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A MULTI-CHAMBERED STORMWATER TREATMENT TRAIN FOR THE TREATMENT OF STORMWATER

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INTRODUCTION

Runoff from paved parking and storage areas, and especially gas station areas, has been observed to be heavily contaminated with concentrations of many pollutants being 3 to 600 times greater than typical receiving water criteria. These paved areas are usually found to contribute most of the toxicant pollutant loadings to the stormwater outfalls in residential and commercial areas. PAHs, the most commonly detected toxic organic compounds found in urban runoff, are mostly from fossil fuel combustion. These compounds are very hard to control by eliminating their use, and, unfortunately, their control by typical stormwater management practices is not well understood. The major benefit of this research project will be to better understand how these toxicants can be controlled at critical source areas, especially automobile service facilities, with the use of a special treatment device or Multi-Chambered Treatment Train (MCTT).

METHODOLOGY

Earlier bench scale treatability studies of this U. S. Environmental Protection Agency (EPA) sponsored research found that the most beneficial treatment for the removal of stormwater toxicants (as measured using the Microtox^{TM} test) included column settling for at least 24 hours (generally 40% to 90% reductions), screening through at least 40 micron (μm) screens (20% to 70% reductions), and aeration and/or photo-degradation for at least 24 hours (up to 80% reductions) (1). Based on these tests and a computer model based upon hydrologic conditions in Birmingham, Alabama, a pilot-scale MCTT has been constructed and is currently being tested on the University of Alabama at Birmingham campus. Two full-scale MCTT units are also scheduled to be constructed in Wisconsin as part of their EPA 319 grant.

The MCTT includes a special catchbasin followed by a two chambered tank that is intended to reduce a broad range of toxicants (volatile, particulate, and dissolved). The runoff enters the catchbasin chamber by passing over a flash aerator (small column packing balls with counter-current air flow) to remove highly volatile components. This catchbasin also serves as a grit chamber to remove the largest (fastest settling) particles. The second chamber serves as an enhanced settling chamber to remove smaller particles and has inclined tube or plate settlers to enhance sedimentation. This chamber also contains fine bubble diffusers and sorbent pads to further enhance the removal of floatable hydrocarbons and additional volatile compounds. The water then enters the final chamber at a slow rate to maximize pollutant reductions. The final chamber contains a mixed media (sand and peat) slow filter, with a filter fabric layer. The MCTT would typically be sized to totally contain all of the runoff from a 12.7 millimeter (mm) (0.5 inch) rain from a typical 0.2 hector (ha) (0.5 acre) gas station. If the area is larger, then multiple, or larger, units will be needed. Figure 1 is a diagram of this device.

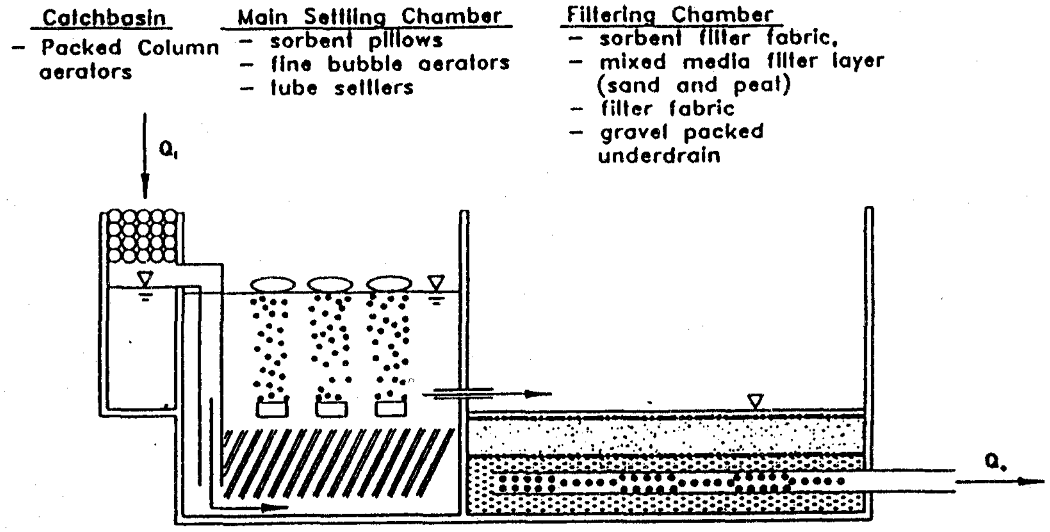

Figure 1. Multi-Chambered Treatment Train (MCTT) schematic.

Catchbasins have been found to be effective in removing pollutants associated with coarser runoff solids (2,3). High reductions in total and suspended solids (SS) (up to 44% reduction, depending on the inflowing water rate) were indicated by a number of prior studies. While relatively few pollutants are associated with these coarser solids, their removal will decrease maintenance of the other chambers of the MCTT. The size of the MCTT catchbasin sump is controlled by three factors: the runoff flow rate, the suspended solids (SS) concentration in the runoff, and the desired frequency at which the catchbasin will be cleaned so as not to sacrifice efficiency. Figure 2 is a plot of the accumulation of SS versus accumulative rain for approximately sizing the catchbasin.

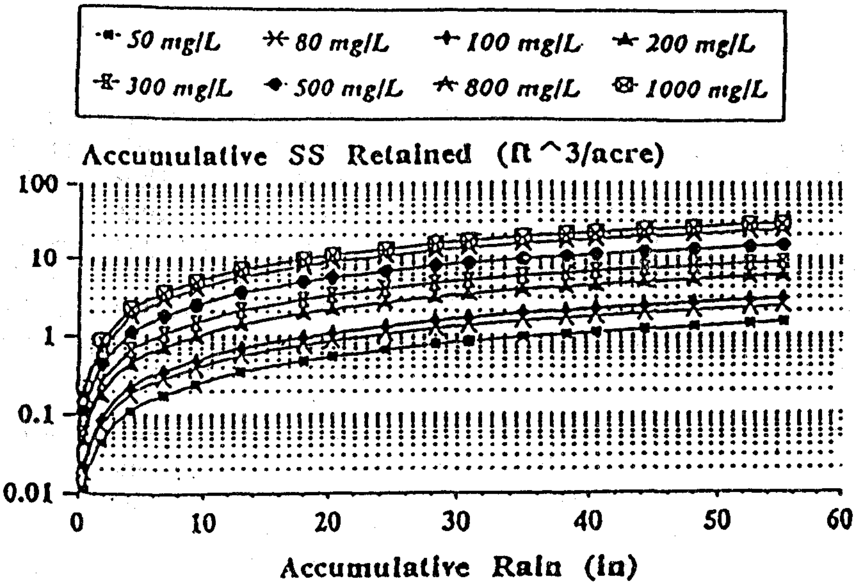

Figure 2. Accumulation of suspended solids in catchbasin sump.

The main settling chamber mimics completely mixed settling column bench-scale tests and uses a treatment ratio of depth to time for removal estimates. In addition to housing plate or tube settlers, the main settling chamber contains floating sorbent "pillows" to trap floating grease and oil and contains a fine bubble diffuser. The settling time in the main settling chamber usually ranges from 20 to 70 hours.

For the pilot-scale MCTT set up to capture runoff from a parking and vehicle service area on the campus of the University of Alabama at Birmingham, the catchbasin/grit chamber is a 25 centimeter (cm) vertical PVC pipe containing about 6 liters (L) of 3 cm diameter packing column spheres. The main settling chamber is about 1.3 square meters (m^2) in area and 1 meter (m) deep which with a 48 to 72 hour settling time should result in a median toxicity reduction of about 90 to 95%. The filter chamber is about 1.5 m^2 in area and contains 0.5 m of sand and peat directly on 0.15 m of sand over a fine plastic screen and coarse gravel that covers the underdrain. A Gunderboom™ filter fabric also covers the top of the filter media to distribute the water over the filter surface by reducing the water infiltration rate through the filter and to provide additional pollutant capture.

During a storm event, runoff from the parking lot is pumped into the catchbasin/grit chamber automatically. During filling, an air pump supplies air to aeration stones located in the main settling chamber. When the settling chamber is full, all pumps and samplers cease. After a quiescent settling period of up to 72 hours water is pumped through the filter media and discharged.

In evaluating the pilot scale MCTT located in Birmingham, samples are collected before and after each chamber of the device. To better estimate fate and treatability of toxicants, samples are partitioned into filterable ("dissolved") and non-filterable ("particulate") components before being analyzed for a wide range of toxicants using detection limits from about 1 to 10 micrograms per liter (µg/L) and conventional pollutants. Constituents being analyzed include heavy metals (copper, cadmium, lead, and zinc) and organics (phenols, PAHs, phthalate esters, herbicides, and pesticides). Particle size distributions, using a Coulter Multi-Sizer IIe™, are also being made, in addition to conventional analyses for COD, major ions, nutrients, suspended and dissolved solids, turbidity, color, pH, and conductivity. Samples are also screened using the Microtox™ toxicity test to measure relative reductions in toxicity.

RESULTS

For runoff of 13 storm events treated by the MCTT over a period of four months, 10 were found to be above a threshold value of 12% as measured using the Microtox™ test . The reduction in toxicity ranged from 70 to 100%, with a median reduction of 90% which was the value predicted by initial design. The toxicity of the filtered samples were also substantially reduced (50 to 100%, median of 88%). As expected, almost all of the total sample toxicity reduction occurred in the sand and peat filter and in the main settling chamber. This can be seen in Figure 3 which is a plot of relative toxicity through the MCTT for runoff treated from each storm event. The results from the specific metal and organic analyses are not yet available, but these toxicity data indicate excellent toxicant removals, as expected based on earlier bench-scale tests.

Overall COD reductions varied substantially ranging from 0 to 100% (median of 53%) with influent concentrations ranging from 0 to 197 mg/L (median of 56 mg/L). Most of these reductions occurred in the filtering chamber. Dissolved COD reductions also showed substantial variations with concentration increases occurring in the filtering unit for some events and most of the dissolved COD reductions occurring in the main settling chamber.

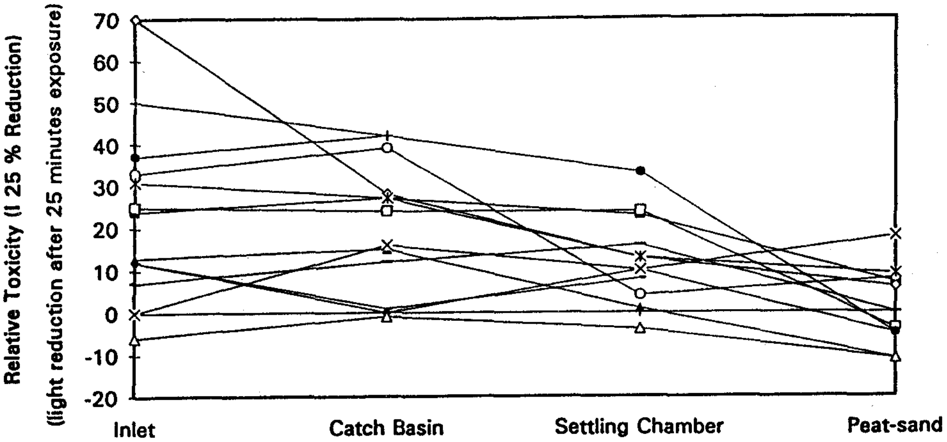

Figure 3. Relative toxicity through MCTT.

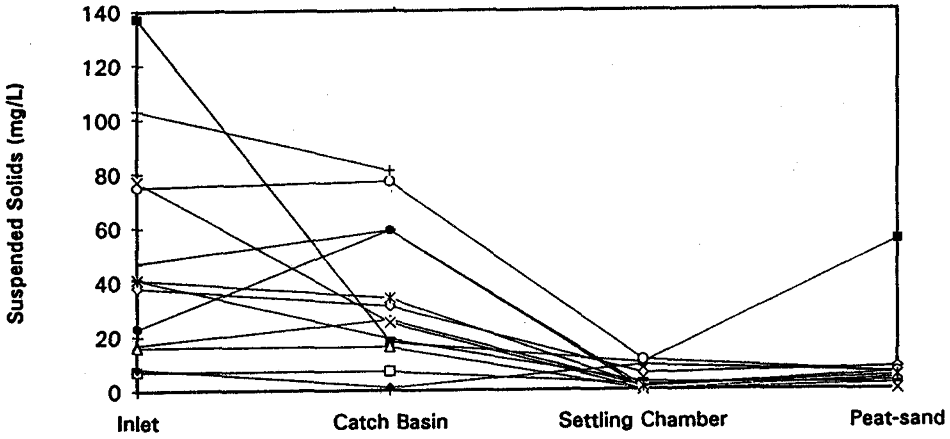

Figure 4. Suspended solids concentration through MCTT.

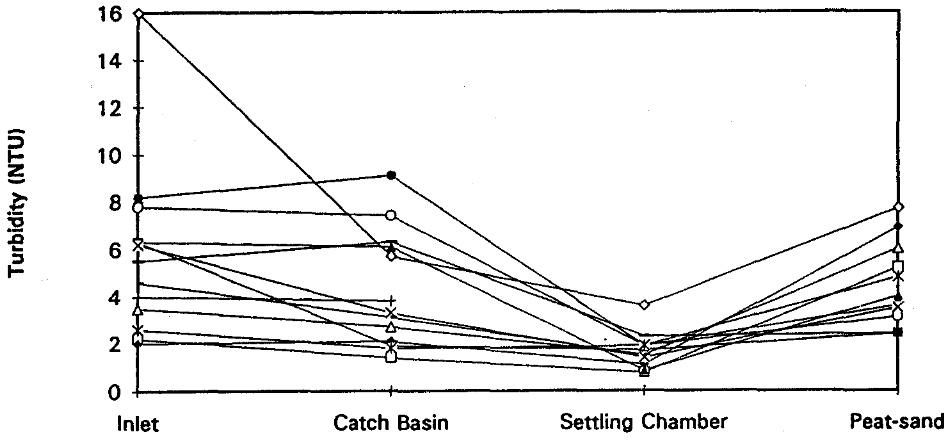

Figure 5. Turbidity changes through MCTT.

Suspended solids reductions ranged from 25 to 100% overall for samples with concentrations ranging from 7 to 137 mg/L. This includes increases that occurred in the sand and peat filter due to limited media washout during filtration. The first filtration run resulted in the largest washout, as would be expected. The suspended solids reductions before the filter was much greater, being about 70 to 100%. Figure 4 shows suspended solids concentrations through the MCTT for each storm. Turbidity, shown in Figure 5, and color also experienced substantial increases during the filtration process (turbidity going from 2 to 16 NTU in the influent to the complete treatment unit to effluent values of 2.4 to 7.7 NTU, still relatively low, and color going from 20 to 58 HACH units in the influent to 30 to 100 HACH units in the effluent). The peat also apparently caused a reduction in pH, from 6.29 to 7.27 in the filter influent to 5.93 to 6.78 in the effluent.

CONCLUSIONS

This research examined the design of a multi-chambered tank to collect and treat stormwater runoff from critical urban source areas, including gas stations, oil change facilities, transmission repair shops, and other auto repair facilities. The collected runoff will first be treated in a catchbasin chamber where larger particles will be removed by settling. The water would then flow into a main settling chamber containing oil and grease sorbent material where it will undergo a much longer treatment period (20 to 70 hours) to remove finer particles and to remove oil residues. In practice, the MCTT would be utilized as a subterranean unit for space limited sites.

These preliminary results show that the treatment unit is providing substantial reductions in stormwater toxicants (both in particulate and filtered phases), organics, and suspended solids. Slight increases in turbidity and color and about a unit in pH reduction also occurred during the filtration step. The filter unit appears to be responsible for most of the toxicity reductions. However, the main settling chamber also resulted in substantial reductions in the dissolved toxicity fraction, total and dissolved COD, suspended solids, turbidity, and color. The catchbasin/ grit chamber also showed suspended solids reductions. The use of the MCTT is seen to be capable of reducing a broad range of stormwater pollutants that have been shown to cause substantial receiving water problems (4).

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GROUNDWATER CONTAMINATION FROM STORMWATER INFILTRATION

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INTRODUCTION

The research summarized here was conducted during the first year of a 3-yr cooperative agreement (CR819573) to identify and control stormwater toxicants, especially those adversely affecting groundwater. The purpose of this research effort was to review the groundwater contamination literature as it relates to stormwater.

Prior to urbanization groundwater is recharged by rainfall-runoff and snowmelt infiltrating through pervious surfaces including grasslands and woods. This infiltrating water is relatively uncontaminated. Urbanization, however, reduces the permeable soil surface area through which recharge by infiltration occurs. This results in much less groundwater recharge and greatly increased surface runoff. In addition the waters available for recharge carry increased quantities of pollutants. With urbanization, waters having elevated contaminant concentrations also recharge groundwater including effluent from domestic septic tanks, wastewater from percolation basins and industrial waste injection wells, infiltrating stormwater, and infiltrating water from agricultural irrigation. The areas of main concern that are covered by this paper are: the source of the pollutants, stormwater constituents having a high potential to contaminate groundwater, and the treatment necessary for stormwater.

METHODOLOGY

An extensive literature review of stormwater pollutants that have the potential to contaminate groundwater was collected by searching prominent databases. This paper, a condensation of a larger, more detailed report (Pitt *et al.* 1994), addresses the potential groundwater problems associated with stormwater toxicants and describes how conventional stormwater control practices can reduce these problems. Potential problem pollutants were identified, based on their mobility through the unsaturated soil zone above groundwater, their abundance in stormwater, and their treatability before discharge. This information was used with earlier EPA research results of toxicants in urban runoff sheet flows (Pitt and Field 1990) to identify the possible sources of these potential problem pollutants. Recommendations were also made for stormwater infiltration guidelines in different areas and monitoring that should be conducted to evaluate a specific stormwater for its potential to contaminate groundwater.

RESULTS

Sources of Pollutants. Tables 1 and 2 summarize toxicant concentrations and likely sources or locations having some of the highest concentrations found during an earlier phase of this EPA-funded research (Pitt and Field 1990). The detection frequencies for the heavy metals are close to 100% for all source areas, and the detection frequencies for the organics ranged from about 10% to 25%. Vehicle service areas had the greatest frequencies and/or quantities of observed organics.