Bioreactor Garden Operations & Maintenance Manual

ridge to reefs

"Permanent Sustainability for People & The Planet"

Table of Contents

What is the Bioreactor Garden?

The Bioreactor Garden is a nature-based **residential on-site wastewater treatment system***. The system is a constructed wetland-biofilter designed to leverage biological treatment properties of bacteria and plants. The system meets NSF-245 and NSF-40 equivalent standards.

*The Bioreactor Garden (USPTO Provisional Patent Serial # 63/330,629 (April 13, 2022)) was developed by and is the intellectual property of Ridge to Reefs, Inc. DBA Nature-Based Solutions.

How the Bioreactor Garden Works

1

Intercepts Septic Tank Effluent

Water enters the Bioreactor Garden from the septic tank into a level manifold. Septic tank effluent percolates vertically with even distribution through aerobic sand and anaerobic woodchip layers.

2

Nitrification-Denitrification

Bacteria in oxygenated and unoxygenated zones convert dissolved ammonia to inert nitrogen gas.

3

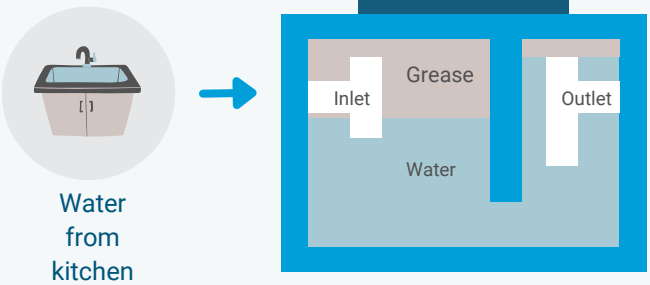
Phytoremediation

Plants uptake excess wastewater nutrients and evapotranspire clean water.

Each of these are important steps in the treatment process!

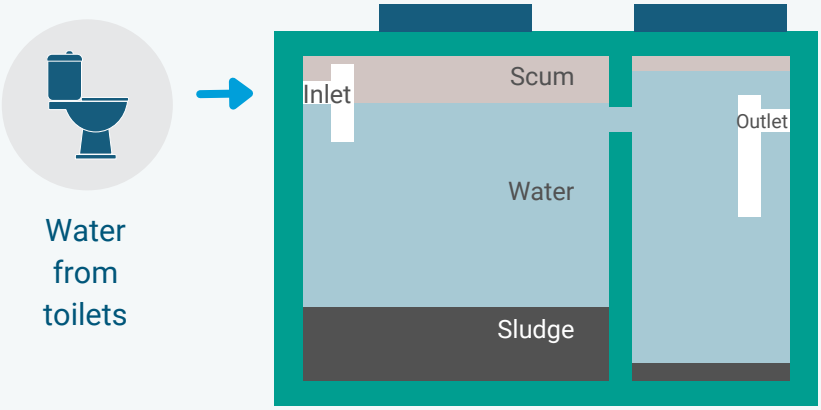
How the Bioreactor Garden Works

1 **Grease trap (restaurants)**
Separate grease and oil from kitchen sink water and provide access to clean out as needed. Homeowners should collect grease before sink.



Water from kitchen sink

2 **Septic tank**
Separate solids from toilet water and provide access to clean out every 1 to 3 years (as needed)



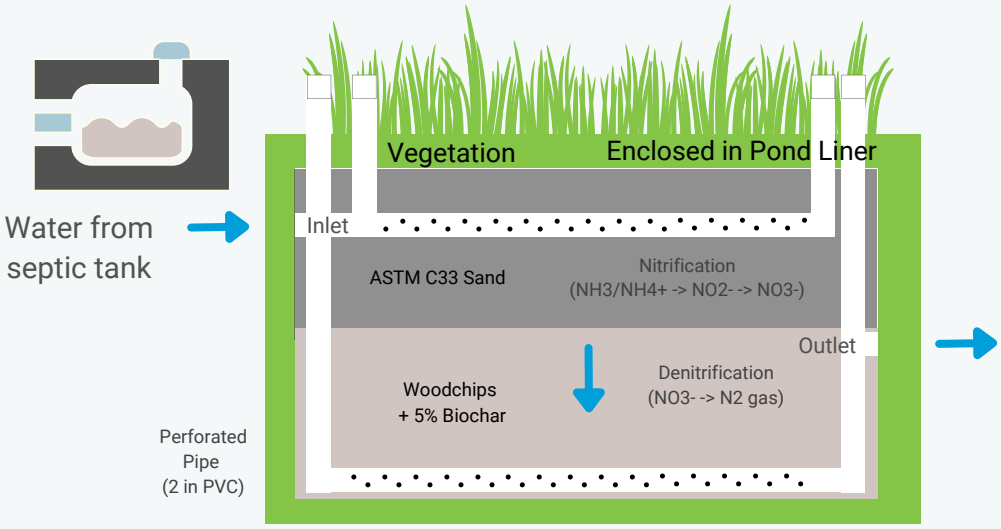
Water from toilets

PVC Tees (4 in)

How the Bioreactor Garden Works

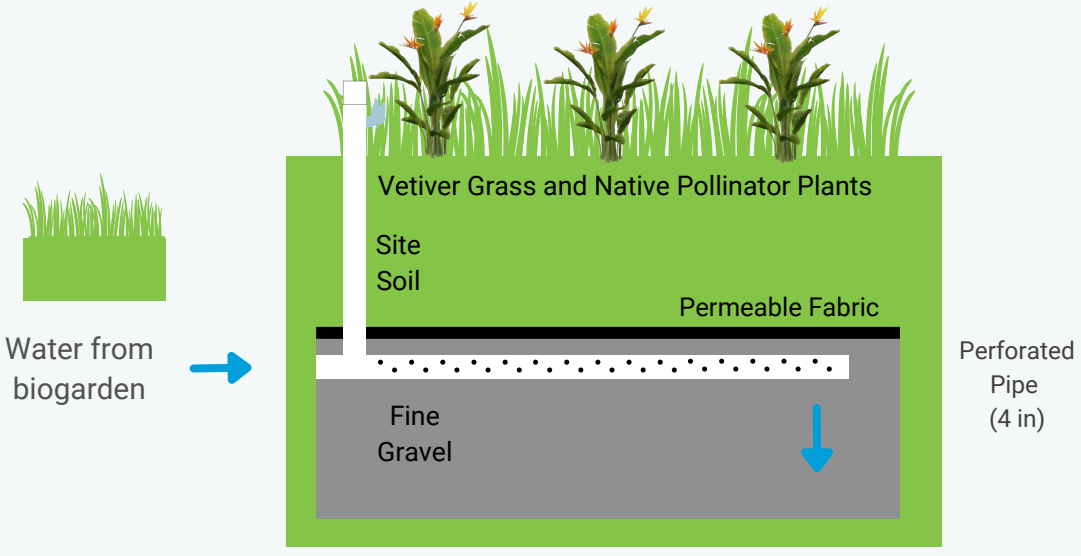
3 Biogarden

Filters, treats, and absorbs wastewater before it is reabsorbed into the ground. Vetiver grass should be trimmed once a year to keep the plants healthy.



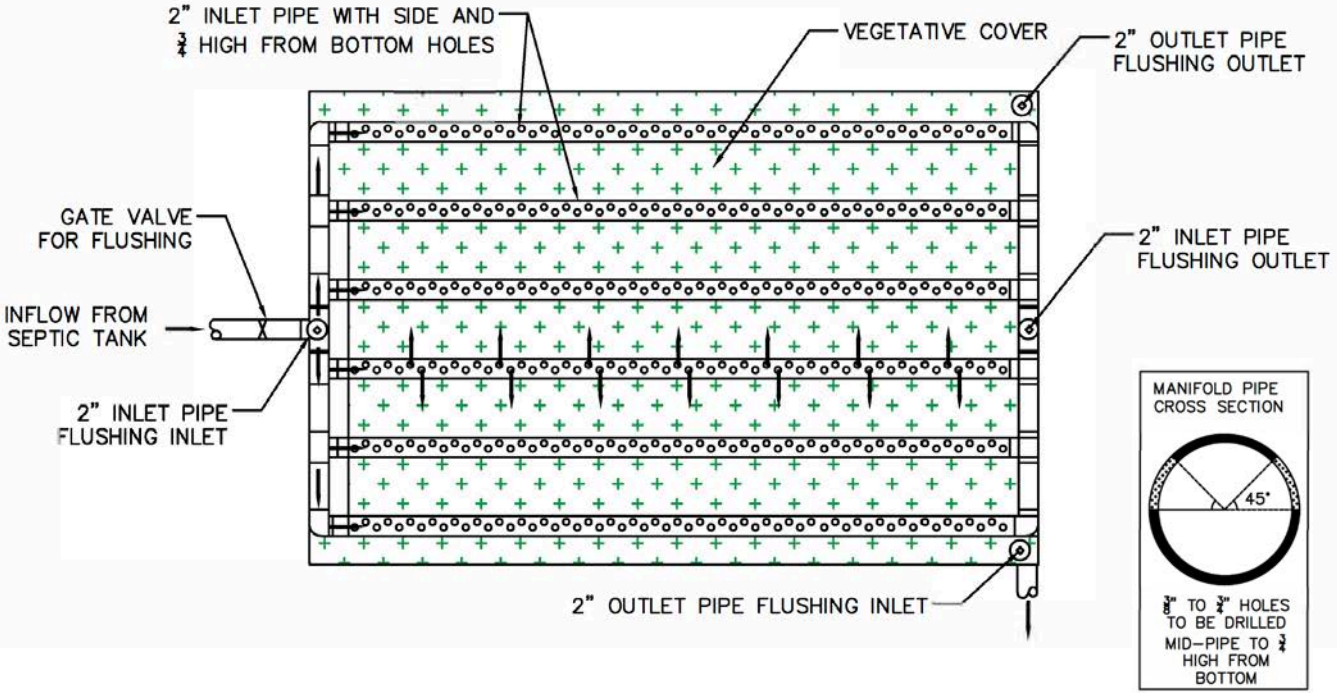
4 Drain field

Reabsorbs water back into the ground. Native pollinator and fruiting plants can be added to attract bees, butterflies, hummingbirds, and other wildlife. Occasional trimming of vetiver grass is required.



Bioreactor Garden Specifications

Aerial View

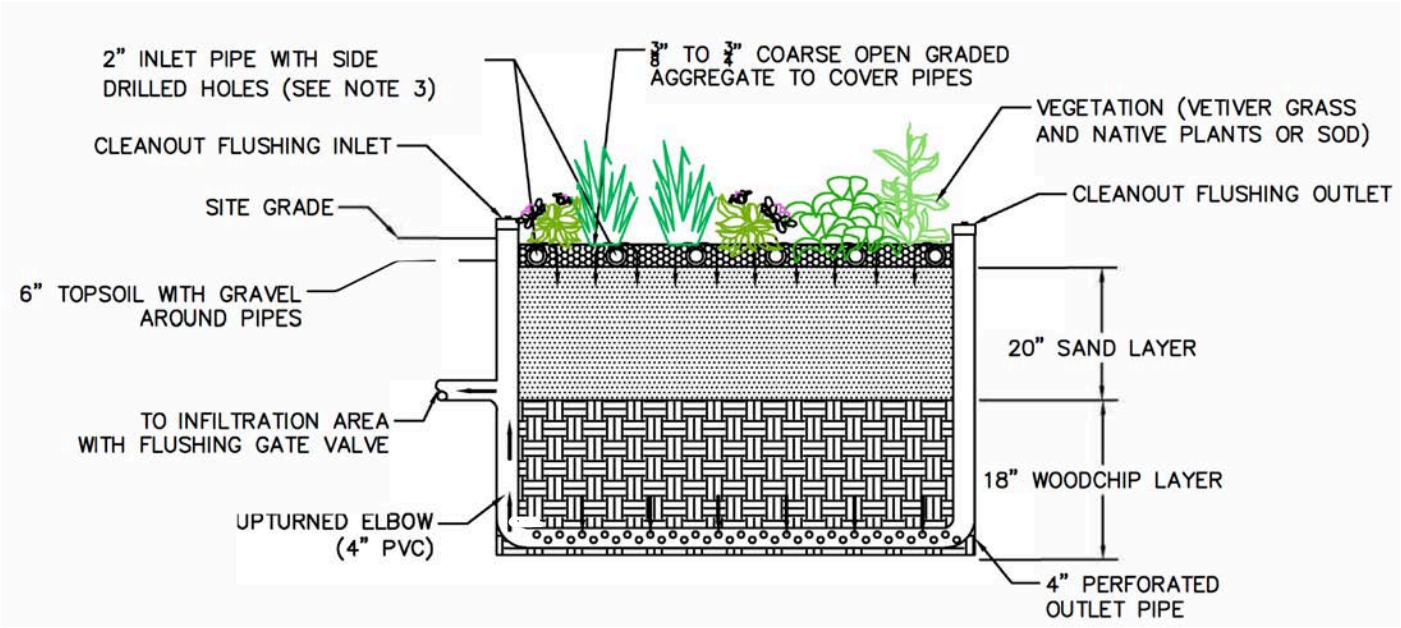


NOTES:

1. INFLUENT SHALL FLOW EVENLY OUT OF INLET PIPES INTO SURROUNDING MEDIA AND VERTICALLY DOWN THROUGH SAND AND WOODCHIP LAYERS.
2. THE TOP LAYER MAY BE PLANTED WITH VETIVER GRASS AND NATIVE SPECIES FOR HIGHEST EVAPOTRANSPIRATION RESULTS.
3. IF DESIRED BY THE HOMEOWNER / REQUIRED DUE TO HIGH PRECIPITATION (P > ET), TH SYSTEM MAY BE FULLY ENCLOSED WITH AN IMPERMEABLE LINER ON THE TOP, BOTTOM AND SIDES (VETIVER GRASS CAN BE PLANTED WITHIN SMALL HOLES IN THE LINER TO PROMOTE EVAPOTRANSPIRATION AND TREATMENT).
4. DISTRIBUTION MANIFOLD SIDE HOLES (¼" TO ⅜") SHALL BE LEVEL TO UNIFORMLY DISTRIBUTE INFLUENT EVENLY THROUGHOUT THE SAND SUBSTRATE SURFACE.
5. MANIFOLD PIPE HOLES CAN RANGE FROM ¼"–⅜" DIAMETER SPACED AT NO GREATER THAN 2 INCHES. SIDE HOLES SHALL BE EVENLY DRILLED AT MID-PIPE WITH TOP HOLES AT ¾ HIGH FROM BOTTOM. PIPE SHALL BE INSTALLED FLAT TO ENSURE UNIFORM FLOW DISTRIBUTION THROUGHOUT THE SAND.
6. THE BOTTOM AND SIDES OF THE SYSTEM SHALL BE ENCLOSED IN AN IMPERMEABLE LINER IN ALL CASES.
7. OUTDOOR SPIGOT SHALL HAVE FUNCTIONING BACKFLOW PREVENTER PRIOR TO SYSTEM FLUSHING ACTIVITIES.

Bioreactor Garden Specifications

Cross Section View



NOTES:

1. INLET PIPE SPECIFICATIONS IN THE ABOVE SCHEMATIC APPLY TO GRAVITY FED SYSTEMS ONLY. PUMP FED SYSTEM MANIFOLD SPECIFICATIONS (I.E. PIPE AND HOLE DIAMETER) WILL NEED TO BE SITE SPECIFICALLY DESIGNED TO ENSURE EVEN DISTRIBUTION OF INFLUENT BASED ON INFLUENT VELOCITY.
2. THE SYSTEM SHALL BE INTERNALLY LINED WITH >=30 MIL HDPE LINER
3. HOLES CAN RANGE FROM ¼"–⅜" DIAMETER SPACED AT NO GREATER THAN 2 INCHES. SIDE HOLES SHALL BE EVENLY DRILLED AT MID–PIPE AND AT ¾ HIGH FROM BOTTOM. PIPE SHALL BE INSTALLED FLAT TO ENSURE UNIFORM FLOW DISTRIBUTION THROUGHOUT THE SAND.
4. PRE–PERFORATED SEWAGE DRAIN PIPE MAY BE USED FOR 4" PIPES.
5. SEPTIC EFFLUENT DISTRIBUTION 2" PIPE SHALL BE PLACED LEVEL TO EVENLY DISTRIBUTE THROUGH SAND.
6. VETIVER GRASS/VEGETATIVE MEDIA LAYER MAY BE SLIGHTLY ABOVE GRADE TO AVOID PONDING.
7. OUTDOOR SPIGOT SHALL HAVE FUNCTIONING BACKFLOW PREVENTER PRIOR TO SYSTEM FLUSHING ACTIVITIES.
8. 5% BY VOLUME OF A WOOD BASED BIOCHAR SHALL BE DISTRIBUTED EVENLY THROUGHOUT THE WOODCHIP LAYER.
9. SAND SHALL BE COMPRISED OF SILICATE OR IGENOUS BASED MATERIAL WITH LESS THAN 5% PASSING THE 200 OPENINGS PER INCH SIEVE.
10. DELIVERED SAND SUBSTRATE SHALL BE TESTED ON SITE USING THE JAR SHAKE TEST METHOD BY FILLING QUART JAR WITH 2 INCHES SAND THEN FILLING JAR ¾ FULL OF WATER. JAR SHALL BE VIGOROUSLY SHAKEN THEN ALLOWED TO SETTLE FOR 30 MINS. NO GREATER THAN ⅛ INCH OF FINES NOR CLOUDY WATER SHALL BE ALLOWED.

Materials & Media

Vetiver grass
A non-invasive, fast-growing perennial grass plant with an extensive, dense and deep root system

Activated Biochar
Charcoal created by heating untreated scraps of wood in a low-oxygen environment through a process called pyrolysis

Fine gravel
Fine gravel or sand, silicate or igneous based material with less than 5% passing a 200 openings per inch sieve

Woodchips
Woodchips made of natural, untreated wood (> 2 in or 5 cm size), smaller sizes decompose more quickly and reduce the lifespan of the system

Pond Liner
30 mil or thicker HDPE or PVC impermeable plastic liner (0.2 - 0.7 mm thick).

PVC Pipes & Fittings
Use high-grade (schedule 40) 2" PVC pipes and unions for all biogarden components. Use 4" PVC pipe from toilets to the septic tank and in the drainfield. Schedule 40 grade 4" PVC is recommended, lower grades should only be used in areas that will never be driven over and where no trees are within 15 ft.

***All components should be clean or washed. Keep mud and dirt out of the system during the construction process. Do not construct during rainy days.**

Design & Installation Sequence

1 Prepare or Obtain an Existing Conditions Site Plan that includes:

- Surface topography
- Soil mapping with associated infiltration rates
- Existing septic pipes (horizontal and vertical positions)
- Cesspool (horizontal and vertical positions)
- Wells
- Electric lines
- Cable lines
- Septic tanks (if present)
- Building footprint and number of bedrooms
- Foundation type and depth

2 Select a Bioreactor Garden System Size based on the expected Daily Flow Rate, i.e. # of Bedrooms

Table 1 - Bioreactor Garden Dimensions

# Bedrooms	GPD	Surface Area Dimensions
1	150	6' W x 4' L
2	300	6' W x 8' L
3	450	6' W x 12' L
4	600	6' W x 16' L

*Appropriate treatment volumes are based on the State of Virginia Department of Health standards for residential wastewater treatment.

Design & Installation Sequence

3 Locate the Bioreactor Garden between the Septic Tank and Leach Field

- When possible, gravity-tie the system by placing the Bioreactor Garden (BG) downslope of the septic tank and upslope of the drain field.
  - Note that the Bioreactor Garden outlet is 20" below the inlet; plan accordingly.
  - If necessary based on site conditions, a pump may be used either before or after the Bioreactor Garden to attain required drain field depths.
- Location shall be positioned to avoid existing building(s).
- Septic tank size, construction and location shall comply with current DOH requirements.

4 Excavate the Bioreactor Garden Cell to Required Volume, Depth & Dimensions

- Choose the required BG size from Table 1
- Depth to the Bioreactor Garden inlet will depend on the septic tank outlet elevation
  - Excavate 38" below the Bioreactor Garden inlet elevation
- Consult your local regulations to determine allowable system depths relative to water table elevation; a pump after the septic tank may be necessary to raise the Bioreactor Garden closer to grade
- The Bioreactor Garden excavated cell shall be level at bottom

Design & Installation Sequence

5 Line the System Using a 30 mil or thicker HDPE or PVC Impermeable Liner

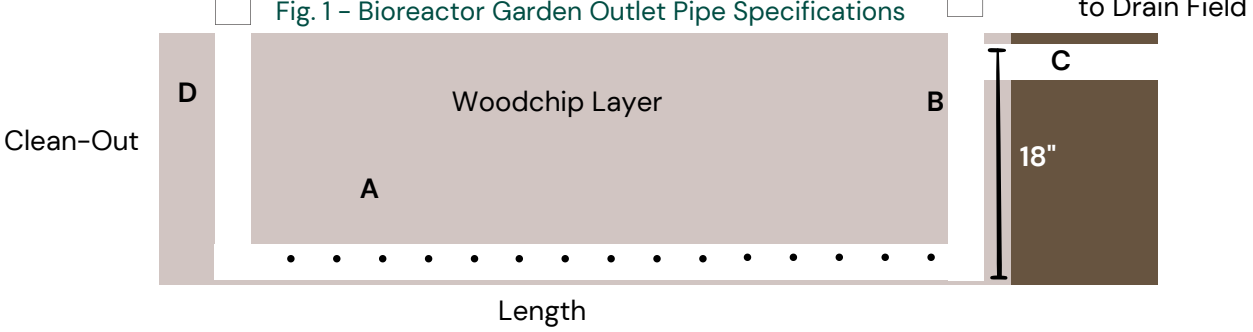
- Install the liner according to manufacturer's instructions
- It is recommended to use a flexible liner at least 30 mil thick that can be easily molded within the excavated cell
- In areas with high rainfall, the liner shall be wrapped over the top of the system to prevent excess rainfall from entering the Bioreactor Garden

6 Build & Install the Bioreactor Garden Outlet Pipe*

*Refer to Fig. 1

- Use 2-inch Sch 40 PVC for all pipes and fittings
- The outlet bottom (*section A*) length shall equal the system length minus 6" (L = system length - 6")
- The outlet shall be drilled with 3/8" to 1/2" holes in the bottom quarter of the pipe
    - Clean effluent will enter the outlet pipe through the holes; bottom quarter-drilled holes achieves the highest treatment
- Cut and attach section B to A and C using (2) 90° elbows to achieve 18" distance from the bottom of section B to the top of section C

Fig. 1 - Bioreactor Garden Outlet Pipe Specifications



Design & Installation Sequence

6 Build & Install the Bioreactor Garden Outlet Pipe (continued)

- Place the outlet pipe in the center of the excavated cell along its length
- Attach an inlet clean-out pipe (section D) to section A using a using a 90° elbow, and an outlet clean-out pipe to B using a tee fitting
    - The clean-out port shall extend at least 4" above grade and be capped
- Drill a hole into the liner at 18" from the cell bottom
- Thread Section C through the liner using a Bulkhead Screw Connector
- Hold the outlet pipe in place by the cleanout pipe while filling the cell with 18" of woodchips

7 Fill the Anaerobic (woodchip, biochar) Layer

- Using a backhoe or dump truck, place clean 1-3 inch wood chips in lined excavation over outlet pipe to the required anaerobic media depth (18") (to the top of Section C of the outlet pipe). Mix in 5% biochar by volume.

8 Fill the Aerobic (e.g. sand) Layer

- Using a backhoe or dump truck, place 20" of aerobic substrate (coarse washed ASTM-C33 sand or washed termite barrier basalt aggregate) in lined excavation above the woodchip layer to the bottom of the distribution pipe invert elevation

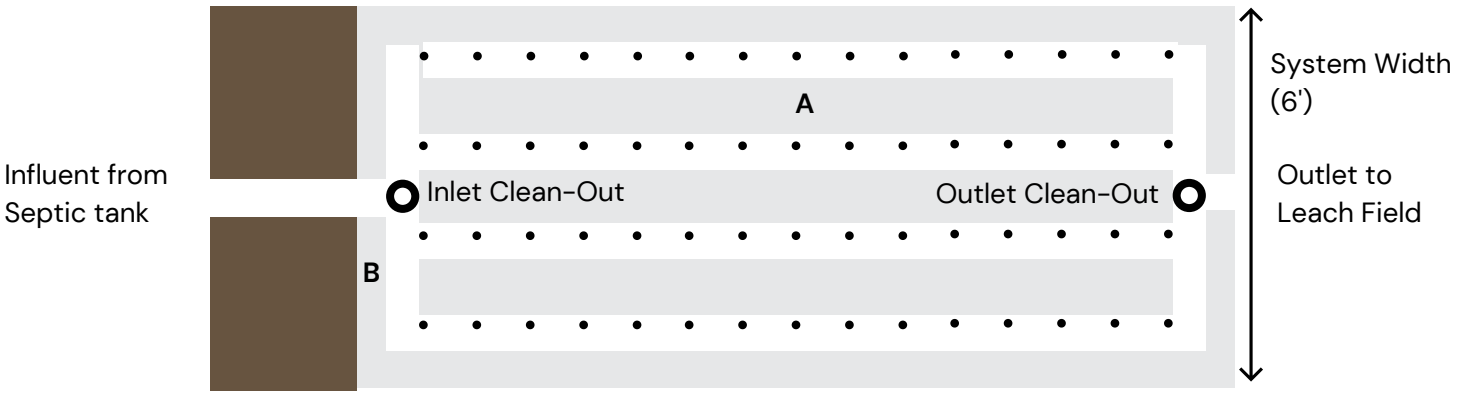
Design & Installation Sequence

9 Construct the inlet distribution manifold

*Refer to Fig. 2

- Use 2-inch Sch 40 PVC for all pipes and fittings
- Cut (4) laterals (A) at a length equal to (system length - 1')
  - e.g. for a 6' x 12' system, cut 4 laterals at 12' - 1' = 11' each
- Drill 1/4" to 3/8" holes in the top quarter of each pipe
- Cut (2) connecting pipes (B) equal to (system width - 1.5')
  - e.g. for a 6' x 12' system, cut 2 pipes at 6' - 1.5' = 4.5'
- Cut (2) clean-outs to be stubbed out and capped 4" above grade
- Connect (4) laterals to the (2) connecting pipes at a distance 1.5' apart at centerline
  - Use (4) 90-degree elbows on the corners and (2) tees for the center pipes
- Connect (1) clean-out pipe on the inlet and (1) on the outlet using a tee fitting
- Prime and glue all connections and fittings to form the manifold
- Connect the inlet pipe from the septic tank to the manifold
  - A 4" to 2" reducer will need to be used prior to entering the Bioreactor Garden
- Connect the outlet pipe to the leach field
- Set the manifold level on top of the sand layer

Fig. 2 - Bioreactor Garden Outlet Pipe Specifications



Design & Installation Sequence

10 Plant the System with Vetiver Grass and Native Plants

- Plant the system with at least 80% vetiver grass, with 18" distance between plants and 6" from manifold laterals.
    - The remaining 20% can be planted with native plants appropriate for bioretention gardens (refer to local guidance)
- In areas of high rainfall, plant through small holes cut through the top-wrapped liner

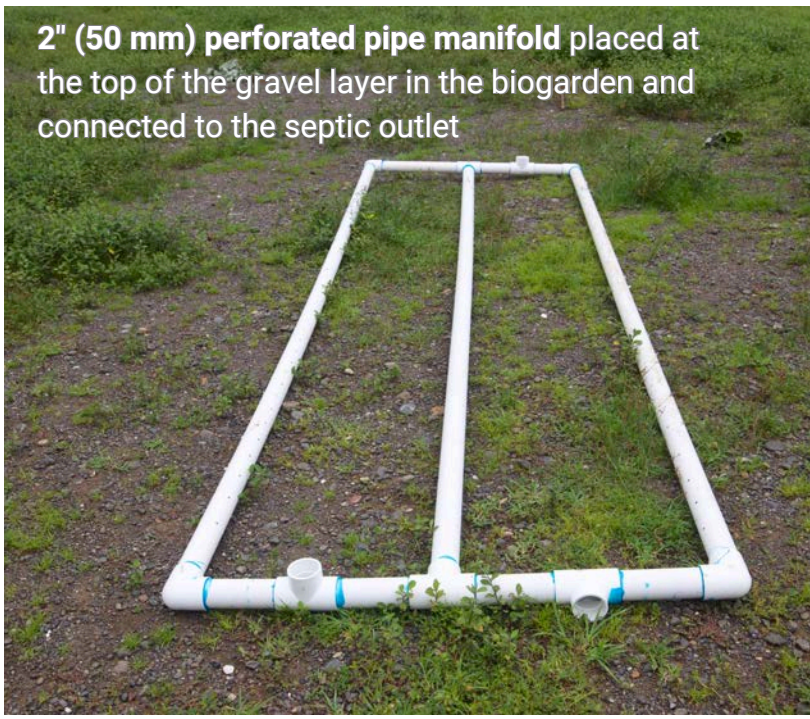
11 Cover the Inlet Pipes

- Cover the inlet distribution pipes with coarse gravel
- For high rainfall or wet areas, a crowned top grade and top liner may be used to facilitate the shedding of precipitation runoff
- For drier areas, the gravel and planted layer can be finished flat or level

Bulkhead connector used to seal the inlet and outlet of the biogarden to the PVC pipe and plastic liner

Perforated 4" (100 mm) pipe connected to the biogarden outlet in the drainfield with a cleanout point

PVC Tees placed inside the septic tank at the inlet (bottom) and outlet (top)



2" (50 mm) perforated pipe manifold placed at the top of the gravel layer in the biogarden and connected to the septic outlet

2" (50 mm) perforated pipe manifold (closeup of hand-drilled holes

2" (50 mm) perforated pipe placed at the bottom of the woodchip layer at the biogarden outlet and connected to the drainfield


Woodchip layer fills the bottom of the biogarden up to the outlet pipe


Biogarden (right) and Drainfield (left)


Manifold connection from the septic outlet and placement at the top of the gravel layer


ASTM C33 sand or washed coarse crystalline sand above the woodchips


Vetiver grass planted through holes in the plastic liner


Biochar is mixed throughout the gravel and woodchip layer

Operations & Maintenance

Bioreactor Gardens require relatively little operational control or maintenance.

Once wastewater is applied to the Bioreactor Garden, it takes from a few days to two weeks before the aerobic and anaerobic systems fully mature. TN, TP, BOD and TSS concentrations in the effluent will normally drop rapidly after several days to a week. Practices should meet NSF Equivalent Standards for NSF-40 and -245 for water quality and denitrification systems.

Clogging of the aerobic layer can occur when pore spaces between the media grains begin to fill with inert and biological materials. Once hydraulic conductivity falls below the average hydraulic loading, ponding can occur. Although effluent quality may not initially suffer, conditions within the aerobic filter could result in further clogging and a cessation of nitrification. Application of wastewater to the BG should be discontinued if continuous ponding occurs at levels above the BG surface, and the pipes shall be flushed using a strong hose fitted with a backflow preventer.

Proper pretreatment maintenance is of paramount importance, i.e. thoroughly washing the sand prior to construction.

Maintenance of the BG aerobic media includes both routine maintenance procedures and media regeneration upon clogging. BGs require weed removal as well. Eventually, filter clogging requires media regeneration. Routine raking of the surface will prolong the aerobic media bed life minimizing the need for more extensive rehabilitation. The removal of the top media layer and replacement with clean media and flushing the distribution inlet piping is very effective for deeply clogged aerobic filter media.

The anaerobic cell wood chip media is much less prone to clogging as compared to the aerobic media. Inspection should be executed twice (2) times per year for clogging via the associated pipe cleanouts. Should clogging be observed, flushing with a garden hose fitted with a backflow preventer should be executed.

Homeowner Maintenance Tips

- Trim vetiver grass to 12 inches (30 cm) once or twice a year
- Keep chemicals and oils out of your water and use natural, biodegradable cleaning and personal hygiene products.
  Keep track of your maintenance schedule:
  - Clean your septic tank every 3 years
  - Clean your grease trap every 3 months
- Keep the area around your septic tank and drainfield clear of large trees, vehicles, and impermeable surfaces
- Flush ONLY toilet paper and human waste (urine or feces)
- Conserve water! Install water efficient fixtures such as dual flush toilets and water saving showers. Separate graywater and use for irrigation, check for and fix leaks.
- Don't spray any herbicides, pesticides, or chemicals near or onto the biogarden.

Contact Us

For questions regarding the Design, Installation, or Operations and Maintenance of the Bioreactor Garden, please contact:

Kelly Harris
Ecological Engineer, Ridge to Reefs
kelly@ridgetoreefs.org

Ridge to Reefs, Inc.
DBA Nature-Based Solutions