A robust biobed design for managing pesticide rinsate under Canadian conditions

Construction, operation and maintenance manual

Agriculture and Agri-Food Canada
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A robust biobed design for managing pesticide rinsate under Canadian conditions: Construction, operation and maintenance manual

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FORWARD

This manual provides information on the design, construction, operation and maintenance of pesticide rinsate biobeds in Canada. It is written from a Prairie perspective but most of the information is applicable or easily adaptable to other regions in Canada. The information presented borrows heavily from the extensive European experience which was enhanced by four years of laboratory and field studies, as well as three years of recent testing of the proposed design in Saskatchewan and Alberta. Because there are still some information gaps, the manual is expected to be updated as new knowledge is gained.

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INTRODUCTION

WHY BIOBEDS?

Pesticides are an integral part of today's agriculture. Although best practices exist to minimize impacts to the environment from pesticide use, pesticides are still often detected in wetlands, rivers, lakes and in groundwater. Their presence in drinking water sources necessitates their removal and adds to water treatment costs.[1] In addition, public scrutiny can lead to increased regulations, restrictions and, in some cases, outright bans of some agricultural chemicals producers rely on. Furthermore, producers are consumers themselves and live in the same communities that can be affected by improper pesticide waste disposal – they too are concerned about the health of their family, pets and livestock. However, by taking a proactive approach to proper pesticide waste disposal, these issues can be mitigated or avoided. Biobeds provide a safe and effective solution for managing pesticide waste disposal.

THE IMPORTANCE OF PESTICIDE HANDLING AREAS

Research has shown that the pesticide handling area – the site where the sprayer is filled, rinsed and washed – can be a major contributor of pesticide contamination found in surface water bodies (streams, lakes and wetlands)[2] as well as groundwater. Often, this area is close to a water source, has been stripped of topsoil to provide a solid foundation and receives sprayer rinsate with high concentrations of pesticides. These factors reduce local absorption of pesticides and contribute to contaminated runoff into surface water and seepage into groundwater. By focusing on the pesticide handling area and providing a proper catchment and disposal facility, this source of contamination can be essentially eliminated.

WHAT IS A PESTICIDE RINSATE BIOBED?

A biobed is typically an open tank or lined hole in the ground filled with a biomixture ("biomix", a mixture of woodchips or straw + field soil + compost or peat). Sprayer rinsate and spills are collected from a sloped pad that drains into a sump and is then pumped into a holding tank. From the holding tank, a low daily volume of rinsate is trickled or sprayed over the top of the biobed. Some of the water in the rinsate evaporates while the rest percolates through the biomix. Treated rinsate that collects at the bottom of the biobed can be used to irrigate grass or a shelterbelt (Figures 1 and 2).

Figure 1. Early stage construction showing black polyethylene liner and two biobeds. Inset: Top view of filled biobeds with drip irrigation lines on top of biomix; black rinsate storage tank sits behind biobeds

[1] Dearmont, D., B.A. McCarl and D.A. Tolmen. 1998. Costs of water treatment due to diminished water quality: A case study in Texas. Water Resources Research, 34(4): 849-853.

[2] Helweg, A. 1994. Threats to water quality from pesticides—Case histories from Denmark. Pesticide Outlook 5, 12-18; as reported by Castillo M.D.P. and L. Torstensson. 2008. Biobeds - Biotechnology for Environmental Protection from Pesticide Pollution. In: Annable M.D., Teodorescu M., Hlavinek P., Diels L. (eds) Methods and Techniques for Cleaning-up Contaminated Sites. NATO Science for Peace and Security Series C: Environmental Security. Springer, Dordrecht.

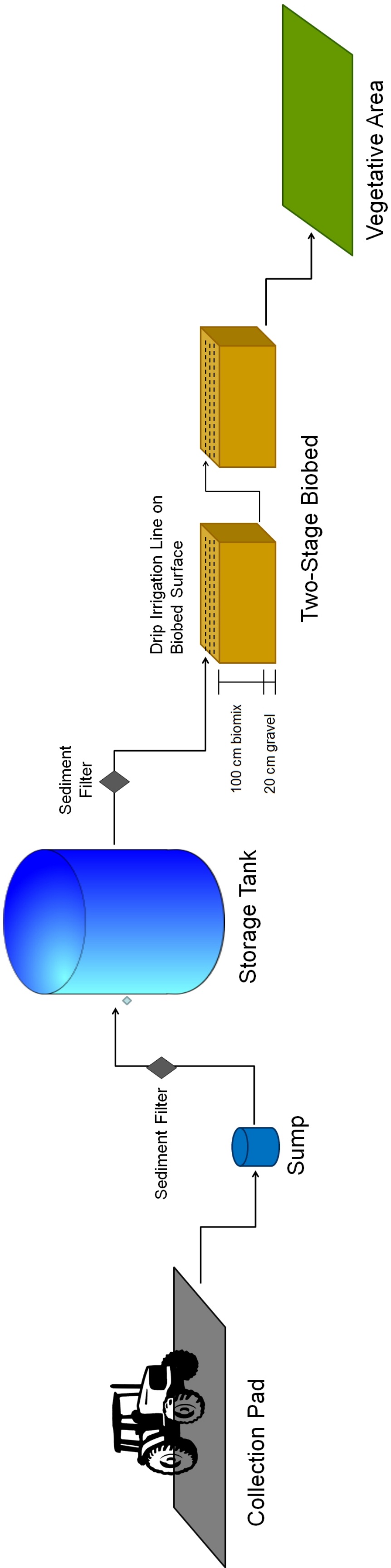

Figure 2. General diagram of a two-stage biobed system

HOW DOES A BIOBED WORK?

The biobed removes pesticides from the rinsate by adsorption and degradation. Adsorption is a process where ions or molecules adhere to a solid surface forming a thin layer. In this case, the pesticide molecules in the rinsate solution or spilled pesticides adhere to the soil particles and organic biomix components. Naturally occurring bacteria and fungi that can break down pesticides are introduced into the biomix with the field soil component. It makes sense that pesticide degrading micro-organisms would be present in agricultural field soil because it has been exposed to pesticides over time, thus encouraging the development of microbial communities that can biodegrade and use pesticides as food sources.

Because pesticide biodegradation is the ultimate objective, an environment that favours microbial growth is critical to ensure high biobed performance. Microbes thrive in a moist and warm (20°C to 30°C) environment. To encourage bacterial and fungal growth (and hence pesticide biodegradation), it is essential that the biobed has (1) good drainage to manage moisture levels and (2) a heating system to thaw/ warm the biobed in spring to ensure the biobed is ready to go in early May, in time for spray operations. Without heating, the biobed can remain frozen into June, greatly reducing the time when effective treatment occurs by several weeks.

WHAT KINDS OF PESTICIDES CAN A BIOBED TREAT?

You can use biobeds to treat herbicide, insecticide and fungicide rinsates separately or in mixtures. Concentrated pesticides should not be applied directly to the biobed because they may negatively affect the microbial communities. In addition, microbial communities may not be large or diverse enough to biodegrade high concentrations of pesticide if applied directly to the biobed.

Fungicides may affect fungi in the first biobed, but fungal communities can recover within a month. If using a two stage system, the second biobed usually remains rich in fungi.

WHY ARE TWO BIOBEDS IN SERIES BETTER THAN ONE?

Single and two biobeds in series with various depths were tested by AAFC. The results showed that the single biobed could remove about 90% of the pesticides and adding a second biobed could remove about 85% of the remaining pesticides. This means that a single biobed removes 90% and the two biobeds in series usually remove greater than 98% of the pesticides. In addition, it was found that challenging pesticides were often removed at a higher rate in the second biobed compared to the first biobed. Increasing the depth of the biobed made little difference in pesticide removal efficiency.

WHAT AFFECTS THE EFFICIENCY OF THE BIOBEDS?

The pesticide removal percentage decreases with higher application rates and greater rainfall. Research also showed that three pesticides have lower removal than others: the herbicides clopyralid (Lontrel, Stinger, Transline, Confront), bentazon (Basagran, Storm) and imazethapyr (Pursuit, Arsenal). For these three, roughly 60% is removed. More research is needed to understand how and why these pesticides are not removed as efficiently as others, and to develop methods to increase their removal efficiency. Until this issue is resolved, reduce the amount of these pesticides entering the biobed by spraying out all tank mix and rinsate in the application field when possible.

HOW MUCH RINSATE CAN A BIOBED TREAT?

Biobed size determines how much rinsate can be treated over a growing season. At a 1-centimeter/day application rate, you can apply ten liters per square meter (see drip tubes, page 14). To calculate total capacity of the biobed, simply multiply the biobed surface area (in square meters) by 10 and then multiply by the number of days in which an application may be made to the biobed. For example, a typical biobed with five square meters will treat 5000 litres in 100 days:

$$\text{Volume treated} = 5\ m^2 \times 10\ L/m^2 \times 100\ \text{days} = 5000\ L$$

The design in this manual is based on applying one centimeter of rinsate depth over the entire bed each day during the growing season (~100 days). Typical farm operations generate 5000-7000 litres of rinsate per year (1100-1500 gallons/year) but some operations with many different crops may generate double or triple that amount.

A typical farm operation requires five square meters (54 square feet) of biobed surface (see above). The design provides a safety factor for size to accommodate expansion or higher than expected volumes. If necessary, daily application rate can be doubled with little reduction in removal efficiency. However, application rates higher than two centimeters per day will reduce removal efficiency.

Best practice: minimize the amount and concentration of the pesticide in the rinsate by (1) completely spraying out the tank mix on the target field and (2) if possible, spray your first rinse on the same field or crop.

HOW MUCH DOES A BIOBED SYSTEM COST TO SET UP?

The cost of a biobed system can range from $6000-$23,000 depending on the size and materials used to construct the collection pads and on the size of the system required to treat the annual volume of rinsate [see Costs, page 17].

HOW LONG CAN I EXPECT THE BIOBED TO FUNCTION EFFICIENTLY BEFORE THE BIOMIX NEEDS TO BE REPLACED?

In Europe, producers typically replace the biomix every five to seven years. In Canada, with colder temperatures, the biomix may last longer. However, with artificially heating the biobed in early spring, microbial activity would be higher which may cause the biomix to degrade more rapidly. Until more research is completed, it is recommended to replace the biomix every five years [see Biomix Rejuvination and Disposal, page 21].

ARE THERE OTHER OPTIONS?

There are different types of biobeds than the recommended two-celled design in this manual. Alternative designs include:

1. Stacking: small cubes (1 m^3 size) containing biomix, stacked three high. Rinsate is applied to the top and flows by gravity through each container to the one below. With less than a metre of head (2 psi) on the distribution system, it is often challenging to obtain good coverage, but the design eliminates pumps and is less costly.

2. Drive over: the biobed sits under the wash area and covered by a heavy-duty grate (capable of supporting a tractor and spray equipment). Rinsate is applied to the biobed at the time of washing – no slow metering over time. This design eliminates some pumps but the grating can be costly. However, the biobed is exposed to variable application rates making it less effective and rainfall cannot be diverted.
3. Covered: under a roof, a one-cell biobed with a recirculation system works extremely well. With evaporation eliminating most of the water in the rinsate and no water added through rainfall, it can be more effective than the recommended two-celled design. The roof adds to the cost and it is often an inconvenience when working in the biobed.

EXAMPLE 1

Q: How much pesticide rinsate can you treat per square meter (m^2) of biobed over the growing season (100 days) using an application rate of 1 centimeter/day?

A: 1000 L per square meter

Quick calculation: since 1 cm rinsate depth = 10 L per m^2 biobed area (see below), multiply daily rate by number of days

$$10 \text{ L/m}^2\text{/day} \times 100 \text{ days} = 1000 \text{ L/m}^2$$

Calculate daily volume that can be applied (1 centimeter rinsate depth) per square meter per day:

1. Convert m^2 to cm^2

$$1 \text{ m}^2 = 10{,}000 \text{ cm}^2$$

2. Next, calculate the daily biobed capacity (volume of rinsate that you can apply each day) per square meter by multiplying the area by daily recommend rate

$$10{,}000 \text{ cm}^2 \times 1 \text{ cm/day} = 10{,}000 \text{ cm}^3\text{/day}$$

3. Convert to cm^3 to liters

Since $1 \text{ L} = 1000 \text{ cm}^3$ then $10{,}000 \text{ cm}^3\text{/day} \div 1000 \text{ cm}^3\text{/L} = 10 \text{ L/day}$

EXAMPLE 2

Q: How long it would take to apply 1000 liters of pesticide rinsate to a 5 m^2 biobed at the recommended daily rate (1 centimeter/day = 10 Liters/m^2/day)?

A: 20 days

$$\text{Time} = (1000 \text{ L} \div 10 \text{ L/m}^2\text{/day}) \div 5 \text{ m}^2 = 20 \text{ days}$$

DESIGN AND CONSTRUCTION OF THE BIOBED SYSTEM

DESIGN AND CONSTRUCTION CONSIDERATIONS

- Site selection.
- Collection pad: size, materials.
- Storage tank: size.
- Biomix: composition.
- Biobed: size, materials.
- Other system components: silt trap, sump, pumps, timers, drip tubing, heating, electrical.
- Treated rinsate disposal.

SITE SELECTION

Choose a site for the collection pad and biobeds that is protected from flooding and is not in a drainage path to minimize the installation cost and maintenance issues. Consider the following:

- Locate on high flat land or on land with a slight slope to allow drainage away from the collection pad. Redirect natural surface flow as necessary. Steep slopes increase earthwork required to level the collection area.
- The collection pad should be at a high enough elevation to restrict external drainage from entering the pad.
- Locate away from wells, streams, drainage paths and roof rainwater downspouts and environmentally sensitive areas.
- Choose a site with a thin topsoil layer. A thick topsoil layer will need to be stripped to subsoil and replaced with fill to create a stable surface for the biobed system and equipment traffic.
- Locate adjacent to existing/previous chemical handling areas because existing water supply, electricity, chemical storage and stabilized ground for tanks may be reused. Occasionally, an existing concrete pad can be adapted for the collection pad.
- Choose a site upwind or away from trees. While trees provide wind protection, if the site is located too close to trees, time will need to be spent following storms to remove debris (leaves and branches) from the pad before rinsing the sprayer tank.
- Locate away from livestock pens, grain storage, footpaths, children's play zone and other similar high use/sensitive areas to avoid potentially contaminating these spaces through drift and accidental spills.

COLLECTION PAD(S): SIZE, MATERIALS

Size, for the sprayer boom: The pad should be large enough to capture the spray coming off the nozzles and in a sheltered location to reduce losses due to drift. Generally a 2.1-meter (7-foot) wide pad for the booms is sufficient to minimize losses. However, size will depend on the height/width of the booms, the amount of sheltering and the prevalence of wind.

Size, for the sprayer equipment: Base the collection pad size on the type of sprayer equipment. It should be large enough to retain water from rinsing the tank and surfaces that have come in contact with spray drift. The front tires do not need to be on the pad but the pad should be at least 3.2 meters (10 feet) wider than the equipment to capture spray from the rinsing operation.

Materials, Concrete: The concrete pad should be constructed using accepted construction methods and specifications:

- Strip top soil.
- Cover with a minimum 15 centimeters (6 inches) of compacted granular backfill (road base or crusher dust).*
- Minimum concrete strength of 30 MPa (4400 psi) and sulphate resistant.
- Minimum thickness 12.5 centimeters (5 inches).
- M15 rebar at 30-centimeter (12-inch) spacing (see Figure 3, cross-section B-B).

Materials, Polyethylene Liner:

- Remove topsoil layer.
- Cover area by a minimum 15-centimeter (6-inch) layer of compacted granular backfill (road base or crusher dust).*
- Use crusher dust to create a slope (min 1:100 = 1%) from the edge to the middle of the pad.
    - All edges should be a minimum of 5 centimeters (2 inches) above grade.
- Cover the crusher dust layer with a non-woven geotextile fabric. The fabric layer protects the top polyethylene liner.
- Cover the fabric with a reinforced or non-reinforced polyethylene (RPE or PE) liner.
- Cover the edge of both liners with crusher dust to secure (see Figure 3, Cross section A-A and C-C).
- Optional: Use rubber floor pads along the sprayer tire paths to add additional protection to the liner.

*Crushed rock does not work well as granular backfill because fine particles from the top crusher dust layer will wash into voids and compromise the shape and slope of the foundation.

Materials, Mixed: An option is to use a combination of materials for the collection pads: concrete for the equipment pad and polyethylene (PE or RPE) liner for the spray boom pad.

Drainage: Create a minimum slope of 1:100 (1%) toward the drain and a 5 centimeter (2 inch) raised lip or berm around the perimeter of the pad(s) to contain the rinsate. The rinsate should flow through a silt trap into a sump. From the sump, pump the rinsate into the holding tank (Figure 3).

(See the section on Pumps (page 14) for more information on the size and type of recommended pumps.)

Addressing rainwater on the collection pad: Rainwater from a wet year can contribute 30,000 litres or more to the typical 100 square meter (1100 square feet) collection pad (eg. 30-centimeters rain x 100 m^2 = 30,000,000 cm^2 = 30,000 litres). This can be handled by either diverting water from the collection pad during times of heavy rainfall or equipping the sump outlet with a branch and valving to pump the rainwater during heavy rainfalls to the final disposal area.

Best practice: wash off the pad and drain the sump prior to rainwater diversion or only begin diverting after rainwater has washed the pad and the sump pump has run and flushed the rinsate from the sump.

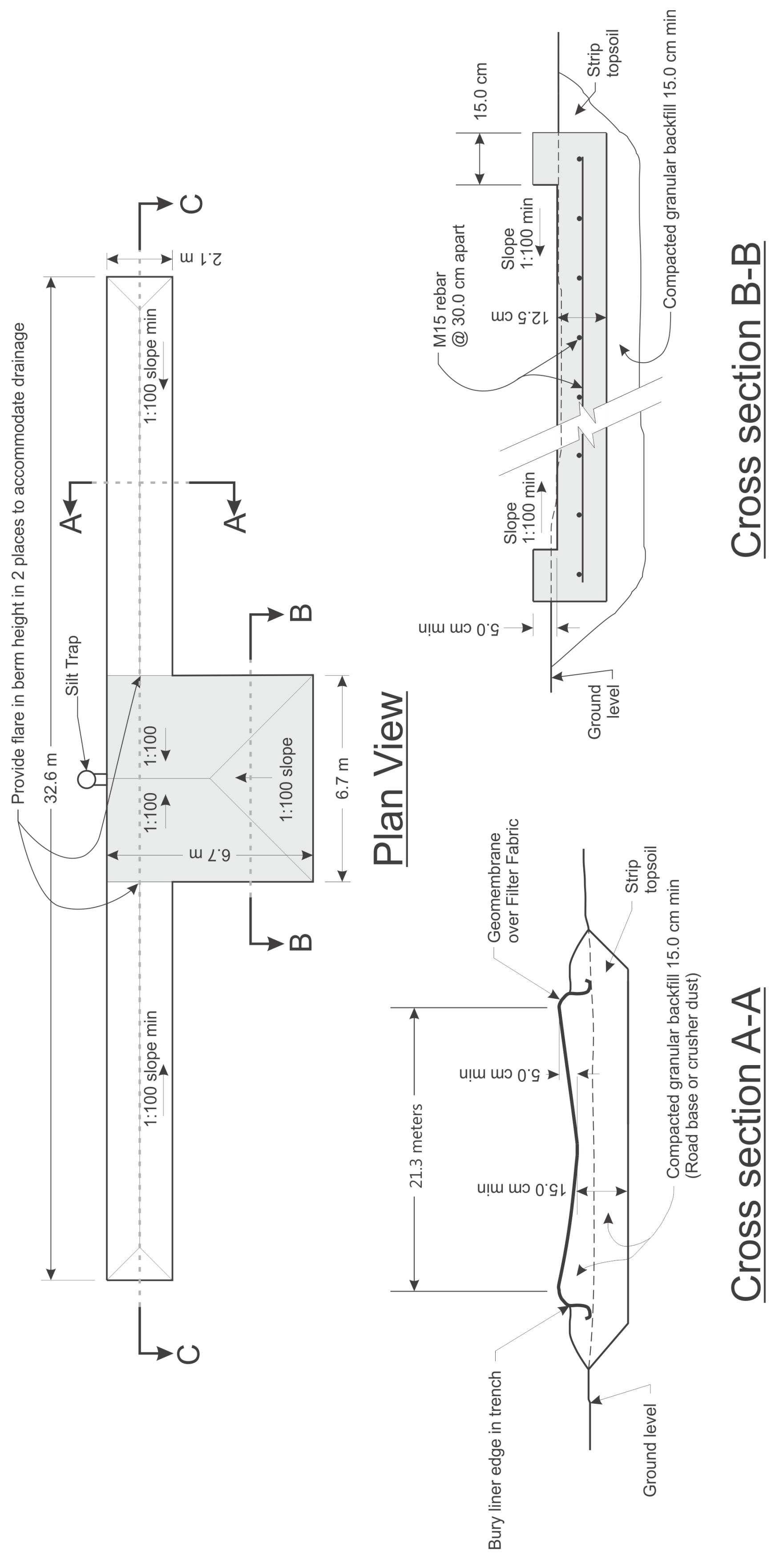

Figure 3. Collection pad details for a 30.5 meter (100 foot) sprayer

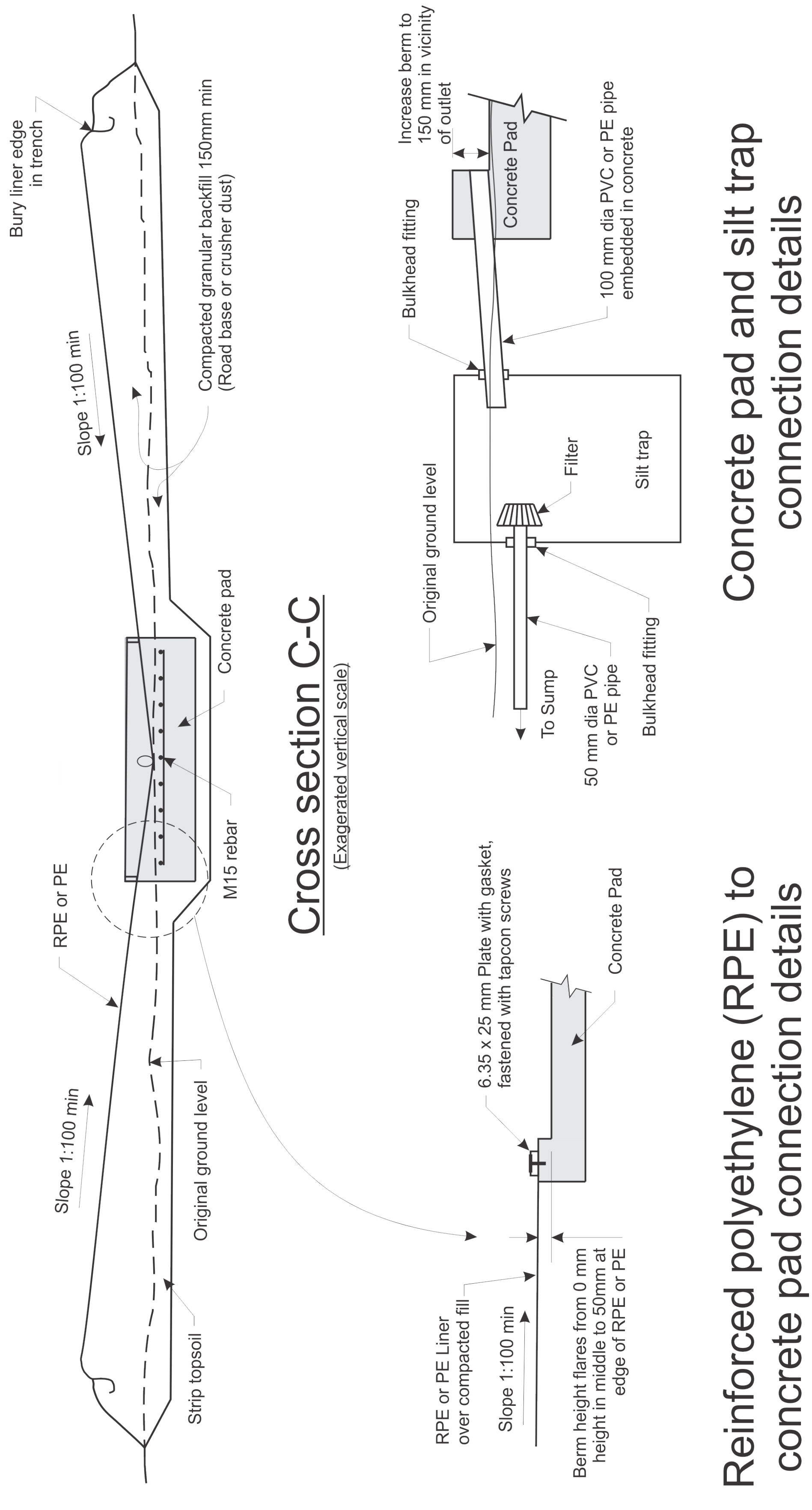

Figure 3. (continued)

STORAGE TANK

The storage tank should have a capacity to store a minimum of one-third of the expected yearly volume. As with any tank, provide a good foundation: strip topsoil and replace with compacted granular backfill.

Figure 4. Pesticide rinsate storage tank

BIOMIX

The biomix is composed of three components:

- Chopped straw or woodchips (not cedar)
    - 50% by volume.
    - Compress lightly (e.g. push down with pitch fork) to gauge volume.
    - Straw is a lignin source that provides energy for the fungi.
- Field soil (topsoil) exposed to pesticides
    - 25% by volume.
    - Inoculant to introduce microbes into the biobed.
    - Organic rich loam is preferred; heavier clay soil will reduce water movement through the biomix and sandy soil has less surface area, therefore will have reduced capacity to accommodate microorganisms.
- Peat or compost
    - 25% by volume.
    - Vegetation-based compost is preferred to manure-based compost as manure has not been extensively tested in biobed systems.
    - The organic matter provides sites for pesticide adsorption.

Before use, let the biomix stand or mature for up to 8 weeks and add water as needed to keep the mix moist (not wet). Time biomix preparation to coincide as close as possible to when it will be used in the biobed – the biomix will heat up if rinsate or water is not added within the first two weeks of placement (Figure 5).

Figure 5. Biomix components [Two parts straw (left) + one part soil (top right) + one part compost (bottom right)]
Photo credits - straw: cc by Miquel Pujol Palol; soil: AAFC; compost: cc by C.K. Gurney

BIOBED

The biobed can be a lined belowground hole or an aboveground lined wooden structure (Figure 6), open polyethylene (PE) plastic (Figure 1) or fibreglass fish tank, or corrugated steel ring. When lining is required, the minimum recommended PE thickness is 20 mil – this thickness provides sufficient strength yet enough flexibility to line the hole or container.

For a 2.4-meter (8-foot) diameter biobed (area = 4.7 m^2 = 50 ft^2), the most economical option is a fish tank or belowground lined hole. Another option is to use a 2.4-meter (8-foot) diameter water tank: cut off the top to create an 1-meter (3-foot) deep open tank; place a strap or band at 60 centimeters (2 feet) from the bottom to reinforce and maintain its shape (contact manufacturer for recommendations). For larger biobeds, the best option is to use a corrugated steel ring or lined hole in the ground.

The biobed should be a minimum of 80 centimeters (32 inches) deep with a 15-20-centimeter [6-8-inch] gravel layer on the bottom topped with a 60-centimeter [24-inch] biomix layer. For a belowground biobed, line the bottom with a sand layer to protect the PE liner. For above ground biobeds that require a lining, line the bottom with a non-woven geotextile fabric (filter fabric) in place of the sand.

Figure 6. Top: Belowground lined hole. Bottom: Aboveground lined wooden box

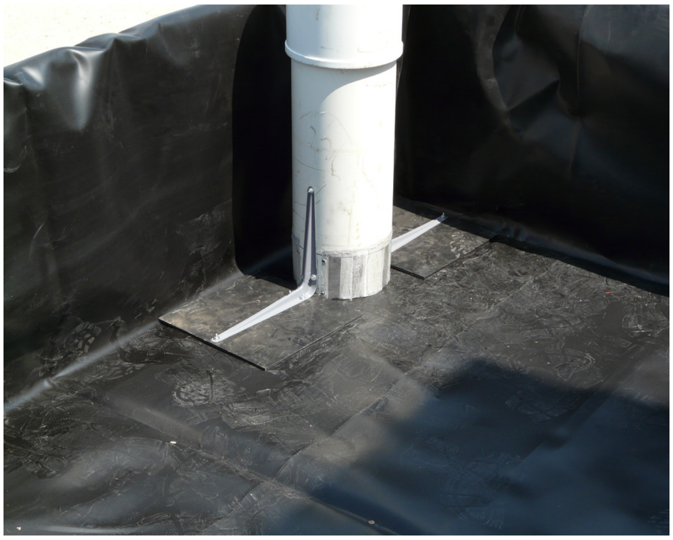

Figure 7. In-bed sump installed in an aboveground biobed. The bottom of the sump is perforated and lined with a screen to prevent particles from entering and fouling pump.

For belowground biobeds, install an in-bed sump before adding the gravel layer (i.e. drainage layer). The sump is simply a tube that extends from the top of the biobed to the bottom against the side of the biobed.

The section that is imbedded in the gravel is perforated. The tube must be wide enough to accept a sump pump (20- or 30-centimeter / 8- or 12-inch diameter) (see Pumps, page 14). For aboveground biobeds, install a sump in the first biobed before adding gravel (Figure 7); in the second, you can install either an in-bed sump or tank bottom outlet before adding gravel.

If using crushed gravel in a PE-lined biobed, first place a layer of non-woven filter fabric on top of the PE liner to prevent damaging the liner. If using pea gravel, the fabric padding is not required. The higher cost of pea gravel vs. crushed gravel is likely offset by eliminating the cost of adding the filter fabric layer.

Cover the gravel layer with filter fabric to separate the gravel and the biomix layers. Use enough filter fabric to run it 30 centimeters (12 inches) up the sides. When using a sump, seal around the sump and the side of the biobed securing the filter fabric to the sump with clamps.

When adding the biomix layer (top layer), dump the first lift in the middle of the biobed. Ensure the filter fabric is fitted up the side of the biobed as you spread the biomix with a shovel. Compaction will keep the fabric layer in place.

Place the heat tape or solar heating coil on the biomix 20 centimeters (8 inches) above the gravel layer (i.e. at the 1/3 level of the biomix layer) (Figure 8). Run the cables up the side of the biobed. Add the remaining biomix layer. The minimum thickness of the biobed layer should be 60 centimeters (24 inches).

Figure 8. Install heating coil in the biomix layer 20 centimeters above the gravel

Best practice: Seed a mixture of **grasses**, including lawn and wheat grasses, on top of the biobed. You can also use small plugs or even sod. Allow the plants to become somewhat established before applying rinsate.

The plants have two purposes. (1) Increased evaporation through evapotranspiration will reduce the total volume of the rinsate for treatment. (2) The root zone provides additional microbial colonization sites as well as potentially supplying some nutrients and energy to the microbes (Figure 9).

Note: depending on pesticide mix and concentration in the rinsate, plant growth on the first biobed may be poor or die out completely. Plants on the second biobed will readily establish and even flourish since the treated rinsate from the first biobed applied to the second should contain dramatically lower herbicide concentrations.

Figure 9. Plants growing on top of a biobed remove water through evapotranspiration and can support microbial growth (photo courtesy Tom Wolf, Agrimetrix Research & Training).

OTHER BIOBED SYSTEM COMPONENTS

Between the collection pad and the storage tank, there should be a **silt trap** and a **sump**. The silt trap intercepts the rinsate and is a settling chamber for dirt and other particles. It can be made of fibreglass, PVC or PE pipe; is covered; and sealed at the bottom with a bulkhead fitting on the side exiting to the main sump. The top of the silt trap must be high enough above soil level to restrict entry of surface water runoff from the surrounding area.

Rinsate flows from the collection pad through a grating (to intercept large debris) into a 15-centimeter (6-inch) pipe before entering the silt trap. Recommended size of the silt trap is 45- to 60-centimeter (18- to 24-inch) diameter and deep enough to be 30-45 centimeters (12-18 inches) below the rinsate entry level. Connect the silt trap to the sump with a 10-centimeter (4-inch) diameter pipe. A coarse filter (5 or 10 mesh) is usually fitted on the silt trap side of the pipe connected to the sump to capture floating debris. Seal pipe-silt trap/pipe-sump connections with bulkhead fittings (aka pipe-to-tank seals) to prevent outside water intrusion (Figure 3).

The main sump collects water from the collection pad through the silt trap and houses the pump that lifts the rinsate into the holding tank. The sump can be a concrete, fiberglass, PVC, PE or galvanized corrugated steel pipe. Typical dimensions for a sump are 75-centimeter (30-inch) diameter by 120 centimeters (48 inches) height, allowing for 20 centimeters (8 inches) to extend above ground and a 10 centimeter (4 inch) concrete plug on the bottom. To create the concrete plug, insert 2 to 4 pieces of rebar through the side of the pipe, 5 centimeters (2 inches) above the bottom of the pipe before pouring the concrete. After hardening, seal the joint between the concrete and the pipe with polyurethane sealant to prevent seepage.

Optional: On the pipe between the sump and the storage tank, install a manual **diverter valve** and line to direct rainfall overflow to the same area as the treated rinsate.

Pumps are required to lift water at the following points:

- From the sump to the holding tank.
- From the holding tank onto the first biobed.
- From the first biobed onto the second biobed.
- From the second biobed to the discharge on grass or shelterbelt.

The pump to transfer rinsate from the storage tank to the first biobed can be a small chemical pump. The other three pumps will need to be submersible sump pumps equipped with either a float or water sensing plate. If using a 20-centimeter (8-inch) diameter sump in the biobeds, you will be restricted to using a submersible pump with a water sensing plate. The downside is that water sensing plates are prone to fouling and are difficult to clean. You will likely have to replace these smaller pumps every two years. A 30-centimeter (12-inch) diameter sump is required to accommodate large pumps with the more dependable float system and longer life, but at a higher initial cost.

A **timer** is required to control the biobed heating system in the spring. Additional timers are required to time the pump operation from holding tank to the first biobed, between the first and second biobeds and from the second biobed to the treated rinsate disposal area. A digital timer is the best option because it has more flexibility for small time increments. However, a mechanical timer with half hour time-steps may also work. Most hardware stores have outdoor digital timers for approximately $30. While they are rated for outdoor use, timers should be placed in an enclosure to protect them from the rain and sun.

Apply the rinsate to the top of the biobed uniformly through a **drip tube** with emitters (Figure 10). Drip tube often comes with 1 US gallon/hour emitters spaced every 30 centimeters (1 foot). In terms of application rate, with drip tube spacing of 30 centimeter (1 foot), this works out to 40 liters/square meter per hour, about two to four times the daily required rate. In this case, the timer for the pump from the storage tank should be set to 15 minute per day for a 1-centimeter application rate.

Figure 10. Rinsate is applied uniformly to the biobed through drip tubes laid on top of biomix layer.

The emitters are prone to blockage after the first year, especially from liquid that has passed through the biomix. To address this issue, there are 3 solutions:

- Best: Filter the water with a 40 or 80 mesh filter inserted inline and upstream of the drip tube.
- Replace the drip line as required.
- Drill a 1.6 mm (1/16 in) hole adjacent to each plugged emitter.

Realizing that it takes about 30 minutes to drain the biobed following rinsate application, following is a typical schedule:

- Storage tank pump (influent): Start 9 am, Stop 9:30 am.
- Biobed 1 sump pump: Start 10 am, Stop 1:00 pm.
- Biobed 2 sump pump: Start 2 pm, Stop 5 pm.

> Note: The above schedule reduces cycling of the biobed sump pumps and reduces the potential for overloading a circuit if two pumps start simultaneously. More information is included in the electrical section.

Heating the biobed in early spring is very important because the cold Canadian Prairie winters can result in a frozen biobed well into May. Either passive solar energy or heat cables can be used to warm the biobed. The heating coil should be placed at about one-third depth from the bottom of the biomix and run during April (See Operation and Maintenance Section for details). A 250-300 watt heat cable (15-30 meters / 50-100 feet) or a 1.25 meter x 2.5 meter (4 feet x 8 feet) solar collector is adequate to warm a 5 square metre biobed (approximately 50 watts/meter^2). Heat cables are usually rated for either 10 or 16 watts/meter (3 or 5 watts/foot); 15 meters (50 feet) of 16 watts/meter (5 watts/foot) cable will be the most economical option. Annual electricity cost for a typical 5 square metre biobed is approximately $20 (assuming $0.15/kilowatt hour).

Use a small aquarium air pump, tubing and diffuser to provide **aeration** in the holding tank to mix the rinsate and maintain a homogeneous mixture. This prevents stratification or layering of the various pesticides in the rinsate solution and reduces the chances of applying concentrated pesticides to the biobed. Microbes perform better with a consistent concentration of pesticides.

Electrical: Power requirements depend on the type and number of pumps. For a standard two-celled biobed system with a main sump, storage tank and two biobeds, one chemical pump and three submersible pumps are required. The small chemical pump has a low power draw but the other three pumps can draw up to 15 amps when starting.

In order to protect against overtopping the storage tank during an intense rainfall event (which can also be mitigated by having a manual bypass valve between the silt trap and main sump, see text box, page 13) or running the storage tank pump dry, wire the system according to Figure 11. With this configuration, the storage tank pump will run continuously when the rinsate level exceeds a maximum high level and shut off when a minimum level mark is reached, regardless of timer settings.

> **Solar power:** Powering the system with solar energy is possible. However, to minimize the number or size of solar panels requires expensive submersible 12 volt pumps. On the other hand, using more affordable submersible 120 volt pumps would require large solar panels, inverters and battery storage. This makes the solar options more costly than conventional grid power and is therefore outside of the scope of this manual.

Run an underground cable to a box with two sets of outlets and float switch wiring. Each set of outlets should be on separate 15-amp breakers. Connect the main sump pump and the storage tank pump to one breaker and the two biobed sump pumps to the other. To ensure two pumps do not start simultaneously, add timers and limit operation of the biobed sump pumps to 3 hours per day (see schedule in Other biobed system components-Pumps, page 14), allowing generous time for the biobed to drain yet limiting on/off operation as the pump senses for water.

TREATED RINSATE DISPOSAL

Dispose of the treated rinsate by irrigating either a

- Grassy area approximately ten times the area of the biobed with a sprinkler system, or
- Hedge/shelterbelt with a 30-meter (100-foot) drip tube.

This provides a tertiary treatment because the soil organic matter will adsorb any remaining pesticide and the existing soil microbes will degrade them.

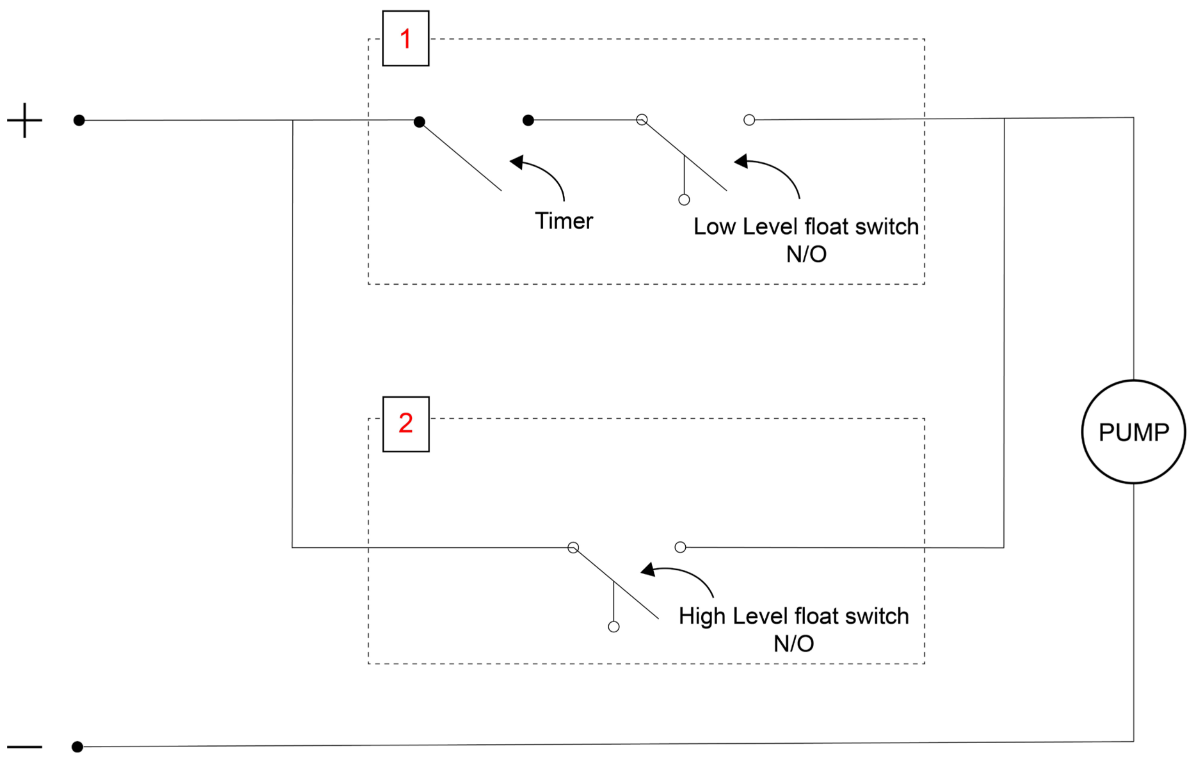

Figure 11. Wiring diagram for controlling pump to deliver pesticide rinsate from the holding tank to biobed trickle irrigation lines. [1] When the timer switch closes, the pesticide rinsate level must be high enough to close the low level float switch in order to run the pump. This safeguard ensures that the pump will not run dry. [2] If the pesticide rinsate level is at or above a maximum level, the high level float switch will close causing the pump to run, regardless of the timer, until the pesticide rinsate level drops below the maximum level. (N/O = normally open)

COSTS

Biobed system costs can vary from $6000-$23,000 for materials depending on the amount of rinsate to be treated and the size and material used for the collection pad. Most of the cost is associated with the collection pad, varying from $3000 for a small, reinforced PE lined area to $15,000 for a full concrete pad. The material cost for storage and treatment of the rinsate starts at $3000 for a typical farm operation but for larger rinsate volumes the cost may reach $8000.

Material costs (except concrete) in Table 1 (page 18) are based on 2017 prices. These are based on a 30-meter (100-foot) sprayer and a 6000-liter (1500-US gallon) annual rinsate volume with a concrete pad for the machine and reinforced PE lined area under the booms. Costs do not include delivery or installation except for concrete. Costs can be adjusted to accommodate a different size of sprayer or larger rinsate volume as per notes at the bottom of Table 1.

TABLE 1: TYPICAL 2017 BIOBED MATERIAL COSTS TO HANDLE 6000 LITRES (1500 US GALLONS) PESTICIDE RINSATE PER YEAR

Item	Quantity‡	2017 Unit Cost‡,§	Total§
Collection Pad			
- Concrete Pad (installed)	41 m^2 (440 ft^2)	\$139.50/m^2 (\$13.00/ft^2)	$ 5,720
- RPE Lined Area*	57 m^2 (608 ft^2)	\$32.00/m^2 (\$4.00/ft^2)	$ 1,830
Silt Trap & Sump	1	$700.00	$ 700
Holding Tank†			
- 4000 liters (1000 US gallons)	1	$700.00	$ 700
Biobed Open Tank†			
- 2.4 meter (8-foot) diameter	2	$1000.00	$ 2,000
- Area = 4.7 m^2 (50 ft^2)			
Plumbing			
- Main sump pump	1	$200.00	$ 200
- Biobed sump pump	2	$90.00	$ 180
- Storage tank pump	1	$100.00	$ 100
- Pipe, fittings	1	$100.00	$ 100
- Drip system	24 m (80 ft)	$2.00/m ($0.65/ft)	$ 50
- Filters	2	$50.00	$ 100
Aeration System	1	$100.00	$ 100
Electrical	1	$1000.00	$ 1,000
Heat Cable (5W/ft)	30.5 m (100 ft)	$16.50/m ($5.00/ft)	$ 500
Biobed Contents			
- Peat	1.4 m^3 (50 ft^3)	\$89.00/m^3 (\$2.50/ft^3)	$ 125
- Gravel	1.9 m^3 (2.5 yd^3)	\$34.00/m^3 (\$26.00/yd^3)	$ 65
- Filter Fabric	9 m^2 (100 ft^2)	\$1.30/m^2 (\$0.12/ft^2)	$ 12
- 8 in diameter pipe for sump	2.1 m (7 ft)	$40.00/m ($12.00/ft)	$ 84
Total Estimated Material Cost			**$14,500**

Notes:
* To adjust for a 37 m (120 ft) sprayer, add approximately $600

† To adjust for doubling the treatment capacity, add approximately $3000 for a larger holding tank and additional open tanks.

‡ Number in brackets are in imperial values

§ Numbers have been rounded to account for variation in prices and to simplify the math

OPERATION AND MAINTENANCE SCHEDULE

EARLY APRIL

- Remove the overwintering cover tarp from biobeds.
- Check frost depth. Biobeds are likely frozen to 15 centimeters (6 inches).
  - Record the date and depth.
- Turn on the breakers.
- Plug the heat cable into a timer and run according to the following schedule.
  - Week 1: Run 24 hours per day.
  - Week 2: Run for 6 hours twice per day.
  - Week 3: Run for 3 hours twice per day.
  - Week 4: Run for 1.5 hours twice per day.
- Confirm biomix is thawed. If still frozen run the Week 4 schedule an additional week.
- Trim grass.
- Top up biobeds with additional biomix (5-10 centimeters / 2-4 inches) to raise to original level. The level changes due to breakdown of organic components, settling and compaction.

PREPARING FOR SPRAY SEASON

- Clean off the collection pad.
- Clean any debris from the channels or pipes connecting the collection pad to the silt trap and main sump.
- Clean out silt trap and pipe filters.
- Top up biobeds with additional biomix (5-10 centimeters / 2-4 inches) to raise level to original level.
- Install pumps, fittings and drip line and connect to power .
- Set up the timers to schedule pumps (see page 14).
- Hook up the aeration system and plug in.
  - Check to ensure the air stone is blowing air.
  - Note: The aeration stone is usually replaced each year. However, you can extend its life by immersing it in muriatic acid overnight.
- Check and clean the two in-line filters.
- Run clean water through the ends of the open drip line on the biobeds and close the ends.

WEEKLY MAINTENANCE

- While heat tape is on, change the run time as required (see above, Early April).
- Check and record the depth of water in the biobed sumps and the main sump. It should be 5-8 centimeters (2-3 inches) in the biobed and about half way up the pump in the main sump. If it is more, check to ensure pumps are working properly and check for blockage in the drip line.
- Check and record tank level.
- Monitor the grass growth. Water grass when there is a lull in the application of pesticide rinsate.
- In fall when nighttime temperature is expected to drop near to or below freezing, insulate or cover the storage tank pump.

BI-MONTHLY MAINTENANCE

- Check the two in-line filters and clean as required.
- Check the silt trap for accumulation and clean out as necessary.
  - Because pesticides adhere to soil particles, this soil should be handled as contaminated material.
- Inspect the concrete pad and liner for deterioration or cracks. Repair cracks in the concrete with an elastomeric sealant. Repair defects in the synthetic liner with the appropriate patch and tape/adhesive.

FALL SHUTDOWN

- Remove all pumps, the aeration pump and stone. Store pumps indoors.
- Open all valves and all ends of the pipelines; ensure no water has ponded at the valves.
- Open all ends of drip lines.
- Place tarp over the biobeds with some slope to discourage ponding.
- Divert water away from the silt trap.
- Cover the silt trap to prevent snow or water from entering.
- Turn off breakers.

Biomix rejuvenation and disposal

- The biomix provides a source of organic matter, nutrients and pH stabilization to adsorb pesticides and provide an environment conducive for microbial growth. Over time these sources are depleted. In Europe the biomix is replaced every 5 to 7 years and this is recommended until better knowledge is developed related to the longevity of biomix in Canadian conditions.
- Removal of the biomix should be done carefully to avoid damaging the liner.
- Disposal of biomix includes composting for one year then spreading with a manure spreader at the lowest possible application rate. The composting process should be carried out in an area that is away from any water body or well to prevent any contamination issues.

Future research topics

The next research phase will include investigating (i) options for increasing the extent of degradation of challenging pesticides, (ii) determining how long biomix remains effective in the Canadian environment, (iii) evaluating biobed system performance over the life of the biomix, (iv) applicability to horticultural systems, (v) improved understanding of pesticide removal mechanisms, and (vi) developing a protocol for dismantling/decommissioning a biobed system.

Additional reading

Biobeds – A Swedish contribution to environmental protection from pesticide pollution
- By Maria del Pilar Castillo, Lennart Torstensson and John Stenström
- www.slu.se/globalassets/ew/org/inst/molsci/research/volkmar-passoth/biobeds-2011.pdf

Degradation of pesticides in biobeds: the effect of concentration and pesticide mixtures
- By Paul Fogg, Alistair BA Boxall and Allan Walker
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.653.6011&rep=rep1&type=pdf, Chapter 2, pp 19-37

Guidance on using a lined biobed to dispose of agricultural waste consisting of non-hazardous pesticide soluutions or washings (exemption 52)
-By Paul Fogg, prepared for the Environment Agency, Bristol, England
-http://adlib.everysite.co.uk/resources/000/244/456/EA_Biobed_guidance_0507.pdf

APPENDIX A: BIOBED FUNDAMENTALS FOR HIGH PERFORMANCE

Based on past AAFC research, literature reviews and discussions, following are some fundamental concepts that appear to drive the performance of biobeds.

PHYSICAL ENVIRONMENT

- Biomixes are composed of three components:
  - Organic matter material (peat/compost) for adsorption.
  - Soil to introduce microbes.
  - High lignin material (straw/wood) as a nutrient for white rot mold.
- The ideal soil has good drainage but not too high a hydraulic conductivity. Organic matter provides good drainage, good water retention and high level of microbial sites.

CHEMICAL ENVIRONMENT

- Pesticide rinsate treatment starts with adsorption followed by degradation.
- Adsorption is affected by:
  - Pesticide properties (sorption co-efficient* [Koc], water solubility, polarity [positive vs. negative ions], volatility).
  - Properties of biomix [soil type and structure (hydraulic conductivity and adsorption sites), organic matter, pH and temperature].
  - Physical properties (saturated/unsaturated, pH).
- Pesticides are adsorbed in the biobed according to the Freundlich adsorption isotherm equation. Based on this concept, we should expect the following:
  - The higher the concentration of pesticides in the rinsate (influent), the more pesticide will be adsorbed per unit area; however the treated rinsate (effluent) will also have a higher pesticide concentration.
  - Most of the pesticide is adsorbed at the top of the biobed and the concentration front slowly moves down through the biomix.
  - With excessive rinsate loading, the biobed can become saturated. When this occurs, the pesticide concentration in the effluent will be similar to that in the influent.
  - With a smaller biobed, saturation will happen more rapidly and there is a smaller margin of safety for unexpected events.
  - Soil adsorption coefficient* [Koc] indicates affinity for adsorption to soil:
    - ♦ Greater than 1000 is good.
    - ♦ Less than 500 is a concern.
    - ♦ Less than 100 is worrisome.

*tendency of pesticide to bind to soil particles

- Unsaturated flow provides significantly better adsorption than saturated flow:
  - High application rate of rinsate may saturate the pores and leach out adsorbed pesticides.
  - Maintain a well-drained biobed.
  - Note: Biomix has about 40 to 60% pore space. Saturated flow occurs when all the pores are filled with liquid. With unsaturated flow, air is present in some of the pores. Unsaturated flow allows the pesticide molecules to make more intimate contact with the soil particles.
- Degradation can be microbial or chemical (eg., hydrolysis) and is affected by:
  - Pesticide properties (susceptibility to breakdown/half-life).
  - Properties of biomix (nutrient content, aeration, structure/microbial sites, permeability, vegetation).
  - Physical properties (temperature, pH, moisture content).
  - Microbial population.
  - Pesticide concentration:
    - When diluted by more than 1000 times, microbial performance is usually not affected.
    - Higher pesticide concentrations can reduce microbial performance.

MICROBIAL ENVIRONMENT

- Most degradation occurs in the top 10-15 centimeters (4-6 inches) and microbial bio-degradation is enhanced by plants growing on top of the biobed.
- Microbes perform best in environments that are:
  - Moist.
  - Well drained.
  - Have a large surface area.
  - Aerated.
  - Non-saturated.
  - Lower pesticide concentrations.
- pH – molds (fungi) generally perform better at lower pH (i.e. more acidic) conditions compared to bacteria. Peat maintains a lower pH to provide a better environment for mold. A lower pH also improves adsorption for certain pesticides.
- Temperature – affects microbial performance, water solubility of pesticides, and may affect adsorption. At temperatures less than 5°C, minimal degradation occurs; for every 10°C increase, microbial activity approximately doubles.

APPENDIX B: PESTICIDE BIOBED SYSTEM COMPONENT LIST

ITEM	SPECIFICATION
Biomix components	
Soil	Rich organic loam, preferred
Organic matter	Peat, compost
High lignin materials	Straw or wood chips
Pumps	
Sump pump	20 or 30 cm diameter, with water sensor or float
Chemical pump	Self-priming
Liners	
Polyethylene (PE) or Reinforced PE (RPE)	Biobed: 20 mil Collection pad: 40 mil
Filter Fabric	
Non-woven geotextile fabric	Minimum 270 grams/m^2 (8 oz./yd^2)
Aggregate	
Crusher dust	Well graded with 100% passing the 10 mm sieve
Road base	Well graded with 100% passing the 25 mm sieve
Holding Tank	
Tank	High Density Polyethylene - to accommodate one third of rinsate generated annually
PVC pipe	
From pad to silt trap	100 mm diameter
From silt trap to main sump	150 mm diameter
Electrical	
Breakers	15 amp
Timers	
Digital Timer	Exterior grade
Aeration system	
Aerator	Stone aerator

Drip tubing	
Drip tube	Many options to accommodate untreated rinsate
Silt trap	
Silt trap	Material: PVC, concrete, fibreglass Size: 450-600 mm diameter x 300-450 mm below rinsate entry level
Sump, main	
Main Sump	Material: Concrete, fiberglass, PVC, PE, galvanized corrugated steel pipe Size: 75 cm diameter x 120 cm tall
Sump, biobed	
Biobed Sump	Materials: PVC, PE Size: 20- or 30-cm diameter
Heating, biobed	
Solar collector	Size: 1.25 x 2.5 meters
Heat Tape	Wattage: 250-300 watts Rating: 10 or 16 watts/meter Length: 15-30 meters
Collection pad	
Concrete pad	Minimum thickness: 5 inches Minimum strength: 30 MPa (4400 psi) Other: Sulphate resistant Rebar: M15, at 30 cm spacing
Misc	
Pipe Fittings	
Bulkhead gaskets	
Electrical wire	14-gauge (minimum)

Notes

Notes

Notes

A ROBUST BIOBED DESIGN FOR MANAGING PESTICIDE RINSATE UNDER CANADIAN CONDITIONS