

**Fate and Environmental Impact of Sediments  
Removed from Stormwater Ponds  
A Review**

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## SUMMARY & RECOMMENDATIONS

A review of available literature demonstrates that, at least in terms of metals, the sediments accumulating in stormwater ponds are not significantly different from biosolids that are generated at MCES' wastewater treatment plants.

Although no data were found, estimates were generated for the quantity of sediment generated. For typical communities served by stormwater ponds, the quantity of sediment will substantially exceed the quantity of biosolids. A rough estimate of 100,000 to 200,000 tons was generated for the annual rate of sediment accumulation in the metro area. The Minnesota Pollution Control Agency recommends that stormwater ponds be designed for 25 years of sediment storage. Current accumulated sediment thus may exceed 1,000,000 tons.

Given that most existing ponds were constructed less than 25 years ago, metro communities have little experience with dredging and disposing of the sediment. As a result, little is known about the ultimate disposal of sediment that has been removed from ponds and the associated environmental and public health risks.

It is recommended that the Metropolitan Council conduct the following preliminary tasks necessary for an assessment the environmental and public health risks associated with the handling and disposal of pond sediments in the metro area.

- Document the relevant physical, chemical, and biological characteristics of sediments currently accumulating in the metro area.
- Estimate the sediment accumulation rate in metro area.
- Estimate the annual quantity of sediment currently dredged and disposed and identify utilization/disposal practices.
- Estimate the quantity of accumulated pond sediment in the metro area.

## INTRODUCTION

EPA's most recent evaluation of the nation's water bodies found that 35% of stream miles and 45% of lake area were impaired. Although agricultural activities were found to be the major source of impairment, urban runoff accounted for approximately 32,000 miles of stream and 930,000 acres of impairment.<sup>1</sup> It is clear that, although urban runoff is not the major source of water quality impairment from a national perspective, it certainly does produce local impacts. As a result, communities use a variety of management practices to mitigate the impacts of urban runoff.

The stormwater pond is perhaps the most common structural management practice used to control and/or treat urban stormwater discharges. Although a pond and its associated buffer can require 2% to 4% of the area available for development, it is popular with both developers and governmental agencies for a number of reasons. Ponds provide open space, esthetic quality, wildlife habitat, and require little maintenance. In fact, EPA has identified a number of case studies where properties, located near or within sight of a wet pond, generated rent/sell premiums of 10% to 15%.<sup>2</sup>

Removal of accumulated sediment is the primary long-term maintenance activity for stormwater ponds. Relatively high sediment loads are expected during the period required for build-out of a typical development. After removing this initial sediment load, solids may accumulate in the pond for many years. The Minnesota Pollution Control Agency (MPCA) recommends that ponds should be constructed with approximately 25 years of sediment storage.<sup>3</sup> The Wisconsin Department of Natural Resources (WDNR), on the other hand, recommends that sediment should be removed every 5 to 10 years.<sup>4</sup> In any case, pond cleaning is conducted on an infrequent basis and there is a dearth of local data on the quantity and quality of the sediment that is removed. In fact, WDNR found that the long-term accountability for pond maintenance was often difficult to determine.<sup>4</sup>

The following sections characterize the magnitude of the potential environmental problems associated with the handling and ultimate disposal of pond sediment

## **PROBLEM STATEMENT**

From a theoretical standpoint, as significant sediment accumulates in a pond the TSS removal efficiency decreases because of a decrease in the hydraulic detention time and an increase in scour potential. The goal is, of course, to maximize the removal of TSS and the associated pollutants. However, an increased TSS removal efficiency results in a more rapid accumulation of sediment, which decreases efficiency. Sediment removal at the appropriate times is thus the key to addressing this apparent dichotomy. Although the timing of sediment removal is thus important from a pond performance perspective, it is also important from a regional sediment handling and disposal perspective as described below.

Personal observations over the past 25-30 years suggest that most of the stormwater ponds in the Twin Cities metropolitan area are located in the newer suburban areas and have been constructed in the past 15 years. If [a] the above observation is correct and [b] local municipalities and/or developers are following the MPCA's recommendation on sediment storage, then most of the existing ponds have never been dredged (after build out) and the inventory of sediment is high. Unfortunately the magnitude of the inventory is unknown. Note, however, that well over one million people live in the suburban area surrounding the core cities. If half of these people live in communities/developments served by stormwater ponds, the sediment inventory is likely very high. In addition, the chemical and biological characteristics of the sediments are unknown.

Given their age and history, it is quite likely that many of the existing ponds will need to be dredged in the next 10 years. Some municipalities may periodically monitor sediment inventory and plan for disposal. It is more likely, however, that the need for dredging will become apparent only when a delta appears and/or pond performance significantly degrades.

Although the MPCA<sup>3</sup> does provide some general guidance on the handling and disposal of pond sediment, the practices do not appear to be regulated in Minnesota. In addition, it does not appear that the State or the Metropolitan Council have developed any plans to deal with the issue of sediment use or disposal.

## SEDIMENT QUALITY

Sediment data were found for well over 100 ponds in a number of references. It appears that the state of Florida and the province of Ontario have taken a leadership role in characterizing and managing pond sediments. However, the descriptions of the ponds were not always complete and it is quite possible that some data were used in more than one of the references. In addition, the drainage characteristics were described in varying detail and the list of metals and organics analyzed varied considerably as did the method of data presentation - raw data, averages, and ranges. For these reasons, the data summary in TABLE 1 is limited to concentration ranges. The resulting concentration ranges are quite wide (up to three orders of magnitude) and provide little help in predicting sediment quality for any specific community or source.

**TABLE 1. SUMMARY OF REPORTED POND SEDIMENT DATA** \*(references)

Constituent	Concentration Range – mg/kg dry
Arsenic	1.3 – 75
Cadmium	0.4 – 30
Chromium	7 – 817
Copper	2 – 310
Lead	2 – 1,280
Nickel	3 – 300
Zinc	29 – 3,170
Mercury	0.03 – 8
PCB	0.04 – 1
Total Phosphorus (TP)	725 - 1,790
Total Kjeldahl Nitrogen (TKN)	1,370 – 13,990

\* 5 6 7 8 9 10 11 12 13 14

Much of the data summarized in TABLE 1 was obtained from obscure sources and some effort was required to identify and assemble the reference materials. An alternate method of estimating sediment constituent concentrations was utilized prior to completing the literature survey. Loading and removal data were used to generate concentration estimates using typical runoff loadings (TABLE 2) and median removal efficiencies in ponds from Brown and Schueler<sup>17</sup>. The resulting estimates for pond sediment quality are summarized in TABLE 3. Note that the estimated concentrations are similar to the literature observations summarized in TABLE 1.

**TABLE 2. TYPICAL URBAN RUNOFF LOADINGS – kg/ha/yr**

<b>Constituent</b>	<b>High Density Residential<sup>16</sup></b>	<b>Industrial<sup>16</sup></b>	<b>Highway<sup>15</sup></b>
Cadmium	0.015	0.024	0.037
Chromium	0.028	0.044	0.1
Copper	0.049	1.0	4.7
Lead	0.17	6	21
Zinc	0.63	12	10
TSS	400	1,000	12,000
TKN	10	12	40
TP	3	4	8

**TABLE 3. ESTIMATED QUALITY OF POND SEDIMENT**

<b>Constituent</b>	<b>Concentration Range – mg/kg dry</b>
Cadmium	2 – 25
Chromium	6 – 50
Copper	95 – 770
Lead	400 – 5,600
Zinc	625 – 7,140
TKN	1,400 – 10,700
TP	450 – 4,900

## SEDIMENT QUANTITY

No data on sediment quantity were found in the literature. However, that did not present a significant problem because it is relatively easy to estimate sediment quantity. Typical literature values for solids loads in urban runoff (excluding highways) fall in the range of 400 to 1000 kg/hectare/year.<sup>16</sup> This is equivalent to 114 to 285 tons solids per square mile per year.

In 1997 the Center for Watershed Protection summarized data obtained from 123 BMP performance studies - including 43 ponds (35 wet ponds). The average TSS removal was approximately 62% and the median removal was 70%.<sup>17</sup> The observed TSS removal efficiencies are significantly lower than required for design in Minnesota and Wisconsin. MPCA requires ponds be designed for 90 % removal of suspended solids (TSS) whereas WDNR requires 80%.<sup>3 & 4</sup> Since wet ponds are more efficient in removing solids and most new ponds use that approach, a TSS removal efficiency of 80% is used to estimate sediment quantity in the following example.

Consider a city of 10,000 with a moderate population density of 500/mi<sup>2</sup> (approximate density for Mpls/St Paul in 1990<sup>18</sup>). If all of the surface runoff in this city of 20 mi<sup>2</sup> is routed through ponds, this city will generate between 1,800 and 4,500 tons of sediment per year assuming an 80% capture rate. Given that actual sediment yields will be a function of impervious area, soil type and slope, commercial and industrial development, etc., it is acknowledged that this estimating approach is not appropriate for planning purposes. It does, however, illustrate the order of magnitude of sediment accumulation in storm water ponds.

In order to put the quantity of pond sediment into perspective it may be of value to compare it to the quantity of sewage sludge generated for the same population. Approximately 2.0 lb/1,000 gal is a reasonable estimate for sludge generation for an activated sludge treatment plant<sup>19</sup>. At a typical sewage generation rate of 100 gal/capita/day, a city of 10,000 would then generate approximately 365 tons of sewage sludge per year. From a materials handling perspective, dredging and disposing of pond sediments thus appears to be a significant maintenance requirement (albeit conducted infrequently).

If a half million people in the metro area are served by stormwater ponds, the above example suggests that total annual sediment accumulation is approximately 90,000 to 225,000 tons. Accumulation of sediment for 25 years yields approximately  $2.2 \times 10^6$  to  $5.6 \times 10^6$  tons. Again these numbers are not generated for planning purposes but they do illustrate the magnitude of the problem that is developing.

## COMPARISON WITH OTHER RESIDUALS

Those individuals knowledgeable about biosolids utilization will notice that the metal concentrations found in sediment (TABLE 1) and biosolids are similar. It thus might be of value to compare the pollutant concentrations of pond sediments to those in sewage sludge. TABLE 4 summarizes sludge data for 1999 for four MCES treatment plants (Cottage Grove, Empire, Hastings, and Seneca) along with national median values.

When the sludge values from TABLE 4 are compared to the sediment values in TABLES 1 and 3 it becomes clear that, with the exception of lead and zinc, the metal content of sewage sludge and pond sediment are similar. Pond sediments appear to have a significantly higher lead concentration but a lower zinc concentration when compared to sewage sludge.

**TABLE 4. CONCENTRATION DATA FOR SEWAGE SLUDGE – mg/kg dry**

<b>Pollutant</b>	<b>MCES Range<sup>20</sup></b>	<b>National Median<sup>19</sup></b>
Arsenic	3.2 – 32.7	10
Cadmium	2.0 – 6.0	10
Copper	368 – 1635	800
Lead	11 – 146	500
Mercury	0.2 – 6.9	6
Molybdenum	3.3 – 37.5	4
Nickel	16 – 162	80
PCB	<0.2 – 0.33	
Selenium	2.9 – 45.8	5
Zinc	283 – 3507	1700

Given this similarity and Schueler's<sup>12</sup> recommendation that sediments may be valuable as a soil amendment, it may be interesting to discuss sediment disposal in terms of the MPCA regulations for biosolids. In addition to the limits summarized in TABLE 5, sludge applied to agricultural land in Minnesota must, at a minimum, meet class B pathogen reduction criteria as well as vector attraction criteria. The pathogen reduction criteria can be accomplished via several treatment processes or by demonstrating fecal coliform densities of less than 2,000,000 per gram of dry solids. The vector attraction requirements can be obtained by volatile solids reduction processes, chemical addition, obtaining very high solids content (> 90%), and injection into the soil.<sup>21</sup> Note that although pathogen data were not found in the references cited (see TABLE 1), Zaroni<sup>6</sup> did find fecal coliform concentrations in the range of approximately 150,000 to 3,000,000 organisms per gram of storm water residuals.

When the observed concentration ranges summarized in TABLES 1 and 3 are compared to the ceiling concentrations of TABLE 5 it appears that only lead has some significant likelihood of exceeding the limits. Note however that, since the metal concentrations can be significant, the annual loadings and cumulative loadings would be limited. However, lead at the maximum reported concentration (TABLE 1) would limit sediment loadings to approximately 5 dry tons per acre which is still a significant loading.

**TABLE 5. MPCA LIMITS FOR LAND APPLICATION OF SLUDGE**

<b>Pollutant</b>	<b>Ceiling Concentration mg/kg (dry)</b>	<b>Cumulative Loading Rate lb/acre</b>	<b>Annual Loading Rate lb/acre</b>
Arsenic	75	37	1.8
Cadmium	85	35	1.7
Copper	4,300	1,339	67
Lead	840	268	13
Mercury	57	15	0.76
Molybdenum	75	NA	NA
Nickel	420	375	19
Nitrogen – available	NA	NA	Meet crop needs
PCB	50	NA	NA
Selenium	100	89	4.5
Zinc	7,500	2,500	125

## CURRENT FATE OF POND SEDIMENTS

The MPCA recommends that sediment disposal sites should be located directly adjacent to ponds when possible. When this is not possible several general guidelines are presented as follows.

- Sediments are not generally hazardous.
- Never place sediments in water.
- Divert runoff from sediment disposal areas.
- Limit human contact with sediments.

In addition, MPCA suggests that sediment may be used as daily cover at landfills, but prefers that it be used as cover on lined areas of permitted sanitary landfills or demolition landfills that monitor ground water quality.<sup>3</sup>

The fate of pond sediments in Minnesota and other states appears to be largely undocumented. Graham and Lei<sup>22</sup> recently summarized sediment handling practices for a number of cities in Canada. They reported sediments deposited in landfills, used as daily cover at landfills, deposited in an unused gravel pit, spread on agricultural land, and used as residential fill. In addition, there is some local anecdotal evidence that sediments are used as fill in residential areas.<sup>23</sup> This is a particularly bad practice given the potentially high lead content of the sediments.

Although the Wisconsin Stormwater Design Manual addresses sediment removal as a regular maintenance item, it does not discuss disposal other than to require safe disposal. In fact, the WDNR states that *the responsibility for maintenance and long-term accountability for maintenance are often difficult to establish.*<sup>4</sup> Given this observation, it is understandable that the current fate of sediments is largely unknown. It should be noted, however, that the Maryland requires that *maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or local permitting processes.*<sup>24</sup>

## ENVIRONMENTAL ISSUES

It is clear that materials with high lead concentrations should not be used in area frequented by young children. It is not clear how to restrict the use and/or disposal of materials with the characteristics summarized in TABLE 1 using chemical criteria or standards; however, several governmental jurisdictions have attempted to do just that.

Florida recommends that sediments from residential ponds be used as cover material for lined landfills. The sediment can be used in unlined landfills and other areas if sediment quality guidelines for eight metals (TABLE 6) and 23 organics are met. Sediments from industrial areas should be screened to determine if they are hazardous (via TCLP leach procedure). Non-hazardous industrial sediments can be treated as residential sediments. Note that as of 1998, only one industrial sediment failed the TCLP criterion for lead.<sup>25</sup>

**TABLE 6. TARGET LEVELS FOR INORGANICS – mg/kg dry**

<b>Constituent</b>	<b>Florida</b> (deposited on land)	<b>Pennsylvania</b> (deposited on land)	<b>Ontario</b> (deposited in water)
Antimony		8.8	
Arsenic	0.8	12	6
Barium	5,200	1,500	
Beryllium		4.2	
Boron		100	
Cadmium	75	0.85	0.6
Chromium	290	360	26
Cobalt		40	
Copper		119.7	16
Lead	500	85.2	31
Manganese		5,150	460
Mercury	3.7	0.3	0.2
Nickel		76.7	16
Selenium	390	2	
Silver	390	5	
Thallium		18	
Tin		10	
Vanadium		13	
Zinc		252.5	120

Pennsylvania proposed the adoption of clean fill criteria in 2000. A total of 20 inorganics were addressed (TABLE 6) along with 23 organics. If concentrations in the tested material does not exceed any of the 43 criteria, the material can be used as unregulated fill in the State of Pennsylvania. The only restriction associated with “clean fill” is that it cannot be placed in the waters of the state without prior approval of the Department of Environmental Protection.<sup>26</sup>

The Province of Ontario allows sediment to be deposited in open water and in 1993 published guidelines for the management of aquatic sediment.<sup>27</sup> Criteria were published for 10 metals, 21 organics, and three nutrients. The criteria were grouped into three categories – no effect level (NEL), lowest effect level (LEL), and severe effect level (SEL). Unfortunately no values were developed for the metals at the NEL. Table 6 summarizes their (LEL) criteria for the metals. If metal concentrations fall below the LEL, the material cannot be placed in an area where the existing sediment quality is better. If the metal concentrations exceed the LEL, a management plan must be developed. This would likely involve additional testing.

In addition to their unusual “in water” criteria, Ontario has very comprehensive guidelines for both land filling and land spreading sediments. Leachate criteria have been established for 33 metals, organics, and nutrients. Land filling options are then established as a function of the leachate quality as follows.

**TABLE 7. ONTARIO SEDIMENT LANDFILLING GUIDELINES**

<b>Leachate Quality</b>	<b>Landfill Requirements</b>
Less than 10 x leachate criteria	Non-registerable waste, does not require landfilling
Between 10 and 100 x leachate criteria	Registered non-hazardous landfill
Over 100 x criteria	Hazardous waste facility

Although the Ministry of Environment does not officially regulate the disposal of non-registerable wastes, it does use a set of guidelines (originally designed for the evaluation and remediation of contaminated sites) to choose the most suitable disposal option. The criteria matrix addresses 117 elements/compounds for surface and subsurface application on agricultural land, residential/park land, and industrial/commercial land. In addition it accounts for both potable and non-potable ground water conditions.<sup>28</sup>

The above examples demonstrate how some state/provinces have attempted to address the environmental issues related to the handling and disposal of contaminated sediment. The complexity of the approaches varies substantially. Even the most complex approach, however, is based on a set of assumptions that will not be appropriate in all cases.

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