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

Part 1: Removal of Urban Toxic Contaminants

Prepared for:

Toxics Work Group
Chesapeake Bay Partnership

Prepared by:

Tom Schueler and Anna Youngk
Chesapeake Stormwater Network

Date: December 7, 2015

Foreword

This project was developed by the Toxic Contaminant Work Group to evaluate whether best management practices (BMPs) used to reduce nutrient and sediment loads for the Bay pollution diet might also offer additional benefits to reduce toxic contaminants. The results of this one year research synthesis are summarized in two technical memos. This memo is the first installment in the series, and looks at how stormwater BMPs remove urban toxic contaminants.

The second memo examines how toxic contaminants are influenced by the agricultural and wastewater sectors in the Chesapeake Bay, with an emphasis on croplands, animal feeding operations and manure application, as well as discharges from wastewater treatment plants and land application of biosolids. The second memo focuses on the following toxic contaminants:

- Pesticide applications (especially herbicides used for no-till)
- Biogenic hormones produced by both sectors
- Human and veterinary pharmaceuticals and antibiotics generated from both sectors.

Acknowledgements

This project was supported by a contract with the Chesapeake Bay Trust which developed the project in consultation of the Water Quality Goal Implementation Team and the Toxic Contaminants Work Group. Special thanks to Jana Davis (CBT), Greg Allen (EPA), Scott Philips (USGS) and James Davis-Martin (VA DEQ) for their work in designing the project. Thanks are also extended to the members of the Toxic Contaminant, Urban Stormwater and Agricultural Work Groups for their comments on the initial work plan and providing research citations. The assistance of David Wood and Emma Giese (both from CRC) was invaluable in getting the report done. The massive literature review that supports this report could not have been completed without the tireless dedication, organization and hard work provided by Anna Youngk.

Executive Summary

A group of 12 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 washes 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 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
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	Y	Y	Y
OTM	Y	Y	Y	Y	y	y
PP	Y[a]	Y	Y	Y	y	y
OCP	Y[a]	Y	Y	Y	y	y
OPP	Y[a]	Y	Y	Y	y	ND
Plasticizer	y[w]	y	y	Y	y	y
PBDE	y[w]	y	y	Y	y	y
Dioxins	Y	y	y	Y	ND	ND

UTM: Urban Trace Metals (Cd, Cu. Pb and Zn)
OTM: Other Trace Metals (As, Cr, Fe and Ni)
PP: Pyrethroid Pesticides, OCP: Organochlorine pesticides, OPP organophosphate pesticides.
PBDE

Y = Yes, based on strong evidence
y = Yes, supported by limited monitoring data
ND = no data available to assess
a: moderate loads are also produced by the ag sector
w: wastewater can also produce moderate loads

Table E-1 shows the strength of evidence for classifying the twelve 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.

Overall Findings For All Urban Toxic Contaminants

Despite differences in their origin and chemical characteristics, the 12 UTCs shared some common findings when it came to removal by urban stormwater BMPs.

- Most urban BMPs in the Bay watershed have a high capability to remove suspended sediment from urban runoff. Suspended sediments and UTCs share many common characteristics- they are hydrophobic, non-soluble, have a strong affinity for organic matter, and bind, adsorb or otherwise become attached to sediment particles. In addition, both sediments and UTCs are relatively inert, persistent and have low rates of biodegradation. Both are also associated with fine and medium grained particles that can be entrained in urban stormwater runoff. Most importantly, both are subject to the same BMP removal mechanisms (i.e., settling and filtering) and frequently achieve reductions on the order of 50 to 90% in most urban BMPs.

Table E-2: Comparison of BMP Treatability for the 12 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
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
PP	TSS	E	Y	y	CR
OCP	> TSS	E	Y	y	MR
OPP	< TSS	E	Y	ND	MR
Plasticizers	< TSS	E	Y	y	ND
PBDE	< TSS	E	Y	Y	ND
Dioxins	< TSS	E	Y	ND	ND

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

- Given the close relationship between suspended sediment and UTCs, it is possible to link UTCs to a benchmark sediment removal rate. This is helpful because it allows users to infer UTC removal rates based on known TSS removal rates that have been developed by more than a dozen expert panels and approved for use by the CBP partnership. Table E-2 compares the relative treatability of the 12 urban toxic contaminants.

- It is clearly evident that existing urban BMPs are effectively removing UTCs in urban runoff and are preventing many of them from reaching the rivers and estuaries of the Chesapeake Bay. Currently, about a third of urban areas are treated by urban BMPs in the Chesapeake Bay watershed, and BMP coverage should steadily increase as states and localities implement the Bay TMDL.

- While a precise estimate is not possible, rough calculations indicate that urban BMPs are reducing UTCs by about 25% now and perhaps by as much as 40% by 2025. This finding suggests that efforts to reduce nutrients and sediments for the Bay TMDL can produce other significant water quality benefits, such as reducing toxicity to fish, wildlife and humans. Continued implementation of BMPs in the urban sector for the Bay TMDL is a key element of a comprehensive strategy to reduce loads of UTCs across the Bay watershed (along with existing strategies such as pollution prevention and product substitution).

- Due to major data gaps, this review could not evaluate the degree of UTC reduction due to implementation of on-site pollution prevention practices that are required under industrial and municipal stormwater permits. The potential impact 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.

- 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. 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.

- The environmental benefits of UTC reductions may not be immediately realized, since they experience a long lag time from when they are first deposited in the watershed, slowly cycle through the stream network and ultimately reach the Chesapeake Bay. Researchers project watershed lag times of several decades for the most persistent UTCs, which include PCBs, PAH, mercury, urban trace metals, flame retardants and OC pesticides. Other UTCs are expected to have watershed lag times measured over multiple years (petroleum hydrocarbons, OP pesticides and pyrethroid pesticides).

- 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.

- Older stormwater ponds built in the 1980s and 1990s appear to have the greatest risk of sediment toxicity. Monitoring has revealed that as many as 8 UTCs could potentially reach toxic levels in pond sediments, including PCB, PAH, Hg, Ni, Cr, Cu, Cd, and Zn. Some UTCs appear to be slowly declining in pond sediments (e.g., legacy pesticides), whereas the potential risk associated with other UTCs is simply not known at this time (e.g., PBDE, dioxins and pyrethroid pesticides).

- Despite these risks, pond sediments remain an acceptable option to (temporarily) trap toxics in the urban landscape for several reasons. First, the actual toxicity risk to aquatic life in the stormwater pond environment may be limited. The simplified food webs and low species diversity found in ponds may reduce the potential for bio-accumulation in urban fish and wildlife tissues. In particular, the benthic community in pond sediments that would be most exposed to UTCs is already highly degraded. Lastly, human fish consumption is extremely limited in stormwater ponds and recreational contact with sediments is uncommon.

- More research is urgently needed to measure UTC concentrations in pond sediments to fully assess the risk of future toxicity and develop safer methods to maintain BMPs and clean out their sediments. Work is needed to determine which types of stormwater ponds pose the greatest risk (e.g., age, contributing land use, surface area or other factors) and to define the optimal places in the urban landscape where pond sediments can be safely disposed after they are cleaned out (e.g., fill, mix w/ bio-solids, landfill, etc.). In addition, further tissue tests are recommended to determine if toxins are bio-accumulating in the fish and wildlife that utilize the habitat created by urban BMPs.

- On a more positive note, recent research indicates that LID practices that are now required by all Bay states (e.g., bioretention, biofilters and swales) are very effective at trapping UTCs and may actually break them down as a result of microbial biodegradation and phytoremediation processes that occur in the soil media and/or vegetation. The risk of UTC bioaccumulation also appears to less pronounced in LID practices such as bioretention. These smaller practices do not create aquatic habitat and their maintenance schedule calls for frequent removal and replacement of surface mulch and sediments where most UTCs will be preferentially trapped.

- While the urban BMPs required by the Bay states are effective in trapping UTCs, the ultimate strategy is to keep the toxins out of the environment. Several other UTC management strategies could be very effective in reaching this goal. These include:

  - Past bans and/or product substitution efforts have been effective (e.g., lead, PCB, DDT).

  - New bans and product substitution may be warranted in some cases:

    - Coal tar sealant (for PAH)
    - Brake pads and rotors (for UTMs)
    - More sustainable roofing materials (for UTMs)
    - Further restrictions on the use of dichlorvos and other urban insecticides

  - Enhanced recycling and disposal outreach (batteries, thermostats fluorescent light bulbs).

  - Targeted street cleaning at older watersheds and industrial sites.

  - Enhanced air quality controls at power plants and incinerators to reduce UTC emissions.

Overall Findings on Polychlorinated Biphenyls

- 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, most 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 and sediments which slowly move through the watershed in a recurring cycle of mobilization, deposition and re-suspension.

- PCBs 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 primarily conveyed through urban watersheds by stormwater runoff.

- Considering 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 BMPs. Given the characteristics of PCBs and limited settling column experiments, it is estimated that PCB removal rates will be comparable to suspended sediment removal rates for most urban BMPs.

- 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. 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, given the simplified food chain that exists in most stormwater pond communities. Likewise, the risk to human health is low, given fish consumption is rare in stormwater ponds, and few other modes of direct human exposure are likely.

- 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. 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, demolition controls during redevelopment projects and continued cleanup of legacy industrial sites and hotspots.

Key Findings on Polycyclic Aromatic Hydrocarbons

- 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 contamination in pond sediments, based on the contributing land use, age of the facility or other 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 Petroleum Hydrocarbons

- 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 was 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 can 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 the TPH are effectively removed by stormwater BMPs (or surrogate hydrocarbon parameters, such as oil and grease or benzene). TPH removal rates appear to be equal to or greater than total suspended solids 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 over time is toward lower levels of mercury in lake and estuarine sediments, and 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, mammals and 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 few monitoring studies have been undertaken to determine if urban BMPs can effectively remove mercury. Based on the limited data available, it appears that mercury does behave very much like a sediment particle, and should be removed by urban BMPs that can effectively 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 are measured at concentrations that are consistently higher than any other watershed land use. Consequently, they are referred to as "urban trace metals" or UTMs.

- The data quality for the four UTMs was rated as moderate to very high and ranked 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 urban 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. Depending on the metal, as much as 10 to 60% of UTMs are found in soluble form which also 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 material.

Key Findings for Other Trace Metals

- The quality of monitoring data to assess the sources and pathways of arsenic, chromium, iron and nickel was rated as moderate to high, although BMP removal data was 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.

- 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.

- 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 with extensive industrial operations. The metals are exposed on many surfaces in the urban landscape where they "weather" or corrode in response to acid rain, and become entrained in stormwater runoff.

- 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.

- 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 removal rates.

- There was insufficient data to assess the risk that any of the four metals might breakout or be otherwise released from BMP sediments over time. Stronger evidence was found that trace metals can accumulate in the bottom sediments of stormwater ponds at levels that may sometimes exceed sediment toxicity guidelines.

Overall Findings on Pyrethroid Pesticides

- Pyrethroid pesticides are a new class of insecticides that have entered the insect control market in the last decade. As a group, pyrethroids are relatively non-persistent in the environment and are unlikely to bio-accumulate in vertebrates. Nonetheless, pyrethroids are extremely lethal at very low concentrations to aquatic invertebrates in urban streams.

- Pyrethroids meet most of the basic criteria to qualify as an UTC, although there is no monitoring data to confirm whether they are trapped in BMP sediments and persist over time. In addition, the majority of the research has been conducted in unique climate and landscape conditions of California, which may limit its transferability to the Chesapeake Bay watershed.

- Pyrethroids have a strong affinity for sediment and organic matter and they are routinely detected in urban creek sediments where they exert their toxic effects. Consequently, pyrethroid removal rates in urban BMPs should be broadly comparable to those observed for suspended sediment, although more monitoring data is needed to confirm this. More research is also needed to assess the risk of that pyrethroids will persist and exert toxicity in pond sediments.

- Given how much aquatic toxicity has been linked to pyrethroids and other insecticides, it may be wise to expand public outreach and social marketing efforts to educate homeowners, landscape contractors, applicators and others about the proper methods and timing to apply insecticides.

Overall Findings on Legacy Organochlorine (OC) Pesticides

- Organochlorine (OC) pesticides include insecticides such as DDT, DDE and dieldrin that have been banned for decades but still persist in the environment.

- These legacy pesticides meet all the criteria to classified as an urban toxic contaminant (UTC), despite the fact that were also historically applied to crops, orchards and wetlands (i.e., mosquito control). The main reason is that urban soils that were contaminated by OC pesticides in the past tend to be much more mobile in urban watersheds.

- The encouraging news is that nearly all monitoring studies have shown sharply declining trends in OC pesticides in urban stormwater runoff and creek sediments, which appears to have greatly reduced their bioaccumulation and toxicity in vertebrates, such as fish, eagles and marine mammals.

- Very limited monitoring data has been conducted to date on whether OCP pesticides are trapped with urban BMPs, but given their affinity for sediment particles, it is very likely that they would be present within BMP sediments and persist over time. The greatest risk would presumably be for older stormwater ponds that have trapped sediments laden with OC pesticides for many decades.

- OC pesticides are a classic example of how highly persistent and lipophilic insecticides can have an enduring environmental impact nearly a half century after their use was banned. The long watershed lag time associated with OC pesticides in the Chesapeake Bay watershed suggest that continued tracking may be warranted for another decade or two.

Overall Findings Legacy Organophosphate (OP) Pesticides

- Organophosphate (OP) pesticides refers to a group of insecticides that include chlordane, chlorpyrifos, diazinon and dichlorovos that were introduced toward the end of the last century to replace the more persistent OC pesticides.

- Research emerged in the late 1990s that confirmed that that these relatively non-persistent insecticides were highly toxic to aquatic invertebrates in urban streams at extremely low concentrations.

- Consequently, the use of most OP pesticides has been banned or highly restricted (chlordane in 1978, chlorpyrifos and diazinon in 2000-2002). The use of dichlorvos is still allowed, although it is more restricted than in the past.

- This class of legacy pesticides meets most (but not all) of the criteria to be classified as an urban toxic contaminant. They are predominately found in urban watersheds, are highly mobile, are carried by urban stormwater runoff and generally behave like a sediment particle.

- No research could be found on how effective urban BMPs were in reducing OP pesticides, nor was there any research available on their presence and persistence within BMP sediments. Given their chemical characteristics, however, it is not very likely that OP pesticides would persist long in pond sediments.

- The encouraging news is that levels of the two most common OP pesticides -- diazinon and chlorpyrofos -- have declined sharply in stormwater runoff and urban creek sediments since they were banned some 15 years ago. This represents a real success story about how quickly less persistent pesticides can be eliminated from the environment due to short watershed lag times.

Overall Findings on Plasticizers

- Phthalates are a type of plasticizer that is emitted from a diverse array of flexible PVC products and coatings. These plasticizers are increasing detected in urban stormwater and sediments, and are suspected to be an endocrine disrupting compound (Clara et al , 2010).

- Less than a dozen monitoring studies have been conducted on phthalates around the globe, all of which were located in Europe or the west coast. While phthalates appear to meet many of the criteria to be classified as a UTC, major data gaps on their sources and pathways in the Bay watershed prevent us from conclusively assigning them to the UTC category.

- For example, several European studies suggest that wastewater treatment discharges and/or land application of municipal biosolids are responsible for significant phthalate loads. At this time, it cannot be determined whether wastewater phthalate loads are greater than urban stormwater loads at the watershed level.

- A handful of monitoring and modeling efforts have sought to estimate the phthalate removal rate that occurs in urban BMPs. Based on this limited data, it is estimated that phthalate removal will be comparable to the TSS removal benchmark.

- Other management strategies to reduce phthalates could involve wastewater treatment plant upgrades and deeper incorporation of municipal biosolids.

Overall Findings on Flame Retardants (PBDE)

- Only a handful of research studies have assessed this potential UTC, most of which were located in Europe or California. As with phthalates, flame retardants appear to meet many of the criteria to be classified as a UTC, but major data gaps for the Bay watershed makes it difficult to conclusively assign them to this category.

- For example, some studies indicate that wastewater discharges and/or land application of municipal biosolids could also be a significant potential source of flame retardants at the watershed scale.

- PBDE is a flame retardant that includes numerous compounds that are persistent and tend to bio-accumulate in fish and wildlife tissues in much the same way as PCBs or dioxins.

- PBDE is emitted from several sources, including atmospheric deposition over urban watersheds. Like many other UTCs, PBDE strongly sorbs to soil, sediments and organic matter, and moves through the watershed when these particles are mobilized by stormwater runoff.

- Given the characteristics as PBDE, it is expected that it can be effectively reduced by urban BMPs that are able to trap or filter out sediment particles. The limited European research on PBDE removal by biofilters and retention ponds suggests that it falls within the same general range as suspended sediment removal.

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 watersheds. The environmental risks posed by these low concentrations, however, are not well understood.

- The primary sources of dioxins in urban watersheds are 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.

- It appears that dioxins/furans meet most, if not all, of the six criteria to qualify as an urban toxic contaminant, although this conclusion is based on very limited monitoring data. As such, it is likely that dioxins 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.