Stormwater Research Summary Banner

Title: Polycyclic Aromatic Hydrocarbons in Stormwater Pond Sediments throughout Minnesota

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Background

Previous work by Minnesota Pollution Control Agency (MPCA) researchers demonstrated that many stormwater ponds in the Twin Cities metropolitan area contain sediments contaminated with polycyclic aromatic hydrocarbons (PAHs). PAHs are organic chemicals present in some petroleum products (e.g., coal-tar sealcoats used on driveways and parking lots) and are formed during the burning of organic materials (e.g., wood, coal, liquid fuels). In 9 out of the 15 ponds sampled, the concentrations of carcinonogenic PAHs in the sediments exceeded the industrial soil reference value (SRV) (3 mg/kg as benzo[a]pyrene or B[a]P equivalents). Stormwater ponds need to be dredged periodically to remove accumulated sediment and maintain the overall performance in terms of stormwater retention and sediment capture. Ideally, the dredged sediments would be used as fill material by the pond owner. Contaminated sediments (i.e., those exceeding an industrial SRV), however, would require costly transport to and disposal in a secure landfill after dredging. Although many ponds in the Twin Cities metropolitan area and elsewhere in the state have been sampled and tested for PAHs, there have been no comprehensive studies by a single entity concerning PAH contamination of sediments in ponds in Minnesota (i.e., both within and outside of the Twin Cities metropolitan area). In this study, sixty sediment samples were collected from 20 stormwater ponds (3 locations in each pond) in both the Twin Cities metropolitan area (5 ponds) and greater Minnesota (5 ponds each in Duluth, St. Cloud, and Rochester). The PAHs were extracted from the sediments and the concentrations of 32 PAHs were determined. A statistical analysis was performed to identify major sources of PAH contamination to stormwater detention ponds. Potential relationships between pond sediment PAH levels and several attributes of the stormwater ponds, such as local land use, ratio of catchment area to pond area, and age of the pond, were also investigated. Finally, experiments were performed to determine the bioavailability of the sediment PAHs.

Conclusion #1: PAH-contaminated sediments were found not only in Twins Cities area ponds but also in greater Minnesota ponds.

The total concentration of the 32 analyzed PAHs (ΣPAH_{32}) in the sediments from the 15 stormwater ponds in greater Minnesota ranged from 0.01 to 131 mg/kg with a median of 6.9 mg/kg, where the median is the value at which half of the results are lower and half are greater. These ΣPAH_{32} results are comparable to those for the Twin Cities metropolitan area ponds (0.87 to 190 mg/kg with a median of 9.7 mg/kg). Clearly, PAH concentrations in pond sediments vary widely, with some samples having negligible levels of PAHs while others are significantly contaminated.

Conclusion #2: Sediment from 35% of the ponds (representing 22% of the samples) exceeded Minnesota's Industrial Soil Reference Value (3 mg/kg).

We analyzed for 17 carcinogenic PAHs (cPAHs) as specified in the MPCA Managing Stormwater Sediment Best Management Practices Guidance (MPCA, 2017) in order to compute the sediment SRVs. Eight of those cPAHs were included in the original set of 32 PAHs and nine more cPAHs were subsequently analyzed for. Sediment from 35% of the ponds (representing 22% of the samples) had

benzo[a]pyrene (B[a]P) equivalent values that exceeded Minnesota's industrial SRV of 3 mg/kg, meaning that the sediment from these areas would need to be disposed of in a secure landfill. It is important to note that additional SRVs exist for a number of individual PAHs and two metals. Sediments should be characterized against all of these SRVs to determine terrestrial disposal or reuse options. This study focused on the B[a]P equivalent SRV. Thus, some samples that did not exceed a B[a]P equivalent SRV may nevertheless have exceeded SRVs for other analytes; this assessment was beyond the scope of this study. It is important to note that, of the 6 ponds with sediments exceeding the industrial SRV in our study, only 2 of those exceeded the industrial SRV at all three sampling locations in each pond and in 3 of the ponds only 1 sampling location exceeded the industrial SRV. These results suggest that many ponds may only have contaminated sediments in small areas so that landfilling may not be necessary for all of the dredged materials in a 'contaminated' pond.

Conclusion #3: PAHs in Minnesota stormwater pond sediments originated from a variety of sources including gasoline and diesel engine emissions and coal tar sealcoats.

The results from source apportionment modeling using positive matrix factorization indicated that the major sources of PAHs to Minnesota pond sediments varied greatly from site to site. The weighted average source contributions to the Twin Cities metropolitan stormwater ponds we sampled were diesel emissions (35%), gasoline emissions (21%), coal combustion (21%), coal tar sealcoat (13%) and wood combustion (10%). For Duluth, the major sources from sampled ponds were coal tar sealcoat (36%), wood combustion (26%), coal combustion (18%), diesel emissions (14%) and gasoline emissions (6%). For Saint Cloud the major sources to ponds sampled were gasoline emissions (43%), wood combustion (32%), coal tar sealcoat (13%), coal combustion (10%) and diesel emissions (1%). For the Rochester area ponds sampled, the major sources were coal combustion (35%), wood combustion (29%), coal tar sealcoat (25%), gasoline emissions (7%) and diesel emissions (5%). Even this summary, however, may oversimplify the trends. There were several samples dominated by gasoline emissions (~10% of the samples), several dominated by coal combustion (~20% of the samples) and eight samples where coal tar sealcoat was clearly the dominant source (≥50% of the PAHs within those samples). The gasoline emissions-dominated samples were from Duluth, St. Cloud and Rochester. The coal combustion-dominated samples were from all four regions, and the coal tar sealcoat-dominated samples were from the Metro Area, Duluth and St. Cloud.

Conclusion #4: The PAHs are strongly bound to the sediment and exhibit low bioavailability, but the bioavailable fraction varies across different sediment samples.

From this survey of 20 stormwater ponds, 7 sediment samples with relatively high PAH concentrations from 7 different ponds were selected for an assessment of PAH bioavailability. The bioavailability assay that was performed is a measure of the ability of the PAHs to move from the sediments into the water. The assumption is that sediments containing PAHs that are strongly bound to the sediments and not able to move into the water will be less 'bioavailable', meaning that those sediments may be less toxic to sediment-dwelling organisms than the overall sediment PAH concentrations may suggest. It is important to note that such assays do not, at the present time, have any bearing on the overall sediment toxicity designation and hence fate of the dredged sediments, which are determined by comparing the sediment PAH concentrations to the SRVs. After 42 days of incubation, the total PAHs desorbed from the sediments and transferred to the water, i.e., the bioavailable fraction, ranged from 0.36 to 12.08%. Thus, it appears that most of the PAHs are strongly bound to the sediment. Hence, the PAHs are largely non-bioavailable, which is not surprising given that the PAHs in these sediments are comprised mostly of

large and very hydrophobic (i.e., water-hating) compounds. The reason for the wide range in bioavailabilities appears to be due to differences in the amount of black carbon (e.g., soot particles) in these sediments, as PAHs tend to bind strongly to black carbon particles. In fact, a preliminary treatability study involving dosing of powdered activated carbon (PAC) – an engineered black carbon material - to pond sediments indicated that small mass fractions of PAC (as low as 2.5%) can be very effective at sequestering PAHs and virtually eliminating their already low bioavailability. It is important to note that such treatments may benefit benthic or sediment-dwelling organisms but do not affect the SRV values.

What does this mean for pond management?

This study suggests that PAH contamination of pond sediments in Minnesota is a statewide problem that will likely require many pond owners to dispose of dredged sediments in secure landfills or seek treatment options. According to the Minnesota stormwater pond inventory, there are 30,855 stormwater ponds used for stormwater detention, treatment and flood control in the state. From this study, sediment from at least one sampling location in 35% of ponds sampled exceeded Minnesota's industrial Soil Reference Value (3 mg/kg), which indicates a level of contamination requiring disposal in a secure landfill. These results were extrapolated to estimate the total cost of dredging and disposal of contaminated pond sediments in Minnesota. It was assumed that 35% of all stormwater ponds in the state (10,799 stormwater ponds) contain sediments exceeding the industrial SRV. In addition, the median plan area for ponds in this study (0.67 acres) was used together with an assumed sediment depth of 2 feet to obtain a dredged sediment volume of 2,160 cubic yards per pond. Applying a cost of $40 to $60 per cubic yard for dredging, transport, and disposal (landfill) results in a total cost range of $0.9 billion to $1.4 billion for managing PAH-contaminated ponds. For comparison, the total cost would be approximately 2 to 3 times lower (i.e., ~$20 per cubic yard) if these ponds contained non-contaminated sediments. It is important to note that these estimates should be used with caution given that it is unknown how well the studied ponds represent the more than 30,000 ponds that were not sampled. Furthermore, many 'contaminated' ponds are likely to have sediments that exceed industrial SRVs in only a small area of the pond (i.e., near the inlet), so that potentially only a fraction of the dredged sediments would need to be landfilled.