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EPIC™ ROAD FILTER DYNAMICS

ABSTRACT:

The Environmental Passive Integrated Conveyance (EPIC™) Road Filter is a passive multifunctional filter designed for storm water **capture and treatment** of common contaminants associated with roads, industrial paved areas or other hardscapes. While the minimum width of the filter beds are 18”, the filters can be designed for any larger width with unlimited length sections and surface treatment finishes as fine gravel, porous pavers, porous concrete, porous epoxy stone, or finished with vegetative plants. The EPIC™ Road filter provides many unique features advantageous for storm water management:

- **Passive gravity driven filtration without plugging the core distribution chamber.**
- **No moving parts or components that need replacing.**
- **Load bearing surface suitable for H-30 loads.**
- **Passive and automatic oil separation.**
- **Bio-treatment in highly aerobic profile.**
- **Ideal vector control to prevent rodent and mosquito access to storm systems.**
- **Ideal pre-filtration component for water harvesting collection and storage.**
- **Easy and permanent installation**
- **Easy and infrequent surface access for servicing**

HISTORY:

In reviewing the history of drainage pipe the industry has been and is dealing with many combinations of pipe structure, pipe openings, stone, gravel, soil, sand, geo-textiles, root blockage, "caked fabrics" etc. The industry markets the positive points and ignores or downplays the negative points. In the need to solve a problem (poor drainage) engineers debated variations of the same principle. Is a slitted round pipe better than a slitted flattened pipe? Is a flat pipe on its side better than flat pipe on its end? Is geo-fabric better than gravel around the same pipe? Can Styrofoam pellets replace gravel?

From ancient times to modern times the "science" in conventional drainage pipe design, the so called "active ingredient", is the opening to the pipe itself, the interface structure that transitions water flow <u>into</u> (drainage) or <u>out of</u> (leaching) the pipe. The physical size and form of the pipe structure itself is a minimal factor. Until the mid-1960's 1/8" (3mm) gaps in 4" clay tile pipe was the standard. In the 1970's Orangeburg and cement asbestos pipe was replaced by 4" plastic pipe with ½" lateral holes along the side of the pipe. In the 1980's round slitted pipe (2mm wide) of various diameters made by many manufacturers became dominant. A flat edge drainage pipe was introduced in 1999 (a slitted flat pipe wrapped in **geo-fabric**). In that same time period introduction of a large half dome pipe with 1/8" side wall slits as a substitute for stone leach lines was made. In the last decade attempts were made of stacked small diameter slitted pipe wrapped in **geo-fabric**. More recently separate manufacturers produced all-purpose **geo-fabric socks** with foam pellets (stone replacement) to be applied to standard perforated pipe.

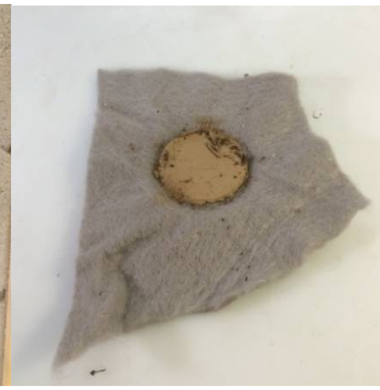
The commonality of all the above drainage pipes is that **<u>the openings</u> in the form of slits or holes <u>are smaller than the particles immediately adjacent to the holes and slits</u>**. If a pipe employs a 2mm wide slit as the opening to the pipe, the gravel on the other side has to be larger (4mm +) or else the particle moves into the pipe. A pipe with a ½" hole needed to be surrounded by rock that is at least 5/8" in diameter. The openings in **geo-fabric** are 0.1mm to prevent the entry of sand particles which may be 0.5mm to 1mm in diameter. All conventional designs were doomed to two physical realities in particle movement in soils.

> **A. The smaller the opening the more apt it is to plug because it acts as a filter.**
>
> **B. The larger the opening the more it will allow the movement of smaller particles (sand) around the larger particles (stone) and into the pipe itself.**

As illustrated in the following pictures conventional drainage pipe is doomed to fail by blockage either due to infiltration or filtration.

Common Drainage Pipe and Fabric

Sand Infiltration into a slitted pipe



Geo-fabric blockage by soil fines

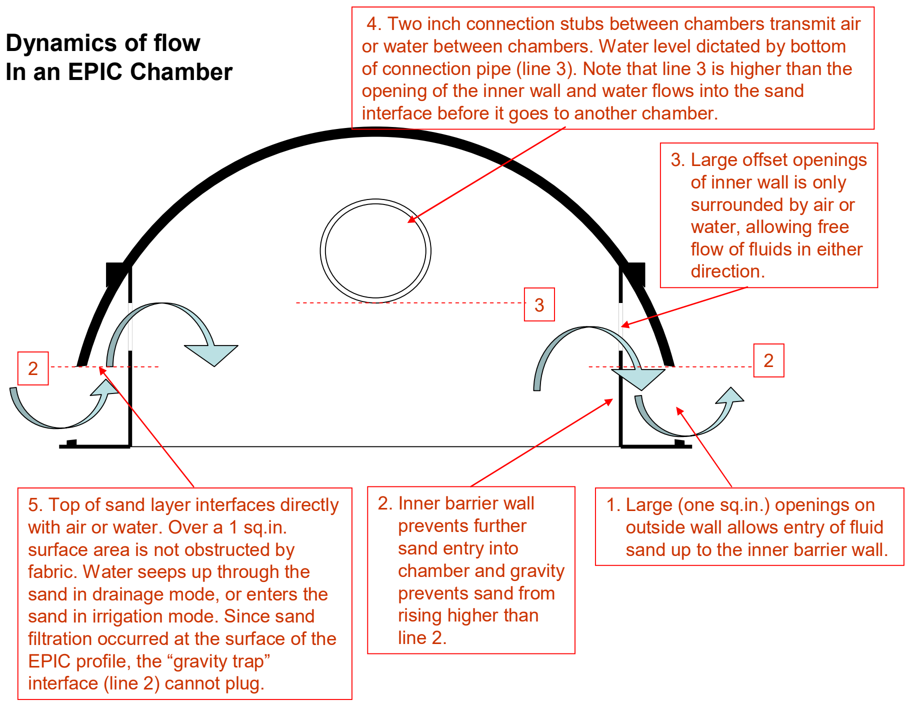
EPIC™ CHAMBER STRUCTURE:

The uniqueness of the EPIC™ chamber is that it was specifically designed to work in an environment of fluid sand (quicksand). EPIC™ employs the principle that <u>**the openings**</u> at the chamber (pipe) <u>**are actually larger than the particles adjacent and outside the opening of the chamber**</u>. This principle, at first glance, seems to be at odds with common sense and logic. After all how can large openings, let's say an open door; prevent the entry of a small particle (a marble for example) into the house? The easiest explanation is to look at the following pictures and diagram which depicts the cross section of an EPIC chamber and the water flow dynamics it controls.

Actual EPIC™ chamber slice in front of display aquarium

Gravel fill in Display Aquarium

The following diagram explains the structure and dynamics of the EPIC™ Chamber which was first introduced to the public in 2000.

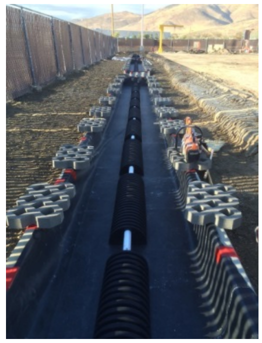


The simple design employs gravity and two offset holes to create a "gravity trap" that creates a phase separation between the sand/gravel fill and air/or water within the interior of the pipe. The third 2" diameter connection hole controls, lateral movement of water and the limits of "head pressure" and retained water level within the chamber and the EPIC™ profile it serves.

In summary the unique EPIC™ chamber made three dimensional control of water movement below ground not only possible but controllable.

EPIC™ FILTER PROFILE STRUCTURE:

A typical EPIC™ filter starts with a 15" (+) deep and level excavation. The bottom and sides of the excavation cavity are lined with an impermeable membrane. EPIC™ chambers are placed in the center of the 15" deep cavity on top of the liner. The chambers are connected with 2" SCH 40 PVC/ABS pipe stubs to move filtered water laterally between chambers. After the connections are made the entire profile is filled with the appropriate fine gravel, bridging gravel, and/or washed sand. The profile is optionally capped with permeable pavers, decorative gravel, porous concrete, serviceable screens or removable geo-fabrics. Then, depending on intended function and design, the 2" SCH 40 PVC/ABS pipes are connected to an outflow point, a larger transition pipe, a secondary reservoir, or another EPIC™ profile that grows plants for final bio-filtration.



Cavity excavation in native soil		Chambers placed on liner		Gravel fill vibra-tamped and capped

FILTRATION:

The EPIC™ Filter is a passive gravity driven sand/gravel filter. Particles and debris that are 8 times smaller than the smallest particles in the filter media will simply be retained at the surface. For example if the EPIC filter medium is ¼" (7mm) gravel, particles larger than 0.5mm (500 microns) are retained at the surface. This retained size group is the largest component that sheds with storm water from a paved surface and includes winter sanding applications, asphalt decomposition particles and miscellaneous litter.

SIZE OF FILL MATERIAL	SIZE OF PARTICLES RETAINED	PARTICLE CLASSIFICATION
¼" FINE GRAVEL (7mm)	0.5mm - 2.0mm	All medium to coarse sands
0.5mm – 2.0mm	0.06mm – 0.25mm	All fine sands
0.06mm – 0.25mm	0.007mm – 0.03mm	Most silts and bound clay

Over a very long time the retained particles spread out by gravity and water flow over the constructed filter bed material and become secondary filter barriers themselves to additionally filter smaller particles, making the EPIC™ filter even more effective with age. Depending on the pollutant load, continued filtration of finer and finer particles will slow water penetration into the EPIC™ filter and the filter will have to be serviced. However, because filtration occurred at the surface, servicing is simply a matter of raking, sweeping off or vacuuming the very top and exposed (1/2") surface layer of the filtered material and the filtration process starts over again as a new filter.

For example, in following pictures, one small cell (picture on left) of the surface permeable paver array was deposited with a clump of tan colored sand/clay. As water flow dispersed the particles over the fine grey gravel, the final thickness of the deposit was less than ¼" thick (when pushed aside at the center).

In the center picture break up of asphalt particles are simply retained on the surface. Since even small particles are retained at the surface the EPIC™ chamber itself cannot plug, has no moving parts, and never is in need of replacement.

In the far right picture, leaves and other organic debris are also retained at the surface.

Fine deposits on top of course grey gravel

Asphalt deposits retained at surface

Leaves retained at surface

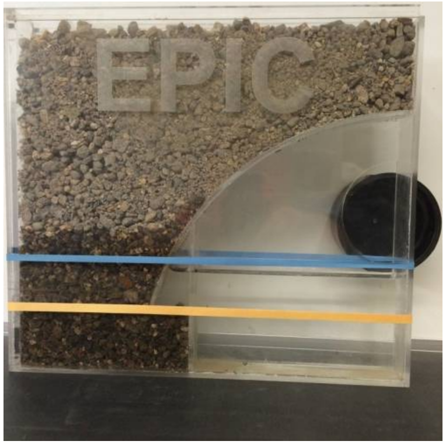
FILTRATION RATE:

Filtration rates can be designed by incorporating desired application factors with climatic conditions and surface area that is going to be serviced by the filter. Fine ¼" minus gravel (ASTM C33 #89) will move water at a very fast rate. One inch of water in less than 1 sec/SF. Washed concrete sands (ASTM F2396) will move one inch of water in less than 5 minutes/SF. Even EPIC™ filters growing 3 year old turf in a sand profile will still move one inch of water per hour. The larger the surface area of the filter, the larger its capacity to collect and filter water. The limiting factor for the EPIC chamber is the 20 gallon per minute flow rate of the 2" connector pipe that leaves the system. Note in the picture above, a 1" rain in the last several hours created a large "sheet flow" over the hardscape area; however the EPIC™ filters in the low area to the right show no signs of puddling. As such planned connections to larger transfer pipe or direct connections to secondary reservoirs increase the transfer rate needed to keep up even with 100 year storm events.

OIL SEPARATION:

A big concern in storm water run-off loads is the effective management of oil drippings and spills from vehicles that are deposited on a road surface. These drippings are generally not noticeable, but in proper lighting appear as oil sheens. These colorful sheens are only a few molecules thick and ride the top of the oil/water interface. In managing water/oil mixtures the best approach is to take advantage of the density differences between water and the broad class of petroleum derived compounds. Diesel fuel, gasoline and lubricating oils are lighter than water and thus in mixtures ride on top of the water.

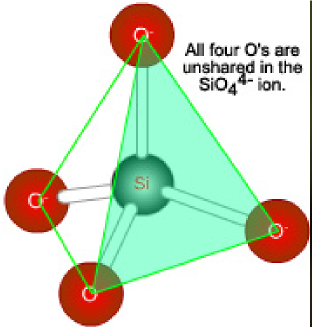
By design the EPIC™ filter incorporates and acts as a passive oil-water separator. In the picture to the right of the EPIC™ chamber cross section note that the blue line is the most frequent water level in the profile. It is the level where water flows between the chambers and the level where water flows out of the level system.

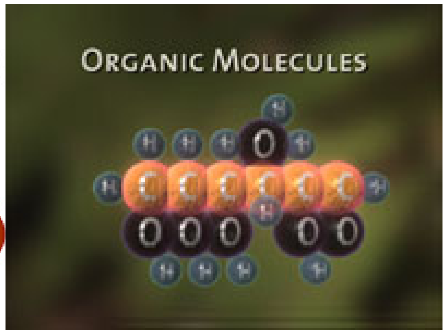


The yellow line is the earliest point of entry into the interior of the chamber from the outside. This entry point is 1.25" below the water line in the system, thus oils are retained in the sand/gravel media above the water line.

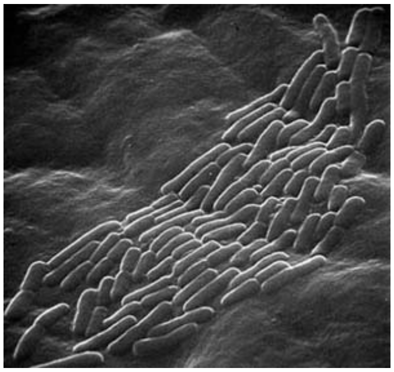
BIO-FILTRATION:

Besides fuels and oils, other organic materials can be present in storm water – spilled drinks, body fluids, insect residues and parts, etc. Large organic parts are simply filtered at the surface, liquids and very small particles that can pass the initial surface filter will have a tendency to adhere (stick) to the surface area of sands and gravel. Organic molecules, in general due to their outside positive charge of Hydrogen atoms, quickly adhere to the negative charged nature of Quartz (Silicon dioxide) the primary component of sand and gravel.





A 15" deep sand/gravel fill in an EPIC™ filter provides a vast exponential surface area of adhesion not only for organic materials but also for soil bacteria that use the surface area of a sand grain to colonize. While a medium sized sand grain is very small to the human eye with an average diameter of 1 mm, bacteria cells that grow and expand to colonies are invisible because their average size is a thousand times smaller (1 micron).



To bacteria a sand grain is a huge boulder providing an unlimited surface area to anchor and thrive. The picture on the right is an electron microscope image of soil bacteria forming a colony on the surface of a single particle of sand.

In nature the decomposition process of organic materials – petroleum compounds, pesticides, carbohydrates, sugars, cellulose etc. – starts at the microorganism level. For a myriad of micro and macro organisms, even complex organic materials as hormones are simply a food source for their metabolism. The prerequisites for efficient decomposition are:

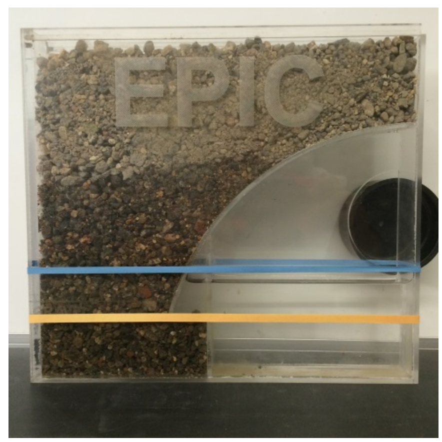
a) **Moisture** – present as a water film.

b) **Oxygen**- second largest component of air.

c) **Micro-organisms**- bacteria, mold etc. prolific in aerobic environments.

d) **Temperature** – ideal decomposition range 55º - 120º F.

The EPIC™ filter provides all of those factors. The profile being highly porous, oxygen readily penetrates the shallow profile to provide a constant aerobic environment. By design the initially retained water slowly capillarizes into the gravel/sand mixture to provide moisture to the existing living microorganisms. Note moisture rise in the form of a water film (darker area above the blue line) in the picture to the right.



Direct surface sunlight vaporizes volatile compounds, provides **uV** decomposition, and heats the surface of the rock mass which then transfers ambient heat to the thriving biological zone in the lower levels of the sand profile.

VECTOR CONTROL:

Ordinary catch basins with their large openings provide ready access to rodents to travel the network of storm drains below the surface. At the same time, water deposits at the bottom of catch basin structures, provide an opportunistic breeding site for mosquitoes.

The standing water at the bottom of the EPIC™ filter profile is simply not accessible to vectors like mosquitoes as the water surface is covered with 12” of a sand/gravel mix. The porous, not structured fill is also not suitable for rodent burrowing as the tunneling quickly collapses when started, or much less prohibited from starting by the porous paver cap.

HEAVY METALS:

Some regulatory concern is the presence of brake dust (asbestos particles) and heavy metal particulates such as lead and cadmium from automobile wear parts or fuel additives that may be present in storm water runoff from road surfaces. Particles formed as a very fine dust may not be efficiently blocked by a course sand/gravel filter and move with the water stream. Water moves quickly through the relatively small constrictions among the sand grains and into the EPIC™ chamber, but drastically slows down in the relatively large cavity in the interior of the chamber. By design, the backbone of the EPIC™ filter is a series of interconnected chambers with definitive end-wall sections every four feet.

The slowdown of water flow in the interior of the chamber allows heavy particles to settle to the bottom. Water transfer from chamber to chamber is a slow decanting process that first skims off the water from the top layer into adjoining chambers. Periods between rain events allows additional quiet time for heavy particles (if present) to coalesce and settle to the bottom of the chamber.

TOTAL DISSOLVED SOLIDS (TDS):

No ordinary filters besides Reverse Osmosis systems (RO) can remove contaminants that are dissolved in a water solution. Dissolved negatively charged Solids as Nitrates, Sulfates, and Chlorides will move wherever water moves in a negatively charged soil environment. Positive charged ions of Potassium, Phosphorus, Calcium, Sodium, Iron, Magnesium etc. can adhere to negative charged surfaces for retention but will also move with water flows that are relatively fast.

To accomplish complete treatment of even the TDS component, the EPIC™ filter design can be converted to a biological filter. If the top 12" of the 15" (+) deep profile is filled with washed sand, the profile converts to an efficient plant growing cell. Extensive root growth in the porous sand profile then provides the uptake mechanism to transfer most of the TDS components as nutrients into plant tissue. All of the ions highlighted in red above are nothing more than nutrients essential to plant growth. The EPIC™ chambers then passively provide three dimensional irrigation water flows to the plants. Nutrients along with water move vertically by capillary action through the sand.