Marine Pollution Bulletin 107 (2016) 22–35

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

An assessment of mercury in estuarine sediment and tissue in Southern New Jersey using public domain data

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ARTICLE INFO

Article history:
Received 28 August 2015
Received in revised form 14 March 2016
Accepted 14 April 2016
Available online 6 May 2016

Keywords:
Mercury
Sediment
Mussel
Tissue
Estuary
New Jersey

ABSTRACT

Mercury (Hg) is considered a contaminant of global concern for coastal environments due to its toxicity, widespread occurrence in sediment, and bioaccumulation in tissue. Coastal New Jersey, USA, is characterized by shallow bays and wetlands that provide critical habitat for wildlife but share space with expanding urban landscapes. This study was designed as an assessment of the magnitude and distribution of Hg in coastal New Jersey sediments and critical species using publicly available data to highlight potential data gaps. Mercury concentrations in estuary sediments can exceed 2 μg/g and correlate with concentrations of other metals. Based on existing data, the concentrations of Hg in mussels in southern New Jersey are comparable to those observed in other urbanized Atlantic Coast estuaries. Lack of methylmercury data for sediments, other media, and tissues are data gaps needing to be filled for a clearer understanding of the impacts of Hg inputs to the ecosystem.

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1. Introduction

Mercury (Hg) is a contaminant of global concern for coastal and estuary systems as it can affect both human and ecosystem health (Risher and DeWoskin, 1999; Driscoll et al., 2013). Coastal and estuarine waters mainly receive Hg through atmospheric deposition, riverine inputs, discharges from residential and industrial activities, and submarine groundwater discharge (Eagles-Smith and Ackerman, 2014; Prestbo and Gay, 2009; Balcom et al., 2008; Laurier et al., 2007; Bone et al., 2007). The fate and transport of Hg in the environment are complex due to interacting biogeochemical processes and the propensity for transformation, remobilization, and biological uptake over various environmental geochemical conditions, (Lambertsson and Nilsson, 2006; Merritt and Amirbahman, 2009; Driscoll et al., 2013). Mercury may partition to and transform between aqueous (e.g., surface and pore waters) and solid phases (e.g., sediment and biota), therefore Hg in the environment can be widely re-distributed and may not be sequestered near point sources or known impacted areas. Furthermore, development of oxygen-deprived conditions and concomitant microbial activity within changing depositional estuarine environments, such as tidal flats, enhance the production of methylmercury (MeHg), which is the most bioaccumulative and toxic form of Hg (Eagles-Smith and Ackerman, 2014; Lambertsson and Nilsson, 2006). Such oxygen-poor conditions enhance the potential for increase in uptake (biomagnification) with trophic level in a food web (Mason et al., 1996; Lawson and Mason, 1998; Driscoll et al., 2012).

As a result of its bioaccumulative properties, the most common exposure route to the toxic MeHg for the human population is consumption of large piscivorous fish, sources of which are the productive coastal, estuarine, and shallow continental shelf fisheries. Indicative of the scale of this exposure to the population of the United States is a recent study by the U.S. Environmental Protection Agency (EPA) of blood samples; this showed that, in 1990–2000, 2.3% of the women of child bearing age (estimated 1.4 million women) had blood mercury concentrations greater than 5.8 micrograms per liter (EPA, 2013). Although a decrease in that elevated level in subsequent years was associated with changes in fish consumption, elevated blood mercury levels are still an issue for this sensitive population. Understanding the occurrence and accumulation of MeHg in fish and subsequent human exposure is important for assessing the overall effects of environmental mercury.

1.1. Study area

A substantial amount of data for Hg concentrations in water, sediments and biota is available for coastal areas of northern New Jersey (NJ), USA (EPA, 1997); however, more limited Hg data are available for the southern NJ coastal region. Within the southern coastal region of NJ, estuarine waters and numerous streams discharging to the coast have been listed as impaired by the New Jersey Department of

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http://dx.doi.org/10.1016/j.marpolbul.2016.04.027
0025-326X/Published by Elsevier Ltd.

Environmental Protection (NJDEP), mainly because of Hg concentrations in fish tissue, which generally exceed 0.30 μg/g (NJDEP, 2012). However, data for Hg concentrations in water are limited in many of these impaired waterbodies.

Our study area encompasses nearly all the coastal salt marsh and estuary systems of the Atlantic Coast region of southern NJ (the southern part of the New Jersey/New York Bight coastal and continental shelf region; Hapke et al., 2010), stretching from the Point Pleasant Canal in the north to Great Egg Harbor Bay in the south (Fig. 1). The area north of the Point Pleasant Canal to Sandy Hook, where the coastal landform is mainland beach (Hapke et al., 2010), is excluded, as are marshes of the Cape May Peninsula where no major rivers from the mainland discharge to the bays (Carson et al., 1988). The study area includes the major bays along the southern NJ coast, all of which receive drainage from inland watersheds (Fig. 1).

The northern Barnegat Bay-Little Egg Harbor estuary is 70 km in length with a surface area of 280 km^2 and is the largest of the system of bays along coastal NJ (Defne and Ganju, 2014). Marshes and smaller bays from Little Egg Harbor Inlet to Great Egg Harbor Bay extend southward an additional 43 km with a composite surface area of 180 km^2 (Hapke et al., 2010). Along the coast, a narrow strip of barrier islands bounds the shallow bays and wetlands (Kennish et al., 2007; Hapke et al., 2010); sediments of these estuaries range from fine-grained muds to sands that are extensively bioturbated (Ashley and Grizzle, 1988; Smith and Reinfelder, 2009). Major rivers or large creeks and numerous small streams discharge to the wetlands and bays north of Little Egg Harbor Inlet. Freshwater input is more limited south of Little Egg Harbor Inlet except at the river mouths emptying into the bays (Crerar et al., 1981; Yan et al., 1991). Substantial loads of organic carbon and nutrients are transported to the estuaries and bays from the rivers (Crerar et al., 1981; Yan et al., 1991; Flynn, 2008) and organic carbon-rich fine-grained sediment is deposited in the local bays, especially to the south of Barnegat Bay-Little Egg Harbor Inlet because of the lesser currents there (Ashley and Grizzle, 1988). Due to the low topographic relief, the tidal reaches of rivers and stream extend as much as 18 to 20 km inland for rivers south of Barnegat Inlet, but 3 to 5 km inland north of the inlet. The bay(s) are growing owing to rising sea level (Miller et al., 2013) drowning the mouths of the rivers, while the successive associated shoreline sediment deposits are being submerged (Psuty, 1986).

Extending 80 km from Mantoloking to Absecon Bay is an undeveloped coastal area that includes managed wetlands and is part of Edwin B. Forsythe National Wildlife Refuge (EBF). The EBF is an ecologically sensitive habitat containing about 190 km^2 of protected lands and waters (Fig. 1). More than 82% of the Refuge area is covered by wetlands (U.S. Fish and Wildlife Service, 2009) that serve as critical habitat for spawning, feeding and nursery grounds for a variety of species. The EBF plays an important role in ecological preservation efforts as the entire southern NJ coastal and estuary system hosts a diverse range of marine life, including macroinvertebrates, shellfish, and fish. Many of these species that are consumed by both wildlife and humans spend part of their life cycles between the estuaries and the adjoining shallow shelf fisheries of the New York/New Jersey Bight (Sherman et al., 1988; U.S. Geological Survey, 1998; Able et al., 2006; Burger and Gochfeld, 2011). The area is also a critical habitat for migratory and nesting birds along the Atlantic Flyway (Burger and Gochfeld, 2004; Burger, 2013).

The hydrodynamics of the bay-estuary system largely control sedimentation patterns. Salt water enters the Little Egg Harbor Inlet and flows northward. Some saltwater returns to the ocean at Barnegat Inlet; the rest, mixing with freshwater inputs, returns at Point Pleasant Canal (Defne and Ganju, 2014). Fine-grained sands underlie nearly the entire Bay north of Barnegat Inlet and accumulate at the mouths of the rivers, but otherwise, net sediment erosion tends to predominate. South of the Little Egg Harbor Inlet is the only part of the northeastern Atlantic Coastal margin that is actively aggrading (Hapke et al., 2010). Because fresh- and salt-water flows in the bays are less in the south than those in the north, there is rapid deposition of fine-grained sands on the southern tidal channel deltas (Ashley and Grizzle, 1988; Yan et al., 1991) and formation of extensive salt marshes in quiescent bays.

Land-use within the study area is mixed. Urban areas that are largely residential occupy much of the northern part of the study area, including the barrier islands east of Barnegat Bay (Wieben et al., 2013). Urban areas also encompass Atlantic City, both inland and on the barrier islands in the southernmost parts of the study area (Conway, 2007). Agricultural land is interspersed with residential land, particularly in the northern part of the study area and inland along the Great Egg Harbor River to the south. Although historically the southeastern mainland area has been less heavily developed than northeastern tracts, the southeastern mainland area has also undergone increasing residential development (Conway, 2007). Eutrophication of Barnegat Bay from large nutrient inputs has been documented (Kennish et al., 2007; Wieben et al., 2013). Organic pollutants (polychlorinated biphenyls and polycyclic aromatic hydrocarbons) from industrial activities have been detected in surface sediments of Barnegat Bay, especially near river mouths and near the light industrial centers (Kennish, 2001; Vane et al., 2008). Watersheds for many of the tidal wetlands south of Barnegat Inlet lie mostly within the protected Pinelands National Reserve (Kennish et al., 2007).

Similar aspects of the major characteristics of the study area were found to group geographically either to the north or the south of the Barnegat Inlet, including landscape characteristics, sediment deposition and erosion, (Farrell et al., 1999; Hapke et al., 2010; Defne and Ganju, 2014), and degree of urbanization (Wieben et al., 2013). Therefore, the study area was split at Barnegat Inlet for spatial comparison purposes, with the respective areas to the north and south of the Barnegat Inlet termed: "Barnegat North" and "Barnegat South" (Fig. 1). The boundary between the two areas reflects the hydrodynamics determining the nature and mode of sediment deposition, and is approximately coincident with the boundary used by Yan et al. (1991) in their evaluation of estuarine water quality along the NJ coast.

1.2. Potential sources and mobility of mercury to coastal regions

The southern NJ coastal area is underlain by unconsolidated quartz sand, with thin layers of Holocene sand veneer (Miller et al., 2013) capping thick sands of the Miocene Age Cohansey Formation. In some areas of the Cohansey Formation, interspersed lenses of silt and clay are common. The outcrop of this formation extends more than 50 km inland and forms the upper portion of the major potable unconfined aquifer in the region (Kirkwood-Cohansey aquifer system; Barringer et al., 1997). The natural Hg concentration of the Cohansey Sand has been found to range from 0.008–0.05 μg/g, with higher concentrations (~0.10 μg/g) found in organic-rich clay samples (Barringer and Szabo, 2006).

Mercury and other trace metals can enter ecologically important estuaries such as Barnegat Bay through groundwater discharges, riverine watershed inputs and precipitation. Although atmospheric deposition is considered a major source of Hg to waterbodies in southern NJ (Reinfelder et al., 2004), groundwater discharge to small streams and major rivers has recently been determined to be an important source of Hg (Barringer et al., 2013). Recent studies have also revealed that groundwater discharging to coastal waters can transport Hg at unexpectedly high concentrations that, in some cases, may adversely affect marine organisms (Laurier et al., 2007; Bone et al., 2007).

Over the past 30 years in southern NJ, concentrations of THg in shallow residential well water withdrawn from the Kirkwood-Cohansey aquifer system have, in some samples, substantially exceeded State and Federal Maximum Contaminant Levels (2 μg/L; Barringer et al., 1997). Definitive sources of Hg to these wells are unknown. Atmospheric deposition is considered a major input due to elevated mercury in undisturbed forest soils (0.1–0.15 μg/g) throughout southern NJ (Barringer and Szabo, 2006). The use of mercurial pesticides on agricultural land is considered a likely source of Hg to some shallow wells in inland areas that have been converted to residential land-use (Barringer