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Stormwater Treatment At Critical Areas

The Multi-Chambered Treatment Train (MCTT)

By

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EPA Project Summary

Stormwater Treatment At Critical Areas
Vol. 1: The Multi-Chambered Treatment Train (MCTT)

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This is the first volume for this report series and describes the work conducted during the early years of this project through recent full-scale tests. Other volumes in this report series describe the results of field investigations of storm drain inlet devices and the use of filter media for stormwater treatment.

The first project phase investigated typical toxicant concentrations in stormwater, the origins of these toxicants, and storm and land-use factors that influenced these toxicant concentrations. Nine percent of the 87 stormwater source area samples analyzed were considered extremely toxic (using the Azur Environmental Microtox ā toxicity screening procedure). Thirty-two percent of the samples exhibited moderate toxicity, while fifty-nine percent of the samples had no evidence of toxicity. Only a small fraction of the organic toxicants analyzed were frequently detected, with 1,3-dichlorobenzene and fluoranthene the most commonly detected organics investigated (present in 23 percent of the samples). Vehicle service and parking area runoff samples had many of the highest observed concentrations of organic toxicants. All metallic toxicants analyzed were commonly found in all samples analyzed.

The second project phase investigated the control of stormwater toxicants using a variety of conventional bench-scale treatment processes. Toxicity changes were monitored using the Azur Environmental Microtox ā bioassay screening test. The most beneficial treatment tests included settling for at least 24 h (up to 90 percent reductions), screening and filtering through at least 40 µm screens (up to 70 percent reductions), and aeration and/or photo-degradation for at least 24 h (up to 80 percent reductions). Because many samples exhibited uneven toxicity reductions for the different treatment tests, a treatment train approach was selected for testing during the third project phase.

The third project phase included testing of a prototype treatment device (the multi-chambered treatment train, or MCTT). However, the information provided in this report can also be used to develop other stormwater treatment devices. This device, through pilot and initial full-scale testing, has been shown to remove more than 90% of many of the stormwater toxicants, in both particulate and filtered forms. The MCTT is most suitable for use at relatively small and isolated

paved critical source areas, from about 0.1 to 1 ha (0.25 to 2.5 acre) in area. These areas would include vehicle service facilities (gas stations, car washes, oil change stores, etc.), convenience store parking areas and areas used for equipment storage, along with salvage yards. The MCTT is an underground device that has three main chambers: an initial grit chamber for trapping of the largest sediment and release of most volatile materials; a main settling chamber (providing initial aeration and sorbent pillows) for the trapping of fine sediment and associated toxicants and floating hydrocarbons; and a sand and peat mixed media "filter" (sorption-ion exchange) unit for the reduction of filterable toxicants. A typical MCTT requires between 0.5 and 1.5 percent of the paved drainage area, which is about 1/3 of the area required for a well-designed wet detention pond.

A pilot-scale MCTT was constructed in Birmingham, AL, and tested over a six month monitoring period. Two additional full-scale MCTT units were constructed and were monitored as part of Wisconsin's 319 grant from the U.S. EPA. During monitoring of 13 storms at a parking facility, the pilot-scale MCTT was found to have the following overall median reduction rates: 96% for total toxicity, 98% for filtered toxicity, 83% for SS, 60% for COD, 40% for turbidity, 100% for lead, 91% for zinc, 100% for n-Nitro-di-n-proplamine, 100% for pyrene, and 99% for bis (2-ethyl hexyl) phthalate. The color was increased by about 50% due to staining from the peat and the pH decreased by about one-half pH unit, also from the peat media. Ammonia nitrogen was increased by several times, and nitrate nitrogen had low reductions (about 14%). The MCTT therefore operated as intended: it had very effective reduction rates for both filtered and particulate stormwater toxicants and SS. Increased filterable toxicant reductions were obtained in the peat/sand mixed media sorption-ion exchange chamber, at the expense of increased color, lowered pH, and depressed COD and nitrate reduction rates. The preliminary full-scale test results substantiate the excellent reductions found during the pilot-scale tests, while showing better control of COD, filterable heavy metals, and nutrients, and less detrimental effects on pH and color.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Runoff from paved parking and storage areas, and especially gas station areas, has been observed to be contaminated with concentrations of many critical pollutants. These paved areas are usually found to contribute most of the pollutant loadings of toxicants to stormwater outfalls. Polycyclic aromatic hydrocarbons (PAHs), the most commonly detected toxic organic compounds found in urban runoff, along with heavy metals, are mostly associated with automobile use, especially during the starting of vehicles.

Numerous manufacturers have developed small prefabricated separators to remove oils and solids from runoff. These separators are rarely specifically designed and sized for stormwater discharges, but usually consist of modified grease and oil separators. The solids are intended to settle within these separators, either by free fall or by counter-current or cross-current lamellar separation. Many of these separators have been sold and installed in France, especially along highways. These have been found to be greatly under-sized for the actual flows expected and they are not designed to be easily cleaned. In addition, the basic designs assume free floating oils that are relatively rare in stormwater. It is felt that these devices would perform much better if apprporiately sized and if cleaned frequently. However, their oil removal efficiencies will still be quite small because of the nature of petroleum contamination in stormwater.

The Multi-Chambered Treatment Train (MCTT) was developed to specifically address many of the above concerns. It was developed and tested with specific stormwater conditions in mind, plus it has been tested at several sizes for the removal of stormwater pollutants of concern. Figure 1 shows a general cross-sectional view of a MCTT. It 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 is then pumped to the final chamber at a slow rate to maximize pollutant reductions. The final chamber contains a mixed media (sand and peat) slow filter/ion exchange device, with a filter fabric top layer. The MCTT is typically sized to totally contain all of the runoff from a 6 to 20 mm (0.25 to 0.8 in) rain, depending on interevent time, typical rain size, and rain intensity.

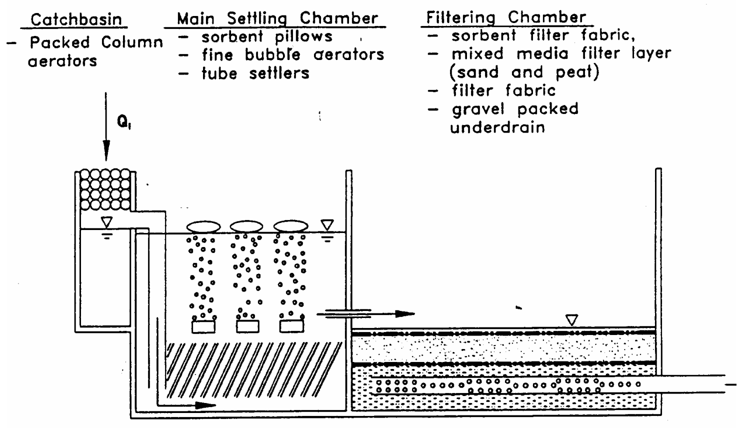

Figure 1. **General Schematic of the Multi-Chambered Treatment Train (MCTT)**

A pilot-scale MCTT was constructed and tested in Birmingham, Alabama, at a parking and vehicle service area on the campus of the University of Alabama at Birmingham. The catchbasin/grit chamber is a 25-cm vertical PVC pipe containing about 6 L of 3-cm diameter packing column spheres. The main settling chamber is about 1.3 m^2 in area and 1 m deep which with a 72-hour settling time was expected to result in a median toxicity reduction of about 90%. 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. Samples are collected before and after each chamber of the device and were partitioned into dissolved and particulate components before being analyzed for a wide range of toxicants, as listed on Table 1.

Results

Observed Performance of the Pilot-Scale MCTT

Table 2 summarizes some of the significant percentage changes in concentrations of the constituents as they passed through each chamber (settling chamber, filter, and overall) of the pilot-scale MCTT. No data is shown for the catchbasin/grit chamber because of the lack of significant concentration changes observed. Figures 2 and 3 are example plots showing the concentrations of suspended solids and unfiltered zinc as the stormwater passed through the MCTT. The four data locations on these plots correspond to the four sampling locations on the MCTT. The sample location labeled “inlet” is the overall inlet to the MCTT (and the inlet to the catchbasin/grit chamber). The location labeled “catch basin” is the effluent from the catchbasin (and inlet to the main settling chamber). Similarly, the location labeled “settling chamber” is the outlet from the settling chamber (and the inlet to the sand/peat chamber). Finally, the location labeled “peat-sand” is the outlet from the sand/peat chamber (and the outlet from the MCTT). The slopes of the lines indicate the relative removal rates (mg/L reduction) for each individual major unit process in the MCTT. If the lines are all parallel between two sampling locations, then the removal rates are similar. If a line has a positive slope, then a concentration increase occurred. If the lines have close to zero slope, then little removal has occurred (as for the catchbasin/grit chamber for most constituents and samples).

Table 1. **Compounds Analyzed during MCTT Pilot-Scale Testing**

Compound Category	Compounds	Testing Methodology (Detection Limits)
Semi-Volatile	Polycyclic Aromatic Hydrocarbons	GC/MSD – particulate and dissolved

Organics (BNA Extractable)	Phthalate Esters Phenols	fractions (1 to 10 µg/L MDL)
Pesticides	Pesticides	GC/ECD – particulate and dissolved fractions (0.01 to 0.1 µg/L MDL)
Heavy Metals	Cadmium Copper Lead Zinc	GFAA – particulate and dissolved fractions (1 to 5 µg/L MDL)
Toxicity	Toxicity Screening Test	Microtox™ - particulate and dissolved fractions
Nutrients	Nitrite + Nitrate Ammonia Phosphate	Ion Chromatography – dissolved fraction (1 mg/L MDL)
Major Ions	Cations (Ca, Mg, K, Na, Li) Anions (Cl, SO_4, F)	Ion Chromatography – dissolved fraction (1 mg/L MDL)
Conventional Pollutants	Chemical Oxygen Demand Color Specific Conductance Hardness Alkalinity pH Turbidity Solids (total, dissolved, suspended, volatile)	
Particle Size	Particle Size Distribution (1 – 128 µm)	Coulter Multisizer IIe

Table 2. **Median Observed Percentage Changes in Constituent Concentrations**

	Main Settling Chamber	Sand/Peat Chamber	Overall Device
Common Constituents			
Total solids	31%	2.6%	32%
Suspended solids	91	-44	83
Turbidity	50	-150	40
pH	-0.3	6.7	7.9
COD	56	-24	60
Nutrients			
Nitrate	27	-5	14
Ammonia	-155	-7	-400
Toxicants			
Microtox™ (unfiltered)	18	70	96
Microtox™ (filtered)	64	43	98
Lead	89	38	100
Zinc	39	62	91

n-Nitro-di-n-propylamine	82	100	100
Hexachlorobutadiene	72	83	34
Pyrene	100	n/a	100
Bis (2-ethylhexyl) phthalate	99	-190	99

The suspended solids trends (Figure 2) show the significant reductions in the suspended solids concentrations through the main settling chamber, with no removal occurring in the catchbasin/grit and sand/peat chambers. However, the first storm had a significant increase in suspended solids concentration as it passed through the peat due to flushing of fines from the incompletely washed media. This contributed to the negative removals of the filter chamber. For the other monitored storms, removal occurred (although the percent reduction was small). The relative toxicity changes (as measured using the Microtox™ unit) (not shown) indicate significant reductions in toxicity, especially for the moderate and highly toxic samples. No effluent samples were considered toxic (all effluent samples were "non toxic", or causing less than a 20% light reduction after 25 minutes of exposure using the Azur Microtox™ screening toxicity test). Figure 3, for zinc removal, shows significant and large reductions in concentrations, mostly through the main settling chamber (corresponding to the large fraction of stormwater toxicants found in the particulate sample fraction). Zinc also had further important decreases in concentrations in the peat/sand chamber, where removal of much of the remaining dissolved zinc in the stormwater occurred.

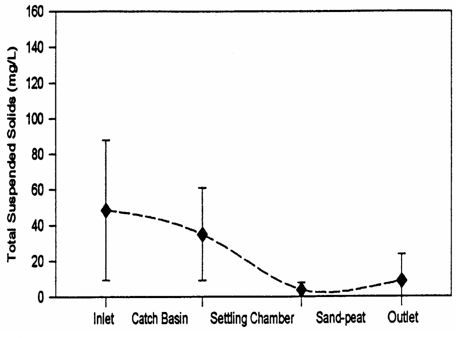

Figure 2. **MCTT Performance for Suspended Solids**

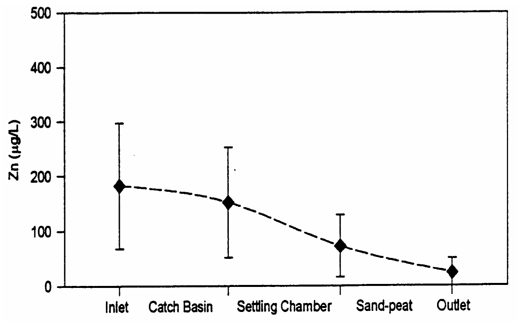

Figure 3. **MCTT Performance for Unfiltered Zinc**

Preliminary Full-Scale MCTT Test Results

Preliminary results from the full-scale tests of the MCTT in Wisconsin were encouraging and corroborate the high levels of treatment observed during the Birmingham pilot-scale tests. Table 3 shows the treatment levels that have been observed during seven tests in Minocqua (during one year of operation) and 15 tests in Milwaukee (also during one year of operation), compared to the pilot-scale Birmingham test results (13 events). These data indicate high reductions for SS (83 to 98%), COD (60 to 86%), turbidity (40 to 94%), phosphorus (80 to 88%), lead (93 to 96%), zinc (90 to 91%), and for many organic toxicants (generally 65 to 100%). The reductions of dissolved heavy metals (filtered through 0.45 μm filters) were also all greater than 65% during the full-scale tests. None of the organic toxicants were ever observed in effluent water from either full-scale MCTT, even considering the excellent detection limits available at the Wisconsin State Dept. of Hygiene Laboratories that conducted the analyses. The influent organic toxicant concentrations were all less than 5 μg/L and were only found in the unfiltered sample fractions. The Wisconsin MCTT effluent concentrations were also very low for all of the other constituents monitored: <10 mg/L for SS, <0.1 mg/L for phosphorus, <5 μg/L for cadmium and lead, and <20 μg/L for copper and zinc. The pH changes in the Milwaukee MCTT were much less than observed during the Birmingham pilot-scale tests, possibly because of added activated carbon in the final chamber in Milwaukee. Color was also much better controlled in the full-scale Milwaukee MCTT.

Discussion

The Milwaukee installation is at a public works garage and serves about 0.1 ha (0.25 acre) of pavement. This MCTT was designed to withstand very heavy vehicles driving over the unit. The estimated cost was $54,000 (including a $16,000 engineering cost), but the actual cost was $72,000. The high cost was likely due to uncertainties associated with construction of an unknown device by the contractors and because it was a retrofit installation. It therefore had to fit within very tight site layout constraints. As an example, installation problems occurred due to sanitary sewerage not being accurately located as mapped. The Minocqua site was a 1 ha (2.5 acre) newly paved parking area serving a state park and commercial area. It was located in a grassed area and was also a retrofit installation, designed to fit within an existing storm drainage system. The installed cost of this MCTT was about $95,000.

Table 3. **Preliminary Performance Information for Full-Scale MCTT Tests, Compared to Birmingham Pilot-Scale MCTT Results (median reductions and median effluent quality)**

	Milwaukee MCTT (15 events)	**Minocqua MCTT (7 events)**	**Birmingham MCTT (13 events)**
suspended solids	98 (<5 mg/L)	85 (10 mg/L)	83 (5.5 mg/L)
volatile suspended solids	94 (<5 mg/L)	na[a]	66 (6 mg/L)
COD	86 (13 mg/L)	na	60 (17 mg/L)
turbidity	94 (3 NTU)	na	40 (4.4 NTU)
pH	-7 (7.9 pH)	na	8 (6.4 pH)

ammonia	47 (0.06 mg/L)	na	-210 (0.31 mg/L)
nitrates	33 (0.3 mg/L)	na	24 (1.5 mg/L)
Phosphorus (total)	88 (0.02 mg/L)	80 (<0.1 mg/L)	nd[b]
Phosphorus (filtered)	78 (0.002 mg/L)	na	nd
Microtox® toxicity (total)	na	na	100 (0%)
Microtox® toxicity (filtered)	na	na	87 (3%)
Cadmium (total)	91 (0.1 µg/L)	na	18 (0.6 µg/L)
Cadmium (filtered)	66 (0.05 µg/L)	na	16 (0.5 µg/L)
Copper (total)	90 (3 µg/L)	65 (15 µg/L)	15 (15 µg/L)
Copper (filtered)	73 (1.4 µg/L)	na	17 (21 µg/L)
Lead (total)	96 (1.8 µg/L)	nd (<3 µg/L)	93 (<2 µg/L)
Lead (filtered)	78 (<0.4 µg/L)	na	42 (<2 µg/L)
Zinc (total)	91 (<20 µg/L)	90 (15 µg/L)	91 (18 µg/L)
Zinc (filtered)	68 (<8 µg/L)	na	54 (6 µg/L)
benzo(a)anthracene	>45 (<0.05 µg/L)	>65 (<0.2 µg/L)	nd
benzo(b)fluoranthene	>95 (<0.1 µg/L)	>75 (<0.1 µg/L)	nd
dibenzo(a,h)anthracene	89 (<0.02 µg/L)	>90 (<0.1 µg/L)	nd
fluoranthene	98 (<0.1 µg/L)	>90 (<0.1 µg/L)	100 (<0.6 µg/L)
indeno(1,2,3-cd)pyrene	>90 (<0.1 µg/L)	>95 (<0.1 µg/L)	nd
phenanthrene	99 (<0.05 µg/L)	>65 (<0.2 µg/L)	nd
pentachlorophenol	na	na	100 (<1 µg/L)
phenol	na	na	99 (<0.4 µg/L)
pyrene	98 (<0.05 µg/L)	>75 (<0.2 µg/L)	100 (<0.5 µg/L)

na[a] : not analyzed
nd[b]: not detected in most of the samples

It is anticipated that MCTT costs could be substantially reduced if designed to better integrate with a new drainage system and not installed as a retrofitted stormwater control practice. Plastic tank manufactures have also expressed an interest in preparing pre-fabricated MCTT units that could be sized in a few standard sizes for small critical source areas. It is expected that these pre-fabricated units would be much less expensive and easier to install than the custom-built units tested to date.

Design of the MCTT

Catchbasin. Catchbasins have been found to be effective in removing pollutants associated with coarser runoff solids. Moderate reductions in total and suspended solids (up to about 45%, depending on the inflow water rate) have been indicated by prior EPA studies. While few pollutants are associated with these coarser solids, their removal decreases maintenance problems of the other chambers. 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.

Main Settling Chamber. 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 plate or tube settlers, the main settling chamber also contains floating sorbent “pillows” to trap floating grease and oil and a fine bubble diffuser. The settling time in the main settling chamber typically ranges from 1 to 3 days.

Peat/Sand Ion Exchange Chamber. Based on literature descriptions of stormwater filtration, it was determined that a mixed media sand and peat “filter” should be used as a polishing unit after the main settling chamber. This unit provides additional toxicant reductions, especially for filtered forms of the organics and metals. The surface hydraulic loading rate of this filter/ion exchange chamber should be between 1.5 and 6 m per day (5 and 20 ft per day). The 50%/50% mixture of the sand and peat should have a depth of 0.5 m (18 in), resting on 0.15 m of sand. The sand used in the testing had the following size: 71% finer than #30 sieve (0.6 mm), 65% finer than #40 sieve (0.425 mm), and 0.5% finer than #50 sieve (0.18 mm). The effective size (D_{10}) of the sand was 0.31 mm and the uniformity coefficient (D_{60}/D_{10}) was 1.45. A filter fabric was used to separate these layers from the gravel and perforated pipe underdrain. In order to facilitate surface spreading of water on top of the media and to prevent channelization, another filter fabric (Gunderboom™) was placed on top of the media.

Example Design

The design of the MCTT is very site specific, since it is highly dependent on local rains (rain depths, rain intensities, and interevent times). A computer model was therefore developed to determine the amount of annual rainfall treated, the toxicity reduction rate for each individual storm, and the overall toxicity reduction associated with a long series of rains for different locations in the U.S. Table 4 gives the simulation results for the sizing of the main settling chamber for selected cities. The rain depths range from 180 mm (7.1 in) for Phoenix to 1500 mm (60 in) in New Orleans per year.

Table 4. **MCTT Settling Chamber Sizes (48 hr hold times, except as noted; 1.5 m settling depths)**

City	Annual Rain Depth (mm)	Runoff Capacity (mm) for 70% Toxicant Control	Runoff Capacity (in) for 90% Toxicant Control
Phoenix, AZ	180	6.35 (24 hours)	8.89
Reno, NV	191	5.08 (18 hours)	5.08
Bozeman, MT	325	6.35	10.2
Los Angeles, CA	378	7.62	11.4
Rapid City, SD	414	5.08 (18 hours)	5.59
Minneapolis, MN	671	8.13	2.70
Dallas, TX	749	2.70	24.4
Milwaukee, WI	785	9.14	16.5

Austin, TX	800	5.59 (18 hours)	8.13
St. Louis, MO	861	7.62	12.5
Buffalo, NY	953	8.89	2.70
Seattle, WA	986	6.35	10.2
Newark, NJ	1074	12.2	24.4
Portland, ME	1105	10.7	18.3
Atlanta, GA	1234	14.0	24.1
Birmingham, AL	1384	9.40	13.5
Miami, FL	1463	10.2	18.5
New Orleans, LA	1516	20.3	23.4

The overall range in MCTT size varies by more than three times for the same level of treatment for the different cities. The required size of the main settling chamber generally increases as the annual rain depth increases. However, the interevent period and the rain depth for individual rains determine the specific runoff treatment volume requirement. As an example, Seattle requires a much smaller MCTT than other cities having similar annual total rains because of the small rain depths for each rain. Rapid City requires a smaller MCTT, compared to Los Angeles, because Los Angeles has much larger rains when it does rain. Similarly, Dallas requires an unusually large MCTT because of its high rain intensities and large individual rains, compared to upper Midwest cities that have similar annual rain depths.

In all cases, the most effective holding time is 2 days for 90% toxicant control (for the 1.5 m, or 5 ft, settling chamber depth). In most cases, a toxicity removal goal of about 70% in the main settling chamber is probably the most cost effective choice, considering the additional treatment that will be provided in the sand/peat chamber. Figure 4 shows the runoff volume requirements for an MCTT having 0.6, 1.5, 2.1, or 2.7 m (2, 5, 7, or 9 foot) settling depths in the main settling chamber for Milwaukee, WI. This example shows that the required runoff depth storage capacity increases as the depth of the main settling chamber increases. As an example, for 90% toxicant control at Milwaukee, the storage requirement for a 1.5 m (5 ft) settling depth was shown to be 16.5 mm (0.65 in) on Table 2. Figure 4 indicates that the required storage volume for a 0.6 m (2 ft) settling chamber would only be 14 mm (0.55 in) of runoff, while it would increase to 19 mm (0.75 in) of runoff for a 2.1 m (7 ft) settling depth and to 23 mm (0.9 in) for a 2.7 m (9 ft) settling depth. The greater depths require more time for the stormwater particulates to settle and be trapped in the chamber, while the shallower tanks require a greater surface area. The best tank design for a specific location is based on site specific conditions, especially the presence of subsurface utilities or groundwater and hydraulic grade line requirements. A tank having a large surface area is usually much more expensive, even though the required volume is less, especially if heavy traffic will be traveling over the tank.

A combination of a 48 hour holding time and 11 mm (0.45 in) runoff storage volume, for a 1.5 m (5ft.) settling depth, would satisfy a 75% treatment goal (in the main settling chamber) for Milwaukee conditions, as shown on Figure 4. This 11-mm runoff volume corresponds to a rain depth of about 13 mm

(0.51 in) for pavement (Pitt 1987). The 11-mm runoff storage volume corresponds to a live chamber volume of 22 m^3 (770 ft^3) and a surface area of 10 m^2 (110 ft^2) for a 0.2 ha (0.5 acre) paved drainage area. The surface area of the MCTT would therefore be about 0.5 percent of the drainage area. The main settling chamber would capture and treat about 80% of the annual runoff at a 95% toxicity reduction level, resulting in an annual toxicity reduction of about 75% (0.8 X 0.95). The height of the main settling chamber would need to be greater than this because about 0.7 m (two feet) of "dead" storage must be added to provided for standing water below the outlet orifice (or pump) which would keep the inclined tubes submerged to help prevent scour. About a 0.2 m (6 inch) height is also needed below the inclined tubes for the flow distribution system and for long-term storage of fine material that will accumulate.

Additional treatment beyond the 75% level would occur in the filter/ion exchange chamber. The effluent from the main settling chamber would be directed towards a mixed peat/sand filter/ion exchange chamber, which must provide a surface hydraulic loading rate of between 1.5 and 6 m per day (5 and 20 ft per day), and have a depth of at least 0.5 m (18 in). In addition to the pumped effluent, any excess runoff after the main settling chamber is full could also be directed towards the filter.

Each of the treatment chambers need to be vented, mosquito proofed, and be easily accessible for maintenance. The device needs to be inspected, the initial catchbasin should be cleaned, and the sorbent pillows should be exchanged, at least every six months. It is expected that the ion exchange media should last from 3 to 5 years before requiring replacement (as determined during our filtration experiments).

Conclusions

The development and testing of the MCTT showed that the treatment unit provided substantial reductions in stormwater toxicants (both in particulate and filtered phases), and suspended solids. Increases in color and a slight decrease in pH also occurred during the filtration step at the pilot-scale unit. The main settling chamber resulted in substantial reductions in total and dissolved toxicity, lead, zinc, certain organic toxicants, suspended solids, COD, turbidity, and color. The filter/ion exchange unit is also responsible for additional filterable toxicant reductions. However, the catchbasin/grit chamber did not indicate any significant improvements in water quality, although it is an important element in reducing maintenance problems by trapping bulk material. 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.

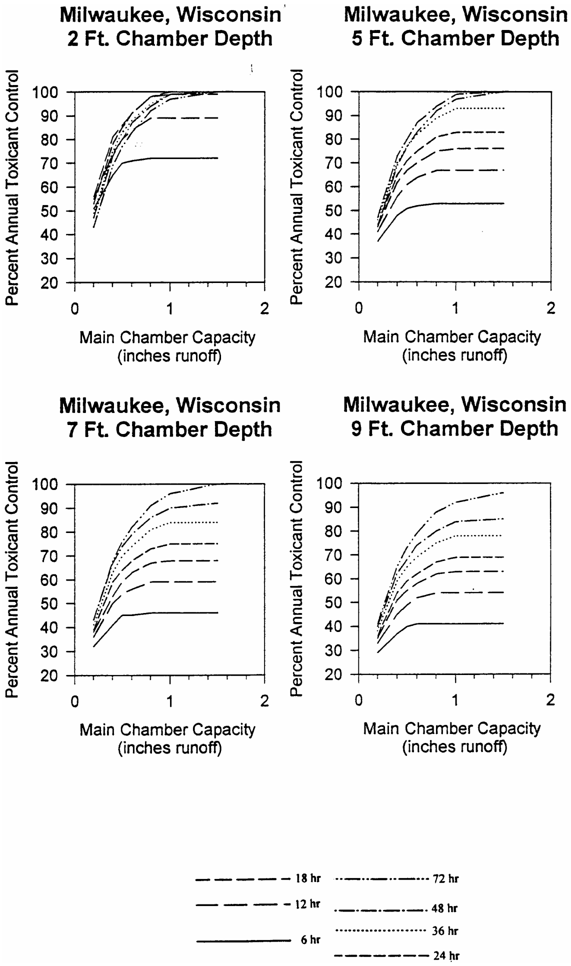

Figure 4. **MCTT Main Settling Chamber Required Capacities – Milwaukee, WI**

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Robert Pitt, Brian Robertson, Patricia Barron, Ali Ayyoubi, and Shirley Clark were with the Department of Civil and Environmental Engineering, the University of Alabama at Birmingham. Birmingham, AL 35294 when conducting this research.
***Richard Field** is the EPA Project Officer (see below).*

The complete report, entitled " Stormwater Treatment At Critical Areas; Vol. 1: The Multi-Chambered Treatment Train (MCTT)*," (Order No. PB98 - XXXXXX/XX; Cost: $XX.XX, subject to change) will be available from*

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