Toxics, BMPs and the Chesapeake Bay: Headlines for Bay Managers

URBAN STORMWATER WORK GROUP

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Presentation Outline

1. Project Background
2. Most Toxics are Generated from Urban Watersheds
3. Urban BMPs are Very Effective at Removing Them
4. Risk: UTC Accumulation in BMP Sediments
5. Pollution Prevention Still Trumps BMPs
6. Troubling Trends in Urban Insecticides
7. Legacy Pesticides and Watershed Lag Times
8. Conservation Tillage and Herbicides
9. Antibiotics and Biogenic Hormones are Removed and then Re-emerge

Project Background

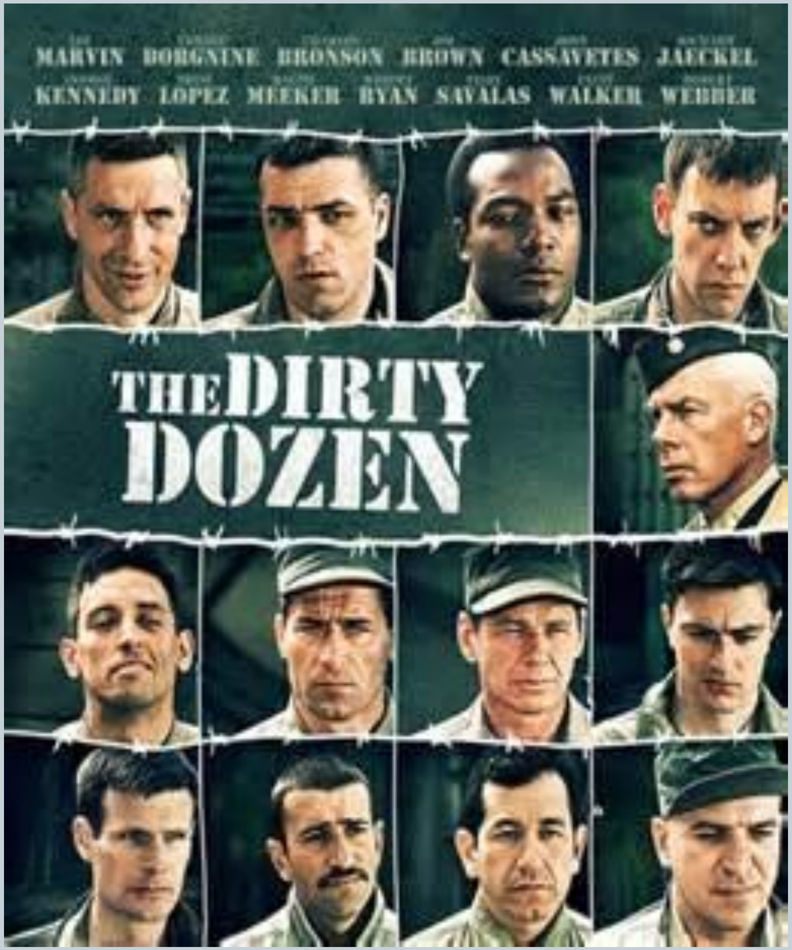
One year research synthesis project that evaluated 35 group of toxins generated by the ag, urban wastewater sectors

Goal: Investigate toxic reduction benefits associated with Bay BMP implementation for the TMDL, and give managers better data for local TMDLs to control toxic pollutants in the watershed

Scope: More than 400 papers reviewed

Funding: From CBT and WQGIT

2. Most Toxins are Generated from Urban Watersheds



THE DIRTY DOZEN UTCs

- PCBs
- PAH
- TPH
- Mercury
- UTM (Cd, Cu, Pb, Zn)
- OTM (As, Cr, Fe, Ni)
- Pyrethroid Pesticides
- Legacy OC Pesticides
- Legacy OP Pesticides
- Plasticizers (Phthalates)
- Flame Retardants (PBDE)
- Dioxins

Urban Toxic Contaminant (UTC) Criteria

- The toxin is primarily associated with urban land use, compared to other sectors in the watershed.
- The toxin is either generated within the urban sector or is deposited from the atmosphere onto impervious surfaces and subsequently washed off.
- Urban stormwater runoff is the predominant pathway for transporting it thru the watershed.
- The toxin has "sediment-like characteristics" and can be removed by settling or filtering practices.
- 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.
- Physical evidence exists that the toxin is captured and/or retained within an urban stormwater BMP.

Urban Toxic Contaminants

Toxin Category	1. urban land use?	2. urban sources ?	3. stormwater pathway ?	4. Sediment characteristics	5. Upland Position ?	6. Urban BMP Retention?
PCBs	Y	Y	Y	Y	Y	y
PAH	Y	Y	Y	Y	Y	Y
TPH	Y	Y	Y	Y	y	Y
Mercury	Y	Y	Y	Y	Y	y
UTM	Y	Y	Y	Y	Y	Y
OTM	Y	Y	Y	Y	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, supported by limited monitoring data ND = no data available to assess		

Urban Toxic Contaminants
(continued)

Toxin Category	1. urban land use?	2. urban sources ?	3. stormwater pathway ?	4. Sediment characteristics	5. Upland Position ?	6. Urban BMP Retention?
PP	Y	Y	Y	Y	y	y
OCP	Y	Y	Y	Y	y	y
OPP	Y	Y	Y	Y	y	ND
Plasticizer	Y	Y	y	Y	y	y
PBDE	y	Y	y	Y	y	y
Dioxins	Y	Y	y	Y	ND	ND
PP: Pyrethroid Pesticides, OCP: Organochlorine pesticides, OPP organophosphate pesticides. PBDE: Polybrominated diphenyl ethers				Y = Yes, based on strong evidence y = Yes, supported by limited monitoring data ND = no data available to assess		

3. Urban BMPs are Very Effective at Removing UTCs

- Since most UTCs have sediment-like properties, they are effectively trapped by most urban BMPs before they get to local waterways and the Bay.

UTC and TSS Removal Benchmarks

- Linking UTCs to a benchmark TSS removal rate
- Allows users to project UTC removal rates based on known TSS removal rates
- Can calculate reductions based on much larger CBP database on sediment removal by urban BMPs

BMP Treatability for Urban Toxic Contaminants

Toxin Category	BMP Removal Rate?	Measured or Estimated?	Behaves like Sediment?	BMP Retention?	Sediment Toxicity Concern?
PCBs	TSS	E	Y	Y	Mod
PAH	> TSS	E	Y	Y	High
TPH	> TSS	M	Y	Y	Low
Mercury	> TSS	E	Y	Y	Mod
UTM	< TSS	M	Y	Y	Mod
OTM	< TSS	M	Y	Y	Mod

BMP Treatability for Urban Toxic Contaminants
continued

Toxin Category	BMP Removal Rate?	Measured or Estimated?	Behaves like Sediment?	BMP Retention?	Sediment Toxicity Concern?
PP	TSS	E	Y	y	High
OCP	> TSS	E	Y	y	Low
OPP	< TSS	E	Y	?	Low
Plasticizers	< TSS	E	Y	Y	?
PBDE	< TSS	E	Y	Y	?
Dioxins	< TSS	E	Y	?	?

Urban Trace Metals (UTMs)

- Cd, Cu, Pb and Zn are detected in nearly 100% of urban stormwater samples, and soluble levels of these metals exceed aquatic life standards
- Abundant research on EMC and BMP removal for all four metals
- Unique urban sources: roofing materials, brake pads, tire wear, vehicle emissions, and air deposition
- Despite solubility, monitoring data generally show high to very high UTM removal by BMPs (especially bioretention).

Comparison of Urban Trace Metals

Factor	**Cadmium**	**Copper**	**Lead**	**Zinc**
Runoff EMC (ug/l)	1	16	17	115
Solubility (%)	45%	60%	10%	50%
Acute Toxicity (%)	50%	50%	18%	45%
Sediment Level (ug/g)	0.2 to 0.5	40-150	20-200	200-500
Removal Rates (%)	40 to 70%	40 to 60	50 to 90	55 to 75
Sediment Risk	Low	Mod.	Low	Mod.

Comparative Ability of Stormwater BMPs to Remove Urban Trace Metals

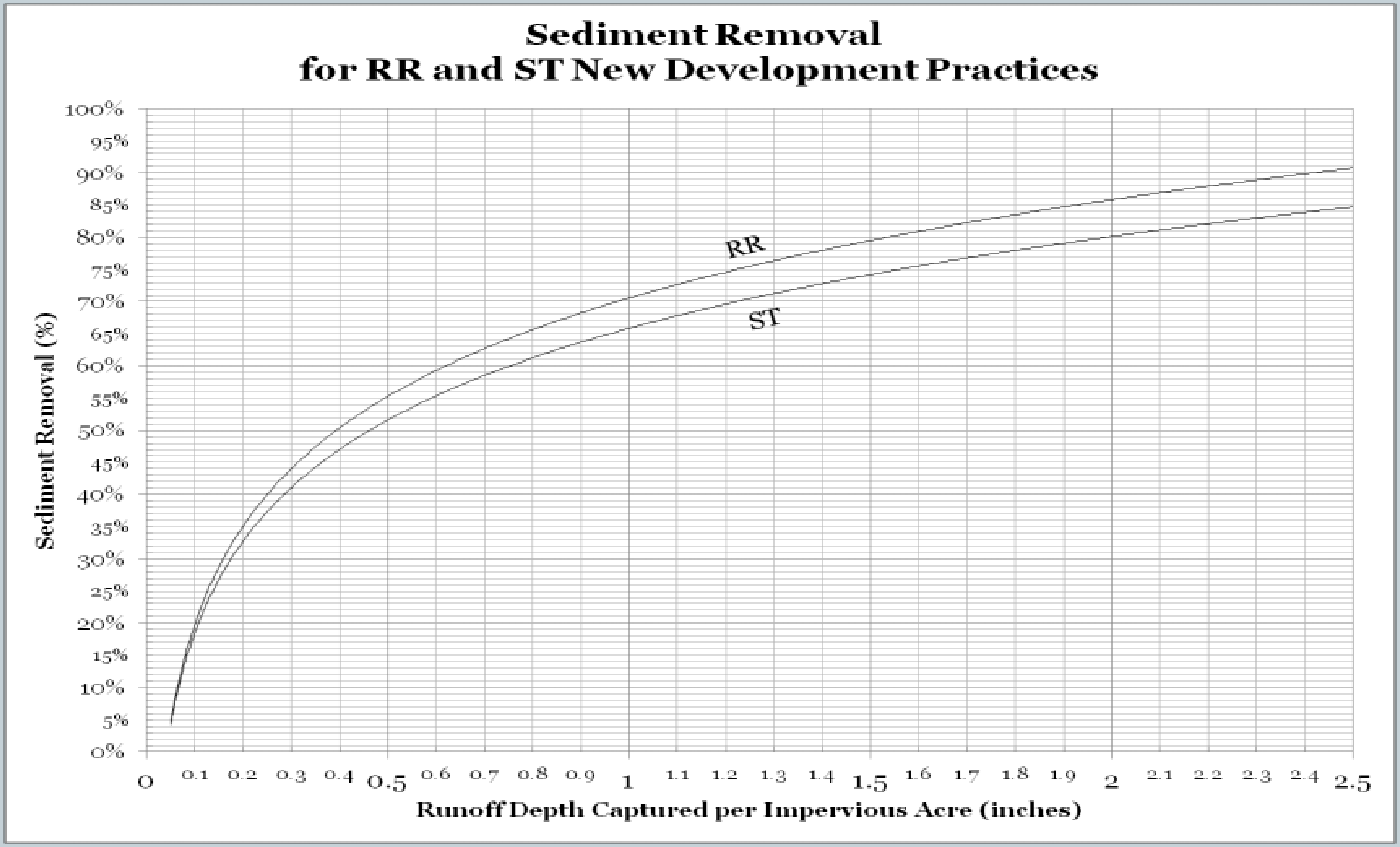
Stormwater BMP	Urban Trace Metals			
	Cadmium	Copper	Lead	Zinc
Bioretention	H	VH	VH	VH
Wet Pond	M	H	H	H
Wetland	M	H	M	M
Sand Filter	H	M	VH	H
Permeable Pavement	L	M	VH	VH
Dry Swale	L	H	--	VH
Grass Channel	M	L	L	M
Grass Filter	L	M	L	M
Dry Pond	L	L	M	M

VH: Very High Removal (76% to 100%) H: High Removal (50% to 75%)
M: Moderate Removal (26% to 50%) L: Low Removal (0% to 25%)

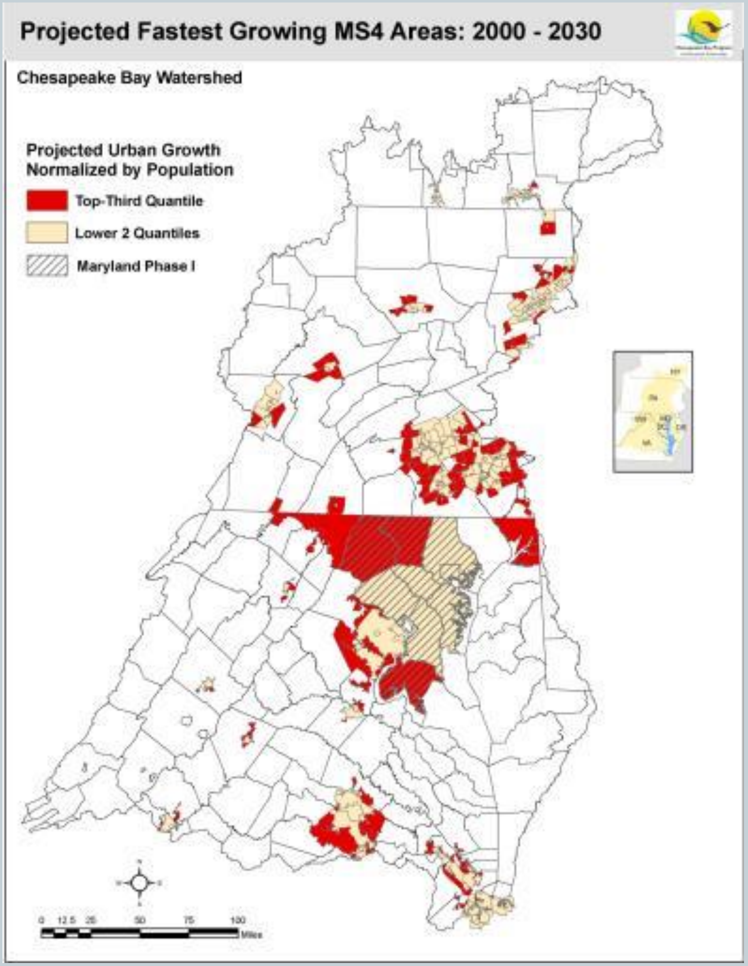
Summary of Trace Metal Removal by Bioretention

Trace Metal	Research Studies (N)	Removal Rate (%)
Cadmium	2	66-90
Copper	10	43-98
Lead	12	75-98
Zinc	11	62-99
Source: LeFevre et al (2014)		

More precise removal estimates using expert panel adjustor curves



Urban BMP Coverage in Bay Watershed



- Urban BMPs now cover 30% of urban land in the watershed – most of any region in the nation
- BMP coverage could increase to 40 or 50% by 2025 due to TMDL compliance in the urban sector
- UTC removal by nearly all urban BMPs is moderate to very high

4. Risk of UTC Accumulation in BMP Sediments

- Cautionary tale that some persistent UTCs are accumulating in the sediments of older ponds, but the Bay-wide shift to LID practices, such as bioretention, are minimizing this future risk

UTC Accumulation In BMP Sediments

- Persistent UTCs accumulate in BMP sediments over many decades at levels that trigger sediment toxicity guidelines.
- As many as 8 UTCs pose a risk for sediment toxicity: PCB, PAH, Hg, Ni, Cr, Cu, Cd, and Zn
- Most research on older stormwater pond sediments

PAH and Pond Sediments

Percent of MD Stormwater Ponds with Potential PAH Sediment Toxicity		
Individual PAH	**TEC**	**PEC**
Napthalene	3%	0%
Flourene	12%	1%
Phenanthrene	46%	12%
Anthracene	15%	1%
Flouranthene	34%	13%
Pyrene	34%	15%
Benzo[a]anthracene	24%	7%
Chrysene	34%	10%
Benzo[a]pyrene	38%	7%
Dibenz[a,h]anthracene	44%	NA
Source: Gallagher et al, 2010		

Managing the BMP Sediment Toxicity Risk

- Are BMP sediments an acceptable place to trap toxics in the urban landscape ?
- Where is the **next** place that sediments should go when they are cleaned out from BMPs ?
- Is UTC sediment accumulation only a concern for older stormwater ponds in highly urban/industrial watersheds ?
- What is the **real** risk to aquatic life and human health in the stormwater pond environment versus the LID environment ?

Not a Bad Place, After All ?

Toxicity risk to aquatic life in the stormwater pond environment may be limited:

- Simplified food webs and low species diversity reduce bio-accumulation in urban fish and wildlife tissues.
- Not much of a benthic community in pond sediments
- Ponds appear to be effective at retaining UTCs over time
- UTC levels are also high in other non-BMP sediments (e.g., urban creeks, rivers and estuaries).
- Extremely limited fish consumption from ponds and recreational contact with sediments is non-existent

New LID practices (e.g., bioretention) do not create aquatic habitat and removal of surface sediments is frequent

5. Pollution Prevention Still Trump BMPs

Further Reduction Due to Pollution Prevention Practices ?

- No data on impact of pollution prevention practices in reducing toxins required under industrial and municipal stormwater permits.
- The potential effect of these practices could be considerable, given that:
  - 2,700 industrial sites have stormwater permits in Bay watershed (25,000+ acres of impervious cover)
  - 1,000 MS4 facilities and public works yards are subject to the same regulations.

Pollution Prevention Works

- Past bans and/or product substitution have worked (lead, PCB, DDT)
- New bans and product substitution (coal tar sealant for PAH, brake pads and rotors for UTMs, more sustainable roofing materials for UTMs)
- Recycling and disposal (batteries, thermostats, fluorescent light bulbs).
- Targeted street cleaning at older watersheds and industrial sites

6. Troubling Trends in Insecticides

- The insecticides applied to crops and urban areas have changed over time, and are now less persistent in the environment and do not bioaccumulate in tissues.
- However, they are still mobile in the environment and are deadly to aquatic invertebrates at the part per trillion level

Evolution in Insecticides Over Time

Era	Insecticide	Types	Notes
1940 to 1970	Organochlorines (OC)	DDT	Banned in the 1970s
		DDD/DDE	DDT degradation products
		Dieldrin	Banned in 1985
1960 to 2000	Organophosphate (OP)	Chlordane	Banned in 1978
		Chlorpyrifos	Restricted in 2002
		Diazinon	Restricted
		Dichlorvos	Increased use after 2002
2000 to present	Pyrethroids	Bifenthrin	Replacements for OCP and OPP
		Permethrin	Less toxic than bifenthrin
2005 to present	Fipronil	Fipronil	Most aquatic life toxicity in recent surveys
	Neonictinoids	Imdiacloprid	Emerging concerns about aquatic toxicity

Pyrethroid Pesticides

- Pyrethroid pesticides include bifenthrin, permethrin and others
- New class of insecticides introduced in the last decade
- Non-persistent in the environment and unlikely to bio-accumulate in vertebrates
- Extremely lethal to aquatic invertebrates in urban streams, even at part per trillion level
- Routinely detected in urban creek sediments

Pyrethroid Pesticides

- Meet criteria to qualify as an UTC, although some data gaps remain
- Strong affinity for sediment and organic matter
- BMP removal rates should be comparable to suspended sediment
- More research needed on persistence and toxicity in BMP sediments.

Legacy Organochlorine Pesticides

- Organochlorine (OC) pesticides include DDT, DDE and dieldrin that were banned decades ago but still persist in the environment. Classified as a UTC, but were also used on crops and for mosquito control.
- Soils contaminated by OC pesticides more mobile in urban watersheds. Likely present in older pond sediments
- Sharply declining trends in OC pesticide levels in urban runoff and creek sediments and reduced bioaccumulation in fish, eagles and marine mammals.
- Continued tracking of OC pesticides may be warranted for another decade or two.

Legacy Organophosphate Pesticides

- Organophosphate (OP) pesticides include chlorpyrifos, diazinon and dichlorovos and were introduced 15 to 20 years ago to replace OC pesticides.
- Relatively non-persistent but still very highly toxic to aquatic life in urban streams, most were banned by the turn of the century
- Found in urban watersheds, are highly mobile, are carried by urban stormwater runoff and generally behave like a sediment particle.
- No data on BMP removal or persistence in BMP sediment
- Sharp declines in stormwater runoff and urban creek sediments since they were banned
- Less persistent pesticides can be eliminated from the environment due to short watershed lag times.

8. UTCs and Watershed Lag Times

- Environmental benefits of reducing toxins may not be fully realized for several decades
- Long lag time between when they are first deposited on watershed surfaces or soils and cycle through the stream network to ultimately reach the Chesapeake Bay.

- Researchers suggest long lag times for the following UTCs:
  - PCBs
  - PAH
  - Mercury
  - UTMs
  - DDT and Chlordane
- What does this signify for nutrients?

8. Conservation Tillage and Herbicides

- How the profound shift to conservation tillage as a cornerstone BMP for corn and soybeans in the Bay watershed has changed herbicide use and impacts over the last 3 decades

Trends in Herbicides Applied to Corn and Soybeans

ERA	1970's -1980's	1990-2000	2001 to present
Most Common Herbicides Detected	• Atrazine	• Atrazine • Metoachlor • Acetochlor • Alachlor	• Glyphosate • AMPA • Some Atrazine
Tillage Practices	>25% of crops use conservation till	Climbs to about 50 to 60% of crop acres	Climbs to nearly 90% of row crops
Genetically Engineered Crops	None	GE corn and soybeans enter market in mid to late 1990's	GE seeds comprise 92 to 94% share of crop acres

Changes in Herbicide Impacts Over Time

ERA	**1970's -1980's**	**1990-2000**	**2001 to present**
Most Frequently Detected	• Atrazine	• Atrazine • Metoachlor • Acetochlor • Alachlor	• Glyphosate • AMPA • Some Atrazine
Water Quality Risks	Atrazine suspected in SAV loss, but later exonerated	Aquatic life criteria frequently exceeded for metoachlor and atrazine. Possible Endocrine disruptor	Routinely detected in surface waters, but aquatic life criteria not exceeded
Groundwater Concerns	Major concern for rural drinking water wells	Declining levels measured toward end of the era	Rarely detected in groundwater or soil water at this time

Herbicide	Groundwater Advisory ?	Exceeds Aquatic Life Benchmarks ?	MCL	Half-life in Soils	Half-life in Water
			(ug/l)	Days	
Atrazine	Yes	Yes	3	146	742
Simazine	Yes	Yes	4	91	32
Metoachlor	Yes	Yes	100	26	410
Alachlor	Yes	Yes	2	21	640
Glyphosate *	No	No	700	35	96
AMPA*	No	No	nd	7-14	76-240

Glyphosate and AMPA

- Glyphosate and its degradate, AMPA, are mobile in the environment and are frequently detected in surface waters, but are not as persistent in soil or water as the herbicides they replaced.
- Glyphosate and AMPA are much less toxic to bird, fish and aquatic life, do not bioaccumulate in tissues, and have minimal impacts of human health.
- Limited monitoring data suggest that vegetated buffers, constructed wetlands, biofilters and ponds all have a moderate to high capability to remove and degrade glyphosate and AMPA.

9.Antibiotics and Biogenic Hormones are Removed But then Re-emerge

Biogenic Hormones

- Biogenic hormones include estrogen, testosterone, estrone, estradiol and progesterone
- Concern about their potential endocrine disrupting properties.
- Concentrations of biogenic hormones in the part per trillion range can negatively impact aquatic life and possibly cause intersex fish.
- Discharged from animal feeding operations and wastewater treatment plants.
- Higher concentration w/ high watershed density of either animal feeding operations or sewage effluent

More on Biogenic Hormones

- Vegetated buffers, constructed wetlands and lagoons are highly effective in removing biogenic hormones in runoff from AFOs
- BNR upgrades are very effective in removing biogenic hormones in wastewater effluent
- Hormones concentrate in animal manure and municipal biosolids.
- When treatment residuals are applied to crops, they can potentially migrate back into the watershed.

More on Biogenic Hormones

- Sustainable strategy to keep unnecessary hormones out of the food supply chain.
- Livestock producers, groceries and restaurant chains are p
- Reminder about the power of social and economic forces advocating for food quality and safety

Antibiotics

- Antibiotics detected in streams and groundwater in the Chesapeake Bay include tetracycline, oxy-tetracycline and sulfamethoxazole.
- Concern about increased bacterial resistance that could reduces the therapeutic effect of these medicines
- Can degrade soil microbial community and reduce denitrification rate
- Half of human antibiotic use, and most livestock use "is unnecessary, inappropriate, and makes everyone less safe" (CDC, 2013).

More on Antibiotics

- Same 4 watershed sources as biogenic hormones
- Antibiotics are persistent, hydrophilic and very soluble -- may not be effectively removed by conventional WWTPS or BMPs
- Recent trend to phase out of antibiotics used in poultry, swine and cattle feeding operations.

Better Treatment, More Residuals

- Improved manure management at AFOs and the shift to BNR at WWTPs has increased removal of antibiotics and biogenic hormones from effluent, but the residuals are concentrated in animal manure and municipal biosolids that are applied back to croplands.
- Poor data quality make it difficult to fully assess this risk
- The phase out of antibiotics and hormones from livestock production and better antibiotic stewardship are the long term solution

Questions and Answers