Preliminary Evaluation of Post-Dredging PCBs in Upper Hudson River Surface Sediment

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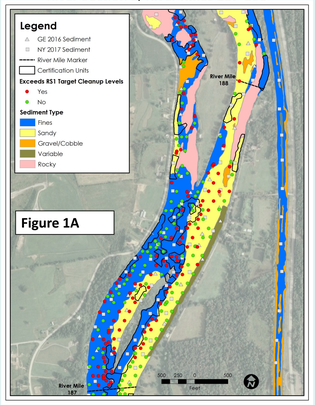
Introduction

More than 2.75 million cubic yards of PCB-contaminated sediment were dredged and subsequently backfilled or capped between 2009 and 2015 under the EPA's 2002 Record of Decision for the Hudson River PCBs Superfund Site. This 40-mile stretch of the Hudson River (River Sections (RS)1-3) extends between Ft Edward and the Federal Dam. Target cleanup levels (TLC) for RS2 and RS3 were about 3X higher than for RS1. Pre-dredging data for RS2 and RS3 revealed highly elevated PCBs in sediment deposits in the surface and at depth, the majority proximate to dredge prisms (Field et al. 2011a; Field et al. 2011b). Approximately 175 acres surrounding the dredged areas in RS2 and RS3 exceeded the more stringent cleanup levels for RS1 for PCB mass (MPA) or surface (top 12 inches) PCB concentration (Field et al 2016).

Recent sampling efforts conducted by GE in 2016 and NYSDEC in 2017 were designed to provide a post-construction baseline of the top 2 inches of sediment PCBs for future evaluations of remedial effectiveness. The objective of this study is to conduct a preliminary analysis of these post-dredging sediment data and compare to EPA model projections and pre-dredging data and calculate post-dredging surface weighted area concentrations and sediment decay rates. We also compare results obtained by different PCB analytical methodologies.

Figures from example areas in RS2 (Fig. 1A) and RS3 (Fig. 1B) show the pre-dredging data in the vicinity of dredging certification units. The figures show the samples that exceed the RS1 TCLs for surface (top 12 inches) Tri+ PCBs or mass-per-unit area (MPA). RS1 TCLs are used as a metric because earlier work showed that using RS1 TCLs for RS2 and RS3 would have reduced surface concentrations consistent with expectations in the ROD. The figures illustrate that much of the remaining inventory of PCB contamination is found in the immediate vicinity of the dredge certification units and most of those samples were collected from fine-grained (cohesive) sediments. Cohesive sediments are particularly important for bioaccumulation. Both EPA and GE bioaccumulation models identified cohesive sediments as the primary exposure area for fish.

River Section 2, River miles 187-188



River Section 3, River miles 169-170

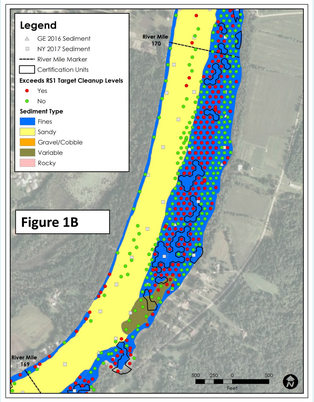


Figure 1. Examples from RS2 (1A) and RS3 (1B) of sediment type and pre-dredging SSAP samples exceeding EPA's (2002) RS1 target cleanup levels outside dredge certification units and locations of GE 2016 and NY 2017 sediment samples. RS!: Thompson Island Pool; RS2: Fort Miller and Northumberland Pool; RS3: Stillwater, Upper and Lower Mechanicville, Troy and Waterford Pools.

Data

Sediment Sampling and Analysis Program (SSAP) (QEA 2005, 2007):

- Pre-remedial, collected in 2002-2005 in support of remedial design under 2002 ROD
- Sediment cores including top 2 inch slice
- RS1: grid sampling of entire pool; approximately unbiased design
- RS2 and RS3: almost exclusively fine-grained (cohesive) sediment; approximately unbiased design for fine-grained sediment
- PCB Aroclor and ~4% PCB homologue analysis

GE 2016 (Anchor QEA and ESI 2017):

- Post-remedial Operations, Monitoring, & Maintenance (OMM), collected in 2016 to establish PCB baseline for future sediment recovery by 3 river sections
- N=215, including non-dredge areas only
- Sediment grabs, top 2 inches
- Random unbiased sampling over 3 river sections
- PCB Aroclor analysis with ~10% EPA splits for PCB congener analysis

NY 2017 (EA Engineering 2017):

- Post-remedial OMM, collected in 2017 to establish PCB baseline for future sediment recovery by 8 river reaches (pools)
- N=1130 including dredged and non-dredged mainstem areas, excluding duplicates
- Sediment grabs, top 2 inches
- Unbiased grid sampling each reach
- PCB Aroclor and ~10% congener analysis

Comparison of PCB Analytical Methods

Split-Sample Analyses: The GE 2016 and NY 2017 studies reported PCB congener analysis (EPA Method 1668A) on a subset of samples to assess performance of the PCB Aroclor Method 8082 used for all samples. Both studies demonstrated that the Aroclor analysis underestimated Total and Tri+ PCBs (Table 1). We calculated and applied the geometric mean ratio of the 1668 congener to Aroclor Tri+ PCBs - 2.15 for GE 2016 and 1.18 for NY 2017 - to adjust the Aroclor Tri+ PCBs in our analyses, similar to the approach used by EPA for fish (USEPA 2017).

Table 1. Geometric and arithmetic mean ratios of congener to Aroclor Tri+ and Total PCBs. Tri+ PCBs represent the sum of PCB congeners with three or more chlorines.

	Ratio of Congener PCBs to Aroclor PCBs Method 1668A / Method 8082				
	Geometric Mean	Arithmetic Mean	95% LCL of Arithmetic Mean	95% UCL of Arithmetic Mean	Number of Samples
GE 2016					
TRI+ PCBs	2.15	2.74	1.78	3.85	23
Total PCBs	2.14	2.84	1.83	3.70	23
NY 2017					
TRI+ PCBs	1.18	1.48	1.24	1.71	122
Total PCBs	1.37	1.79	1.50	2.07	122

Evaluation of Sediment Type Sampled

GE used side-scan sonar to classify the sediment surface into 5 categories (see Figure 1) during the remedial design. Sediment type classifications are used here to provide a common frame of reference because the pre-dredging SSAP samples were collected primarily from fine-grained sediments (cohesive) in RS2 and RS3, while the post-dredging GE 2016 and NY 2017 samples were collected without regard to sediment type.

Figure 2 illustrates the distribution of non-dredge area samples by sediment type resulting from the three different sampling designs. The distribution of samples by sediment type are comparable for RS1 among the three studies. In contrast, a higher percentage of RS2 and especially RS3 SSAP samples were collected from fine-grained sediments. Similarly, total organic carbon (TOC) content was much higher in the SSAP samples from RS2 and RS3 than in the GE 2016 and NY 2017 studies (not shown).

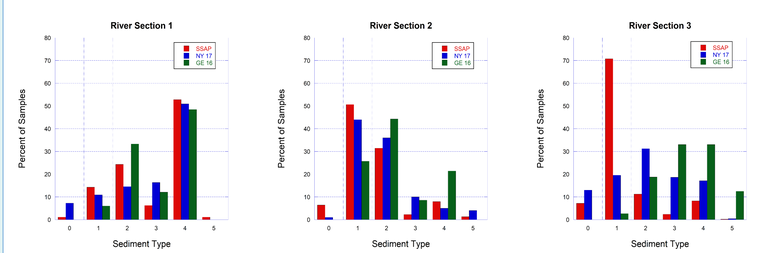


Figure 2. Percentage of samples by sediment type outside dredge Certification Units for SSAP, GE 2016, and NY 2017 for each river section. **Sediment Type:** 0-Missing; 1-Fine; 2-Sandy; 3-Gravel/Cobble; 4-Variable; 5-Rocky

Estimated Natural Recovery Outside Dredge Certification Units

The SSAP data represent comprehensive pre-dredging coverage of RS1 and cohesive sediment in RS2 and RS3. The GE 2016 sample collection was designed to provide unbiased coverage of each river section outside of the dredged Certification Units. The NY 2017 study provides more robust unbiased coverage of each river reach (RS1: 1 reach, RS2: 2 reaches, RS3: 5 reaches), including dredged and un-dredged areas. RS1 (SSAP and NY 2017) provides the most consistent comparison of pre-dredging and post-dredging average Tri+ PCB concentrations in samples collected outside of dredged areas. The lower percentage of GE 2016 and NY 2017 samples collected from cohesive sediment areas (Figure 2) and the highly contaminated areas surrounding the dredged areas (see Figure 1) in RS2 and RS3 is a consequence of different sampling designs. Estimating natural recovery in the top 2 inches of surface sediment is complicated by the lack of consistency between the pre- and post-dredging sediment sampling programs and the analytical issues revealed by the split-sample PCB congener analyses. Estimates of rate of recovery may also be affected by the distribution of backfill that likely added sand to areas surrounding the dredged areas.

EPA Post-Dredging Model Projections Compared to NY 2017 Data

EPA models predicted area-weighted post-dredging Tri+ PCBs (top 2 inches) in 2012 (expected dredging completion in 2011 rather than actual completion in 2015) (USEPA 2012). We projected Tri+ PCBs in 2017 using the EPA model predicted 8% exponential decay between 2012 and 2017 (Table 2). Data for NY 2017 represent arithmetic averages by river section, which are equivalent to area-weighted averages. NY 2017 adjusted Tri+ PCBs were higher than EPA model projections for 2012 by factors of 1.2, 6.4, and 4.8 for RS1, RS2, and RS3 respectively. The ratios for NY 2017 Tri+ PCBs (adjusted) to projected EPA model Tri+ PCBs in 2017 were 1.8, 9.5, and 7.2 for RS1, 2, and 3 respectively. Post-dredging reported and adjusted Tri+ PCBs (NY 2017 study) are substantially higher than predicted by the EPA model.

Table 2. Comparison of EPA model projections of area-weighted average Tri+ PCBs (mg/kg) to reported and adjusted NY 2017 data by river section.

	EPA Model Predicted		NY 2017 Tri+ PCBs (Reported)			NY 2017 Tri+ PCBs (Adjusted*)		
River Section	Predicted Tri+ PCBs in 2012	Predicted Tri+ PCBs in 2017 (8% decay)	Tri+ PCBs (mg/kg)	Ratio NY17/EPA2012	Ratio NY17/EPA2017	Tri+ PCBs (mg/kg)	Ratio NY17/EPA2012	Ratio NY17/EPA2017
1	0.96	0.64	0.99	1.03	1.53	1.16	1.21	1.81
2	0.42	0.28	2.27	5.40	8.06	2.68	6.38	9.52
3	0.20	0.13	0.82	4.08	6.08	0.96	4.81	7.17

* *NY 2017 data were adjusted by 1.18 (Table 1)*
EPA model post-remediation predictions in 2012 for area-weighted average for all sediment types from USEPA 2012, Appendix A, Table 1

Conclusions

1. A much smaller percentage of cohesive sediment samples were collected in the post-dredging sampling compared to pre-dredging sampling in RS2 and RS3. Cohesive sediments are particularly important for estimating bioaccumulation as both EPA and GE bioaccumulation models identified cohesive sediments as the primary exposure area for fish.
2. The GE 2016 and NY 2017 studies provide a statistical basis for evaluating future recovery in the top 2 inches, but neither study addresses the highly contaminated sediments surrounding the dredge Certification Units in RS2 and RS3 that were identified in the SSAP.
3. PCB Aroclor analyses in the GE 2016 and NY 2017 studies significantly underestimated Total and Tri+ PCBs according to split-sample analysis with the current standard PCB congener method. Unless resolved, the uncertainty created by the underestimation of PCBs in the recent Aroclor analyses will make future estimates of the rate of recovery highly uncertain.
4. EPA model projections substantially underestimated NY 2017 post-dredging area-weighted Tri+ PCBs. Post-dredging adjusted Tri+ PCBs in RS2 and RS3 were 9.5 and 7.2 times higher than the EPA model predicted post-dredging concentrations for 2017. Reported Tri+ PCBs were similarly elevated above EPA model predictions.
5. Major differences between the pre- and post-dredging areas and sediment types sampled, in addition to analytical uncertainty, make determination of recovery rates using pre-dredging data highly uncertain. A future sampling plan that treated the areas surrounding the dredged areas as separate strata in a randomized sampling plan could be used to compare to the SSAP data to evaluate the recovery of those highly contaminated areas in RS2 and RS3.
6. Post-dredging data provide no information on PCBs below the top 2 inches and underestimate the amount of unremediated and bioavailable PCBs in the surface, which EPA defined as the top 12 inches. For RS3, pre-dredge SSAP Tri+ PCBs calculated as the length-weighted average for the top 12 inches (EPA defined surface or bioactive zone) were almost 4X higher than in the top 2 inches.
7. The NY 2017 sediment sampling was much more robust than GE 2016 and provides a basis for evaluating individual reaches, which are most important for relating to fish recovery

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