Persistent Toxics Have Declined Over Past 30 Years

Uncertainties Remain about Impact of Novel Contaminants

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WHY IT MATTERS

Our society releases thousands of biologically active chemicals into the environment. These compounds include medications, pesticides, industrial chemicals, and byproducts of combustion, corrosion and wear, among others. Such compounds are called toxic when they have negative impacts on human health or the environment, especially if they have negative effects at low environmental concentrations.

By definition, toxic chemicals can harm living organisms, including humans, animals, plants, and microorganisms. Contaminants can have both severe short-term and subtle long-term effects. Effects include mortality, neurological impairment, developmental effects, impacts to metabolic processes, increased risk of genetic mutations and cancer, disruption of hormonal systems, and changes in behavior. Toxic contaminants in the environment can affect success of individuals and species, thus altering composition of ecological communities and ecosystem processes.

Many organisms can concentrate persistent contaminants in their bodies, increasing contaminant exposure to organisms who eat them. In marine food webs, that process can occur repeatedly as predator becomes prey, in a process called "biomagnification". Biomagnification means that even low environmental levels of persistent contaminants can pose health risks to organisms (from osprey and seals, to humans) who eat large, predatory fish.

Industrial uses of many persistent contaminants (like DDT and PCBs – See the sidebar for information on persistent toxic compounds) were phased out in the 1970s and 1980s, leading to reductions in environmental concentrations. We see the effects of those bans in long-term trends in levels of persistent contaminants in Casco Bay. Yet use of less-persistent toxic chemicals (including novel industrial chemicals, modern pesticides, pharmaceuticals and personal care products) has expanded. For many bioactive compounds, relatively little is known about their persistence or impacts in the marine environment.

PERSISTENT ORGANIC CONTAMINANTS

PAHs
Polycyclic aromatic hydrocarbons are principally derived from petroleum products or combustion of petroleum or other organic materials. Transportation and industrial activity are major sources.

PCBs
Polychlorinated biphenyls are chlorinated hydrocarbons that found a variety of industrial uses 50 years ago. Because of their toxicity, their use was phased out in 1979. Today, PCBs may be released when older products are improperly disposed of, or as a byproduct of poorly controlled burning of plastics.

Dioxins and furans
Dioxins and furans are not industrial products in their own right, but byproducts of incomplete combustion of organic matter and some industrial processes such as chemical manufacturing and chlorine bleaching of pulp and paper.

Butyltins
Tributyltin is a metal-organic molecule used in anti-fouling paint on large ships. Because of its toxicity and persistence in the marine environment, its use on smaller boats has been phased out. In the marine environment, it breaks down into related mono- and di-butyltins, so the group of related compounds are often studied together.

DDT Residues
DDT is well known as one of the more troublesome members of a class of pesticides known as organochlorines. Other members of this class include chlordane and lindane. Most organochlorine pesticides were banned decades ago because of their persistence in the environment. Like many organochlorines, DDT breaks down into closely related chemicals in the environment.

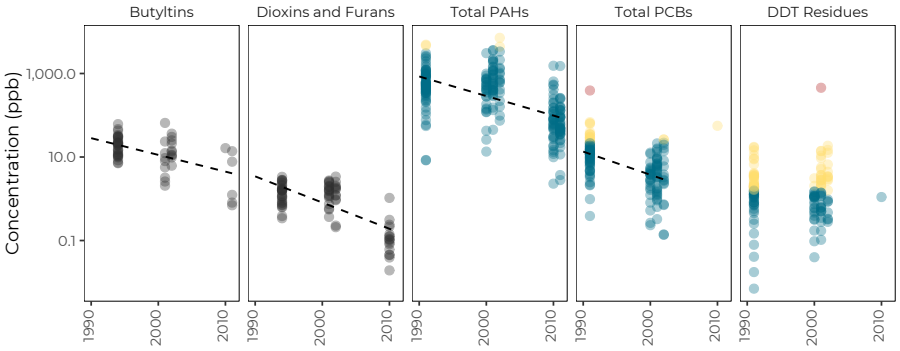
BENCHMARKS FOR RISK ASSESSMENT

A common way to evaluate risks associated with contaminants in sediments is to compare concentrations to published risk benchmarks, such as ERL and ERM:

- **Effects Range Low (ERL)** – A concentration below which negative effects on marine organisms are seldom observed.
- **Effects Range Median (ERM)** – A concentration at which negative effects are about as likely as not.

STATUS & TRENDS

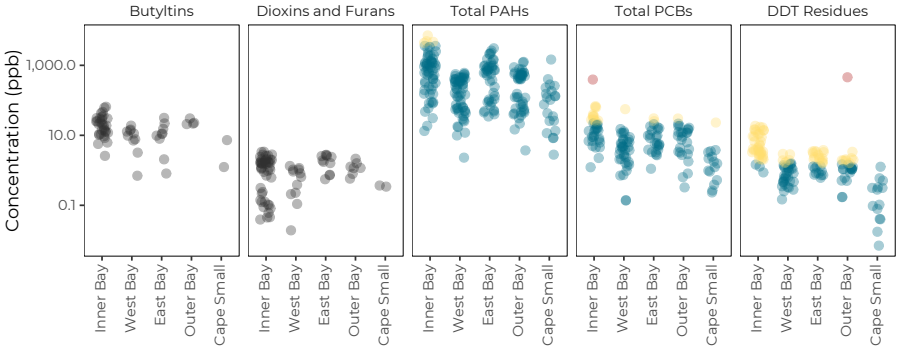
Persistent Organic Contaminants on the Decline in Casco Bay's Sediments

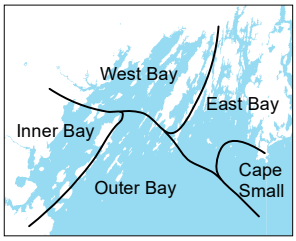


In 2016, CBEP released analysis of twenty years of sediment data from dozens of sites around Casco Bay. From 1990 to 2010, concentrations of many groups of toxic organic contaminants in the Bay's sediments declined. (Note: The y-axis is on a log scale.) More recent sediments are less contaminated than older sediments, which are now buried. Changes in analytic methods made it impossible to detect low levels of PCBs and pesticides in 2010, so recent trends are uncertain, but continued declines are likely.

Above ERM
Between ERL and ERM
Below ERL
No Reference Defined

Sediment Contamination Tends to Be Highest Near Portland





Since 1990, contaminant levels have varied across regions of the Bay. (Note: The y-axis is on a log scale.) Several contaminants tend to be highest in the Inner Bay (near the Portland metropolitan area) or lowest in the Outer Bay and off of Cape Small (in Phippsburg). However, levels of PAHs are high in the East Bay, perhaps because of historic discharges of contaminants from industries along the Kennebec and Androscoggin Rivers.

Almost All Metals Decreasing in Sediments

Many metals are toxic and all are persistent in the environment. As each poses different risks, they need to be assessed separately. Almost all metals are decreasing in Casco Bay's sediments. None were observed at levels above the ERM threshold, and thus levels are thought to pose limited risks to marine organisms. Persistent elevated levels of arsenic reflect presence of natural sources in the Casco Bay watershed. Elevated mercury bay-wide reflects atmospheric deposition.

	ABOVE ERL*					TREND**		
METAL	FREQUENT	COMMON	UNCOMMON	RARE	NEVER	INCREASING	DECREASING	DIFFERENCES AMONG REGIONS OF CASCO BAY
Arsenic	✓						*No trend*	Cape Small < Other regions
Nickel	✓						↓	Cape Small < Other regions
Chromium		✓					↓	Cape Small < East Bay and West Bay
Mercury		✓					*No trend*	Cape Small < Outer Bay and West Bay < East Bay < Inner Bay
Cadmium				✓		↑		Cape Small < Outer Bay < Other regions
Copper				✓			*No trend*	Cape Small < Outer Bay < Other regions
Lead				✓			↓	Cape Small < Other regions < Inner Bay
Silver					✓		*No trend*	Cape Small < Other regions < Inner Bay
Zinc					✓		↓	Cape Small < Other regions; Outer Bay < Inner Bay
Iron* **			*N/A (No ERL)*				*No trend*	Cape Small < East Bay and West Bay
Selenium			*N/A (No ERL)*				↓	No differences.

* Rare: < 10%; Uncommon: < 25%; Common: <50%, Frequent > 50%. No metals were above ERM.
** Trend analysis based on robust regression, including non-detects.
*** Iron is widespread in soil and sediments and is functionally non-toxic.

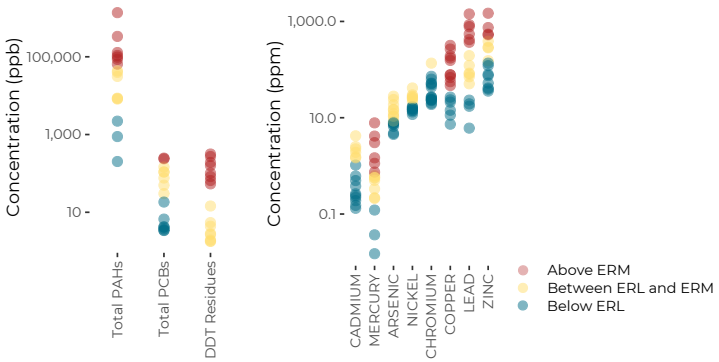
Results from Casco Bay Sediment Sampling (1991-2011)

CHEMICAL GROUP	MOST RECENT CONDITIONS (2010-2011)	TRENDS SINCE 1991
Metals	Generally below concentrations likely to be harmful*	Mostly declining/stable**
PAHs	Below concentrations likely to be harmful	Decline since 2000-2002
PCBs	Rarely detected	Decline 1991 to 2002; likely continued through 2010***
Dioxins and Furans	Low concentrations****	Decline since 2000-2002
Organochlorine Pesticides	Rarely detected	Decline 1991 to 2002; likely continued through 2010
Butyltins	Low concentrations, often not detected	Declining

*For those metals where sediment screening values are available. **Cadmium and silver show increases, but result could be due to differences in laboratory methods between sampling events. ***Because of changes in laboratory methods, detection limits in 2010 and 2011 were relatively high, obscuring trends. ****ERL and ERM levels are not available for dioxins and furans.

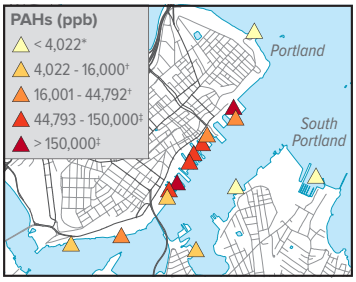
Deep Sediments of Portland Harbor Are More Contaminated

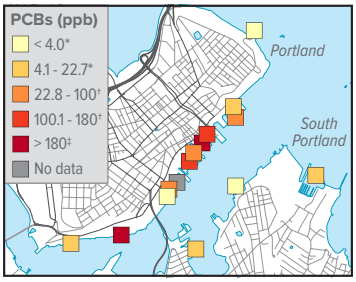
In 2018, the Portland Harbor Commission commissioned a study of contaminants in sediments of Portland Harbor. The study was undertaken as part of designing a "Confined Aquatic Disposal" facility to safely dispose of potentially contaminated dredged material from the Harbor. The results provide a window into historic levels of contaminants in the Harbor, because samples were collected from material buried under several feet of sediment, which has accumulated over many decades. The deep sediments of the Harbor act as a time capsule, revealing levels of contamination that were commonplace in the harbor 50 years ago, before passage of major environmental laws.

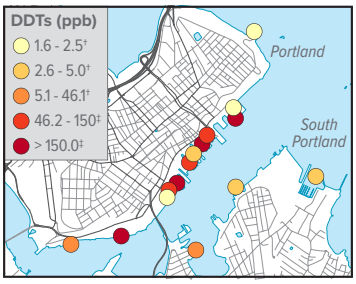


Right: The highest levels of contaminants were generally found along the Portland waterfront. That partially reflects the waterfront's industrial heritage but also decades of runoff from the City and uncontrolled wastes discharged directly to the Bay before construction of wastewater treatment plants.

* Below ERL (effects range low)
† Between ERL and ERM
‡ Above ERM (effects range median)







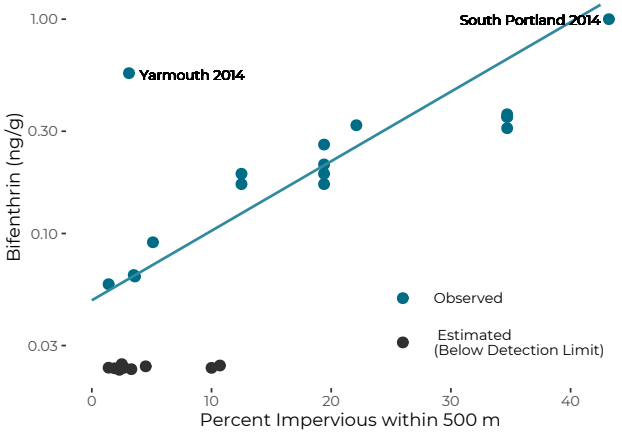
Above: *Levels of organic contaminants (left graph) were substantially higher than elsewhere in Casco Bay, and also higher than in shallow sediments from Portland Harbor. (Note: The y-axis is on a log scale.) Over half the samples had concentrations of PAHs at or above levels of concern. Levels of PCBs are less extreme, although still higher than elsewhere in Casco Bay. DDT residues are consistently at levels of concern, an especially striking result, as the pesticide has been banned for decades, probably because of DDT's long environmental persistence and low mobility in the Harbor's sediments. Levels of metals (right graph) in Portland Harbor deep sediments regularly exceeded screening levels. Concentrations are often several times higher than seen in Casco Bay's shallow sediments. Levels for mercury, copper, lead, and zinc, regularly exceeded levels of concern.*

Urbanized Shores Have Higher Levels of the Pesticide Bifenthrin

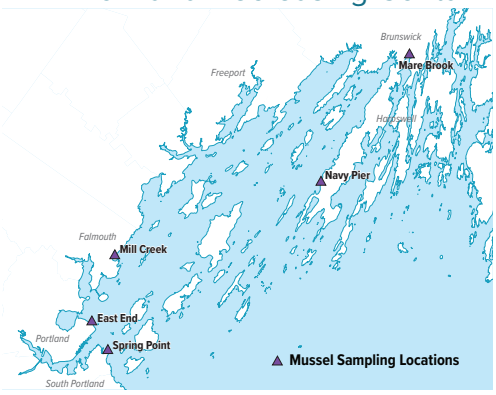
Many persistent toxic chemicals, including DDT and most other organochlorine pesticides, were restricted or outlawed in the later part of the twentieth century. As a consequence, levels of such persistent toxics have declined in the environment. Novel compounds, such as less persistent pesticides, have come to replace outlawed or restricted chemicals in many uses. Replacement chemicals can pose lower environmental risk, but they are not risk-free, and many are less studied.

Because lobsters and other crustaceans may be vulnerable to certain pesticides, Maine's Board of Pesticides Control conducted studies of fourteen "pyrethroid" pesticides, in Maine's intertidal marine sediments in 2014 and 2015, including 18 locations around Casco Bay. Only bifenthrin, which is relatively easy to detect at low concentrations, was detected regularly. Bifenthrin (first approved for use in the U.S. in 1985) was detected in most samples, although at levels well below levels of concern.

As shown in this graph, the levels of bifenthrin are related to urbanization. Higher levels were observed when impervious surfaces like roads and parking lots were common within 500 meters of the sampling location. The relatively high sample from Yarmouth from 2014 is unexplained.

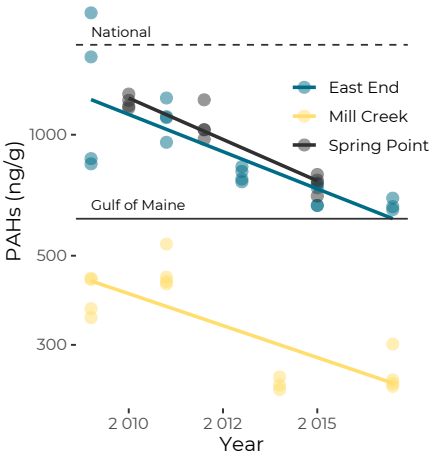


Low and Decreasing Contaminant Levels in Casco Bay Blue Mussels

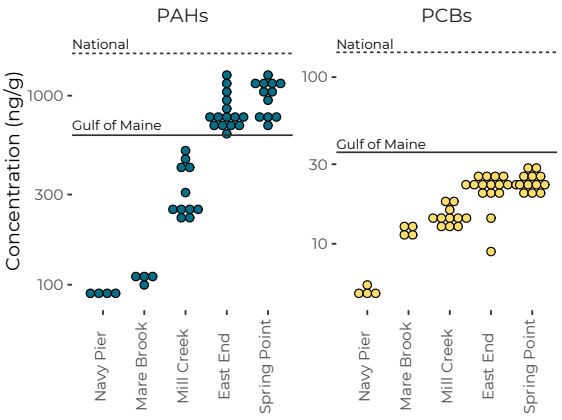


From 2010 to 2019, data on toxic contaminants in mussels were collected from five locations in Casco Bay. Data has been collected multiple times since 2006 at Mill Creek, East End, and Spring Point.

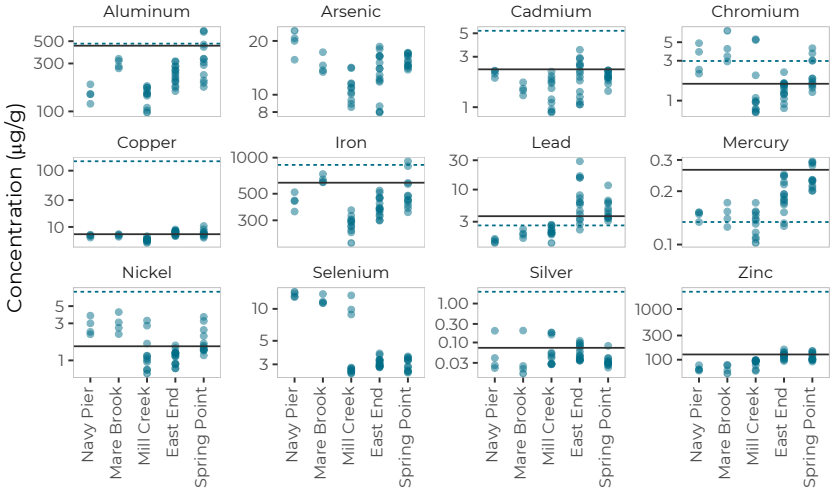
Contaminants in the ocean can pose human health risks if they find their way into seafood. Maine's Surface Water Ambient Toxics (SWAT) program collects data on persistent contaminants in several marine species, including blue mussels. Mussels are filter feeders, and can concentrate contaminants from their surroundings. National and regional programs have tracked contaminants in mussels and oysters for many years. CBEP analyzed Casco Bay mussel data in relation to Gulf of Maine (Gulfwatch) and National (NOAA) benchmarks. Benchmarks used here (85th percentiles) show levels exceeded by 15% of observations from regional and national studies.



PAHs in blue mussels from all three long-term monitoring sites have declined over the past 15 years. PCBs (not shown) have shown no significant trends.



PAHs in Casco Bay mussels near Portland are elevated compared to regional, but not national benchmarks. PCBs are consistently below benchmarks. Published benchmarks compare the sum of a subset of PAHs and PCBs to levels of similar totals from national and regional samples. Health-based comparison levels are not available for PAHs. DEP reports that levels of PCBs were below health action levels. Recent data on pesticides and dioxins are unavailable.



Most metals in Casco Bay mussel tissue are well below benchmarks, with only lead and chromium showing frequent levels above the national benchmark. Most metals show scattered values above regional benchmarks, with only nickel frequently above regional but not national benchmarks. Lead and mercury are highest near Portland, while selenium is highest at Navy Pier and Mare Brook. Few metals show clear long-term trends, but arsenic is increasing, while iron is decreasing Bay-wide, and chromium is decreasing at East End and Spring Point (data not shown).

SUCCESSES & CHALLENGES

- Concentrations of most toxic chemicals that have been studied in Casco Bay are below established levels of concern. Exceptions tend to occur principally, but not exclusively, in our more urban waters. Most persistent contaminants are less abundant today than in prior decades.
- Many persistent toxic chemicals, like PCBs and certain pesticides, were phased out in the late 20th century. Those policies led to reductions in concentrations in the Bay. Reductions of other toxic chemicals may reflect better stormwater management or reductions in tailpipe emissions from more fuel efficient, cleaner automobiles.
- Mercury still occurs at levels of potential concern for marine organisms in sediments across much of the Bay. A primary source of mercury entering the Bay is atmospheric deposition, associated with discharges from power plants to our west. Conditions may improve as coal-fired power plants are retired and replaced by natural gas and renewables.
- Historically, data collection on toxic contaminants in the marine environment has focused on persistent compounds which were identified as problematic in the 1960s and 1970s. Data on modern contaminants of concern, from flame retardants to microplastics, pharmaceuticals to personal care products, remains scarce.