Healthy Coastal Ecosystems: Are Sewage-Derived Steroidal Estrogens a Problem in Massachusetts Bay?

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Project Report

We release over 35 billion gallons of treated sewage into U.S. rivers and oceans *every day*. These waste streams contain a variety of natural and synthetic estrogens that can threaten aquatic ecosystems and human health at extremely low (parts per trillion) concentrations, yet very little is known about the chemical behavior and form of estrogens in receiving coastal waters. Our project was designed to address this concern by characterizing the quantity, speciation, and fate of estrogens in Massachusetts Bay, a coastal water body that receives large treated sewage inputs from the Boston metropolitan area.

We began by characterizing the sewage source of estrogens to Massachusetts Bay. This source, which is processed at the Deer Island Treatment Plant (DITP), is discharged to the bottom waters of the bay at an average rate of 360 million gallons per day. The concentrations and chemical forms of steroidal estrogens contained in this wastewater were largely unknown. Through this project we have developed an analytical method that is capable of detecting a much wider range of steroidal estrogens than was previously possible. The novelty of our method is a focus on halogenated estrogens that are formed during the disinfection stage of wastewater treatment. These chlorinated and brominated estrogens are thought to be less potent than free estrogens, yet their concentrations in wastewater effluent were previously unconstrained.

In DITP wastewater effluent, we found that halogenated estrogens typically represented over 50 % of the total estrogen discharge (Figure 1). The main features of the observed estrogen distribution were corroborated using a mathematical model of estrogen halogenation kinetics, and the results are currently under review at the peer-reviewed journal, *Environmental Science & Technology*.

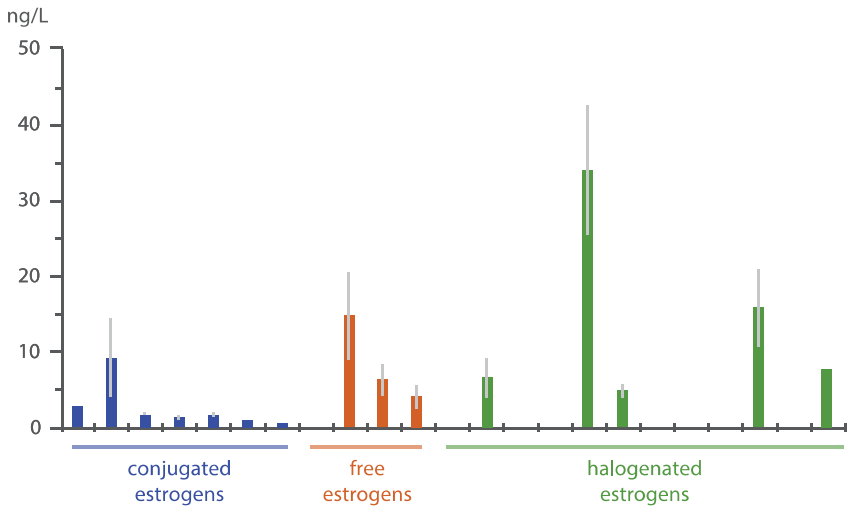

Figure 1. Halogenated estrogens were found at high concentrations relative to free and conjugated estrogens in treated wastewater effluent. Each bar represents a different chemical form, and empty bins

indicate non-detects. The two halogenated forms with the highest concentrations correspond to a singly brominated estrogen and a doubly chlorinated estrogen. Error bars represent ±1 standard deviation.

Our next step was to measure the same suite of estrogens in the receiving waters of Massachusetts Bay with the goal of understanding whether estrogen levels were high enough to harm resident fish and whales. We hypothesized that estrogen concentrations would decrease with distance from the treated wastewater discharge point ("outfall") as dilution with surrounding water and degradation by microorganisms occurred.

What we found was an estrogen distribution near the outfall that was well predicted by dilution (using a conservative pharmaceutical as a tracer of sewage) and a pattern of increasing free estrogen concentrations as we moved offshore, away from the outfall. This latter trend was quite surprising and indicates that there is a large source of estrogen entering Massachusetts Bay that is unrelated to sewage. We have tentatively attributed this "extra" source to the marine vertebrates (fish, whales, seals, etc…) that reside in the bay, especially near the highly productive Stellwagen Bank, and naturally excrete their own endogenous estrogens into the water.

Taken together, the combined potency of steroidal estrogens in Massachusetts Bay (0.2 – 0.4 ng/L) does not seem to be at a level that would cause concern to fish and whales (~ 1 ng/L threshold). Yet, our potency calculations do not consider the myriad chemicals (e.g., bisphenol A and nonylphenol) that have weak estrogenic potency but likely occur at much higher concentrations than steroidal estrogens.

We have uncovered intriguing evidence that fish and whales are the main source of estrogens to the bay, and we are currently in the process of corroborating this finding by searching for fish-specific hormones in our samples.

This project has been an important first step towards understanding the fate of estrogens in wastewater treatment plants and coastal waters and a critical advance for developing predictive models that can help us design effective mitigation strategies and evaluate potential adverse effects of steroidal estrogens and other low-level contaminants *before* they become serious problems for coastal ecosystems.