Article 115

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Pollutant Removal Pathways in Florida Swales

Grass swales are essentially living filters and are thought to be an ideal practice for treating the quality of stormwater runoff. The shallow flow of runoff through grass blades and across soils should provide optimum conditions for pollutant removal. Why then do grass swales exhibit such mediocre performance in removing soluble nutrients and metals from urban stormwater? Prior swale monitoring studies in such diverse locales as Florida, Virginia, Maryland, and Washington have all shown a very limited capability to remove these soluble pollutants (removal rates of 0 to 40%) unless the majority of runoff infiltrates into underlying soils, and effectively disappears (See MWCOG, 1983).

Some answers to this vexing question can be found in the experiments of a team of researchers in the Orlando, FL area (Yousef *et al.*, 1985). Although the Central Florida study is nearly a decade old, its results have not been widely disseminated, and can help in understanding the pollutant removal dynamics within grass swale.

The team took an experimental approach in which they selected two representative test swales. Each test swale was long, and had gentle slopes and moderate infiltration rates (Table 1). Each test swale was then spiked with a known concentration and volume of simulated urban runoff in a series of six experiments. The experiments simulated flow events that ranged from 0 to 2.8 watershed inches of runoff through the swale. This feat was accomplished using a submersible pump to withdraw water from an existing runoff pond, and then distribute it through the test swales for a period of approximately four hours. Samples were collected at various points along the length of each swale, and the change in runoff volume and pollutant concentration were analyzed with respect to distance to determine pollutant removal rates.

Table 1: Characteristics of the Two Test Swales Through Experimental Swale Systems

Swale Characteristic	Maitland	EPCOT
Length	160 feet	550 Feet
Water Table	Low	High
Infiltration Rate (in/hr)	1.4	0.5
Vegetation	short, dense bahia grass	only 20 to 80% grass cover—remainder is exposed earth
Soils	sandy, very low clay and organic matter	sandy w/ higher organic matter
Residence Time (minutes)	30 to 60	30 to 60
Slope	less than 1%	less than 1%

Soluble Nutrients

The results of the experiments were generally consistent with other swale studies that showed little capability to reduce the concentration of soluble forms of nitrogen and phosphorus as they passed through the swale. As can be seen in Table 2, little or no reduction in soluble nutrient concentration was observed, despite the fact that runoff took 30 to 60 minutes to traverse the several hundred feet of each swale. Yousef and his colleagues also examined the longitudinal trend in soluble nutrient concentrations through each swale, and found that concentrations slightly increased, decreased or stayed the same, and showed no discernible pattern.

The bulk of the observed pollutant removal in the swales could be accounted for by simple infiltration of runoff through the bottom of the swale. Indeed, a cursory glance at Table 3 shows that total removal rates and the fraction of total runoff infiltrated into the swale bottom were essentially identical. Low velocities that provide sufficient time for extensive infiltration appear to be essential to achieve high removal rates. When infiltration was low or modest, removal of soluble pollutants was generally quite poor. This implies that the major pollutant removal mechanism in swales is an underground one (infiltration) and not necessarily a surface one (filtering and adsorption).

The behavior of soluble phosphorus through the test swales underscores this point. The concentration of phosphorus in the swale was quite variable (Table 2), showing small increases and decreases along the length of the swale. In general, the soluble phosphorus concentrations in the swale were actually higher than the

Table 2: Percent Change in Nutrient Concentration Through Experimental Swale Systems

Site No.	Nitrate-N	Ammonia	Organic N	Total N	Diss. P	Total P
M-6	2	15	5	(-2)	0	7
E-4	(-6)	(-39)	4	2	11	9
E-5	10	1	18	14	(-20)	(-48)
M-1	7	11	1	9	12	14
M-2	33	32	(-1)	25	47	48
M-3	19	80	(-134)	30	30	17

concentrations in highway runoff coming into the swale. The authors thought that this could reflect the release of soluble phosphorus as a result of the mineralization of grass clipping and thatch within the swale. They also cautioned that the soils of the test swales were very low in clay or organic matter content, and therefore had much less potential for soil adsorption.

Soluble Metals

Most stormwater researchers report removal of total trace metals, but do not independently measure the fraction present in soluble form. This can be significant as soluble metals usually exert the greatest impact or toxicity to aquatic life. Many trace metals are primarily found in soluble forms (cadmium, copper and zinc), while others are mostly attached to sediment particles (iron and lead). Yousef's study indicated that while swales were quite effective in removing total metals in urban stormwater runoff, they were much less effective in removing soluble metal species (Table 4). Two different pollutant removal mechanisms appear to be working in swales. The first involves settling of particulate fractions, and the second involves adsorption of soluble metals to exchange sites in the soil. While settling occurs during every storm, adsorption requires that the metal be present in runoff as a positively charged cation that can be adsorbed to a negatively charged particle in the soil or organic layer. Metals, however, can be found in complex number of ion species depending on the prevailing acidity (pH) of runoff. Some metals such as zinc readily adsorb to soil at pH levels typical of stormwater runoff (6.5 to 8.0), but many others (aluminum, cadmium, copper, chromium and lead) show little tendency to adsorb to soils within this range. Consequently, the ability of swale soils to remove many soluble trace metals tends to be rather low (Table 4). Yousef and his colleagues also note that metal adsorption can be reversed under certain stormwater conditions, thereby releasing metals that had been trapped in the soil back into the runoff stream.

The swale experiments, coupled with recent performance monitoring data, provide useful insights on how to design swales to maximize removal efficiency for soluble pollutants of concern. Some key design features include the use of techniques to promote greater infiltration with swales (locating on sandy soils, soil amendments to promote greater infiltration, sand trenches, and perforated underdrains), greater ponding (checkdams, off-line swales), or longer detention times (broader bottoms, greater length). The key point is that swales cannot be designed to solely rely on adsorption

Table 3: Estimated Nutrient Removal in the Test Swales (Arranged in Ascending Order of Runoff Infiltration Achieved)

Site No.	Infiltration Volume	Nitrate-N	Organic-N	Total N	Diss. P	Total P
M-6	26%	(-2)	22	27	26	31
E-4	38%	48	41	39	43	45
E-5	50%	(-21)	41	24	40	27
M-1	57%	57	64	61	62	63
M-2	60%	67	63	73	797	9
M-3	100%	100	100	100	100	100

Table 4: Removal of Dissolved and Total Trace Metals in Highway Runoff Along Florida Grass Swales

Trace Metals	Percent dissolved (%)	Dissloved fraction removal (%)	Total metals removal (%)	Major removal mechanisms for dissolved fraction
Aluminum	23	20	76	very limited adsorption
Cadmium	90	18	29	some adsorption
Copper	85	19	41	very limited adsorption
Chromium	61	13	44	very limited adsorption
Iron	12	44	71	strong precipitation
Lead	10 to 50	50	91	
Nickel	75	47	88	
Zinc	64	82	90	very strong adsorption

to grass and soils as the primary pollutant removal mechanism. Other, more structural techniques, need to be included in the design to achieve more consistent removal of soluble pollutants.

—TRS

References

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