THE FATE OF FECAL COLIFORM BACTERIA IN THE OSCAR SYSTEM

by Dave Lowe[1]

Abstract

The OSCAR is a patented onsite sewage treatment technology that employs the principles of thin film flow and micro dosing applied through coils of subsurface drip tubing in sand media, thereby maximizing the hydraulic retention time in the sand media. The technology is comprised of a pre-settling tank to produce settled sewage, a pump chamber for surge flow control, a repeat cycle time controller, a pump, an automatic reverse flush headworks with a 120 mesh disc filter, Netafim Bioline, and ASTM C-33 sand. Septic tank effluent is dosed in very frequent, small doses through Netafim Bioline (0.42 gph emitters) into a thin layer of sand (minimum 6 inches deep). The sand has been placed on a prepared soil interface, which is the point of final dispersal. Treated effluent migrates into the soil pores and is assimilated into the environment. OSCAR can receive septic tank effluent or higher quality effluent and achieve up to a 6 log removal of fecal coliform. Monthly geometric mean per day have been as low as 1.2 FC colonies per 100 ml, MPN. The pre-settling tank can be substituted with another treatment technology to achieve enhanced nutrient removal while the OSCAR provides pathogen reduction. The OSCAR, coupled with other treatment processes can produce effluent that meets regulatory requirements for class A reclaimed water.

Background

In the late 19th century, there was a desire to address the sewage treatment problem in US cities. In Massachusetts there was a great deal of research conducted between 1890 and 1910 at the Lawrence Research Station on the use of intermittent sand filters (ISF). The standard design concept that emerged from this research was a simple vessel containing sand with an underdrain. The top of the sand layer was leveled off and flooded with settled sewage to achieve equal distribution. One or two doses per day was applied to the surface. When the previous dose had not infiltrated into the sand before the next dose was delivered, the surface of the sand was raked to break up the biological layer and restore flow through the media.

This process was repeated until no amount of raking would improve the infiltration rate. At that point a portion or all of the sand was removed and new sand was installed and the cycle would begin again. The application rates and sand depths varied from system to system. Sand media depths of 3-4 feet up to 10 feet were used. Application rates range from 0.75 to 10 g/sf/d. Courser sand sizes had less clogging with lower treatment capability and the finer textured sand had slower flow rates and better treatment outcomes. Unless somebody was responsible to manage the sand clogging, it would be difficult to use this process on a single family residence.

---

[1] Dave Lowe, Lowridge Onsite Technologies, Inc.

As materials such as PVC pipe and electronic control panels were developed the design and application of sand based treatment technologies improved. In the 1970s and 80s many states began adopting intermittent sand filters or sand mounds into regulation for use in single family dwellings. Sand filters were built below ground with a soil cover cap. Sand used in these systems usually conformed to the ASTM C-33 standard. Media depth ranging from 24 inches to 36 inches and loading rates of 0.8 to 1.2 g/sf/d were commonly specified. The unique aspects of the modern sand filter is the distribution method, dosing pattern and frequencies. Low pressure distribution networks are placed in a gravel bed atop the sand layer. See Figure 1 and 2 below.

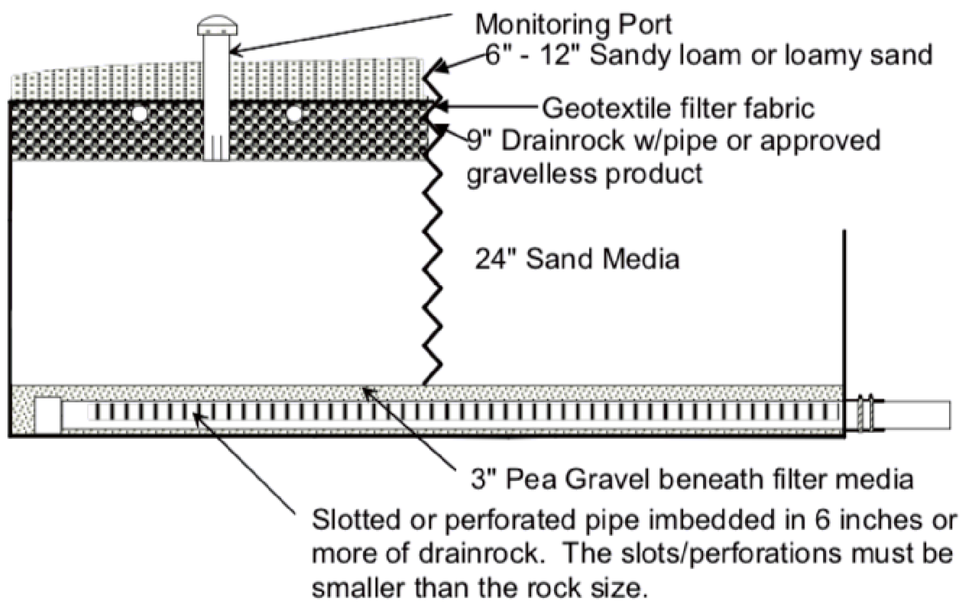


Fig. 1 Typical Intermittent Sand Filter Cross Section, Washington State Department of Health's Recommended Standards and Guidance for Intermittent Sand Filters, July, 2012.

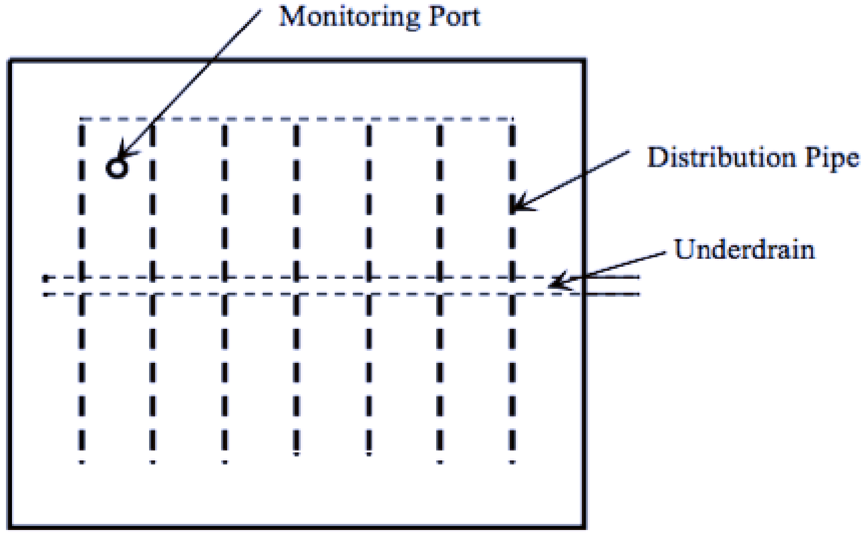


Fig. 2 Typical Intermittent Sand Filter Top View, Washington State Department of Health's Recommended Standards and Guidance for Intermittent Sand Filters, July, 2012.

One of the states that adopted sand based treatment systems was Washington State. As late as 1996, Washington State guidance documents allowed for demand dosing of sand filters 4 times per day. The media was limited to ASTM C-33 sand, and there was no set criteria for the number of distribution points or orifices. The only criteria was that low pressure piping systems must be used. At the time there was a concern for the high rate of intermittent sand filter failures.

In 1996 the guidance documents governing the use of sand filters and mounds were improved to reflect a new understanding of the important aspects of sand filter design: media size, number of effluent distribution points (orifices), timed dosing, dose volume, and frequency.

The changes made by the *Washington State Department of Health* included a courser media, timed dosing in all sand medias, a minimum number of distribution points, and a new minimum dose frequency for the course sand media. See Table I.

Table 1, Sand media compared to minimum required dosage events per day.

Media Specification	Minimum Doses per Day	Distribution points (orifices)
ASTM C-33	4 times per day	1 per 6 sq. ft.
Course Sand Media	18 times per day	1 per 6 sq. ft.

With an increased media size the retention time within the course sand media is reduced, but it is mitigated by increasing the number of orifices or distribution points, increase the number of doses (thereby decreasing the volume of effluent per dose) while daily hydraulic loading rates stayed the same. By manipulating the flow through the media it became more probable that a thin film flow of liquid over the sand particles would be achieved without saturating the media. As a result to these changes, it was expected that the courser sand media would meet the same organic and bacterial reductions as finer textured sand. Both medias, with their respective dosing frequencies, were expected to achieve a reduction of fecal coliform concentration to less than 1,000 FC colonies/ 100 ml, MPN.

These upgrades to the design standards was a step forward in helping to eliminate premature failures of sand based treatment systems. But the overall size of the systems and the economics of the technology were unchanged. More work needed to be done to take the next step forward in developing a technology that required less material, used less space, and was more cost effective and still achieved the same or better treatment level.

But the question remains, what would be the result if the number of distribution points and dosing frequency were further increased, and the dose volume decreased? Could there be an increase of the loading rate, a reduction of the media depth, or both and maintain the same level of treatment?

If effluent could be applied to a media with an eye dropper, one drop at a time, theoretically the retention time and loading rate could be maximized, and media depth reduced. The eye dropper method would control the flow of effluent resulting in a near perfect equilibrium between air, media, organic solids, bacteria, and water. Ideally, water should move through the sand in the form of capillary water while not filling the pore spaces. When the sand moisture level is maintained at field capacity, adding one drop of water to the top of the media will cause a corresponding drop of water to exit the bottom of the media. See Figure 3.

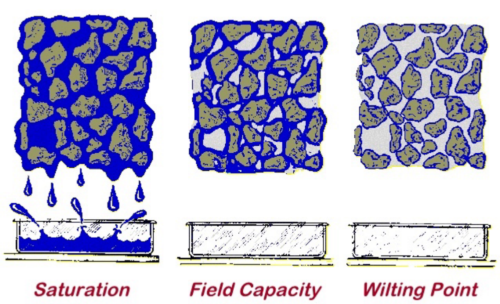


Figure 3, Water Holding Capacity, taken from “Effect of Organic Fertilizer on the Water Holding Capacity Soil in Different Terrains in Jaffna Peninsula in Sri Lanka”.

The closest practical configuration to approach the eye dropper concept is to use subsurface drip tubing with a low emitter discharge rate (0.42 gph). The 0.42 gph emitter discharges at a rate of two drops per second. This flow rate is too fast for continual dosing. Time dosing would need to be incorporated to modulate the flow rate further. OSCAR combines the drip tubing, sand, dosing frequency, and emitter pattern.

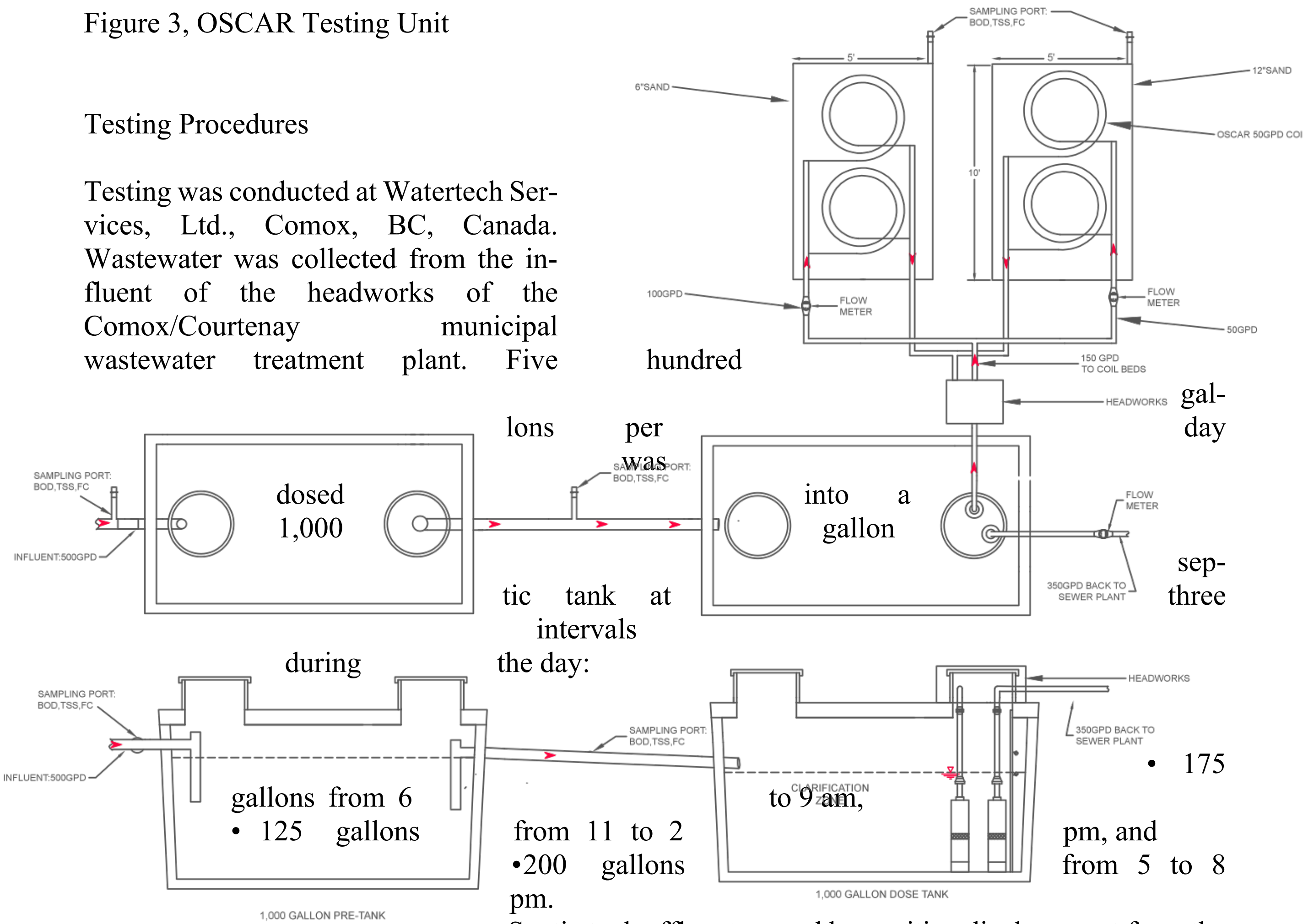
The OSCAR was tested using septic tank effluent with two parallel units to compare two different media depths and two loading rates.

Plant Description

The OSCAR unit that was used to test this theory was built with the following specifications:
- 1,000 gallon septic tank,
- 1,000 gallon surge tank,
- 120 mesh disc filter,
- two (2) 50 sq. ft. OSCAR units.

Each OSCAR unit contained two 25 foot coils of Netafim Bioline with 0.42 gph emitters at 6 inch spacing and ASTM C-33 sand, a total of 100 emitters per unit. One OSCAR unit had 6 inch depth of sand media under the coil and the other had 12 inches. Both units were installed inside separate 30 ml PVC liners. The final effluent was collected in the underdrain and samples pulled for laboratory analysis. See Figure 3.

Figure 3, OSCAR Testing Unit



Testing Procedures

Testing was conducted at Watertech Services, Ltd., Comox, BC, Canada. Wastewater was collected from the influent of the headworks of the Comox/Courtenay municipal wastewater treatment plant. Five hundred gallons per day was dosed into a 1,000 gallon septic tank at three intervals during the day:

- 175 gallons from 6 to 9 am,
- 125 gallons from 11 to 2 pm, and
- 200 gallons from 5 to 8 pm.

Septic tank effluent passed by positive displacement from the septic tank to a 1,000 gallon surge tank. Two pumps were installed in the surge tank: a dosing pump and an overflow pump. The dosing pump was controlled by a repeat cycle timer dosing 100 gpd to an OSCAR unit with 6 inches of sand media depth while 50 gpd was dosed to the OSCAR unit with 12 inches of media depth. The remaining 350 gpd was pumped back to the Comox/Courtenay treatment plant. Twenty-four hour composite samples were taken five (5) days per week at four sampling locations: before and after the septic tank, and after both OSCAR units and analyzed for BOD5 and TSS. *National Sanitation Foundation* standard 40 testing protocol was followed. Also, grab samples were taken from the same four locations three (3) days per week and analyzed for fecal coliform concentrations as per the *Washington State Department of Health's* bacterial removal testing requirements. Results of the six (6) month test are depicted in Table 2 below.

Table 2, BOD, TSS, and fecal coliform removal compared to location in treatment process.

	Pre-septic	Post-septic	Post 6” OS	Post 12” OS
BOD	240 mg/l	100 mg/l	2 mg/l	2 mg/l
TSS	190 mg/l	85 mg/l	3 mg/l	2 mg/l
Fecal coli.	50,000,000	10,000,000	<1,000	<200

Table 3 is a description of the two typical Washington State intermittent sand filters (ISF) and the two OSCAR units. The comparisons encompass doses per day, daily loading rate, concentration of distribution points, distribution point dose volume, and media depth.

Table 3, Comparison between media depth, dosing frequency, distribution pattern, and volume per dose per distribution point.

Treatment unit	loading rate, g/sq. ft./day	Doses/day	Area/ emitter or orifice	dose volume/point	Media depth
12” OSCAR	1	360/day	0.5 sq. ft.	0.18 oz.	12 inches
6” OSCAR	2	360/day	0.5 sq. ft.	0.35 oz.	6 inches
ISF	1	18	6 sq. ft.	42 oz.	24 inches
ISF C-33	1	4	6 sq. ft.	192 oz.	24 inches

Comparisons between the typical intermittent sand filter and the two OSCAR units indicate a significant reduction in the amount of sand media needed to achieve acceptable attenuation of fecal coliform bacteria. The data suggests that increasing the number of distribution points and number of dosing events, and decreasing the dose volume per distribution point has a bigger impact on the treatment capability of sand media than loading rate or media depth. See Table 4.

Table 4 **,** Comparison between media depth, loading rate, and fecal coliform reduction.*Expected levels. No NSF test was conducted.

Treatment unit	Loading rate	Media depth	Fecal coliform level
12” OSCAR	1 gal/sq. ft./day	12 inches	96 FC/100 ml, MPN
6” OSCAR	2 gal/sq. ft./day	6 inches	755 FC/100 ml, MPN
ISF*	1 gal/sq. ft./day	24 inches	<1000 FC/100 ml, MPN

Higher Quality Effluent

So far the conversation has focused on the hydraulic retention time of the wastewater flow as the primary factor for bacterial attenuation. Modifying the tanks to provide a secondary step of treatment provides higher attenuations of fecal coliform bacterial levels through the OSCAR. Another test was conducted to test this theory at the Waco, TX treatment plant. Fecal coliform levels were reduced to approximately 10,000/100 ml, MPN prior to dosing wastewater to the OSCAR. The dosing frequency, application rate, distribution point, dose volume, and media type and depth (6 inches) were held constant from the previous test. Figure 4 depicts the system configuration for the OSCAR-Nitro system.

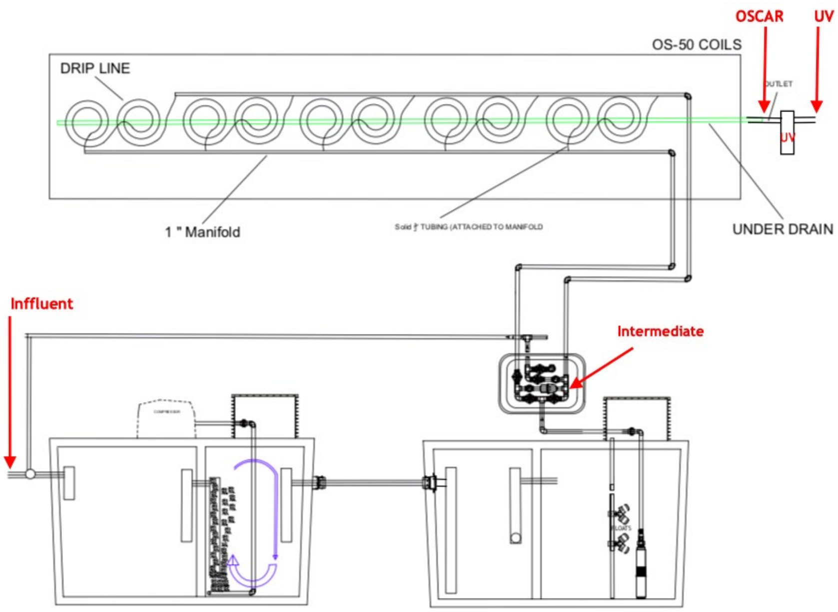


Figure 4, OSCAR-Nitro schematic

In the OSCAR-Nitro system wastewater passes through five stages before entering the soil environment: septic tank, aeration chamber, clarifier, pump tank, and an OSCAR unit.

Wastewater gravity flows into the septic tank where primary treatment occurs. Through positive displacement, septic effluent passes into the aeration chamber through the by-pass ports in the partition wall. Tinny air bubbles are introduced into the aeration chamber through a diffuser stone, which receives compressed air from the blower, increasing the dissolved oxygen. In the aeration chamber organic compounds are reduced to water, carbon dioxide gas, and cell mass. Aerated liquid flows to the clarifier where suspended particles settle out. Liquid from the pump tank is dosed to the OSCAR in small, frequent doses.

The OSCAR is comprised of a 6-inch layer of C-33 sand media and a series of custom manufactured Netafim Bioline drip tubing coils with pressure compensating emitters. OSCAR coils are then placed on the C-33 sand media and then covered with another 6 inches of C-33 sand media.

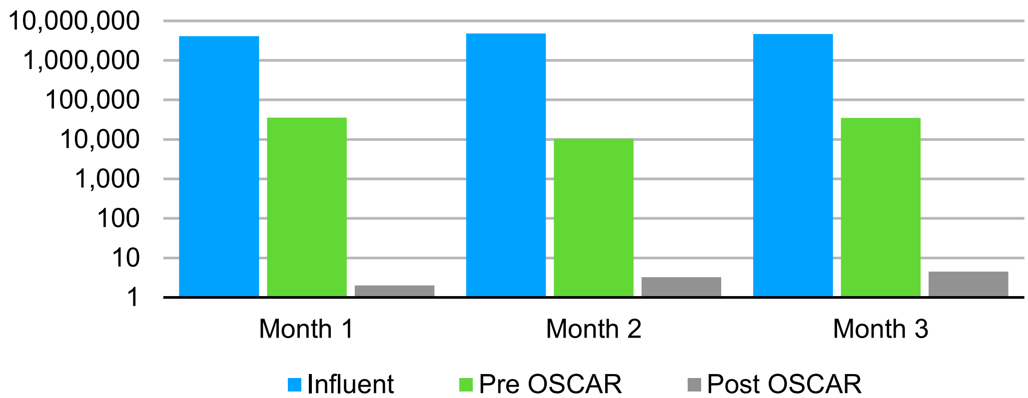


Figure
5, Graph of geometric means of fecal coliform concentration throughout the treatment process.

Table 5 shows the three month geometric means for fecal coliform bacteria. Values are fc/100 ml, MPN

	Influent	Pre OSCAR	Post OSCAR
Month 1	4,093,308	35,459	2
Month 2	4,761,507	10,356	3.25
Month 3	4,650,120	35,000	4.5

Conclusions

Sand media has been proven to be a very effective media in treating domestic strength wastewater, especially as it pertains to fecal coliform removal. The ability of sand to perform as a treatment media is dependent upon many factors. By delivering effluent to the sand media in the smallest, most frequent doses to as many unique distribution points as possible will have more influence on the sand's ability to treat wastewater than loading rate or sand depth. The use of subsurface drip irrigation tubing as the distribution method coupled with time dosing will approach equal distribution over any media surface. Additional refinements in the distribution network could possibly allow for an even greater increase in loading rate. By adding a pre-oxidation step within the system, influent fecal coliform concentrations can be reduced by 3 logarithms. The OSCAR unit is then able to reduce the fecal coliform concentration to near 0 FC/100ml, MPN.