75 mm of rain, which is equivalent to 75 Litres (20 gallons) for a catchment area of 100 m^2 (Regional District of Nanaimo, 2012).

For a low contamination potential environment (such as smooth metal roof surface and relatively clean site), it is recommended the first 0.5 mm of rain be diverted, which is equivalent to 50 Litres (13 gallons) for a catchment area of 100 m^2 (Regional District of Nanaimo, 2012).

Some local suppliers of first-flush diverters include Watertiger, and Barr Plastics.

1.3.4.5 Storage Tank (Cistern)

The primary purpose of the raw water storage tank, or cistern, is to collect rainwater during period of high or intermittent precipitation, and make the water available to satisfy water demands during dry weather periods.

Rainwater storage tanks can be located above or below ground. The type of storage tank, or cistern, depends on the estimated water demands, the size of the available catchment area, the space available for installation, local bylaws and building requirements, aesthetics and budget.

All underground tanks must comply with the Canadian Standards Association (CSA) B66-10 Standard, *Design, material and manufacturing requirements for pre-fabricated septic tanks and sewage holding tanks*.

The most common materials of construction for water storage tanks are plastic (polyethylene/polypropylene), fiberglass, concrete (pre-cast concrete or cast-in-place concrete), and corrugated steel. The tank may be vertical or horizontal. Vertical closed tanks are preferable if static head is desirable to deliver the water to its end use.

Local plastic tank suppliers include Fabco Plastics, Barr Plastic and Canwest Tanks & Ecological System Ltd; and concrete tank suppliers, such as A.E. Concrete Precast products Ltd. and Ultraflo Systems Inc**.**

It is also important that the storage tank be opaque to inhibit algae growth. Further, the tank must be closed and screened to prevent contaminants or animals from entering, and mosquitos from breeding inside, the tank.

Considering one major room wash-down procedure per week for which 10 m^3 (2650 gallons) of water would be consumed, it is estimated that the farm would consume approximately 40 m^3 (10,500 gallons) of water per month. For cost estimation purposes, the following storage volumes were considered;

- 13 m^3 (3,450 gallons);
- 26 m^3 (6,900 gallons);
- 40 m^3 (10,500 gallons); and
- 62.5 m^3 (16,500 gallons).

HDLPE vertical, closed top tanks were quoted by Fabco Plastics (604-882-1564) and concrete tanks (3050 x 3050 mm box culverts) were quoted by Langley Concrete Group (604-533-1656). The figures below indicate the cost for the storage tank per material and per storage capacity. Note that the cost does not include freight and installation.

If more rainwater is harvested than consumed for room wash-down, then the remaining water stored can be used to rinse the outdoor cement slab.

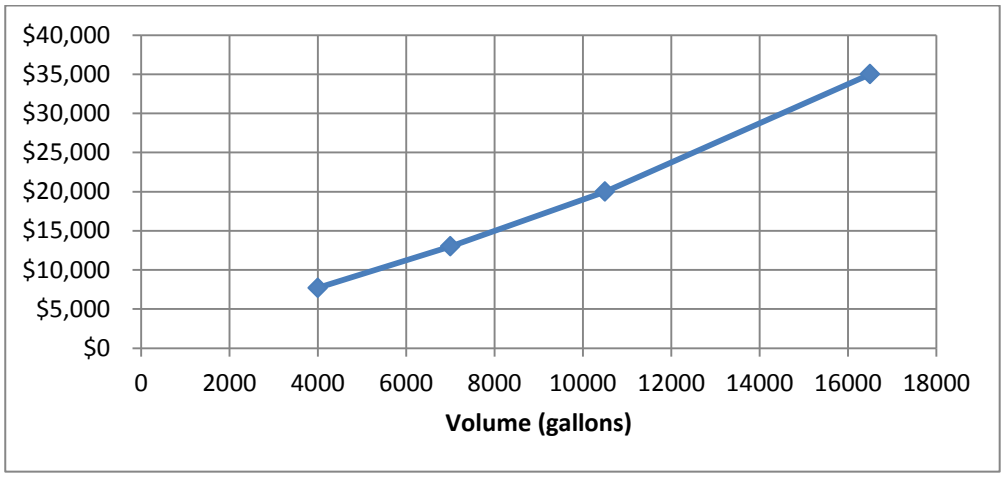


Figure 3: HDLPE Tank Cost Estimate

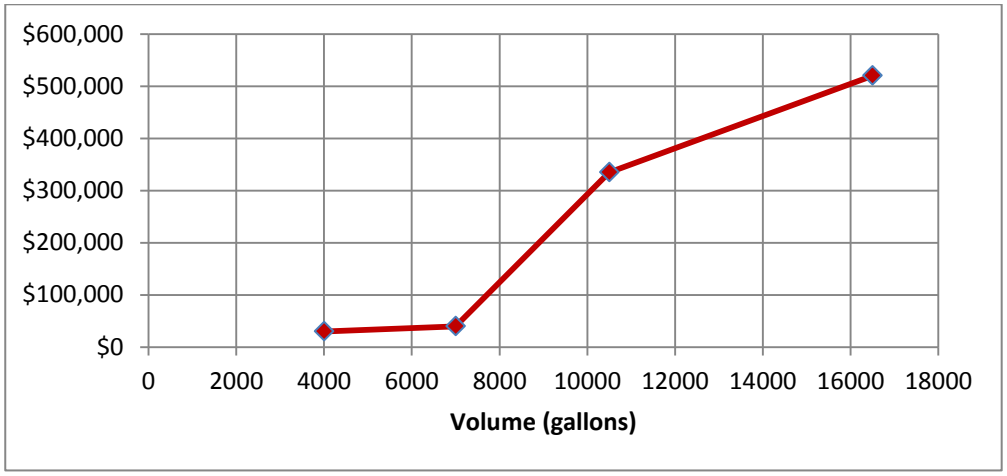


Figure 4: 3050 x 3050 mm Box Culvert Cost Estimate

1.3.4.6 Filters

Assuming that leaf screen on gutters and leaf washer are installed, the first-flush diverter component is generally sufficient to prevent coarse debris from entering the storage tank and eventually clogging hose irrigation systems. However, typically filtration with a 5 micron cartridge filter is required if the water is to be used for irrigation (in particular drip irrigation). Filtration would also be required if the water needs to be disinfected. For further information on filters see Section 1.3.5.1.

1.3.4.7 Pump and Pressure Tank

Gravity pressure may be insufficient to provide adequate pressure for some water applications such as subsurface drip irrigation which requires a minimum pressure of 109 kPa (15 psi).

Important factors to consider before selecting a pump include:

- the maximum flow rate required to meet the water demands;
- storage tank location, pipe length and head losses under maximum flow rates; and
- the elevation of water fixtures in the farm and the maximum pumping distance.

There are three basic pumping systems for the distribution of harvested rainwater. Those are external constant speed pumps; submersible pumps; and on-demand pumps.

An external constant speed pump with a pressure tank consists of a fixed speed pump that pressurizes the water and sends it to a pressure tank which maintains a relatively constant supply pressure. The pumps are equipped with a one-way check valve and a pressure switch. A typical pump-and-pressure system may consist of a ¾ to 1hp pump (usually a. shallow well jet pump or multistage centrifugal pump), check valve and a pressure switch. Jet pump are also available that operate without a pressure tank (e.g., Burr-Cam model 506532SS).

Variable frequency (or speed) drive submersible pumps are located in the storage tank. It is considered a good option for cases in which the tank elevation is substantially lower than the water application elevation.

On-demand pumps eliminate the need for a pressure tank. On demand pump system consists of a pump, motor, controller, check valve and pressure tank function all-in-one unit. This type of pump self-primes and has a check valve built-in. It operates based on the principal of pressure decline and water demand. This system is generally not recommended for a system with frequent water demands due to pump cycling.

Local pump suppliers include Corix, Smith Cameron and Xylem. Local pressure tank suppliers include Barr-Plastics, Home Hardware and Home Depot. For reference purposes, a ¾ HP 16 gpm @ 65 psi Bur-Cam Model 506532SS Tankless Jet Pump, constant pressure pump, is estimated to cost about $400.

1.3.5 Backflow Preventer / Air-Gap

Backflow prevention is required to avoid direct connection between the non-potable rainwater system and the municipal potable-water system. Non-potable water distribution systems must be isolated from potable water system through some form of backflow protection device such as a Reduced Pressure Backflow Assembly (RPBA) or by isolation from an auxiliary supply to storage tank using an air gap. In general, it is recommended that an air gap be used as it can be visually verified and does not require annual testing.

Some local suppliers of RPBA are Acklands Grainger and Engineered Pumps Systems.

1.3.5.1 Sediment Filtration

Sediment filters are intended to remove both coarse and fine solids and are installed in series, usually decreasing in size (e.g., 25um filter followed by a five micron filter), to reduce the potential for clogging. If the water is being disinfected with Ultra Violet (UV) light, it is advisable to remove all particles larger than five microns, as the particles could hide or shadow microorganisms from the UV light.

Sediment filters are disposable cartridges that slide into filter housings, and a variety of filters and matching filter housings are commercially available. Local suppliers for cartridge filters include Water Tiger, Water Siemens, and Donaldson. While most hardware supply stores carry cartridge filters they are generally too small (2.5" dia x 10" L) for commercial use, and are intended for domestic water treatment applications. A commercial-grade 4.5" dia x 20" L dual gradient filter is recommended. For reference purposes, a sediment filter housing kit (housing, mounting bracket) would cost $155 and the individual replacement 50-05 dual gradient design (DGD) sediment filters would cost $85 each, plus taxes, available through Water Tiger (tel: 604-630-1114). Filter replacement depends on the water quality and volume filtered.

When the water goes through the filters, a pressure loss (head-loss) occurs. Therefore, head-loss must be considered and monitored when planning to install any filters. In addition, allowance should be made to have an upstream and downstream pressure gauge installed. The gauge will assist in assessing when the filters need to be replaced.

When the filters are clean the difference in pressure read in the pressure gauges should be minimal. Filters must be changed when the pressure differential has increased according to the manufacturer O&M manual.

1.3.6 Disinfection

Water disinfection equipment is intended to kill or inactivate pathogenic microorganisms such as viruses, bacteria and parasites/cysts that may be present. Depending on the health or jurisdiction or municipal bylaws it may not be required for non-potable water applications, and is unlikely to be required for the farm applications considered in this document. The most common methods of disinfection are: 1) Chlorination; and 2) Ultra Violet (UV) irradiation. As noted in Section 1.2.5.1, if the water is subject to turbidity, it is also advisable to filter the water using a 5 micron cartridge filter prior to UV disinfection to remove suspended particles that may shield the microorganisms from the UV light.

1.3.6.1 Chlorination

Chlorination is effective against bacteria and many viruses; however, it has limited effect on parasitic cysts such as those generated by *Giardia* and *Cryptosporidium*. For that reason, for effective disinfection a combination of filtration to remove cysts and chlorination to kill bacteria and viruses is recommended.

When chlorine is added to water, it reacts with organic matter and other impurities in the water. Thus, the amount of chlorine required for disinfection will depend on the concentrations of these impurities. In general, the concentration of oxidizable impurities is expected to be low in rainwater.

Chlorination can also remove odors from rainwater by oxidizing the responsible chemicals. The chlorine concentration in water decays with time. This is especially important to note if rainwater will be collected and stored in a tank for an extended period of time, there is a potential for bacteria re-growth.

To achieve effective disinfection it is necessary to add sufficient chlorine to provide a free chlorine residual of 0.5 mg/L after a contact time of at least 30 minutes. As a general guide, the addition of 8 mL of liquid sodium hypochlorite (6% sodium hypochlorite solution – household bleach) per 1000 litres of water should result in free chlorine residual doses of approximately 0.5 mg/L.

The chlorine can be added manually throughout the day, injected using a metering pump, or applied using a slow release tablet of calcium chlorite. It is imperative that appropriate personal protective equipment (PPE) such as chemically resistant gloves, safety glasses or googles, long sleeve shirts and pants be worn prior to chemical handling.

The total chlorine residual can be verified using a chlorine test kit or test strip.

1.3.6.2 Ultraviolet (UV) Light

Ultraviolet (UV) light disinfection is a physical process that inactivates microbiological organisms when they pass in front of a high-intensity light in the disinfection chamber. The UV light is absorbed by proteins and nucleic acids, destroying bacteria and disabling bacteria from replicating.

The UV light source should be equipped with both a UV intensity sensor and a UV transmissivity sensor (UVT). The measurement of UV radiation intensity identifies when the UV bulbs need replacing, and the UV transmissivity determines how much radiation actually reaches the target microorganisms. Often UV tranmissivity can drop due to changes in the water quality, and water with UVT values less than 50% are usually not well suited for UV disinfection.

When selecting a UV light, check that:

- it has a high enough capacity to operate at peak performance during peak water demand flow rates in your farm;
- the bulb can be easily removed for cleaning or replacement purposes;
- downstream piping and fittings will not be compromised by concentrated UV light at the exit;
- Any bypass piping could be isolated to prevent water from bypassing the UV system; and
- It has both an intensity and transmissivity sensor that are alarmed.

For reference purposes, should disinfection be desired or required, a UV disinfection unit capable of treating up to 15 gallons per minute has an estimated cost of about $900.

2.0 DRY CLEANING BMP

2.1 Background

The wash-down operation to clear residual solids from the shelves and floor of the growing rooms is responsible for the majority of the water consumed by farm operations; requires an average of four hours of labour to complete, and generates wastewater that must be treated and disposed of at considerable cost. The cost of water is an important factor for the farms that obtain their water from a municipal water service. Although the majority of the farms use groundwater, at minimal cost, for farm operations, the regulations for groundwater extraction are changing and the costs are expected to increase in the future. But regardless of the water source, the water used for cleaning activities results in an equivalent volume of wastewater. Efforts to reduce the amount of water required for cleaning will result in reduced wastewater flows and costs to treat the wastewater as well as reduced contaminant loads to the environment either through ground disposal or surface water release.

Consequently, a method to decrease the amount of water and labour required to clean the surfaces in the growing rooms would be highly desirable, assuming the capital and operating costs associated with that method were substantially less than the status quo.

A less water intensive and more efficient method of cleaning the growing rooms was discussed with individual owners and Ministry staff during the site visits including: 1) pressure washing; 2) pneumatic cleaning; and 3) vacuum cleaning.

Ministry staff advised that the use of pressurized water was of concern with respect to the aerosolization and resulting distribution of spores that could spread disease within and between the growing rooms. Similarly the use of pneumatic cleaning devices and blowers were also of concern with respect to spore distribution.

However, some form of vacuum system coupled with a HEPA filter to trap spores appeared to be a promising alternative, and was deemed worthy of exploration as a Beneficial Management Practice.

2.2 Conceptual Vacuum Cleaning System

2.2.1 Vacuum System Characteristics

For a vacuum system to be effective it would need to be: 1) effective and efficient in removing the majority of solids from the growing room floor and shelves; 2) convenient for farm operations staff to initiate within each growing room; 3) flexible in application to enable staff to extract solids from hard to reach areas, such as under and on top of the growing beds; 4) have a storage capacity that could handle a significant portion of the residual solids in the rooms; and 5) prevent the distribution of spores within the working environment or generally within the farm.

2.2.2 Centralized versus Decentralized Vacuum Systems

The commercial Electrolux Beam Vacuum System, designed for use in residential and commercial office buildings is an example of a centralized vacuum operation. A centralized vacuum approach involves installing a vacuum distribution line throughout the barns with outlets located in each of the growing rooms. The vacuum distribution lines would be connected to a single vacuum source and HEPA filter.

The primary advantage of a centralized system include: 1) the vacuum canister, HEPA filter and vacuum exhaust can be positioned at one central location; 2) the ability to use a more powerful stationary “industrial-grade” vacuum source and HEPA filter; and 3) the vacuum exhaust can be located well away from the work area to avoid generating air turbulence within the growing room.

The disadvantages to the centralized vacuum system include: 1) higher capital cost for the industrial grade vacuum, HEPA filter, distribution lines, and installation of the vacuum system; 2) loss of vacuum, or low vacuum and poor solids transport with increased distance from the centralized vacuum source; 3) potential for blockages to occur within the vacuum lines; and 4) potential inconvenience of having to frequently clean-out and service a vacuum source located at a distance away from the growing room being cleaned.

In contrast a decentralized vacuum application would use a lighter less powerful mobile vacuum source, with an integral HEPA filter, and would be more convenient to empty. Given the industrial-grade mobile vacuums appear to have sufficient vacuum to pick up bulk solids, and the canister and HEPA filters would be more convenient to change, the primary disadvantage or concern is with the vacuum exhausting within the growing room while it is being cleaned.

A hybrid system could also be considered that would use a mobile vacuum source and solids containment, but would use a centralized exhaust system and HEPA filter. The hybrid system would combine the flexibility and mobility of a decentralized vacuum source, with the remote exhaust and improved air quality of a centralized HEPA filter and external exhaust.

2.2.3 Multi-Stage Cleaning Process

The vacuum system is intended to be part of a three-stage cleaning process as follows:

1) First Stage: Bulk Solids Removal

2) Second Stage: Fine Solids (Vacuum) Removal

3) Third Stage: Wet-Cleaning Process

2.2.3.1 First Stage: Bulk Solids Removal

The first stage bulk solids removal would essentially follow the existing initial cleaning stage carried out by the farms. This involves using a shovel and squeegee to collect the bulk of the solids on the growing room floor after the beds have been emptied. Residual solids are scraped along the floor into a corner of the growing room and then removed using a shovel.

Although employees are generally diligent in removing the bulk of the solids from the growing room using squeegees and shovels, on a couple of occasions it was noticed that a lot of solids were left on the floors during this phase. To minimize the amount of solids that have to be handled during the next vacuum stage, as well as reducing the frequency of emptying of the vacuum container, as well as reducing the contaminant loading in the final floor washing stage, employees need to remove as much of the solids as possible with the squeegee and shovel to minimize the subsequent labour, energy, and water requirements and costs of washing the surfaces in the room.

2.2.3.2 Second Stage: Fine Solids Removal (Vacuum)

The second stage of the Dry Clean process involves using the vacuum system to remove the finer residual solids from the floor and shelves of the growing room.

2.2.3.3 Third Stage: Wash

The Third Stage Wet Cleaning process follows the Second Stage Vacuum process and involves washing down the surfaces in the growing room in a similar manner to the current washing procedures, except using less water due to the reduced amount of residual solids present.

During the wet cleaning stage, water and disinfectant would be used to clean and sanitize the floors. Since the majority of the solids are expected to have been removed during the first two stages, it is estimated that the length of time required for the Third Stage Wet Cleaning process will be less than 50% of the previous routine growing room wash-down process, and use less than 50% of the water.

2.2.4 Vacuum System Equipment

The following describes a mobile vacuum with two optional exhaust and filter systems: 1) an integral HEPA filter; and 2) a hybrid vacuum application with a centralized exhaust and HEPA filter system. The latter option will require a farm to be retrofitted with an exhaust system (blower and HEPA filter), along with vacuum lines installed within the building to connect the individual growing rooms with the centralized exhaust and filter system

For both options the applied vacuum system would be portable and include an individual canister. For the centralized exhaust system each room would have an exhaust port connected via an exhaust line to a central industrial-grade HEPA filter similar to that used for clean-rooms. The discharge side of the vacuum system would be connected to the centralized HEPA filter through vacuum exhaust line which would continually draw air through to the filter. Since the cost of retrofitting the farm is expected to vary considerably, the costs provided are for the decentralized vacuum system application only with a built-in HEPA filter.

The following make and model of vacuum systems with built-in HEPA filters were identified:

1) Maxxi II 75, 19 gallon (72 L), wet/dry vacuum with front mount squeegee (tools and hose) from Clarke. The equipment cost, including the Certified HEPA filter, is approximately $1500 before taxes (FOB Factory). The supplier contact information follows:

   Quinn Cannady
   Regional Sales Manager, Western Canada
   Nilfisk-Advance Canada
   240 Superior Blvd.
   Mississauga, ON
   L5T 2L2
   Cell: (403) 360-3764

2) Big Brute Vacuum Cleaners were originally designed for use on farms and have large wheels that make them easy to push around, even on uneven concrete floors. They incorporate HEPA filters with an interceptor system (the latter would keep the damp material away from the cloth primary and secondary filter, facilitating the clean-up of the filters). The supplier did not provide cost estimate for the equipment in time for this information to be included in this report. The supplier contact information follows:

   Tristan Buquet
   Équipement Second Canada Inc.
   52 rue de la Sentinelle, Blainville (Québec) J7C 5A4
   Tel: (450) 818-5761
   Fax: (450) 818-5764

Both suppliers advised that their HEPA filter is certified and capable of filtering small materials such as asbestos and mold. Note that extended custom made vacuum hoses can be purchased for both units.

Note that the equipment costs indicated were provided by the manufacturer during the time that the report was being prepared. As equipment costs can change, farm owners are advised to contact the supplier/manufacturer directly to acquire current quotations.

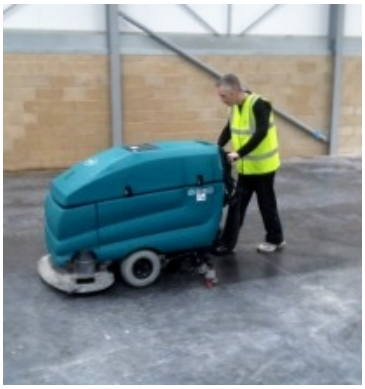
2.3 Auto-scrubber System

During the farm visits a few owners expressed their wish for a device to clean the main corridor of the barn. The intent of the device is to reduce water consumption and to expedite the centre hallway floor cleaning process. Two brands of walk-behind scrubbers were identified:

1) Clarke, Focus II L20 BOOST automatic scrubber, complete with transaxle drive, batteries and on-board charger.

2) Tennant 5680 with ecH2O technology. The latter comes in three different cleaning pad sizes: 28, 32 and 36 inch.

Clarke Focus II L20 Auto-Scrubber



Tennant 5680 Auto-Scubber

The required amount of water to clean a 500 m^2 corridor was calculated based on the maximum operating water flow rate for each auto-scrubber unit. This number should be considered in combination with the capacity of the water and recovery tanks as, ideally, one full water tank should last at least one cleaning event. The following table provides a specifications and cost comparison between four different auto-scrubber models:

Table 2: Auto-scrubbers Comparison

Brand	Unit	Clarke Focus II	Tennant 5680 ecH2O		
Model		**Compact L20 BOOST**	**28 in**	**32 in**	**36 in**
Theoretical Area Performance	m^2/h	1635	2175	2510	2845
Fresh/Dirty Water Tank	L	55/55	114/151	114/151	114/151
Maximum Water Flow	L/min	0.38	0.83	1.25	0.8
Water Consumption	$L/500m^2$	7.0	11.4	14.9	8.4
Cleaning Width	mm	500	711	813	914
Cost	$CAD	$8,000	$16,200	$17,400	$19,000

The water consumption for the ClarkeFocus II LC20 auto-scrubber unit is the lowest of all four units and its price is also the most affordable. However, the Clarke machine fresh and dirty water tanks are less than half the capacity of the Tennant 5680 ecH2O auto-scrubbers.

2.4 Savings

The volume of water consumed during a major room wash-down procedure is about 10 m^3, a 50% decrease in the length of time required to wash the rooms would reduce the water consumption for washing by at least 5 m^3.

The 2014 municipal water rates for Langley and Abbotsford were used to estimate the water savings for the Dry Clean process. The commercial water rate in Langley for 2014 was \$1.12/m^3. A 5 m^3/week per room savings would be equivalent to approximately \$291/year per room. For the same year, the industrial and agricultural water rates for Abbotsford were \$1.04/m^3. The savings for a farm located in the latter municipality would be equivalent to approximately \$270/year per room.

Langley (http://www.city.langley.bc.ca/index.php/city-hall/finance-and-taxes).

Abbotsford (http://www.abbotsford.ca/city_services/utility_billing/water_and_sewer_rates.htm#waterrates).

Assuming that an average a minimum of four hours are required to clean the growing room during a major wash-down procedure, and that the employee is being paid an average \$12/h, by implementing the dry-clean BMP the farm owner would be saving \$24 per growing room washing per day. If one growing room is washed per week, the savings for the farm would be approximately \$1250 per year per growing room for washing.

Figures 3 and 4 provide an estimate of the yearly water and labour costs to clean growing rooms, and the anticipated savings as a result of implementing a vacuum dry-cleaning process, based on cleaning from 1 to 5 growing rooms per week, with and without a dry-clean BMP implementation.

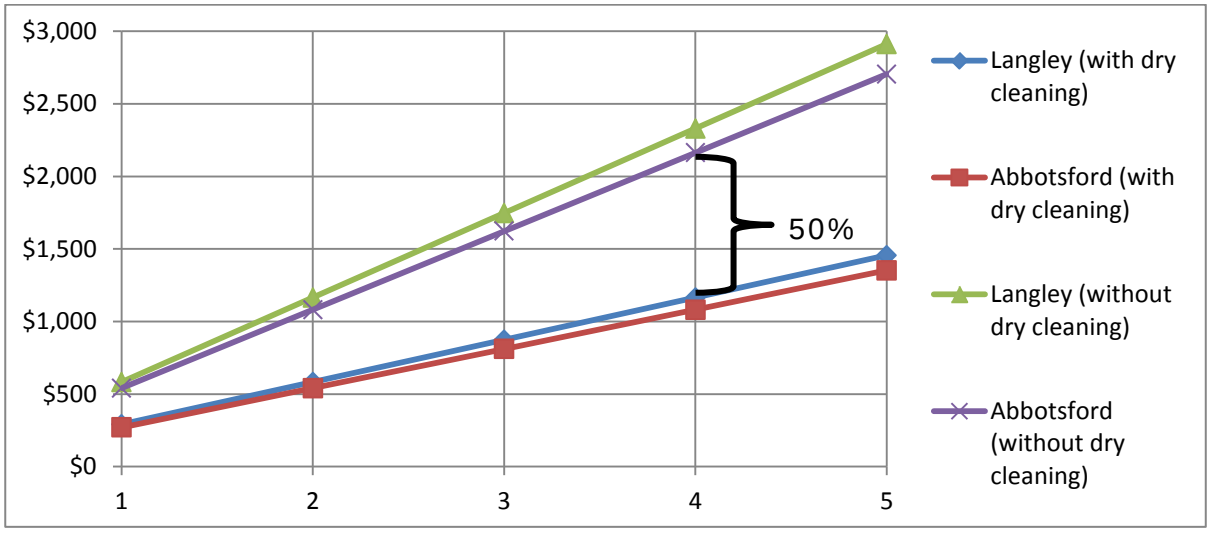


Figure 3: Yearly water charges at municipal rates based on the number of growing rooms cleaned per week and assuming a 50% reduction in average water consumption and labour for cleaning

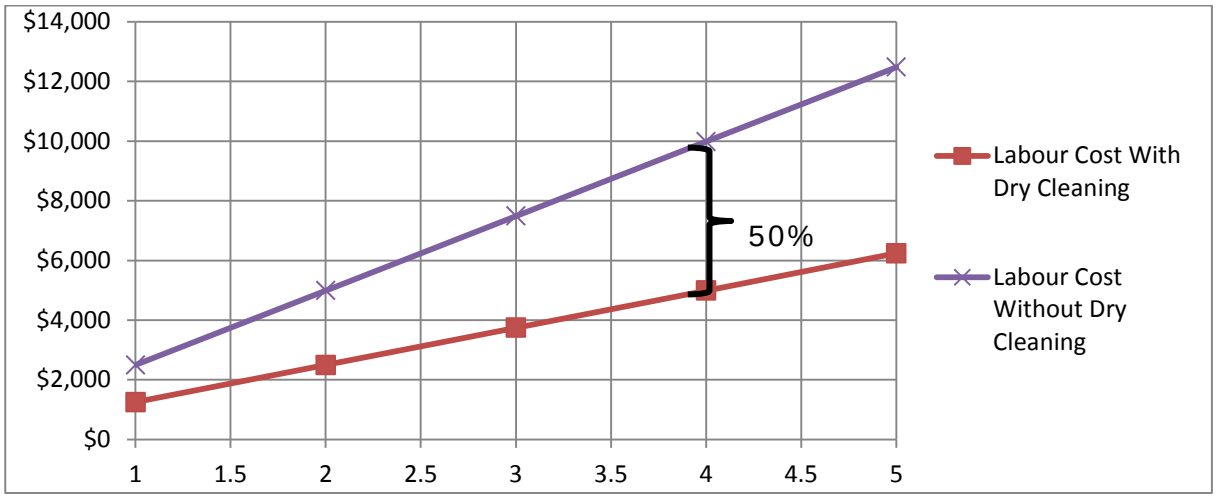


Figure 4: Yearly labour charges based on the number of growing rooms cleaned per week and assuming an average 50% reduction in labour for cleaning

Finally reducing the amount of wastewater required to wash a growing room by 5 m^3/d has an associated capital cost savings for wastewater treatment of approximately $25,000.

3.0 WASTEWATER TREATMENT BMP

3.1 Background

Wastewater generation, treatment and disposal were common concerns for all of the farms involved in this study, and many of the farms were experiencing difficulty with operating their current wastewater treatment systems. Excess suspended solids in the washwater was a particular problem that resulted in septic tanks requiring frequent and costly pump-outs, clogged ground disposal drainfields, saturated soil conditions, and in some cases the inability to achieve the required effluent quality for discharge purposes.

Passive treatment typically refers to enhanced or engineered natural processes and include lagoons, wetlands and overland flow. Mechanical wastewater treatment plants are engineered systems characteristically designed to mimic and enhance natural treatment processes including the physical filtering of solids and bacterial digestion of organic contaminants. This results in more compact treatment system sizes and typically greater operating costs. If land is available, passive treatment processes are generally preferable as they require little attention and have significantly lower operations and maintenance costs in comparison with mechanical systems.

This wastewater treatment BMP is intended to provide guidance to farm owners on selecting wastewater treatment technologies that are appropriate for farm application and emphasize passive treatment. The following are key elements of concern to be taken into consideration when selecting a particular wastewater treatment system:

- Primary solids removal (to prevent downstream clogging and infrastructure failure); and
- Bio-oxidation to remove biodegradable contaminants that otherwise may clog drainfields or impact surface water bodies.

There are an infinite number of passive and mechanical wastewater treatment processes and configurations that could be considered. The following sections describe three biological treatment systems that are appropriate for mushroom farm wastewater treatment applications where treatment is required to reduce the size of the ground disposal system or to address current overloading conditions.

Because surface discharges of treated effluent require extensive receiving environment monitoring, and dilution considerations, this BMP is restricted to ground disposal wastewater applications only.

3.2 Wastewater Characteristics

The wash water sampling program carried out during this study established the growing room wash-water characteristics are similar to domestic wastewater, except for being about half the strength. The primary contaminants of concern include:

- Biochemical Oxygen Demand (BOD) – a measure of how much oxygen will be required by bacteria in the environment or within a treatment process to digest the soluble organic contaminants in the wastewater. Excess BOD can result in bacteria in the receiving environment consuming more oxygen from the water than can be replenished, causing the dissolved oxygen in the water to drop and fish to suffocate. The new federal Wastewater Systems Effluent Regulations require the carbonaceous BOD to be less than 25 mg/L.

- Total Suspended Solids (TSS) – the weight of solids in suspension that, if not removed during treatment, can settle and smother the bottom of surface water bodies, or clog ground disposal systems. The new federal Wastewater Systems Effluent Regulations require the TSS to be less than 25 mg/L.
- Ammonia – a byproduct of organic decay and present in high concentrations in mushroom compost due to manure used in the mushroom growing media recipe. Ammonia can be toxic to fish and can result in excessive nuisance aquatic plant growth as well as affect groundwater quality. Generally passive wastewater treatment processes are effective in converting the toxic ammonia present in the wastewater into nitrate (non-toxic form of nitrogen (nitrification), but are not effective in removing nitrogen altogether (denitrification). The new federal Wastewater Systems Effluent Regulations require the unionized ammonia in the effluent to be less than 1.25 mg-N/L.
- Coliform Bacteria – The effluent water samples collected from the farms contained high concentrations of coliform bacteria. Coliform bacteria are used to determine the effect of treatment and disinfection processes on disease-causing microorganisms that cannot be as readily measured as coliform bacteria, but are expected to be similarly affected by disinfection technologies. The presence of coliform bacteria is to be expected, particularly considering that manure is one of the ingredients in the mushroom growing media. While the removal of microorganisms are typically not a concern with respect to ground disposal systems, removal is a concern for surface water discharges which require disinfection.

The removal of total suspended solids using a septic tank is considered to be primary treatment, and the removal of BOD, referred to as secondary treatment , down to concentrations of less than 10 mg/L can also be expected to reduce the unionize ammonia concentration to within the federal standards.

3.3 Treatment Components

3.3.1 Coarse Screening

During the washing process most of the farms visited use a coarse basket-screen hung below the floor drain to remove bulk solids, stems and pieces of mushroom from the wash water. This is effective (if used) but does pose an operations problem if there are a lot of solids being picked up by the wash water and the baskets can quickly fill and clog the drain. As the larger solids can be difficult to flush through to the septic tank, the use of the hanging basket-screen has an important function and it is important that the filter basket be in place during full duration of the washing procedure.

3.3.2 Primary Treatment – Suspended Solids Removal

3.3.2.1 Settling

The purpose of the primary treatment is to remove the bulk of suspended solids and the associated organic matter from the wash water. The most simple and most passive method of solids removal is to use gravity to settle suspended solids within some form of containment. While this can be achieved using an earth basin or pond, a septic tank is recommended as it can contain the solids within a reasonable volume that can be pumped out completely with a commercial pumper truck. While a pond can be just as effective in removing suspended solids, it is much more difficult to remove and dispose of the accumulated solids.

3.3.2.2 Fine Screening

As an alternative to gravity settling, a more efficient method of removing suspended solids is to use a fine screen installed downstream of the floor drain and basket-screen to remove the suspended solids that pass through the coarse screen.

Fine screens have small openings (around 6 mm) and are typically designed for automatic cleaning, but could be installed with the intent of implementing manual screen cleaning after each cleaning operation. The solids retained by the fine screen should be disposed of at the end of the growing room cleaning operation to prevent clogging and minimize odor.

When selecting a fine screen, it is important to note that the manufacturer's capacity ratings are usually based on clean water. As such, the fine screen capacity rating obtained from the manufacturer should be decreased by approximately 80% to account for partial clogging of the screen.

Examples of self-cleaning micro-screens include: Salsnes, Aqua-Aerobics AquaDisk, and AquaCare Microscreen Filters.

3.3.3 Solids Removal and Disposal

A second problem identified with solids removal, aside from the excess amount of solids that are washed out of the growing rooms with current cleaning practices, is the cost associated with the frequent need to pump out the accumulated solids. A geotextile bag and a trash pump can be used to periodically remove solids from the septic tank and dispose of them with the spent compost removed from the barns. The dewatering can be done over a drainage basin for the purpose of returning the water back to the septic tank. Once the bag is full of solids, it can be left to drain after which the solids can be removed and the bag reused. There are many dewatering bag products that are manufactured for small wastewater treatment plant sludge dewatering and sediment control for use at construction sites – such as the reusable bag sold by Hy-Tex (UK) Ltd. shown in Figure 5.

Figure 5: Example geotextile bag application for solids dewatering (Hy-Tex (UK) Ltd. (http://www.hy-tex.co.uk)

3.3.4 Biological Treatment

3.3.4.1 General

The water quality analyses shows the wash water also has a significant BOD concentration, representing soluble organic contaminants that can result in excess bacterial growth in the receiving environment. If that receiving environment is a ground disposal system, the bacteria feeding on the BOD in the septic tank effluent can clog the drain lines and cause the disposal system to fail. If the discharge is to a stream or other surface water body, the BOD is consumed by bacteria in the receiving body that require oxygen and can deplete the dissolved oxygen levels in the water body – affecting aquatic organisms.

While the natural environment will remove BOD, to avoid the impacts like those mentioned above, an extensive number of biological treatment technologies have been developed to mimic natural phenomena. These range from passive technologies which are essentially enhanced natural treatment processes that require a large amount of land area (i.e., lagoons and wetlands) to highly sophisticated mechanical processes that are designed to accelerate the same biological processes that occur in nature and significantly reduce the land area requirements (e.g., membrane bioreactors). There is a trade-off between land area requirements and lack of operational flexibility and adaptability inherent to passive treatment technologies, and the high capital and operating cost and complexity of sophisticated mechanical treatment processes.

Taking into consideration the farm owners desire to have a treatment process that is simple to operate, and also recognizing that many farms do not have the land area available for a lagoon process, three technologies were selected for this BMP: 1) a constructed wetland; 2) an intermittent (recirculating) sand filter; and 3) a textile (recirculating) biofilter.

Operation and maintenance of the wetland is minimal whereas the intermittent sand filter and the textile biofilter have some mechanical components (i.e., recirculation pumps) that require periodic maintenance. These treatment systems are discussed in the following sections.

3.3.4.2 Constructed Wetlands

Wetlands are natural water treatment systems that incorporate biological and physical processes to remove contaminants from water that flows through them. They typically consist of shallow saturated soils containing emergent vegetation that grow that tolerate their roots being submerged in water. Although the plants can remove some nitrogen and phosphorus from the water, their primary function isn't water treatment, but rather to provide surfaces for bacteria to attach to. It is the attached bacteria that are responsible for the majority of the water treatment. Because natural wetlands seldom have uniform sheet-flow across them, and often have channels develop that carries most of the water flow and reduces the amount of time that water can be treated within the wetland, they are sub-optimal, have inconsistent treatment characteristics, require large land areas, and are therefore not well suited for wastewater treatment. Although natural wetlands can be enhanced to improve the uniformity of flow and depth of water, they are characteristically limited in their treatment capacity by the wetted surface area available (i.e., submerged plant stems and surface of the soil). A few farms visited incorporate natural wetlands as part of their wastewater treatment process.

Constructed wetlands are engineered systems that mimic and significantly enhance the treatment capabilities and conditions within natural wetlands. They are typically constructed of beds of gravel with a depth of about one metre. The gravel in the beds provide a high degree of surface area for attached growth bacteria as well as supporting the roots of the sedges, reeds, and cattails that cover the beds. Piping designs ensure that wastewater flows uniformly throughout the bed, resulting in optimal use of the media for treatment. As a result of the uniform flow and the greater surface area provided, constructed wetlands require significantly less land area than would be required for natural wetland systems. Other benefits associated to the constructed wetlands are vector and odor control.

Effectiveness and longevity of constructed wetlands have shown great variability and therefore this type of treatment is generally considered in combination with other types of passive or active treatment. Constructed wetlands may be used in combination with an advanced secondary or tertiary treatment to achieve further reduction in BOD, suspended solids and nutrient levels.

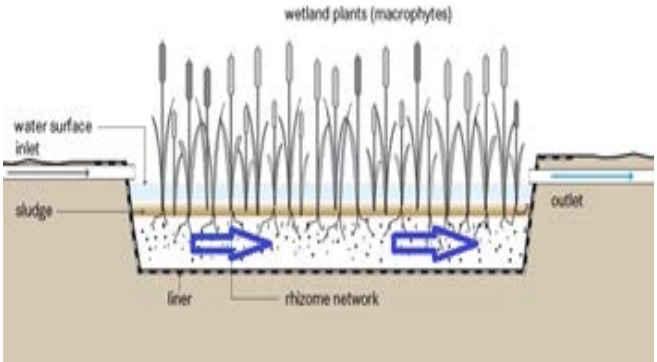
Wetland systems can significantly reduce BOD and suspended solids and, if designed and sized appropriately, they can also fully nitrify the wastewater ammonia. The main treatment mechanisms that occur within a wetland system follows:

- sedimentation;
- filtration;
- chemical precipitation, exchange and adsorption;
- microbial transformations of BOD5, suspended solids and limited nitrogen reduction; and
- vegetation uptake of nutrients.

Plants in constructed wetlands can contribute to treatment in many aspects, such as substrate consolidation, metal accumulation, and adsorption of metal precipitates, and serve as a substrate for microbial growth, as well as providing a wildlife habitat.

The most common form of constructed wetlands is a subsurface flow wetland consisting of a bed of media, with a depth of just over 1 metre, sand underlain by an impermeable liner. Water flows through the media in a horizontal direction. A schematic for a horizontal SFW is provided in Figure 6.

Note that if the effluent from the constructed wetland is intended for discharge into a surface water body, then effluent filtration will likely be required in addition to disinfection.



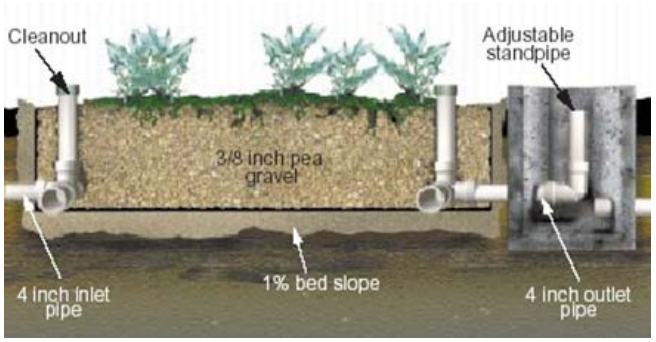


Figure 6: Typical horizontal SFW schematic

Some of the advantages and disadvantages of a SFW wetland include:

- Advantages:
  - Produces effluent with low levels of BOD and TSS;
  - Performance is maintained during low flow periods;
  - Annual or seasonal maintenance requirement to harvest the plants (note that this is considered a low maintenance system);
  - Nonproprietary system;
  - Power supply independent; and
  - Effectively used in conjunction with other secondary treatment to achieve nutrient removal.
- Limitations:
  - May not achieve complete nitrification reliably;
  - Footprint requirement is generally greater than other mechanical secondary treatment options;
  - During wet weather period, the rainwater collected contributes to the overall water flow being treated by the wetland;
  - TSS and BOD removal may not be as efficient as mechanical treatment options, particularly considering the contaminants arising from decomposing plant debris;
  - Performance is reduced during cold weather periods; and
  - Vegetation must be harvested.

It is recommended that a professional with experience in SFW wetland design be contracted to design the systems for the farm. For information purposes, the following design parameters should be considered for a SFW wetland:

- Influent and expected effluent BOD (mg/L);
- temperature-dependent first order reaction rate constant (1/d);
- hydraulic residence time;
- average flow rate through the system (m^3/d);
- depth of submergence (m) = porosity of the bed, as a fraction;
- surface area of the system (m^2);
- slope of bed (as a fraction or decimal);
- hydraulic conductivity of the medium (m^3/m^2-d); and
- bed width (m).

Based on the observation that the wash water generated during the growing room cleaning operation is expected to be about half the strength of domestic wastewater, the organic loading criteria are expected to be in the order of 133 kg BOD/ (ha.day), with a bed length of at least 20 m to ensure adequate retention time and reduce the potential for hydraulic short circuiting.

The following materials and equipment are required for a construction of a SFW wetland:

- coarse gravel;
- substrate media (coarse sand);
- geomembrane liner (usually 60 mil HDPE);
- base layer (e.g., medium or river sand – 1-10 mm);
- outlet flow chamber;
- earth berm;
- pipes and piping appurtenances;
- valves; and
- plants (typically reeds, rushes, sedges, etc.).

Some common issues to look for in wetlands are premature clogging, development of short-circuiting flow patterns, surfacing of effluent, and failure (surfacing of effluent).

Considering the relatively weak growing room wash-water wastewater strength, it is expected that the wetland capital costs including liner, media, piping, baffles and plant components, are expected to range from $12 to $20 per gallon per day ($3000 to $5000/m^3/d).

3.3.4.3 Recirculating Biofilter

3.3.4.3.1 Intermittent Sand Filter

Biological oxidation and treatment can be achieved using an intermittent sand filter (ISF). The mechanisms of treatment in an ISF system are a combination of filtering and biological degradation using sand as the attached growth media.

The benefits of an ISF system include:

- Low power consumption.
- Aerobic conditions are maintained naturally by gravity flow through unsaturated filter media.
- It can produce a higher quality secondary effluent (i.e., good BOD, TSS and ammonia removal) than a constructed wetlands with the same footprint.
- Low maintenance requirements.
- Reduces pathogens.
- Effluent typically does not require additional filtration for disinfection.

In the ISF, treatment occurs as the wastewater trickles downward by gravity through approximately 1.1 m (4 ft) of media consisting of a 0.2 m depth of gravel, underlain by about 0.6 m of sand, 0.1 m of pea gravel and finally 0.2 of washed gravel as illustrated in Figure 3. Bacteria attached to the media obtain food from the liquid trickling downward through the bed and obtain oxygen from air that is able to penetrate the well-drained bed. Because the treated water is recirculated and passed through the bed many times before it is finally released as a treated effluent, the concentration of BOD (food) the bacteria receive is very low. This low BOD characteristic optimizes the growth characteristics for a different group of bacteria that convert ammonia to nitrate, improving the degree of nitrification that can be achieved in comparison with a constructed wetlands with the same land area. Aerobic conditions within the filter will be maintained as long as the system is not overloaded by excess BOD (resulting in clogging due to excess bacterial growth in the bed) or hydraulically overloaded or poorly drained (restricting the amount of oxygen available within the bed). Figure 7 provides an illustration of a typical ISF system:

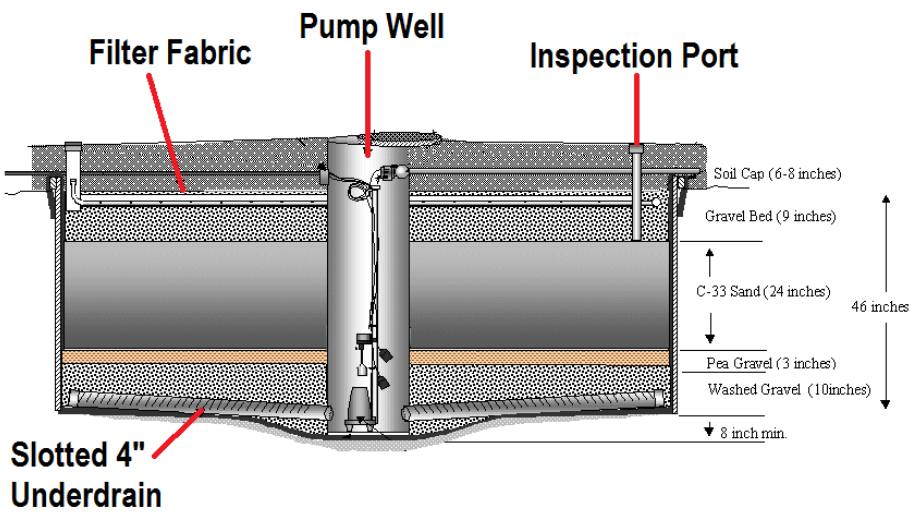


Figure 7: Intermittent Sand Filter Cross Section

The following design parameters should be considered for ISF (Sherwood C., Middlebrooks, & Ronald, 1988).

- Hydraulic loading rate from 0.37 to 0.56 $m^3/(m^2$ day).
- If the influent TSS exceeds 50 mg/L, then the hydraulic loading rate should be reduced to 0.19 to 0.37 m 3/(m^2 day). Consequently, to avoid oversizing the ISF, it is important that the primary solids removal equipment (whether septic tank, pond or fine screen) be properly maintained.
- It is recommended to reduce the hydraulic loading rate to the filters during winter, to prevent clogging of the sand filter. This is because water is most dense (viscous) at a temperature of 4 ^{o}C, which is the temperature of water in contact with ice. For winter conditions in the Langley/Abbotsford area this is likely a 75% loading reduction, and can be determined through pilot testing.
- Effective sand size ranges from 0.2 to 0.3 mm with a uniformity coefficient less than 7.0, and less than 1 per cent of the sand smaller than 0.1 mm.

Considering the relatively weak growing room wash-water wastewater strength, It is expected that the intermittent sand filter component costs for containment, liner, geotextile fabric, underdrain pipe, gravel, pump, media and pump well, would be similar in cost to a constructed wetlands and in the order of $12 to $20 per gallon per day ($3000 to $5000/$m^3$/d).

3.3.4.3.2 Orenco AdvanTex Recirculating Biofilter

The Orenco AdvanTex recirculating biofilter (http://www.orenco.com), illustrated in Figure 8, is similar in concept to an ISF. However, instead of using sand as a filter media, it uses a cloth fiber media that results in a significantly higher surface area for bacteria to grow on, and hence requires a much smaller footprint for the same level of treatment. While the ISF loading rate is approximately 0.04 m^3/m^2, the AdvanTex biofilter loading rate is about 1.2 m^3/m^2. As a consequence, the footprint required by the AdvanTex biofilter is about 1/30th the area required for an ISF system.

The AdvanTex biofilter operates on the basis of bathing the media with wastewater for about 30 seconds every 20 minutes. Like the intermittent sand filter, the bacteria attached to the cloth fibre media are bathed in soluble organic material (food) and are passively provided oxygen by air that circulates through the freely draining media.

The AdvanTex biofilter has a number of advantages over an ISF, including:

- Less land area required (approximately 1/30th);
- Can adapt to variable loading rates, including overloading, without degrading effluent quality;
- Can be designed to denitrify and remove total nitrogen (nitrate loading to groundwater can be of concern); and
- If biomass growth is excessive, the media is easily accessed and can be hosed off; whereas this situation would result in ISF failure and a high cost to remediate.

To cost to supply an AdvanTex treatment system complete with tanks, media pod, recirculation pump, and controls is approximately \$3,000/m^3, which is about the same as the lower end expected capital cost for both the constructed wetlands and intermittent sand filter treatment systems.

Figure 8: Orenco Advantex Recirculating Biofilter

3.3.4.4 Slow Sand Filtration

Where the effluent water quality suspended solids concentration in the effluent from biological treatment process exceed that desirable limit for the intended application, filtration may be required. While this can be achieved with mechanical filters, they can be expensive and problematic if, for example, there is algae in the effluent. Under such conditions, consideration should be given to construct a slow sand filter.

Filtration may be required to remove sloughed solids and algae that may be released with the wetlands effluent. One low-tech method of removing solids down to the colloidal level is to use a slow sand filter.

A slow sand filter consists of a bed of graded sand, generally housed in reinforced-concrete structures with a support layer of graded gravel about 0.3 to 0.6 m deep. The filter contains inlet and outlet piping. Influent water seeps downward by gravity through the sand and gravel and it is collected by an underdrain system, consisting of perforated pipes.

The water level in the structure is above the media bed. The maximum water level above the media dictates the available static head for the system. Filtration rate is controlled by isolation vales located in the influent or effluent line.

The filter bed depth is generally between 0.9 -1.5 m and it generally consists of graded material. Its low filtration rate causes the particles in the water to be removed in the top few centimeters of the bed. The surface of the bed forms a mat material (Schmutzdecke) which functions as an additional filtration layer, physically straining smaller particles from the water.

Slow sand filtration system operates over a cycle with two stages, consisting of filtration stage and regeneration sage. The filter is not backwashed. Pressure loss builds up slowly in these systems and when the available head is reached, the filter is drained and the top 1 to 2 cm of media is scrapped off, hydraulically cleaned and stockpiled on site. The filter is then place back online. This operation can continue during several years before the filter sand needs to be replenished.

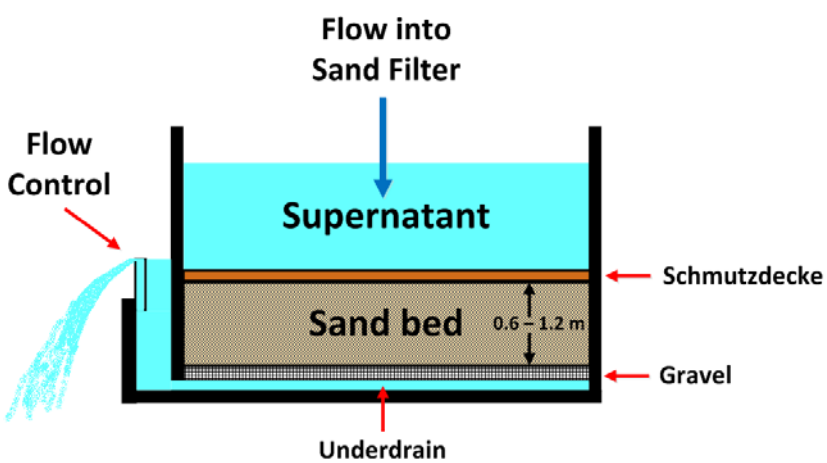


Figure 9: Typical slow sand filter schematic

Breakthrough of contaminants can be noticed during the first days of operation, which is often called as ripening period. For this reason, it is important to provide filter to waste piping to allow for the filtered water to return to the source during the ripening period.

It is expected that the slow sand filter would cost between $5 and $7 per gallon per day ($1,250 to $1,750/m^3/d), including construction.

4.0 WASTEWATER ANALYTICAL DATA SUMMARY

Appendix D provides the analytical laboratory result for the wastewater sample collected from the farm. For comparison purposes, wastewater sample results from all seven farms are summarized in Table 3 below. For confidentiality reasons, the farm names have been omitted.

The analytical data presented in Table 3 indicates the wastewater generated during barn wash has similar characteristics to a low-strength untreated domestic wastewater, with the notable exception that the total suspended solids concentration is typically more than double the concentration of domestic wastewater.

Table 3: Mushroom Farms Wastewater Samples Comparison

Parameter	Units	1	2	3	4	5	6	7	Average	Min.	Max.
Carbonaceous BOD	mg/L	51.2	74.3	189	31.5	120	57.3	13.4	77	13.4	189
Total Organic Carbon (C)	mg/L	111	134	217	52	188	157	36.5	128	36.5	217
Total Phosphorus (P)	mg/L	2.4	3.8	7.9	2.9	6.8	9.1	1.7	5	1.7	9.1
Total Nitrogen (N)	mg/L	24.4	33.7	43.9	19.2	47.3	56.4	12.7	34	12.7	56.4
Total Ammonia (N)	mg/L	4.9	0.4	6.7	11	12	17	0.5	7.5	0.4	17
Total Kjeldahl Nitrogen	mg/L	20.4	33.3	43.5	17.7	46.8	56.4	12.3	33	12.3	56.4
Nitrite (N)	mg/L	0.25	0.10	0.12	0.57	0.16	<0.50	0.1	0.2	0.1	0.6
Nitrate (N)	mg/L	3.7	0.3	0.3	0.9	0.4	<2.0	0.3	1	0.3	3.7
pH	pH	7.1	7.6	7.4	7.9	7.5	7.4	7.9	7.5	7.1	7.9
Dissolved Chloride (Cl)	mg/L	43	31	430	80	88	60	16	107	16	430
Total Suspended Solids	mg/L	156	117	396	462	1310	366	376	455	117	1310
Turbidity	NTU	68.5	162	508	67.5	208	243	177	241	67.5	508
E. coli	CFU/100mL	9.2E+06	4.0E+04	2.0E+06	1.0E+03	1.6E+04	1.8E+02	2.4E+05	1.6E+06	1.8E+02	9.2E+06
Fecal Coliforms	CFU/100mL	9.2E+06	1.6E+05	5.6E+06	7.0E+04	2.7E+05	7.8E+05	2.4E+05	2.3E+06	7.0E+04	9.2E+06
Total Coliforms	CFU/100mL	5.5E+07	4.4E+05	6.6E+07	4.0E+05	3.1E+06	3.6E+06	2.6E+06	1.9E+07	4.0E+05	6.6E+07

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