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Performance of Delaware Sand Filter Assessed

Up to now, our knowledge about the pollutant removal performance of sand filters has been drawn from monitoring data from four filters in Austin, Texas. Some have questioned whether this data is transferable to more humid regions of the country or to other design variations. This gap has been filled by two recent monitoring studies conducted on "Delaware" sand filters in Alexandria, Virginia and Seattle, Washington.

The Delaware sand filter was developed by Shaver and Baldwin (1991) and consists of two parallel trench-like chambers that are installed along the perimeter of a parking lot (Figure 1). Parking lot runoff enters the first chamber, which has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, which consists of an 18-inch deep sand layer. Runoff is filtered through the sand, and then travels down a gradient to a protected outflow grate. Runoff in excess of the desired water quality treatment volume bypasses both trenches, and does not receive treatment.

An investigative team consisting of Warren Bell, Larry Gavan, and Lucky Stokes monitored a modified Delaware sand filter that collected runoff from a 0.7 acre section of a newly built parking lot located near National Airport in Alexandria, Virginia (Figure 2). The filter was constructed in 1992, and was about 95 feet long and had a sand filter bed area of 238 square feet (Figure 1). Additional details on its prototype design can be found in City of Alexandria (1995). The pollutant concentration at the inlet and outlet of the filter was monitored over 20 storm events in 1994. An analysis of pollutant concentrations in incoming stormwater indicated that the runoff was within the national ranges established in the National Urban Runoff Program (NURP) study, with two notable exceptions. First, the concentration of

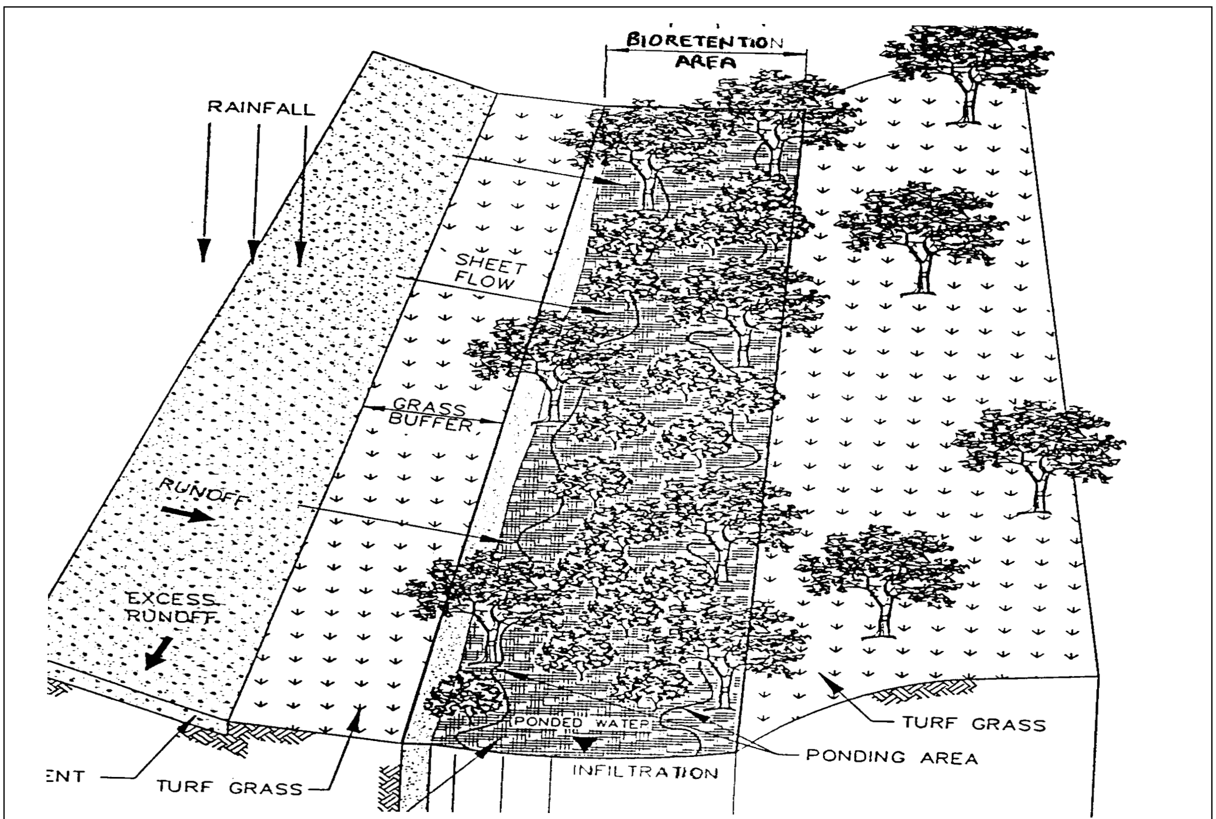

Figure 1: General Layout of AirPark Filters (City of Alexandria drawing)

organic nitrogen (TKN) was about three times the national average, which was thought to be due to greater local air deposition of this pollutant. Second, total petroleum hydrocarbons were never detected in the parking lot runoff, which is unusual for a such a potential hydrocarbon hotspot. Bell speculated that this might be due to the fact that most cars in the private long-term parking lot were newer and more expensive models that are not prone to leakage.

Two similar Delaware sand filters were also monitored by Horner (1995) at a loading facility for a marine terminal in Seattle, Washington in 1994. Horner monitored the removal of sediment, hydrocarbons, phosphorus and metals from these recently constructed facilities. Both studies indicated that the Delaware sand filter had moderate to high ability to remove many pollutants (Table 1). When interpreting the results, it should be kept in mind that each researcher used a slightly different method to calculate removal efficiency. Bell computed the total mass of pollutants removed during his study, while Horner reports the average efficiency during all storm events. In either case, the measured removal rates are still quite high.

For example, Bell reported mass removal rates for sediment, BOD, total organic carbon, phosphorus and zinc in the 60 to 80% range. In particular, the removal of total and soluble phosphorus were among the highest yet reported for a sand filter. Indeed, the performance would have reached 70% for both parameters if not for an "anaerobic" incident within the sand filter that resulted in possible phosphorus release during four storm events. Mass removal of total nitrogen was 47%, which reflected excellent removal of organic nitrogen (71%) coupled with negative removal soluble nitrate (-53%). This follows a consistent pattern noted for other sand, compost or grass filtering systems, where organic nitrogen is trapped and partially broken down into ammonia and nitrate through the nitrification process, resulting in a net export of nitrate (i.e, filter conditions or time do not allow for significant denitrification to transform nitrate into nitrogen gas). During the anaerobic incident, the whole filter was probably anaerobic and undergoing denitrification. Pockets of anaerobic activity persisted throughout the study.

Horner reports the first data that indicate how well sand filters remove petroleum hydrocarbons and oil and grease from parking lot runoff. Mean storm removal rates ranged from 55% to 84% in the two filters tested, which does suggest that sand filters can be an effective stormwater management practice for hydrocarbon hotspots. The mean removal rate for phosphorus, zinc and copper was fairly modest in both Seattle sand filters. In most cases, however, removal efficiency climbed as input concentrations increased.

Bell conducted a detailed analysis of the concentration-removal phenomena using performance data from

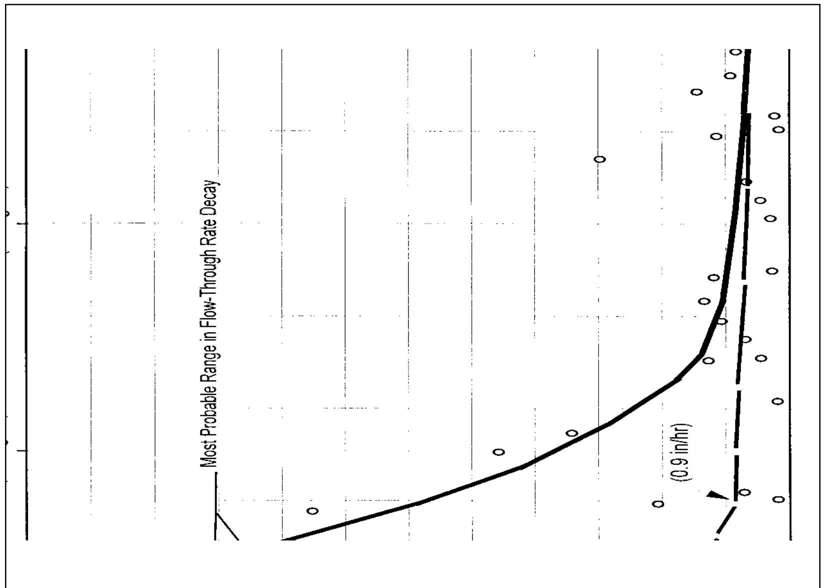

Figure 2: Slotted Curb Delaware Sand Filter (City of Alexandria)

Table 1: Comparative Pollutant Removal Performance of Three "Delaware" Sand Filters

	Alexandria, VA (Bell *et al.*) Mass removed[a]	Seattle, WA (Horner) Mean removal[b]	Seattle, WA (Horner) Mean removal[b]
No. of Storms Sampled	20	14	6
Total Suspended Solids	79%	83%	8%[c]
Oil and Grease	NA	84%	69%
Petroleum Hydrocarbons	ND	84%	55%
Total Organic Carbon	66%	NA	NA
BOD (five-day)	78%	NA	NA
Total Phosphorus	63%[d]	41%	20%
Ortho-Phosphorus	68%[d]	NA	NA
Total Nitrogen	47%	NA	NA
Nitrate+Nitrite	(-53.3)%	NA	NA
TKN	70.6%	NA	NA
Zinc	91%	33%	69%
Copper	25% (b)	22%	31%

Notes:

a — Fraction of total incoming pollutant load retained in filter over all storms

b — Average of storm pollutant concentration reduction, all storms

c — Poor removal due to very low TSS inflow concentrations (4 to 24 mg/l)

d — Removal rates were higher if four anaerobic events are excluded.

NA — Parameter not analyzed during monitoring study

ND — Parameter not detected in runoff during sampling study.

Figure 3: Comparison of Initital TP Concentration vs. TP Removal Efficiency forSand Filters and Peat-Sand Filters (Bell *et al.* 1995)

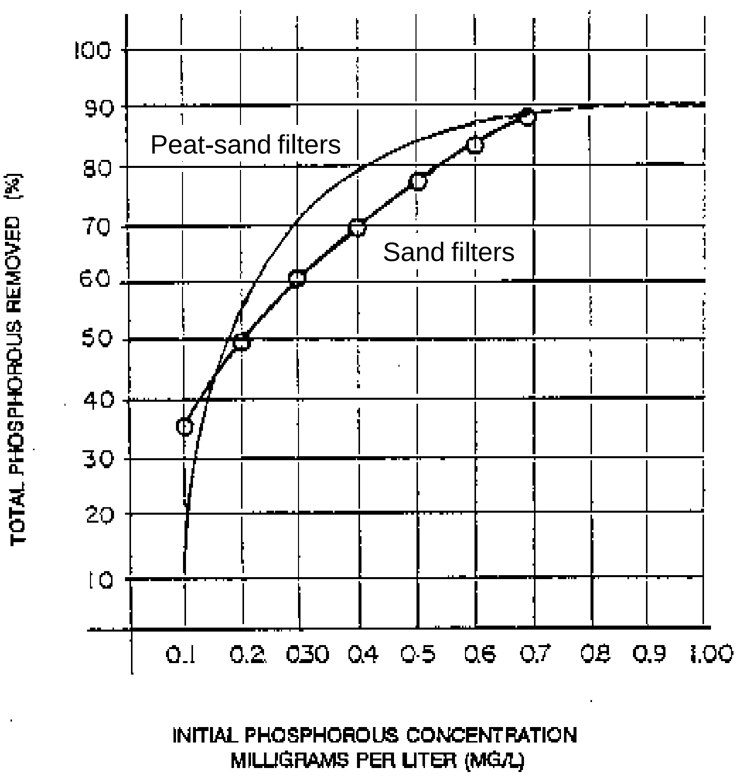

Table 2: Highlights of Design Improvements for Sand Filters (City of Alexandria, 1995)

- The sand layer should be designed to have positive drainage through the sand filter to prevent dead spots from becoming anaerobic and releasing previously captured phosphorus. This is best done by capturing filtered water in underdrain pipes.
- Better nitrogen removal may be achieved by placing a foot deep layer of flooded gravel below the sand filter, if sufficient organic carbon is present in runoff. This layer should be covered by a four inch layer of dry gravel to prevent anaerobic conditions from occurring in the sand filter zone.
- Where practicable, sand filters should be designed to exclusively treat runoff from impervious areas. Use on watersheds with less than 70% impervious cover will likely lead to early failure by clogging of the filter pore spaces.

Alexandria, Seattle and Texas. He detected a strong relationship between inflow concentration and removal efficiency for sediment, phosphorus, organic nitrogen, zinc, and total petroleum hydrocarbons. Simply put, removal efficiency sharply increased when the concentration of pollutants entering the sand filter is high, and dropped when incoming pollutant concentrations were low (and presumably, much less of a water quality problem). Figure 3 illustrates this effect for phosphorus removal.

The new studies provide other insights into the design and operation of sand filters. For example, designers in northern climates have often wondered how sand filters will operate during extended periods of subfreezing weather. The Alexandria site was subject to an unusual arctic blast that extended for several weeks. Although the wet sedimentation chamber did freeze to a depth of several inches, the sand filter bed still operated reasonably well during the subsequent melt period. Bell also analyzed the quality of sediments in the sand filter chamber to determine if they posed a risk for disposal. No priority pollutants were detected in Toxicity Characteristic Leaching Procedure (TCLP) leaching studies of the filter sand, and it was determined that it could be safely landfilled. However, this finding must be tempered by the lack of hydrocarbons in the treated runoff.

Bell's report contains a wealth of useful guidance on how to design better sand filters to remove stormwater pollutants, and some of his key recommendations are summarized in Table 2. Taken together, the two new studies suggest that sand filters can achieve moderate to high pollutant removal rates in humid regions of the country.

—TRS

References

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