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Tracking Sediment Recovery in the Upper Hudson River

Baseline, Remediation and Recovery

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Abstract

The Remedial Action Objectives (RAOs) for the Upper Hudson River, as stated in the 2002 Record of Decision (ROD), include reduction of the cancer risks and non-cancer health hazards for people eating fish from the Hudson River by reducing the concentration of PCBs in fish and reduction of the PCB mass that may become bioavailable. These objectives are closely related to the surface sediment PCB concentration throughout the Upper Hudson. In the selected remedy, reduction of PCBs in surface sediment is achieved through two important processes: 1) sediment removal by dredging and backfilling, and 2) monitored natural recovery (MNR). Both processes are required to achieve the goals of the ROD. The objective of this poster is to assess the surface sediment concentrations during the pre- and post-dredging periods and quantify the rate of change in PCB concentration through time.

Surface sediment concentrations after dredging were assessed using the 2016 and 2017 Operation, Maintenance, and Monitoring (OM&M) program results. The OM&M results showed that nearly all river sections and reaches have an area-weighted average Tri+ PCB[1] concentration less than 1 mg/kg. The average Tri+ PCB concentration across all dredged areas is 0.75 mg/kg, indicating greater than 95% reduction of Tri+ PCB concentrations in dredged areas, and no substantive recontamination. Based on the comparisons of pre- and post-dredging surveys, the apparent percent declines in average Tri+ PCB concentrations in surface sediments were 92, 82, and 78 percent in RS 1, 2, and 3, respectively.

Temporal changes in surface sediment Tri+ PCB were also evaluated by fitting first-order decay model to the long term record with data stratified by sediment texture. The post-dredging data fall below the regression line for all river sections including non-dredged areas, suggesting that resuspension and subsequent redeposition on surface sediments was not evident and was probably minimal.

Introduction

The Hudson River PCBs Site is one of the most extensively monitored contaminated sediment sites with a data record spanning a period of more than 40 years (Figure 1). The 2002 Record of Decision required a dredging remedy, which was implemented by General Electric (GE) between 2009 and 2015. A comparison of pre-dredging and post-dredging sediment surveys documents improvements to the system as a result of dredging and continued natural attenuation. Both the pre-dredging and post dredging surveys are comprised of thousands of coring locations spread across the 40 mile site. Samples characterized the 0-2 inch interval in both surveys. GE collected the pre-dredging data primarily over the period 2002 to 2005. The post-dredging data were obtained by GE in 2016 and by the New York State Department of Environmental Conservation (NYSDEC) in 2017. The historical surveys were generally designed to characterize areas of elevated concentration, and not to yield area-wide averages. In contrast, the 2016 and 2017 sampling designs were both designed specifically for this purpose. One of the challenges in tracking the changes in surface sediment PCB concentrations through time was to account for the sampling biases in the earlier studies.

[1] Tri+ PCB is defined as the sum of PCB congeners with three or more chlorine atoms per molecule. This is the portion generally absorbed by fish.

What are the Hudson River Surface Sediment Concentrations After Dredging?

Mean Tri+ PCB concentrations were estimated for each river reach and river section in two different ways:

1. A straightforward arithmetic mean of the recoverable surficial sediment sampling results by river reach
   - Based on 1,304 locations that yielded measurable sediments (coarse sand or finer)
2. An area-weighted mean, which integrated bedrock and areas with no recoverable sediment
   - Based on nearly 1,900 occupied locations, including the 1,304 from above.

Figure 2 shows the Tri+ PCB concentrations for recoverable surficial sediment by river reach and river section (RS) obtained in 2016 and 2017. The figure also indicates the dredging criteria used to identify locations for dredging (RS 1 >10 mg/kg, RS 2 > 30 mg/kg and RS 3 > 30 mg/kg). The number of points within each river reach is also indicated in the plot. This figure shows that the Tri+ PCB concentrations in the 0-2-inch layer lie below the dredging criteria for surface sediments in all river reaches, except for four locations found primarily in RS 1, meaning that 99.7 percent of all locations with recoverable sediments fell below the dredging criteria, indicating a very high rate of compliance with the ROD. In fact, over 99 percent of the surface sediment samples from Reaches 7 through 1 (i.e., the reaches in RS 2 and RS 3) meet the more restrictive dredging criterion of 10 mg/kg, which was applicable only to RS 1.

Figure 3 presents the results of the two mean calculation procedures listed above: the arithmetic mean of recoverable sediment (blue symbols) and the area-weighted (red symbols) by river reach. Error bars represent 95 confidence intervals on the mean. In all reaches, the area-weighed Tri+ PCB mean concentration is lower than the mean of the recoverable sediment data, as expected, due to the incorporation of the non-recoverable and bedrock areas in the mean estimate. The concentrations of Tri+ PCB generally decrease from Reach 8 to Reach 1 (from upstream to downstream), with Reach 7 showing the highest average surface concentrations. Most of the reaches have a weighted-average mean Tri+ PCB concentration less than 1 mg/kg.

Figure 1—Timeline of Sediment Surveys in the Upper Hudson River
(Blue indicates surveys used for surface sediment trend)

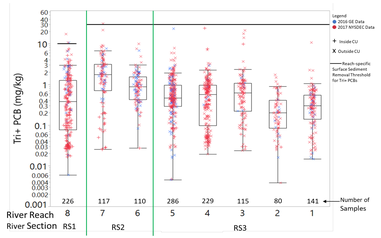

Figure 2—Post-Dredging Tri+ PCBs in Recoverable Sediments by River Reach

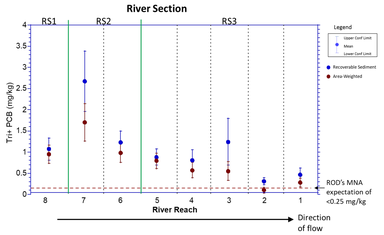

Figure 3—Post-Dredging Tri+ PCB Mean Sediment Concentrations by River Reach

Examination of the Sediment Trend from Pre-Dredging to Post-Dredging

The 2016 and 2017 surveys were specifically designed to estimate average surface sediment concentrations on a river wide basis, integrating dredged areas, non-dredged areas and bedrock. The prior studies were not.

To assess changes over time to the present, historical data sets were compiled to estimate sediment concentrations in these same domains, and area-weighted to yield similarly constructed river-wide averages. Figure 4 presents the results, showing the decline in dredged areas, non-dredged areas and the area-weighted average for each river section. Bedrock was assumed to have an average surface concentration of 0.03 mg/kg Tri+ PCB for this calculation for both pre-dredging and post-dredging averages. The surface sediment concentrations were reduced by 92, 82, and 78 percent in RS 1, 2, and 3, respectively, by the combination of dredging and natural attenuation between the periods 2002-2005 and 2016-2017.

Simple Sediment Trend Analysis

As an alternate approach to comparing only the 2002-2005 and 2016-2017 data, a "naïve" (or simple) estimation of empirical temporal trends of surface sediment PCB levels was developed, which does not attempt to control for differences in sampling, analysis, and sample compositing and handling methods, although it does recognize and take into account the important role of sediment texture. These trends were based on the pre-dredging data only (1976 to 2013). Data collected in 2011 to 2013 were obtained from undisturbed areas only.

The trends may then be compared with the 2016-2017 data, as an assessment of current surface PCB concentrations relative to what might have been expected absent the remedy. Figure 5 shows the estimated mean Tri+ PCB and 95 percent confidence limits against year for each sampling event.

A first-order decay function was fit to each combination of river section and sediment texture. The models were fit using weighted least squares, with weights inversely proportional to relative error. Trends were fit to data from 1976 through 2011 in RS1, 2012 in RS2 and through 2013 in RS3. Mean Tri+ PCB concentration and 95 percent confidence limits were overlain on the plots for comparison. The estimated means and confidence limits for data collected in 2016 (non-dredged areas only) and 2017 (both dredged and non-dredged areas) were overlain on the plots to compare them with the empirical trends (Figure 5).

For RS 1 and 2, mean Tri+ PCB concentrations of the 2016 and 2017 data fall below the regression's 95% confidence band, suggesting that dredging-related resuspension and redeposition had minimal effect on surface sediment concentrations. For RS 3, the 2016 and 2017 data plotted within the empirical trend line 95% confidence limit as expected, since this river section had only limited dredging. However, the mean concentration is already below 1 mg/kg Tri+ PCB.

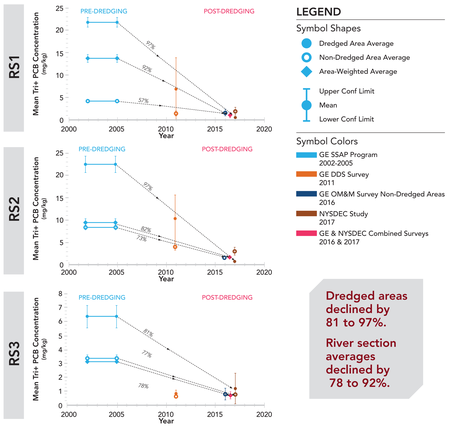

Figure 4—Temporal Trend of Surface Sediment Tri+ PCB Concentrations from Pre-Dredging to Post-Dredging Conditions

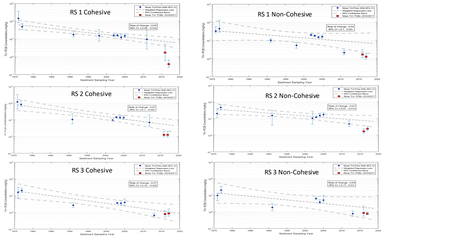

Figure 5—Simple Trend Models Fit to Tri+ PCB Mean Concentrations

Conclusions

Surface sediment PCB concentrations in the Upper Hudson River overall have declined. In the most contaminated areas in RS 1 and RS 2 (i.e., dredged areas), concentrations have declined about 97 percent. Current concentrations in these areas are largely under 1 mg/kg Tri+ PCB. The reductions in the river section-wide average surface sediment concentrations achieved by dredging and natural recovery were 92, 82, and 78 percent in RS 1, 2, and 3, respectively. Area-weighted Tri+ PCB concentrations are under 1 mg/kg in seven of eight river reaches. In non-dredged areas, declines are consistent with ROD model forecasts. The percent declines in surface sediment concentrations are greater than observed in Upper Hudson surface water and fish to date. However, similar reductions are anticipated in all media. Additional monitoring over time will continue to assess the recovery.

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