Contaminants

TEC Significance

The presence of high levels of a variety of chemical contaminants has been a prime driver in the use and management of the Hudson River estuary for the past hundred years. Although contaminants are present at elevated levels in all environmental compartments of the Hudson River estuary (sediments, soil, water, air, and biota), their highest concentrations are generally in the sediments. Chemical contamination of the estuary with persistent legacy pollutants (e.g. polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides, and metals) is a long-standing problem and is now combined with and an ever-increasing suite of newly emerging contaminants. These contaminants are known to enter the system through industrial point sources, wastewater treatment facilities, and non-point sources including atmospheric deposition, municipal runoff, combined sewer overflows, and septic systems. Their presence has and continues to impair ecosystem function, threaten human health, and limit managers' options for recovery and increased use of the system's valuable resources, particularly its fish community and recreational opportunities. Furthermore, the Hudson River corridor is known to contain several brownfields; properties that, the expansion, redevelopment, or reuse of, may be complicated by the presence of contaminants.

The chemical contaminants of greatest concern are PCBs, a class of man-made synthetic compounds manufactured for a variety of 20th century industrial uses and now banned in many countries world-wide. They draw our concern because of their ubiquity, high concentrations in multiple environmental compartments, persistence, and ecological and human toxicities that they may incur including reproductive dysfunction, developmental abnormalities, compromise of immune system function, tumor promotion, endocrine disruption, and likely others. Perhaps the most disturbing property of these hydrophobic chemicals is their environmental persistence because of their failure to physically, chemically, microbially, or metabolically degrade. PCBs released 200 miles upriver in Hudson Falls and Fort Edwards, NY, have been documented to comprise from one-half to two-thirds of the total sediment-borne PCB load to New York Harbor (Rodenburg and Ralston 2017) and Newark Bay (Lodge et al. 2015). Fishes are particularly vulnerable to the early life-stage teratogenic effects of PCBs and some species have experienced dramatic rapid evolutionary change because of their exposure in the Hudson River (Wirgin et al. 2011). Furthermore, populations of avian species bordering the Hudson such as belted kingfisher, spotted sandpipe, and tree swallows are known to bioaccumulate high levels of PCBs (Custer et al. 2010) and mammalian populations, particularly mink, are highly sensitive to reproductive impairment and developmental toxicities from consumption of PCB-contaminated Hudson River fishes (Bursian et al. 2013).

This Target Ecosystem Characteristic interacts strongly with other TEC categories, most notably Fisheries, Sediment, and Storm and Wastewater. First, PCB contamination has resulted in the closure since 1976 of iconic commercial fisheries for key resource species in the estuary such as Striped Bass; the need to limit recreational fishing within regions of the upper River; and a river-wide advisory against consumption of Hudson River fishes for children and women of reproductive age. Furthermore, the Hudson River supported some of the largest populations coastwide of Atlantic Sturgeon, Striped Bass, and American Shad. It is probable that PCB induced toxicities to these highly migratory anadromous species impact fisheries coastwide and overall species viability. Second, since the contaminant of greatest concern, PCBs, are highly lipophilic and only slightly soluble in water, they accumulate to high concentrations in sediments and soils which then serve as sources for contamination to overlaying and interstitial pore waters where they become bioavailable. Thus, the quality of sediments and their distribution play a critical role in determining the toxicity of contaminants to the ecosystem and key resource species for human consumption. Third, the major sources to the river of newly emerging contaminants of concern, such as personnel care products, pharmaceuticals, and chlorinated organic compounds, are wastewater treatment plants and other sources of sewage. Thus, improvements to their decaying and outdated infrastructure and services will significantly impact loads of this class of contaminants to the system.

Goal

Identify and significantly reduce contemporary sources of legacy toxicants, metals, and newly emerging chemical contaminants to the upper Hudson River estuary to decrease future toxic risks to human consumers, improve ecosystem health, and increase use of the river's natural resources. Build upon existing programs, such as the New York State Brownfield Cleanup Program, to clean up brownfields bordering the Hudson for open space, habitat, and resiliency in the face of sea level rise.

TEC Context

Historical Context

Because of the vast network of industrial facilities and multitude of municipalities lining both of its shores, the Hudson River has a 100-year history of chemical contamination from both point and non-point sources (Wirgin et al. 2006). For example, one hundred and twenty chemically contaminated sites are located within 400 m of the Hudson in the stretch of river between the Federal Lock and Dam at Troy and the Governor Mario M. Cuomo Bridge, according to New York State's Registry of Inactive Hazardous Waste Sites. These contaminated sites along the Hudson River corridor include numerous brownfields; i.e. properties that may have hazardous chemicals present. It is important to note that because of the diversity of industrial and municipal sources, the Hudson River is contaminated with complex mixtures of contaminants for which the toxicities are rarely known. Chemical contamination of almost 200 miles of river resulted in great part from the release of 1.3 million pounds of PCBs from 1947 to 1977 from two General Electric (GE) capacitor manufacturing facilities along the upper river. Since 1976, PCB contamination has resulted in the issuance of complete bans or catch and release recreational fishing only in the northern estuary because of PCBs and mercury, and the issuance of a myriad of human health advisories limiting fish consumption in the estuary largely due to PCBs, but also cadmium contamination. Primarily due to PCB contamination, but in conjunction with overharvest, a rich history of commercial fishing for the three iconic anadromous fishes in the estuary (Atlantic Sturgeon, Striped Bass, and American Shad) is now just a memory. Levels of PCB contamination in Hudson River sediments and fishes have generally declined since the mid-1970s when their release from the industrial facilities ceased (except for an early 1990s Allen Mills spike) (Sloan et al. 2005), but, this overall decrease was punctuated by species, spatial, and temporal variability. Furthermore, most of the analyses over this time were restricted to fillets and human health concerns and did not measure whole body burdens which are the vectors of contaminants to the ecosystem. The modeled rate of decline of sediment borne PCBs that were bioavailable to fishes under a "no action scenario" without site remediation was considered insufficient to allow for their acceptable consumption in the future. As a result, six years of remediation of upper river PCB “hotspots” (north of the Federal Lock and Dam in Troy, NY) was completed in fall 2015 to diminish downriver PCB transport and future contamination of sediments and receptors, particularly its fishes, in the estuary.

Metals, including mercury (Hg), cadmium (Cd), lead (Pb), nickel (Ni), and cobalt (Co), have been of concern in the estuary as well (Baldigo et al. 2006). Mercury has been of concern because of its tendency to be methylated by bacteria in aquatic systems, biomagnification of methylmercury at the apex of aquatic food webs, and the extreme neurotoxicity to human consumers of contaminated fishes because of the tendency of methylmercury to cross the blood-brain barrier and the placenta. Unlike other metals and aromatic hydrocarbons, levels of Hg in the Hudson River ecosystem usually emanate from distant upwind sources and are atmospherically deposited in the estuary (Levinton et al. 2008). Cadmium, Ni, and Co were once also of concern because of release from a battery manufacturing facility in Foundry Cove, Cold Spring, New York and their estuary-wide transport (Mackie et al. 2007).

Current State

Although fishes in the estuary are known to bioaccumulate high levels of PCBs (Fernandez et al. 2004) and sometimes other contaminants (Baldigo et al. 2006), their ecological effects on the fish community are controversial and largely unknown (Barnthouse et al. 2003; Henry et al. 2015; Chambers et al. 2012). Remedial actions, implemented under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund law) have served to reduce, but not always eliminate, the threats that some of these contaminants pose to human and ecosystem health. For example, Cd and Ni contamination of Foundry Cove (Marathon Battery Superfund site) were reduced to meet federal standards by an Environmental Protection Agency supervised dredging and excavation project completed in 1994. Export of waterborne Cd from the Cove to the main stem river was significantly reduced by the effort and resulted in significantly lower levels of sediment Cd (Mackie et al. 2007) and Cd bioaccumulation in tissues of blue claw crabs river wide (Levinton et al. 2006).

On the other hand, the massive sediment dredging project, which targeted PCB “hotspots” in 40 miles of the upper river and was conducted under EPA direction, may not have met with such success. The EPA determined that that these “hotspots” were continuing to serve as sources for downriver transport and bioaccumulation of PCBs, and that dredging these sediments, coupled with monitored natural attenuation, was the preferred remedy for cleaning the river and reducing PCB concentrations in fish tissues (Record of Decision; EPA 2002). Although contractors removed over 2 million cubic yards of sediment and an estimated 300,000 lbs. of PCB mass, much greater amounts of PCBs were left behind than originally envisioned under EPA’s Record of Decision (ROD). EPA is currently undertaking a 5-year review to evaluate the remedy. At the same time, the Hudson River Natural Resource Trustees and the NYS Department of Environmental Conservation are in review of existing data sets and now question how effective these remedial actions were in reducing downriver sediment and fish burdens of PCBs by their modeled target dates and argue that more targeted and extensive upriver dredging is needed (Field et al. 2016; NYS DEC 2016). A major unknown in evaluating the success of this project and the overall ecological health of the river is the possible presence of “hotspots” in the freshwater tidal portion of the river that may also serve as continuing sources of PCBs to biota and downstream transport. This possibility has yet to be empirically investigated and there are currently no plans by the EPA to do so.

Recently, concern has intensified over the presence of micropollutants in surface waters of the main stem Hudson and in its tributaries. Sources for micropollutants most often include wastewater treatment plants and combined sewer outflows. Micropollutants, including pharmaceuticals, personal care products, pesticides and industrial chemicals, are found in low concentrations, but may cause toxicities to several levels of the Hudson River food web, from inhibiting photosynthesis in algae (Rosi-Marshall et al. 2013) to changing macroinvertebrate populations (Hoppe et al. 2012) to altered reproductive success in fishes as shown in other ecosystems. Of the 117 micropollutants that were recently screened in the Hudson River, 83 occurred in at least one sample from eight collection locales (Pochodylo and Helbling 2016).

Microplastics constitute another newly emerging contaminant that have gained attention because of their ubiquity in aquatic systems worldwide (Cole et al. 2016) and their demonstrated induced reduced survivorship and behavioral toxicity to larval European perch *Perca fluviatilis* (Lonnstedt and Eklov 2016). The large surface area of microplastics may attract waterborne organic toxicants such as PCBs and dioxins thereby adding another avenue to their toxicity. This may be a problem for the Hudson River where organic toxicants abound. A recent preliminary study detected waterborne microplastics in three Hudson River tributaries and they were most concentrated in the most anthropogenically impacted tributaries (Krout 2016). However, their toxicities to Hudson River fishes and other taxa in the estuary are totally unknown.

Numerous brownfields, which potentially may be hazardous to human and ecosystem health, have been identified in New York State and specifically the Hudson River corridor. New York State instituted a Brownfields Cleanup Program in 2003 that provided various incentives to promote their cleanup. As of April 2016, Certificates of Completion of Cleanup were issued to 244 sites in the State, of which 25 were in municipalities in the estuarine corridor from the Federal Lock and Dam at Troy, NY to the Governor Mario M. Cuomo Bridge.

Trends and Drivers

Due to the reduced inputs of most metals (except mercury) and organic contaminants into the system, natural attenuation, and site-specific remediation, concentrations of contaminants should continue to decrease in future years in the Hudson River estuary. However, the timing for the reopening of Hudson River fisheries is still unknown because of uncertainties in model projections and other non-contamination stressors that may impact recruitment and population abundances. Non-contamination stressors, including global warming, sea level rise, increased frequency of high intensity storms, and ocean acidification, may act to redistribute these contaminants in the system, their bioacummulation, and their toxicities.

Constraints

There is still much uncertainty on the efficacy of upper river remediation under federal Superfund in reducing levels of PCBs in sediments and biota of the estuary to acceptable levels for ecosystem health and human consumption of resources species. Furthermore, there was a paucity of data on PCB levels in the sediments of the estuary and in their resident biota prior to upriver river remediation making “before” and “after” comparisons problematic. Similarly, because PCBs are mixtures of 209 different chemicals termed “congeners,” each with different inherent toxicities to vertebrates including humans, it is critical to characterize environmental PCBs by their individual congener constituents and levels rather than total PCB levels as was invariably done in the past. Knowing the congener constituents and levels of sediments and contaminated biota will allow for the development of quantitative evaluations of their total toxicities using a Toxic Equivalency Quotients (TEQ) approach (Safe 1998). Unfortunately, this approach has yet to be adopted and should be incorporated in future ecosystem characterization. Finally, we know little about the levels and toxicities of many metals and emerging contaminants including microplastics in the sediments and biota of the estuary making remediation prioritization difficult. In summary, this absence of data on levels of legacy and emerging contaminants in sediments and biota of the tidal estuary limits our ability to evaluate impacts of past remedial efforts and prioritize those that should be implemented in the future.

Action Table

Objectives	Actions	Complete by
Objective 1- Reduce bioavailable PCBs at Hudson River estuary hotspots	A: Identify distribution of PCB sediment hotspots and their contaminant levels in the estuary using;	
	1. Archived General Electric and other data sources	2020
	2. New surveys of PCB sediment levels	2020-2030
	B: Remediate 5 of the highest priority PCB estuary hotspots identified above and restore impacted habitats	2030-2070
	C: Regularly monitor and publicize levels of PCBs in fillets of fishes that are traditional and newly targeted species	2020-2070
Objective 2- Better understand the potential bioaccumulation and toxic effects of PCBs to the fish community of the estuary	A: Initiate and maintain annual monitoring program of PCBs levels in key fish populations of the estuary on a congener-specific basis	2020
	B: Initiate a regular program to quantify trends in toxic and biological effects (tumors, age structure, reproductive status, and altered gene expression) of PCBS in select fish populations in the estuary	2030
Objective 3-Understand the potential toxicities and ecological effects of contaminants of emerging concern to the Hudson River estuary ecosystem and develop regulations for their control	A: Characterize the concentrations and sources of emerging contaminants of concern to the main stem river, tributaries, wetlands, and floodplain belts of concern	2020
	B. Characterize concentrations of select contaminants of emerging concern identified in Action 3A and their toxicities in Hudson River fishes	2030
	C. Develop regulations regarding contaminants of emerging concern including plastics and microplastics	2030-2070
Objective 4- Mitigate the effects of contaminants of emerging concern	A. Remediate and remove these emerging contaminants from their sources, including wetlands, riparian areas, and floodplains	2030
	B. Retrofit sewage treatment plants with newly developed technologies	2030
	C. Reduce the impacts of CSOs across the estuary as proposed by the Albany CSO Pool Communities Corporation	2030-2070
	D. Upgrade septic systems abutting the river	2030
Objective 5-Better understand the levels of all contaminants of concern (legacy and emerging) in the main stem river	A. Generate an all-inclusive map, database, and users guide for stakeholders of sediment contaminant levels (PCBs, PCDD/Fs, metals (particularly Hg), contaminants of emerging concern) in the main stem river, floodplains, and tributaries from the Federal Lock and	2020

	Dam in Troy, NY to the Governor Mario M. Cuomo Bridge based upon existing data sources	
	B. Identify and fill data gaps in understanding of distribution and effects of contaminants of concern. Update map and database as new information becomes available.	2030
Objective 6-Remediate brownfields along the Hudson River corridor	A. Map and inventory known and currently unknown brownfields contributing contaminants to the estuary	2020
	B. Design and implement projects that will remediate brownfields and include sea level rise resilience, habitat restoration, and open access to the river	2020-2030

Action Narrative

Objective 1: Reduce bioavailable PCBs at to be identified hotspots in the estuary of the Hudson River

- 2020: Identify distribution of PCB sediment hotspots in the estuary using archived data from GE and/or the NYSDEC
- 2030: Conduct new intensive surveys to identify PCB hotspots in the estuary. Hotspots from upper river contamination are almost certain to exist in depositional northern estuary areas and serve as sources of PCBs to the estuary's biota, particularly its fishes
- 2070: Remediate five PCB hotspots identified above from the archived and newly generated data. As a result, we anticipate a further decline in PCB burdens in key fish populations described in Objective 2.
- 2020-2070: Continue to monitor PCB levels in finfish species that are traditional targets of anglers and in newly developed fisheries.

Objective 2: Better understand the potential bioaccumulation and toxic effects of PCBs to the fish community of the estuary. Currently, little is known regarding the relationship between PCB congener burdens and their specific toxicities in Hudson River fishes.

- 2020: Initiate and maintain an annual monitoring program of PCBs levels in key Hudson River estuarine fish populations on a PCB congener-specific basis. Almost all of the PCB data generated to date has been on a total PCB (or Aroclor) basis. The development of congener-specific PCB profiles will allow for quantification of total toxicity using the Toxic Equivalency Quotients approach in fish populations of the estuary.
- 2030: Initiate a regular program to quantify trends in toxic effects (tumors, population age structure, reproductive conditions, altered gene expression) of PCBs in select fish populations of the estuary.

Objective 3: Understand the potential toxicities of contaminants of newly emerging concern to the Hudson River estuary ecosystem.

- 2030: Characterize the concentrations and sources of emerging contaminants of concern to tributaries, the main stem river, and wetlands of concern.
- 2030: Characterize concentrations of select contaminants of emerging concern, their toxicities, and ecological effects in Hudson River fishes. There is little or no data to date on the

concentrations, toxicities, and ecological consequences of newly emerging contaminants in Hudson River fishes.
- 2070: Remediate "hotspots" of toxic emerging contaminants in the main stem river, its tributaries, and wetlands of concern.

Objective 4: Mitigate the effects of sources of contaminants of emerging concern in the upper estuary.
- 2030: Retrofit sewage treatment plants with newly develop technologies.
- 2030: Reduce the discharges of CSOs across the estuary as proposed by the Albany Pools Committee to better achieve compliance with government regulations.
- 2070: Update septic system abutting the river because they likely serve as additional sources of these contaminants.

Objective 5: Better understand the levels of all contaminants of concern (legacy and emerging) in the main stem river,
- 2020: Generate an all-inclusive map of sediment contaminant levels (PCBs, PCDD/Fs, PAHS, metals, and contaminants of emerging concern) in the main stem river from the Federal Lock and Dam to the Governor Mario M. Cuomo Bridge.
- 2030: Identify and fill data gaps in understanding of distribution of contaminants of concern. Update map and database as new information becomes available, on an ongoing basis.

Objective 6: Remediate brownfields along the Hudson River corridor.
- 2020-2030: Map and inventory likely future brownfields potentially contributing contaminants to the upper estuary.
- 2030-2070: Design and implement brownfield remediation projects that will provide multiple benefits including sea level resilience, habitat restoration, and open access to the river.
- 2030-2070: Evaluate effects of brownfield remediation on contaminant reduction and economic benefits to local communities.

Research Needs

- Little is known regarding the identity, distribution, and ecological consequences of emerging contaminants of concern, personnel care products and pharmaceuticals, in the estuary and its tributaries, only that they are present. Furthermore, their toxicities to the estuary have yet to be empirically addressed and warrant future research, particularly in resident fishes.
- Preliminary studies indicate the presence of microplastics in several Hudson River tributaries, but their sources, levels, distributions and toxicities to the ecosystem are largely unknown. Furthermore, the likelihood is high that lipophilic Hudson River toxicants (PCBs, PAHs, and PCDD/Fs) will adhere to microplastics and enhance their toxicities. The likelihood of this occurring and impacting survivorship of larval Hudson River fishes and other taxa warrants investigation.
- The interactive toxic and ecological effects of mixtures of contaminants found in the estuary, including PCBs and metals such as Hg, are unknown in any system and need to be empirically addressed to fully comprehend toxicities of environmental matrices in the environment.
- The toxicities and ecological effects of contaminants in combination with other non-chemical environmental stressors such as a warming environment or low dissolved oxygen, are unknown and need to be experimentally quantified.
- Many studies have demonstrated significant toxicities of contaminants such as PCBs at levels found in Hudson River sediments and biota under controlled laboratory conditions with native Hudson River taxa such as sturgeons, snapping turtles, and mink. But the relationship between laboratory induced toxicities and compromised health of natural populations in contaminated

natural environments such as the Hudson River estuary is largely unknown and should be addressed.

- Brownfields clean-ups and redevelopment are envisioned as economic boosts to local communities, however, their success and economic benefits are rarely monitored or quantified. Understanding how successful brownfields clean-ups are in terms of contaminant reduction, economic benefit, and resiliency to sea level rise are important areas of future research.

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