Research Proposal

Enhancing existing BMPs for improved removal of dissolved metals

Problem Title. How can basic treatment systems be modified to improve their dissolved metals removal?

Problem Statement. From the regulatory aspect, the '01 Ecology Stormwater Management Manual for Western Washington (SMMWW) mandated "enhanced" treatment (a secondary or tertiary treatment process) with the goal of >50 percent removal of dissolved zinc and copper for untreated highway runoff. Even though the '01 Ecology manual is considered a "guidance" document, it is often implemented as regulation through Section 401 Water Quality Certifications and other permits and approvals. The technical challenge is to develop and/or modify existing BMP designs so that they can also effectively capture dissolved-phase heavy metals to meet the enhanced treatment goals.

Literature Search. Most secondary or tertiary unit operations for treating dissolved metals have been developed outside of the stormwater world. Knowledge derived from the passive treatment of acid mine drainage, aquaculture return flow treatment, and some concepts borrowed from process wastewater engineering provide some tools that may allow WSDOT to modify its treatment BMPs to markedly improve the metals-removal capacity of its stormwater control systems. These options include, but are not limited to:

- *Carbonate/Hydroxide Precipitation* – It is well known that the solubility of metal compounds in aqueous systems and soils are a function of pH. Dissolved heavy metals can be removed from stormwater by direct precipitation using precipitating agents. Passive acid mine drainage (AMD) treatment uses open limestone channels to dissolve carbonates and hydroxides into the influent to boost pH and induce the precipitation of metals. Highway runoff has been shown to be mildly to moderately acidic (4.0-6.0 in most cases unless buffered by soil or vegetation), suggesting that analogies between AMD and highway runoff are apt. It appears possible to use theoretical solubility curves to reduce the solubility of copper by nearly 100% by boosting pH from acidic to weakly alkaline, while still staying within water quality standards for pH (6.5-8.5). Due to theoretical solubility limits, carbonate/hydroxide precipitation may not be very effective at treating very low influent concentrations of copper. Increasing pH has also been shown to improve the sorptive capacity of filter media, suggesting that creating weakly alkaline conditions may optimize metals removal in a variety of primary BMPs. One promising proposal is the use of limestone or oyster shell-lined channels to dissolve carbonates and hydroxides into the runoff flow. These precipitating agents would then form carbonate and hydroxide compounds with the soluble metals, causing these compounds to precipitate as a solid. The runoff would then be routed from the limestone/shell rock trench to a standard wet detention pond, where the metal compounds would settle out by gravity separation.

- *Sulfide Precipitation* – Under anoxic conditions and with a sulfate source (contained in organic humic material or gypsum, calcium sulfate), bacteria will reduce sulfates to sulfides. When this occurs, sulfide-metal compounds form in solution and these compounds will form solid precipitates. The advantage of sulfide precipitation over carbonate/ hydroxide precipitation is that sulfide-metal compounds are highly insoluble, having much lower solubilities than either hydroxide-metal or carbonate-metal complexes at all pHs. Solubilities for metal-sulfide compounds are commonly in the parts per trillion range, much lower than the "cleanest" highway runoff. Sulfide precipitation is the likely unit operation responsible for dissolved metals removal in wetlands systems, as the hydric soils in the wetland can create a thin anoxic zone that results in the sulfate reduction to sulfides. Wetlands tend to be inconsistent treatment devices for capturing dissolved metals, likely because much of the wet weather flows can bypass the thin hydric soil layer. For passive AMD treatment, anoxic limestone drains – thick limestone-lined trenches overlain by soil, has been successfully used to induce sulfate reduction and eventually sulfide precipitation. Extrapolating this method to stormwater treatment may present a challenging technical problem. Most stormwater flows tend to be aerobic. Creating the anoxic conditions needed to induce sulfide precipitation may require relatively large anoxic limestone drains. Conversely, even if an anoxic limestone drain cannot induce sulfide precipitation, the limestone will raise pH and alkalinity to induce carbonate and/or hydroxide precipitation in the stormwater flow stream. As with carbonate/hydroxide precipitation, an anoxic limestone drain would receive pretreated highway runoff and route the water to a standard wet detention pond, where the precipitants would settle through gravity separation.

- *Compost and humic filters* – This treatment option uses the sorptive capacity of agricultural and yard waste products to remove dissolved metals from stormwater by sorption. Stormfilter™ is a commercially-available product that uses processed deciduous tree leaves, and should be considered an option for dissolved metals treatment if used as a tertiary "polishing" step to avoid repeated clogging from sediments blinding off the media. Two other prime options would be composted yard wastes or activated soy bean hulls, a product developed by USDA that has been successfully tested in pilot tests at SeaTac airport. It is likely that humic/compost filters can be installed as components of other primary BMPs, such as compost-amended filter strips, biofiltration swales, or effluent from a detention pond.

- *Gravel/rock biofilters* – This treatment concept uses the biomass formed within a saturated gravel/rock matrix to facilitate uptake of dissolved metals. This treatment concept has been tested successfully in lab-scale pilot tests in Canada. There is a commercial product, the Stormtreat™ system, which is a subsurface-flow gravel "wetland" that uses biofilter principles for stormwater treatment. This treatment concept would be, like humic filters, most appropriate for pretreated stormwater to preclude clogging from sediment loads.

- *Engineered fabric filters* – Several products are on the market and although they are mostly designed to absorb hydrophobic or emulsified hydrocarbons, some products

(Fuzzy Filter™, Xextex™, and many others) have been shown to be effective for treating dissolved metals. One advantage of fabric filters over media filters is the fact that they can have up to 85 percent void space, which results in low head loss due to clogging.

Research Methods. Look for variances to the TAPE protocol, both for time limitation and simplified sampling methods to test modified basic BMPs for dissolved metals capture. Develop draft design protocols for using these treatment concepts for inclusion in the Highway Runoff Manual. Seek transportation projects that would be willing to incorporate these design features into their drainage designs. Seek funding either on the project or programmatic levels for monitoring and performance verification.

Partnering Opportunities. Few, and most are probably limited to Washington and particularly western Washington.

Estimate of Costs and Research Duration. Approximately $75,000 – 150,000 for monitoring each treatment concept, depending on the proportions of resources allocated to laboratory-scale studies and field studies.

Urgency, Payoff Potential, and Implementation. The needs for treatment options are immediate, but testing will be time consuming and may take years.

Research Proposer

- Name
- Office
- Phone Number
- Email Address

Research Monitor (to be assigned, as needed, by the research program administrator)

- Name
- Office
- Phone Number
- Email Address