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STORMWATER TREATMENT AT CRITICAL SOURCE AREAS USING THE MULTI-CHAMBERED TREATMENT TRAIN (MCTT)

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Abstract

The Multi-Chambered Treatment Train (MCTT) was developed to control toxicants in stormwater from critical source areas. The MCTT is most suitable for use at relatively small areas, about 0.1 to 1 ha in size, such as vehicle service facilities, convenience store parking areas, equipment storage and maintenance areas, and salvage yards. The MCTT is an underground device and is typically sized between 0.5 to 1.5 percent of the paved drainage area. It is comprised of three main sections, an inlet having a conventional catchbasin with litter traps, a main settling chamber having lamella plate separators and oil sorbent pillows, and a final chamber having a mixed sorbent media (usually peat moss and sand). During monitoring, the pilot-scale MCTT provided median reductions of >90% for toxicity, lead, zinc, and most organic toxicants. Suspended solids was reduced by 83% and COD was reduced by 60%. The full-scale tests substantiated these excellent reductions.

Introduction

The information presented in this paper is based on the results from a series of related projects sponsored by the US EPA (Pitt, *et al.* 1996, Clark and Pitt 1999, Pitt, *et al*. 1999, and Clark 2000).

Phase 1 of this research included analyzing stormwater samples collected from many source areas in Birmingham, AL. Only a small fraction of the analyzed runoff samples had detected organic toxicants (as is typical for stormwater evaluations), but the majority of samples analyzed had detected heavy metals (Pitt, *et al*. 1995 and Pitt, *et al*. 1999). The study also confirmed that many toxicants are associated with particulate matter in the runoff. Industrial/commercial areas are likely to be the most significant pollutant source areas, with the highest toxicant concentrations and most frequent occurrences found at vehicle service and parking/storage areas. The duration of the antecedent dry period before a storm and the intensity of the storm event were found to be significant factors influencing the concentrations of most of the toxicants detected. These critical areas were further evaluated during later treatability tests. The treatability study (phase 2) found that settling, screening, and aeration and/or photo-degradation treatments showed the greatest potential for toxicant reductions, as measured by the reduction in toxicity of the samples, using the Microtox™ toxicity screening test. The third project phase examined the toxicant reduction benefits of large-scale applications of the most suitable treatment unit processes investigated.

The third phase of this research examined the use of a multi-chambered treatment tank (MCTT) to collect and treat runoff from critical stormwater source areas, including gas stations, oil change facilities, transmission repair shops, and other auto repair facilities. In an MCTT, the collected runoff is first treated in a catchbasin chamber where larger particles are removed by settling. The water then flows into a main settling chamber containing oil sorbent material where it undergoes a much longer treatment period (24 to 72 h) to remove finer particles and associated pollutants. The final chamber contains mixed media (typically comprising equal amounts of sand and peat). This final chamber acts as a polishing "filter" to remove some of the filterable toxicants from the runoff by other processes, such as ion exchange and sorption.

The pilot- and full-scale tests showed that the MCTT provides 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 final treatment step when using peat. The main settling chamber provided substantial reductions in total and dissolved toxicity, lead, zinc, certain organic toxicants, SS, COD, turbidity, and color. The sand-peat chamber also provided additional filterable toxicant reductions. However, the catchbasin/grit chamber did not provide any significant improvements in water quality, although it is an important element in reducing maintenance problems by trapping bulk material.

Zinc and toxicity are examples where the use of the final chamber was needed to provide high levels of control. Otherwise, it may be tempting to simplify the MCTT by removing the last chamber. Another option would be to remove the main settling chamber and only use the pre-treating capabilities of the catchbasin as a grit chamber before the peat "filtration" chamber (similar to many stormwater filter designs). This option is not recommended because of the short life that the filter would have before it would clog (Clark and Pitt 1999; Clark 2000). In addition, the bench-scale tests showed that a treatment train was needed to provide some redundancy because of frequent variability in sample treatability storm to storm, even for a single sampling site.

The MCTT is capable of reducing a broad range of stormwater pollutants that cause substantial receiving-water problems (Pitt 1995a and 1995b; Burton and Pitt 2001). The MCTT has a high potential for cost-effective use as an integrated component in watershed management programs designed to protect and enhance receiving waters.

Description of the MCTT. Figure 1 shows a cross section of the MCTT. The catchbasin functions primarily as a protector for the other two units by removing large, grit-sized material. The setting chamber is the primary treatment chamber for removing settleable solids and associated constituents. The sand-peat filter is for final polishing of the effluent, using a combination of sorption and ion exchange for the removal of soluble pollutants, for example.

The treatability and source area information described in the main research report (Pitt, *et al.* 1999) can be used to develop other source area or outfall stormwater controls. As an example, it would be relatively easy to enhance the performance of typical wet detention ponds by adding some of the unit processes investigated. The most important control process would be to enhance the capture of small particles. In addition, water circulation and aeration may also enhance toxicant control by better utilizing photo-degradation and aeration processes. Care obviously needs to be taken to minimize scour of the deposited sediments. Conventional aeration design usually results in a circulation and aeration system than would have about 1/10 of the energy requirements needed for bottom scour. Subsurface discharges would also be an important addition in a wet detention pond to maximize capture of floatable debris and oils. Obviously, many other small units like the MCTT can be conceived and used for stormwater control at critical areas also. Typical goals would be to use a treatment unit having redundant processes, is easy to maintain, is robust for the changing conditions expected, and has the least cost possible for the needed level of stormwater control.

Catchbasin/grit chamber. Catchbasins have been found to be effective in removing coarser runoff solids. Moderate reductions in total and suspended solids (SS) (up to 45%, depending on the inflowing water rate) have been indicated by prior studies (Lager, *et al*. 1977, Aronson, *et al*. 1983, Pitt 1979, and Pitt 1985). While relatively few pollutants are associated with these coarser solids, their removal decreases maintenance problems of the other MCTT chambers.

Pitt and Field (1998) also evaluated three storm drain inlet designs in Stafford Township, NJ, as part of this EPA research: a conventional catchbasin with a sump, and two representative designs that used filter fabric material. The inlet devices were located in a residential area. Twelve storms were evaluated for each of the three inlet units by taking grab composite samples using a dipper sampler throughout the events. Influent and effluent samples were analyzed for a broad range of conventional pollutants, metals, and organic toxicants, both in total and filtered forms. The catchbasin with the sump was the only device that showed significant removals for suspended solids (0 to 55%, average 32%).

The MCTT catchbasin/grit chamber design is based upon a recommended design from previous studies of catchbasins (Lager, *et al*. 1977 and Aronson, *et al*. 1983). This design suggests using a circular catchbasin with the diameter 4 times the diameter of the circular outlet. The outlet is then placed 1.5 times its diameter from the top and 4 times its diameter from the bottom of the catchbasin, thus providing a total depth of 6.5 times the outlet diameter. The size of the MCTT catchbasin is controlled by three factors: the runoff flow rate, the 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 the completely mixed settling column bench-scale tests previously conducted and uses a hydraulic loading rate (depth to time ratio) for removal estimates. This loading rate is equivalent to the conventional surface overflow rate (SOR), or upflow velocity, for continuous-flow systems, or the ratio of water depth to detention time for static systems. The MCTT can be operated in both modes. If it uses an orifice, to control the settling chamber outflow, then it operates in a similar mode to a conventional wet detention pond and the rate is the upflow velocity (the instantaneous outflow divided by the surface area of the tank). If the outflow is controlled with a float switch and a pump, then it operates as a static system and the hydraulic loading rate is simply the tank depth divided by the settling time before the pump switches on to remove the settled water.

In addition to housing plate or tube settlers, the main settling chamber also contains floating sorbent "pillows" to trap floating oils and a fine bubble aerator that operates during the filling time of the MCTT. Plate settlers (or inclined tubes) increase solids removal by reducing the distance particles travel to the chamber floor and by reducing scour potential. Plate settler theory is described by Davis, *et al.*(1989). The main settling chamber operates much like a settling tank, but with the plate settlers increasing the effective surface area of the tank. The increase in performance is based on the number of plate diagonals crossing the vertical. If the plates are relatively flat and close together, the increase in performance is greater than if the plates are steeper and wider apart. The effective increase is usually about 3 to 5 fold.

The fine bubble aerator serves two functions: to support aerobic conditions in the settling chamber and to provide dissolved air flotation of particles. Aeration was used during the pilot-scale MCTT tests, but was not used during the full-scale Wisconsin or Caltrans MCTT tests. Dissolved air flotation has been utilized in industrial applications and combined sewer overflows (Gupta, *et al*. 1977). The settling time in the main settling chamber typically ranges from 1 to 3 d, and the settling depth typically ranges from 0.6 to 2.7 m (2 to 9 ft). These depth to time ratios provide for excellent particulate (and associate pollutant) removals in the main settling chamber.

Bench-scale tests found that depth/time ratios of at least $3 \text{ X } 10^{-5}$ m/s ($1 \text{ X } 10^{-4}$ ft/s) are needed to obtain a median toxicity reduction of at least 70 percent in the main settling chamber. If the main settling chamber tank was one meter (3.3 ft) deep, then the required detention time would have to be at least 0.4 days to obtain this level of treatment. If the tank was twice as deep, the required detention time would be 0.8 days. The tank surface area is therefore based on the volume of runoff to be detained and the settling depth desired/available. Shallow tanks require shorter detention times than deeper tanks, but the surface areas are correspondingly larger, and scour may be more of a problem. Since the MCTT is placed underground, a tank having a large surface area (and a shallower depth) may be much more expensive than a deeper tank requiring a longer detention time.

The design of a stormwater treatment device, including the MCTT, is greatly dependent on the rainfall pattern for a specific area. In water quality evaluations, a single "design storm" is not evident because of the many factors comprising runoff quality (runoff volume, runoff flow rate, water temperature, concentrations of many different pollutants, etc.). It is not very clear under which storm condition the combination of these factors is critical for the local beneficial uses. In addition, targeting a specific size storm is no guarantee that all storms of lesser magnitude will also be adequately controlled. Continuous simulation is therefore needed to effectively design and evaluate most stormwater quality controls.

If the rains are infrequent, long detention periods are easily obtained without having "left-over" water in the tank at the beginning of the next event. However, if the rains are frequent, the available holding times are shortened, requiring shallower main settling chamber tanks for the same level of treatment. A spreadsheet model was used to develop design curves for many locations of the U.S. based on long-term rain records, desired levels of control, and tank geometry. These design curves are included in the EPA report (Pitt, *et al.* 1999).

This model was used to investigate various storage capacities, holding periods, and settling tank depths for 21 cities throughout the U.S. having annual rains from about 180 – 1500 mm (7 – 60 in.). The model used the rain depths and durations, the time interval between the consecutive storm events, the dimensions of the subsurface tank, and the tank pumpout or drainage time. A random set of 100 rain events from the past 5 to 10 years (from EarthInfo CD-ROMs, Boulder, CO,) was used for each city in these simulations. The annual toxicity reductions were calculated by knowing the individual storm median toxicity reductions and the annual percentage of runoff treated. As an example, if the holding period was 24 h for a 2.1 m (7 ft) deep settling chamber, the individual median storm toxicity reduction would be about 75%. If the MCTT was large enough to contain the runoff from a 38 mm (1.5 in) rain, then about 98% of the annual runoff would be treated, for an annual expected toxicity reduction of 73% (0.75 X 0.98 = 0.73).

Figure 2 is a plot for Birmingham, AL, for different annual control levels associated with holding periods from 6 – 72 h and storage volumes from 2.5 – 51 mm (0.1 – 2.0 in.) of runoff for a 2.1 m (7 ft) deep MCTT. This figure can be used to determine the size of the main settling chamber and the minimum required detention time to obtain a desired level of control (toxicity reduction). If the MCTT is full from a previous rain (because of the required holding period), the next storm would bypass the MCTT with no treatment. Birmingham, AL, rains typically occur about every 3 to 5 d, so it would be desirable to have the holding period less than this value. Similarly, if the storage volume was small, only a small fraction of a large rain would be captured and treated, requiring a partial bypass for most rains.

This plot shows that the most effective holding time and storage volume for a 70% toxicity reduction goal is 72 hours and 22 mm (0.86 inch) of runoff storage. A shorter holding period would require a larger holding tank for the same level of control. Shorter holding periods may only be more cost-effective for small removal goals (<50%). If a 6 hour holding time was used, the maximum toxicant removal would only be about 46% for this tank depth.

Filter/ion exchange chamber. The final MCTT chamber is a mixed media filter (sorption/ion exchange) device. It receives water previously treated by the grit and the main settling chambers. The initial designs used a 50/50 mix of sand and peat moss, while the Ruby Garage full-scale MCTT in Milwaukee used a 33/33/33 mixture of sand, peat moss, and granulated activated carbon. The MCTT can be easily modified to contain any mixture of media in the last chamber. However, care must be taken to ensure an adequate hydraulic capacity. As an example, peat moss alone was not effective because it compressed quickly, preventing water from flowing through the media. However, when mixed with sand, the hydraulic capacity was much greater and didn’t change rapidly with time.

Initial bench-scale tests showed that sand by itself (especially if recently installed) did not permanently retain the stormwater toxicants (which are mostly associated with very fine particles and which were mostly washed from the sand during later events). This lack of ability to permanently retain stormwater toxicants prompted the investigation of other filtration media.

Further research as part of this U.S. EPA supported cooperative research agreement (Clark and Pitt 1999 and Clark 2000) examined the pollutant removal benefits and design criteria for several candidate media.

Combinations of filtration media, including organic materials (peat moss, activated carbon, composted leaves, and a cotton processing waste material), Zeolite, and sand, were investigated for their ability to more permanently retain stormwater pollutants. Sand was mixed with most of these materials in order to maintain adequate hydraulic capacities, especially for peat. Some clogging tests have shown that channeling still occurred in the Zeolite-sand combination media, significantly decreasing the performance by decreasing the contact time provided by simple gravity flow. The use of a restrictive filter fabric placed on top of the peat-sand filter in the MCTT allows the water to spread over the filter and help prevent preferential channel flow.

The sand-peat filter possesses ion exchange, adsorption, and filtration reduction mechanisms. As the media ages, the performance of these processes will change. Ion exchange capacity and adsorption sites, primarily associated with the peat moss, will be depleted. Filtration, primarily associated with the sand, however, is expected to increase, especially for the trapping of smaller particles. Improved performance of sand filters with age has been documented by Darby, *et al*. (1991). Eventually though, the sand-peat filter will become clogged by solids and the exchange capacity of the peat will be exceeded, requiring replacement of the media. Replacement of the media in the MCTT is expected to be necessary about every 3 to 5 years.

Initial pilot-scale tests

Pilot-scale tests on the campus of the University of Alabama at Birmingham at a long-term parking lot and vehicle service area verified the design procedures and indicated very high pollutant removal capabilities. The pilot-scale MCTT was evaluated for 13 storm events. Based solely upon the design of the settling chamber, percent toxicity reductions were predicted to be near the 90% reduction level. Actual performance of the overall MCTT was found to have a median value of 96%. The median toxicity reduction of the filtered samples was found to be 87%.

Exact 1-sided probabilities were calculated by the Wilcoxon Signed Rank Test for paired observations using StatXact-Turbo™ software by Cytel Software Corporation. The exact probability calculated is based upon sign and magnitude of concentration differences occurring across each chamber and across the entire MCTT, while omitting zero differences. The software calculated an exact p value as opposed to a p value obtained asymptotically which would inherently decrease accuracy for the relatively small sample size. The software also expedited data analysis by performing the statistical tests in a batch mode.

Table 1 shows performance summaries for the settling chamber, sand-peat chamber, and for the overall MCTT for the major constituents of interest. The catchbasin was not found to provide significant toxicity reductions, as expected, and is therefore not included on this summary table. The catchbasin was used to provide grit and other coarse solids control to reduce maintenance in the other chambers.

By design, the settling chamber was assumed to provide most of the pollutant reductions. The other two chambers and secondary features were added for extra benefit, especially to reduce variations in performance for the highly variable runoff conditions. As an example, good toxicity reductions occurred in both the settling chamber and the sand-peat filter.

Wisconsin full-scale MCTT test results

Full-scale units were installed in Milwaukee and Minocqua, WI, and monitored for a one-year period. Results from the full-scale tests of the MCTTs in Wisconsin (Corsi, *et al.* 1999) are encouraging and collaborate the high levels of treatment observed during the pilot-scale tests. Table 2 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). 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 these full-scale tests. None of the organic toxicants were ever observed in effluent water from either full-scale unit, even considering the excellent detection limits available at the Wisconsin State Department 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 the added activated carbon in the final chamber in Milwaukee. Color was also much better controlled in the full-scale Milwaukee MCTT.

The Milwaukee installation is at a public works yard 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 total capital cost was $72,000. The high cost was due to uncertainties associated with construction of an unknown device by the contractors and because it was a retro-fit installation.

The Minocqua site is a 1 ha (2.5 acre) newly paved parking lot for a state park and commercial area. It is located in a grassed area and was also a retro-fit installation, designed to fit within an existing storm drainage system. The installed capital cost of this MCTT was about $95,000 and included the installation of the MCTT plus the parking area paving. The MCTT was built using 3.0 m X 4.6 m (10 ft X 15 ft) box culverts for the main settling chamber (13 m, or 42 ft long) and for the filtering chamber (7.3 m, or 24 ft long). These costs are about equal to the costs of installation of porous pavement (about $40,000 per acre of pavement).

Results from the on-going Caltrans full-scale MCTT tests

Three MCTT units are planned for the ongoing Caltrans stormwater monitoring project in Los Angeles County, CA. Two of the facilities have been completed and monitored for two years. Both sites are Park & Ride lots and range from about 0.4 to 0.8 ha (1 to 2 acre). Both drainage areas are 100% impervious. At these installations, pumps were used to ensure that the stormwater remained in the sedimentation chamber for at least 24 h. The filter chambers have a 450 mm (18 in.) layer of mixed media (50/50 mixture of sand and peat moss). The filter areas were sized using a loading rate of 5,000 g SS/m^2/yr (1 lb/ft^2/yr).

Major maintenance items for MCTTs include removal of sediment from the sedimentation basin when the accumulation exceeds 150 mm (6 in.) and removing and replacing the filter media about every 3 years. Neither of these activities were required during the first two years of the Caltrans study. After two wet seasons, the total accumulated sediment depth was less than 25 mm (1 in.), indicating that sediment removal may not be needed for about 10 years. The sorbent pillows were scheduled to be replaced annually, or sooner if darkened by oily stains. Weekly general inspections were conducted during the wet season for such things as trash removal from the inlet and outlet structures. Monthly inspections were also conducted to identify damage to inlet and outlet structures, and evidence of graffiti or vandalism. Because the MCTT test units used by Caltrans were above ground and not initially covered, the permanent pools were available for mosquito breeding. The Via Verde site was finally completely enclosed to prevent mosquito access.

Table 3 is a summary of the average influent and effluent concentrations averaged for the two year monitoring period, and resulting reductions, for these Caltrans tests (Michael Barrett, University of Texas, personal communication). Statistical tests showed no significant differences between the two MCTT sites, so their data was combined for this table. These data indicated comparable performance to the Austin sand filter design that was also tested, even with the additional peat moss and the pre-treatment provided in the MCTT. This was likely due to the low influent concentrations observed at these two parking lot sites and the absence of more contaminated runoff for which the MCTT was designed. Caltrans ranked the performance of the stormwater controls in the following general order (based on SS performance): MCTT and Austin media filter; wet basin; infiltration devices; Delaware media filter; biofilter strip; dry detention basin; biofilter swale; StormFilter®; and drain inlet inserts. Further information concerning the Caltrans stormwater program is available at: www.dot.ca.gov/hq/env/stormwater/.

Conclusions

The pilot- and full-scale test results show that the MCTT provides 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 final treatment step when using peat as part of the filtering/ion-exchange media. The main settling chamber provided substantial reductions in total and dissolved toxicity, lead, zinc, certain organic toxicants, SS, COD, turbidity, and color. The sand-peat chamber also provided additional filterable toxicant reductions. However, the catchbasin/grit chamber did not provide any significant improvements in water quality, although it is an important element in reducing maintenance problems by trapping bulk material.

Zinc and toxicity are examples where the use of the final chamber was needed to provide high levels of control. Otherwise, it may be tempting to simplify the MCTT by removing the last chamber. Another option would be to remove the main settling chamber and only use the pre-treating capabilities of the catchbasin as a grit chamber before the peat "filtration" chamber (similar to many stormwater filter designs). This option is not recommended because of the short life that the filter would have before it would clog from the silt and fine sand in stormwater. In addition, the bench-scale treatability tests conducted during the development of the MCTT (Pitt, *et al.* 1999) showed that a treatment train was needed to provide some redundancy because of frequent variability in sample treatability storm to storm, even for a single sampling site.

The MCTT operated as intended: it provided very effective reductions for both filtered and particulate stormwater toxicants and SS. Because of its high cost, it may only be suitable for critical source areas where high levels of toxicant reductions are needed. Much of the added expense is associated with the underground installation of the MCTT to enable it to be located in areas having little room for alternative stormwater control options. In addition, the pilot-scale and full-scale installations described in this paper were all designed for very high levels of control. This research also examined treatability of stormwater toxicants in general, and this information can be used to develop or improve other stormwater treatment devices.

Acknowledgments

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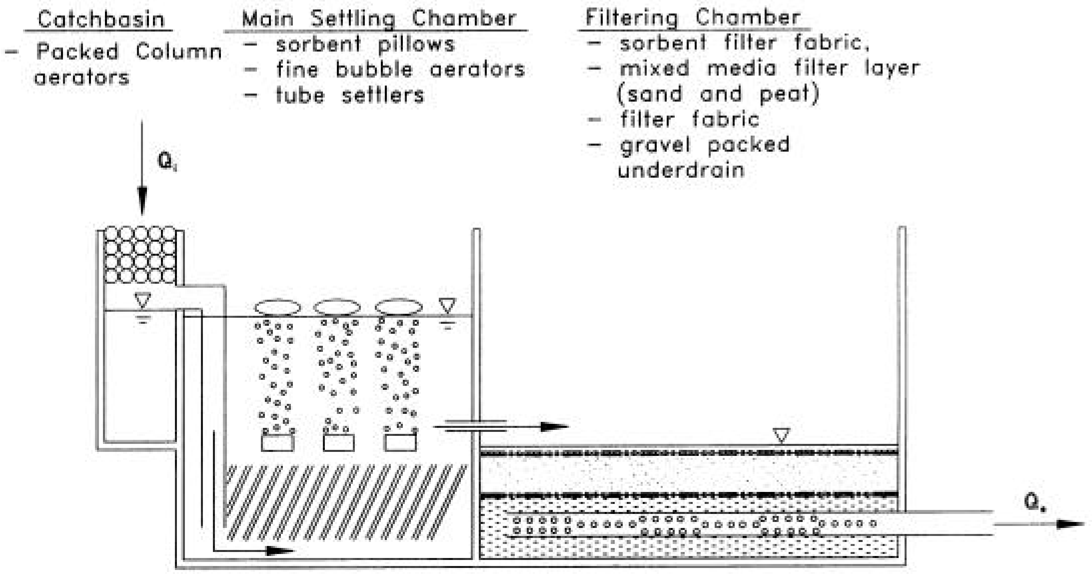

Figure 1. MCTT cross section.

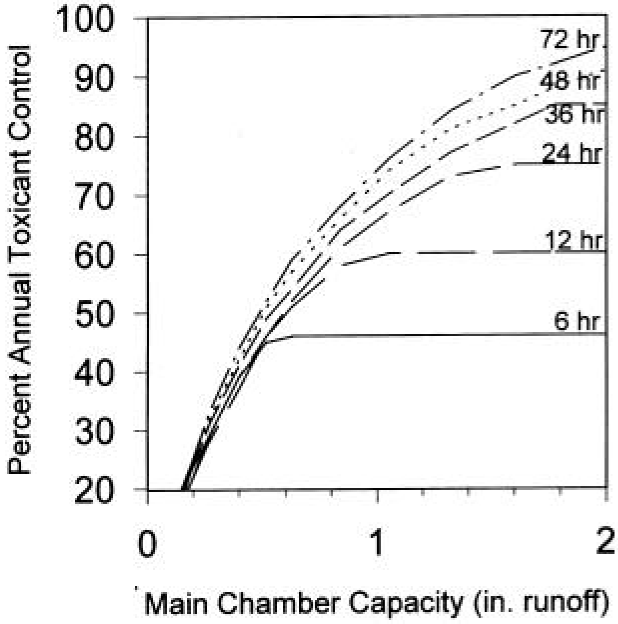

Figure 2 Effects of storage volume and treatment time on annual toxicity reduction, 2.1 m settling depth) (Example storage-treatment plot for Birmingham, AL).

Table 1. Median Percent Reductions by Chamber

Constituent	**Main Settling Chamber (percent)**	**Sand-Peat Chamber (percent)**	**Overall Device (percent)**
Common Constituents			
total solids	***31***[a]	2.6	***32***
suspended solids	***91***	-400	***83***
turbidity	***50***	***-150***	***40***
conductivity	-15	***21***	***11***
apparent color	***16***	***-75***	***-55***
pH	-0.3	***6.7***	***7.9***
COD	***53***	-55	***54***
Nutrients			
nitrate	***27***	-5	***24***
ammonium	***-62***	-7	***-400***
Toxicants			
Microtox™ toxicity (unfiltered)	***18***	***70***	***96***
Microtox™ toxicity (filtered)	***69***	67	***87***
lead	***88***	***18***	***93***
zinc	***39***	62	***91***
n-Nitro-di-n-propylamine	81	64	92
hexachlorobutadiene	29	97	100
pyrene	100	25	100
bis (2-ethylhexyl) phthalate	***99***	N/A	***99***

[a] Note: Bold italics indicate Wilcoxon 1-sided p values of $\leq$0.05

Table 2. Performance Data(1) for WI Full-Scale MCTT Tests (median percent reductions and median effluent quality)

	Milwaukee MCTT (15 events)	Minocqua MCTT (7 events)
suspended solids	98 (<5 mg/L)	85 (10 mg/L)
volatile suspended solids	94 (<5 mg/L)	na[a]
COD	86 (13 mg/L)	na
turbidity	94 (3 NTU)	na
pH	-7 (7.9 pH)	na
ammonia	47 (0.06 mg/L)	na
nitrates	33 (0.3 mg/L)	na
Phosphorus (total)	88 (0.02 mg/L)	>80 (<0.1 mg/L)
Phosphorus (filtered)	78 (0.002 mg/L)	na
Microtox® toxicity (total)	Na	na
Microtox® toxicity (filtered)	Na	na
Cadmium (total)	91 (0.1 μg/L)	na
Cadmium (filtered)	66 (0.05 μg/L)	na
Copper (total)	90 (3 μg/L)	65 (15 μg/L)
Copper (filtered)	73 (1.4 μg/L)	na
Lead (total)	96 (1.8 μg/L)	nd (<3 μg/L)
Lead (filtered)	78 (<0.4 μg/L)	na
Zinc (total)	91 (<20 μg/L)	90 (15 μg/L)
Zinc (filtered)	68 (<8 μg/L)	na
benzo(a)anthracene	>45 (<0.05 μg/L)	>65 (<0.2 μg/L)
benzo(b)fluoranthene	>95 (<0.1 μg/L)	>75 (<0.1 μg/L)
dibenzo(a,h)anthracene	89 (<0.02 μg/L)	>90 (<0.1 μg/L)
fluoranthene	98 (<0.1 μg/L)	>90 (<0.1 μg/L)
indeno(1,2,3-cd)pyrene	>90 (<0.1 μg/L)	>95 (<0.1 μg/L)
phenanthrene	99 (<0.05 μg/L)	>65 (<0.2 μg/L)
pentachlorophenol	na	na
phenol	na	na
pyrene	98 (<0.05 μg/L)	>75 (<0.2 μg/L)

[1] Samples analyzed in accordance with approved EPA or Standard Methods and in accordance with the pre-approved Quality Assurance Project Plan.

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

Table 3. Initial Caltrans Test Results for MCTTs

Constituent	Average Influent Concentration (mg/L)	Average Effluent Concentration (mg/L)	Concentration Reduction (%)
TSS	29.6	6	80
Nitrate	0.42	0.68	-62
TKN	1.27	0.82	35
N Total	1.69	1.50	11
P Total	0.18	0.11	39
Cu Total	0.008	0.005	38
Pb Total	0.006	0.003	50
Zn Total	0.086	0.013	85
Cu Dissolved	0.004	0.003	25
Pb Dissolved	0.001*	0.001*	NA
Zn Dissolved	0.050	0.013	74
TPH-Oil	0.34	0.20*	>41
TPH-Diesel	1.43	0.21	85
Fecal Coliform	973 MPN/100mL	171 MPN/100mL	82

*equals value of reporting limit

Note– TPH and Coliform collected by grab method and may not accurately reflect removal. The concentrations are the mean of the event mean concentrations (EMCs) for the entire monitoring period.