THE FATE OF FECAL COLIFORM BACTERIA
IN THE
OSCAR SYSTEM

Dave Lowe¹

ABSTRACT

The OSCAR is a patent pending 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. 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, a manual 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. 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. 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

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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 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.

As materials such as PVC pipe and electronic controls 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” to 36” 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 2 and 3 below.

![Fig. 2 Typical Intermittent Sand Filter Cross Section, Washington State Department of Health](image-url)
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 of effluent: only 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 were improved to reflect a new understanding of the important aspects of sand filter design: media size, number of effluent distribution points, 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 specific number of distribution points were required, and a new minimum dose frequency for the course sand media. See Table IV.

Table IV

<table>
<thead>
<tr>
<th>Media Specification</th>
<th>Minimum Doses per Day</th>
<th>Distribution points (orifices)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C-33</td>
<td>4 times per day</td>
<td>1 per 6 sq. ft.</td>
</tr>
<tr>
<td>Course Sand Media</td>
<td>18 times per day</td>
<td>1 per 6 sq. ft.</td>
</tr>
</tbody>
</table>

Fig. 3 Typical Intermittent Sand Filter Top View, Washington State Department of Health
With an increased media size the retention time was reduced, but it could be mitigated by changing other aspects of the design criteria, such as increasing the number of orifices or distribution points, increase the number of doses while loading rates stayed the same, and decrease the volume of effluent per dose. 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 course 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 make 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.

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?

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 a near perfect equilibrium between air, media, organic solids, bacteria, and water. Larger, less frequent doses could saturate the media open space, causing a reduced retention time in the media, negatively effecting treatment quality. Ideally, water should move through the sand 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 Illustration II.

Illustration II, Water Holding Capacity

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” spacing and ASTM C-33 sand, a total of 100 emitters per unit. One OSCAR unit had 6” depth of sand media under the coil and the other had 12”. 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 I.
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” media depth while 50 gpd was dosed to the OSCAR unit with 12” 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. 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

<table>
<thead>
<tr>
<th></th>
<th>Pre-septic</th>
<th>Post-septic</th>
<th>Post 6” OS</th>
<th>Post 12” OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>240 mg/l</td>
<td>100 mg/l</td>
<td>2 mg/l</td>
<td>2 mg/l</td>
</tr>
<tr>
<td>TSS</td>
<td>190 mg/l</td>
<td>85 mg/l</td>
<td>3 mg/l</td>
<td>2 mg/l</td>
</tr>
<tr>
<td>Fecal coli.</td>
<td>50,000,000</td>
<td>10,000,000</td>
<td>&lt;1,000</td>
<td>&lt;200</td>
</tr>
</tbody>
</table>

Six month averages: average for BOD & TSS, geometric means for fecal coliform, MPN /100 ml.

Table 3 is a comparison between 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>
<thead>
<tr>
<th>Treatment unit</th>
<th>loading rate, g/sq. ft./day</th>
<th>Doses/day</th>
<th>Area/ emitter or orifice</th>
<th>volume/dose/point</th>
<th>Media depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISF C-33</td>
<td>1</td>
<td>4/day</td>
<td>6 sq. ft.</td>
<td>192 oz.</td>
<td>24 inches</td>
</tr>
<tr>
<td>ISF-Course</td>
<td>1</td>
<td>18/day</td>
<td>6 sq. ft.</td>
<td>43 oz.</td>
<td>24 inches</td>
</tr>
<tr>
<td>12” OSCAR</td>
<td>1</td>
<td>360/day</td>
<td>0.5 sq. ft.</td>
<td>0.18 oz.</td>
<td>12 inches</td>
</tr>
<tr>
<td>6” OSCAR</td>
<td>2</td>
<td>360/day</td>
<td>0.5 sq. ft.</td>
<td>0.35 oz.</td>
<td>6 inches</td>
</tr>
</tbody>
</table>

Comparisons between the typical intermittent sand filter and the two OSCAR units tested 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>
<thead>
<tr>
<th>Treatment unit</th>
<th>Loading rate</th>
<th>Media depth</th>
<th>Fecal coliform level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISF C-33*</td>
<td>1 gal/sq. ft./day</td>
<td>24 inches</td>
<td>&lt;1000 FC/100 ml, MPN</td>
</tr>
<tr>
<td>12” OSCAR</td>
<td>1 gal/sq. ft./day</td>
<td>12 inches</td>
<td>&lt;200 FC/100 ml, MPN</td>
</tr>
<tr>
<td>6” OSCAR</td>
<td>2 gal/sq. ft./day</td>
<td>6 inches</td>
<td>&lt;1000 FC/100 ml, MPN</td>
</tr>
</tbody>
</table>

Table 4 *Expected levels. No NSF test was conducted.

CONCLUSIONS

Sand media has been proven to be a very effective treatment media in treating domestic strength wastewater. 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 then 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 testing will be needed to determine how much more efficient a sand based system could be when media size is reduced and or media depth increased. Additional refinements in the distribution network could possibly allow for an even greater increase in loading rate.

REFERENCES

Dr. George Tchobanoglous

Washington State Department of Health

Lawrence Research Station, Lawrence, MA