Potential Benefits of Nutrient and Sediment Practices
to Reduce Toxic Contaminants in the Chesapeake Bay Watershed

PART 1: REMOVAL OF URBAN TOXIC CONTAMINANTS

REVIEW DRAFT

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Executive Summary

Classification of Urban Toxic Contaminants

A group of seven toxins were classified as urban toxic contaminants (UTC), based on six unique criteria:

1. The toxin is primarily associated with urban land use, compared to other sectors in the watershed.
2. The toxin is either generated within the urban sector or is deposited from the atmosphere onto impervious surfaces and subsequently washed off.
3. Urban stormwater runoff is the predominant pathway for transporting the toxin in the watershed.
4. The toxin has "sediment-like characteristics" and can be removed by settling or filtering practices.
5. The toxin is generated or produced in an upland landscape position in the watershed where it can be effectively treated by an urban BMP that captures surface runoff.
6. Physical evidence exists that the toxin is captured and/or retained within an urban stormwater BMP.

- Table E-1 shows the strength of evidence for classifying the seven groups of toxins as urban toxic contaminants or UTCs. The UTC designation is important as it enables watershed managers to target urban watersheds with effective stormwater BMPs to reduce toxin loads to the estuary.

Table E-1 Degree to Which the Toxin Categories Meet the Six Criteria for Urban Toxic Contaminants

Toxin Category	1. urban land use?	2. urban sources ?	3. stormwater pathway ?	4. Sediment characteristics	5. Upland Position ?	6. Urban BMP Capture or Retention?
PCBs	**Y**	Y	**Y**	**Y**	Y	Y
Dioxins	Y	Y	Y	Y	ND	ND
PAH	**Y**	**Y**	Y	**Y**	**Y**	**Y**
TPH	**Y**	Y	**Y**	**Y**	Y	**Y**
Hg	**Y**	Y	Y	**Y**	**Y**	Y
UTM	**Y**	**Y**	**Y**	M	**Y**	**Y**
OTM	**Y**	**Y**	**Y**	M	Y	Y

UTM: Urban Trace Metals (Cd, Cu. Pb and Zn)
OTM: Other Trace Metals (As, Cr, Fe and Ni

Y = Yes, based on strong evidence
Y = Yes, limited monitoring data provides support
M = Available evidence is mixed
ND = no data available to assess

Overall Findings on UTC Treatability by Urban BMPs

- The key focus of this study was to evaluate potential reductions in urban toxic contaminants that may be produced by current and future stormwater BMPs in the watershed.

- The best estimate of urban BMP coverage in the watershed is that they currently treat about 35% of watershed impervious cover, and perhaps may treat as much as 50% when Bay TMDL is achieved by 2025 (i.e., assuming that the Bay states maintain progress on their commitments in urban load reduction established in their watershed implementation plans). The TSS removal rate achieved by stormwater BMPs was established as the initial benchmark to define removal rates for urban toxic contaminants. Table E-2 compares the relative treatability of the seven urban toxic contaminants.

- For the most part, the UTCs behave like sediment particles, and therefore, are easier to remove from runoff than nitrogen or phosphorus. In all cases, the UTCs had measured or estimated removal rates that were similar to typical TSS removal rates. Lastly, there was conclusive evidence that most UTCs were retained within the media or sediments of urban stormwater BMPs.

Table E-2: Comparison of BMP Treatability for the Seven Urban Toxic Contaminant Groups

Toxin Category	BMP Removal Rate?	Measured or Estimated?	Behaves like Sediment?	BMP Retention?	Sediment Toxicity Concern?
PCBs	TSS	E	**Y**	Y	PR
Dioxins	< TSS	E	Y	ND	ND
PAH	>TSS	E	**Y**	**Y**	CR
TPH	>TSS	M	**Y**	**Y**	MR
Hg	>TSS	E	**Y**	**Y**	PR
UTM	< TSS	M	Y	Y	PR
OTM	< TSS	M	Y	Y	PR

Removal Rate:

>TSS: Higher than TSS Removal
TSS: Similar to TSS Removal
< TSS: Less than TSS Removal

M= Measured
E= Estimated

Y = Yes, based on strong evidence
Y = Yes, limited monitoring data provides support
ND = no data available to assess

PR: Potential Risk
CR: Clear Risk
MR: Minimal Risk

- The sediment toxicity concern column rates the potential risk that toxics trapped in BMPs could be (a) re-suspended or remobilized into the environment, (b) bio-accumulate within fish and wildlife that may inhabit BMPs or (c) warrant special precautions when BMP sediments are periodically cleaned out.

Overall Findings For All Urban Toxic Contaminants

- Despite differences in their origin and chemical characteristics, the seven UTCs shared some common findings when it came to removal by urban stormwater BMPs.

- It is clearly evident that existing BMPs are preventing a significant fraction of toxic contaminants from reaching the rivers and estuaries of the Chesapeake Bay, given the extent of current urban BMP coverage in the Chesapeake Bay watershed, as well as the high UTC removal rates that have been either measured or estimated for urban BMPs.

- While a precise estimate of the UTC load reduction is not possible at this time, BMPs could be reducing overall UTC inputs to the Bay by as much as 25% a year. This finding suggests that efforts to reduce nutrients and sediments for the Bay TMDL can produce other significant water quality benefits, such as toxin reductions.

- The highest UTC levels tend to be generated in older urban watersheds, especially those with extensive industrial, commercial or transport land uses. Communities should target these UTC "hotspots" as they retrofit their watersheds to meet the Bay TMDL in order to promote even greater toxin reductions.

- The environmental benefits of the UTC reductions may not be fully realized for several decades, since most UTC's experience a long lag time between when they are first deposited in the watershed, cycle through the stream network and ultimately reach the Chesapeake Bay.

- This review could find no data to evaluate the additional effect of pollution prevention practices in reducing UTCs that are required under industrial and municipal stormwater permits. The potential effect of these practices could be considerable, as more than 2700 industrial sites have stormwater permits in the watershed, and more than a thousand MS4 facilities and public works yards are also subject to the regulations.

- Greater UTC reduction might be triggered for these potential hotspots if a modest numerical TSS reduction requirements were attached as a permit condition in the next generation of stormwater permits.

- It is important to keep in mind that while urban BMPs are effective at trapping and retaining UTCs, they are not necessarily being removed from the environment -- these persistent compounds could accumulate in BMP sediments over many decades to the point that they might trigger sediment toxicity guidelines.

- More research is urgently needed to measure UTC concentrations in BMP sediments to fully assess the risk of future toxicity and develop safer methods to maintain BMPs and clean out their sediments. In addition, further tissue tests are recommended to determine if toxins are bio-accumulating in the fish and wildlife that utilize the habitat that urban BMPs create.

Key Findings on Polychlorinated Biphenyls (PCBs)

- While evidence suggests that PCB concentrations are declining in urban estuarine sediments, legacy PCBs are still detected in fish and wildlife tissue nearly four decades after they were banned.

- Based on the review, the overall quality of the available PCB monitoring data is limited. On one hand, there were useful data on PCB sources, generating sectors, and pathways, as well as limited data on PCB concentrations in urban stormwater and sediments. On the other hand, there were only a handful of studies that evaluated how urban stormwater BMPs trap and retain PCBs. In addition, much of the research has occurred outside the Chesapeake Bay watershed.

- Research in other estuaries, such as San Francisco Bay, have also documented a decline in PCB inputs. At the same time, they also forecast that it may take many decades for these persistent chemicals to stop bio-accumulating in the estuarine food chain. The main reason is that PCBs contaminate soils, which slowly move through the watershed in a recurring cycle of mobilization, deposition and re-suspension of soil and sediment particles.

- PCB inputs have a very strong association with highly urban watersheds, especially older industrial areas where PCBs were once used. While PCB monitoring data is limited, it is clear that it behaves much like a sediment particle, and is conveyed primarily by stormwater runoff through urban watershed.

- Much of the PCB load moving through urban watersheds is potentially treatable by stormwater retrofits, and a significant fraction of the existing load may already be trapped within existing stormwater BMPs that serve about a third of existing urban land in the Chesapeake Bay watershed.

- Given the pervasive impact of PCBs in the urban environment, it is remarkable how little monitoring has been conducted to measure the degree of PCB removal by urban stormwater BMPs. Given PCB characteristics and the limited BMP performance monitoring data available, it is estimated that for most urban BMPs, PCB removal rates will be comparable to sediment removal rates.

- Consequently, urban stormwater practices installed to meet state performance standards and/or to meet the Bay TMDL should have a significant potential to reduce PCB inputs into the Chesapeake Bay, at the watershed scale. Targeted street and storm drain cleaning in industrial catchments may also be an effective strategy to control PCB hotspots in the urban landscape.

- The effectiveness of stormwater practices in trapping PCBs poses some risk for contamination of BMP sediments. Elevated PCB levels in BMP sediments, however, may not pose a major environmental risk. For example, the risk for bio-magnification is small, given the simplified food chain that exists in most stormwater pond communities. Likewise, the risk to human health is low, given the limited fish consumption from stormwater ponds, and the lack of other modes of direct human exposure.

- The presence of persistent levels of PCBs in BMP sediments may have important implications for stormwater managers regarding how BMP sediments are managed in the long-term, such as testing, safe disposal and other measures. Special emphasis should be placed on testing stormwater sediments from older industrial sites where the risk is presumably the greatest.

- While BMP and retrofits can reduce PCB inputs to the estuary, other PCB management practices will continue to be needed, as well. These include PCB pollution prevention practices, street cleaning, demolition controls during redevelopment projects and continued cleanup of legacy industrial sites and hotspots.

Key Findings on Dioxins/Furans

- Dioxins have a localized impact on three areas in the Chesapeake Bay, where they have been found to contaminate fish tissue, due historic industrial discharges.

- Dioxins and related compounds are also found at lower, but detectable levels. in many urban areas in the watershed. The environmental risk posed by these low concentrations are not well understood.

- The sources of dioxins in urban watersheds primarily involve air deposition onto impervious surfaces (and subsequent wash-off), as well as erosion or wash-off of older contaminated soils.

- In general, dioxins and furans have the least certainty and most data gaps of any class of urban toxic contaminants reviewed in this study.

- Based on the limited monitoring data, it is evident that dioxins/furans meet most if not all of the six criteria to qualify as an urban toxic contaminant. As such, it is likely that dioxin and furans will be trapped by existing or future urban stormwater BMPs.

- There is insufficient monitoring data, however, to derive a credible estimate of the background dioxin load from urban areas in the watershed, what fraction of that load may be effectively removed by stormwater BMPs, and how much the load reduction might diminish the environmental impact of dioxins.

- Much more research is needed on this toxin category, especially to determine whether dioxins are accumulating in stormwater BMP sediments, and whether they are toxic or not.

Key Findings on Polycyclic Aromatic Hydrocarbons (PAH)

- PAHs are ubiquitous in urban sediments across the Chesapeake Bay watershed, and, on a national basis, have been found to contribute more to total sediment toxicity than all other toxin categories combined.

- The quality of existing monitoring data to characterize PAH sources, pathways and loadings in the watershed is classified as moderate, with a few important data gaps in our understanding.

- PAH meet all six criteria to be classified as an urban toxic contaminant -- they are strongly associated with urban land, have unique (and controllable) urban sources, are delivered in urban stormwater, behave in the same manner as sediment, originate in an upland landscape position and are captured and retained by stormwater BMPs.

- Due to the high cost and difficulty of sampling, only a handful of research studies have evaluated whether stormwater BMPs have the capability to remove PAH. Based on this limited monitoring data and given its basic characteristics, PAHs are considered to be highly treatable by most urban stormwater BMPs -- with expected removals slightly greater than those observed for total suspended solids.

- Three recent studies have shown that PAH compounds accumulate and persist in BMP sediments at levels that exceed sediment guidelines, and which may warrant special sediment handling and disposal methods. The risk of sediment PAH contamination is most pronounced within older stormwater ponds, whose hypoxic bottom waters prevent rapid biodegradation of PAH compounds in the sediments. More research is needed to evaluate the comparative risk of PAH pond sediment contamination, based on their age, contributing land use, or other catchment factors.

- The largest and most controllable source of PAH are the coal tar sealcoats applied to extend the life of asphalt parking lots. Numerous studies have documented that the sealcoats generate a very high PAH load, and several state and local governments in the Chesapeake Bay have banned their use. Imposing a Bay-wide coal tar sealcoat ban would not only be an effective strategy to reduce PAH inputs to the estuary, but would also minimize the risk of PAH sediment contamination in upland stormwater ponds.

- A comprehensive PAH reduction strategy for the Chesapeake Bay might combine the seal coat ban with more widespread installation of stormwater retrofits and more stringent vehicle emission controls.

- Like other urban toxic contaminants, however, there is expected to be a multi-decade lag time before the environmental benefits are fully realized, given how long it will take for past PAH inputs to cycle through the watershed.

Key Findings for Total Petroleum Hydrocarbons (TPH)

- TPH refers to a broader group of petroleum hydrocarbons than PAH. Unlike PAH, there are no numerical aquatic life or human health standards that applies to this class of toxins. Instead, most states usually establish a narrative standard (e.g. no visible sheen) or a maximum concentration of a surrogate parameter (such as oil and grease) in order to regulate fuel spills and other discharges of oil, gas or other hydrocarbons into receiving waters.

- TPH is not as well studied as some other toxins, such as PAH. Overall, the quality of monitoring data to assess TPH sources, pathways and loads in the watershed is classified as low to moderate, with some major data gaps in our understanding.

- The limited TPH data that does exist suggests that it meets all six criteria to be classified as an urban toxic contaminant, and that it should be effectively treated by most urban BMPs that are capable of removing sediment particles in urban stormwater runoff.

- A handful of monitoring studies confirm that TPH are effectively removed by stormwater BMPs (including surrogate parameters, such as oil and grease or benzene). In general, TPH removal rates are equal to or greater than total suspended solids removal rates.

- In addition, recent studies have shown that bioretention and rain gardens are not only effective in trapping TPH, but also in breaking it down via microbial processes in the aerobic soil environment of the media. The reported bioremediation that occurs within bioretention areas is encouraging, as it greatly reduces the potential for TPH accumulation over time (unlike PAH).

- While urban BMPs are effective in removing hydrocarbons, it is important to maintain existing pollution prevention practices to prevent and/or contain spills, leaks and other fuel discharges to the environment.

Key Findings for Mercury

- Mercury accumulation in fish tissue is a major cause of widespread water quality impairment in rivers, impoundments and estuaries across the Chesapeake Bay watershed.

- Overall, the quality of monitoring data to evaluate mercury sources, pathways and loads in the watershed is considered high, although there is much less monitoring data available on mercury removal by stormwater BMPs or its presence in BMP sediments.

- Although mercury is a global pollutant that is deposited across the entire watershed and over the open waters of the Bay, it still meets the six criteria to qualify as an urban toxic contaminant.

- Mercury loading rates are highest in urban watersheds, due to the wash-off of mercury deposited on impervious surfaces into the storm drain network.

- Although mercury exists in several forms, it is strongly associated with sediment particles and primarily moves through the watershed during high urban stormwater flows.

- The encouraging trend is toward lower levels of mercury in lake and estuarine sediments over time, as well as lower levels within the Chesapeake Bay bald eagle population.

- Despite these positive trends, mercury levels will continue to be a problem for many decades, given the considerable lag time between when mercury is deposited on watershed soils, and when the contaminated soils move through the stream network in the watershed to reach the Chesapeake Bay.

- Further complicating the issue is the methylation process. Under certain environmental conditions, mercury is transformed in methyl-mercury, which rapidly accumulates in fish tissue, and magnifies up the food chain to cause toxicity to fish, birds and mammals, including humans.

- The treatability of mercury inputs is not as great as other UTCs for several reasons. The first is that significant mercury inputs bypass the stream network and are directly deposited on the open waters of the Bay. The second relates to the methylation process that is enhanced in anoxic and organic-rich sediments of natural wetlands and estuaries.

- Some researchers estimate that more than half the methyl-mercury is produced within the open waters and wetlands of the Chesapeake Bay, which sharply limits any impact from upland stormwater treatment.

- Given the amount of water quality impairment that mercury causes, it is surprising how little monitoring data has been collected to determine if urban BMPs can effectively remove it. Based on the limited data available, mercury does appear to behave very much like a sediment particle, and should be removed by any stormwater practice that can settle out or filter sediment particles.

- One monitoring study showed that constructed stormwater wetlands were very effective at removing mercury from urban runoff, and that mercury was retained in the bottom sediments. The researchers cautioned that that the hypoxic and organic rich conditions that occurred within the constructed wetland also increased the rate of methyl-mercury conversion to that observed in natural wetlands.

- Two pollution prevention practices could also help reduce mercury loads -- recycling of thermostats and fluorescent bulbs. In addition, targeted street cleaning efforts may also have a moderate ability to reduce mercury levels contained in street dirt.

Key Findings for Urban Trace Metals

- Four trace metals, cadmium, copper, lead and zinc, are detected in virtually every sample of urban stormwater runoff, and at concentrations that are consistently higher than any other land use in the watershed. For this reason, they are referred to as "urban trace metals" or UTMs.

- The data quality for the four UTMs is rated as moderate to very high, ranking as the highest of any of the UTCs reviewed in this study. In particular, more than 50 studies are available that evaluate how urban BMPs remove each of the trace metals from stormwater.

- UTMs qualify as an urban toxic contaminant as they meet at least five of the qualifying criteria. They have unique urban sources including roofing materials, brake pads, tires, vehicle emissions and atmospheric deposition.

- The only criteria that UTMs do not fully meet is behaving like a sediment particle. From 10 to 60% of the UTMs are found in soluble form, which exerts the greatest toxic impact to aquatic life.

- In terms of environmental impact, the concentrations of soluble Cd, Cu and Zn exceed acute toxicity standards for aquatic life in about 50% of urban stormwater runoff samples collected across the nation.

- Lead levels in urban runoff have declined sharply in the last three decades, due to the introduction of unleaded gasoline. Consequently, lead levels in runoff no longer exceed aquatic life or human health standards. No long term trend data are available for cadmium, copper or zinc.

- UTMs are highly treatable and their BMP removal rates tend to be slightly lower than total suspended solids. Individual trace metal removal rates range from moderate to very high, depending on the type of stormwater practice employed. In general, the highest overall UTM removal rates were reported for bioretention, wet ponds and sand filters.

- Several studies have looked at UTM accumulation in BMP sediments or media, and the potential for breakout and release of soluble metals over time. The studies have generally found that metal binding sites are finite in number, but several decades would be needed to fully exhaust them. Periodic removal of the top few inches of sediment or media should prevent any soluble metal loss over time.

- While stormwater BMPs are an effective strategy to reduce urban trace metals to receiving waters, they need to be augmented by other management strategies to comprehensively reduce trace metal loads. These include stormwater benchmarking and pollution prevention at industrial sites, as well as product substitution to reduce metals delivered from brake pads, rotors, tires and roofing materials.

Key Findings for Other Trace Metals

- The quality of monitoring data to assess the sources and pathways of arsenic, chromium, iron and nickel is rated as moderate to high, although BMP removal data is somewhat limited. Most of the monitoring data has occurred outside the Chesapeake Bay, and much of our understanding about this group of metals has come from the urban watersheds of San Francisco Bay.

- Arsenic, chromium, iron and nickel are all frequently detected at high levels in urban sediments, stormwater runoff and during high river flow conditions in the Chesapeake Bay watershed.

- Although these metals can be naturally produced through geological weathering and soil erosion, their concentrations tend to be much higher in urban watersheds, especially those industrial land. All four metals are exposed on urban landscape surfaces, where they can "weather" or corrode, often exacerbated by leaching from acid rain.

- All four of the trace metals --arsenic, chromium, iron and nickel--meet the six criteria to qualify as an urban toxic contaminant. Higher concentrations are found in urban watersheds, due to unique urban sources and emissions. They are primarily delivered in the watershed by urban stormwater.

- Higher concentrations of all four metals are strongly correlated with high flow, sediment and/or turbidity levels. The four metals are also strongly associated with sediment and organic matter, and behave like a sediment particle when it comes to stormwater treatment.

- The main environmental risk associated with this group of trace metals is potential drinking water contamination, although the metal concentrations during most storm events fall well below most primary and secondary drinking water standards. Violations of acute freshwater toxicity standards are also generally uncommon. There is insufficient trend data to determine if the concentrations of the four metals are increasing, decreasing or remaining the same.

- Given their upland position, the four metals are treatable with stormwater BMPs, and there is abundant evidence that most BMPs are moderately effective in trapping the metals and retaining them in their sediment.

- The four trace metals are highly treatable with new or existing stormwater practices in urban watersheds. The highest removal rates (50 to 80%) are reported for iron, which is not surprising given its very limited solubility. By contrast, BMP removal rates for arsenic, chromium and nickel are more modest, ranging from 15 to 65%.

- The type of stormwater practice also has a strong influence on metal removal, with wet ponds, infiltration, sand filters and grass channels recording the highest overall rates.

- There was not enough data available to assess the risk that any of the four metals might breakout or be otherwise released from BMP sediments over time. Much stronger evidence exists that these trace metals can accumulate in the bottom sediments of stormwater ponds, and may exceed sediment toxicity guidelines.