Analysis of Soil Geochemistry in Tributary Alluvial Deltas of the Susquehanna River

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Introduction

Alluvial soils form as a result of periodic sedimentation during storm water events and give a picture of the overall environmental impacts of land use in the watershed. Large concentrations of coal legacy sediments are being stored beneath tributary deltaic deposits of the North Branch Susquehanna River (NBSR) and pose a threat worth evaluating. Coal overwash contains elevated levels of chemicals such as aluminum, arsenic, boron, cadmium, chromium, lead, manganese, molybdenum, selenium, and sulfate. These pollutants can cause cancer, birth defects, reproductive problems, damage to the nervous system, and kidneys (NRDC, 2007).

As coal sediments are eroded from uplands and transferred to tributary stream systems, they flow in suspension down to the confluence of the NBSR (Stinchcomb et al. 2013). The slower velocity of the River allows sediments to drop from suspension and build up over time, initiating the creation of a delta. Meanwhile, vegetation begins to colonize these deltaic deposits and stabilize them with extensive root systems. As additional floodwater sediment interacts with established woody vegetation, a positive feedback loop occurs and more sediments deposit on the down-current side of trees and shrubs. Therefore, well vegetated deltas promote alluvial sediment trapping and stabilization of coal deposits and associated trace metal pollutants.

There has not been much research done to quantify the total amount or concentrations of coal contaminated legacy sediment within tributary deltas of the NBSR in Pennsylvania's anthracite coal mining region. Thus, our goal of this research was to examine the amount of coal sand deposited in alluvial soils of the NBSR and associated trace metal concentrations within major tributary deltaic deposits from two streams draining coal mining regions as well as two mixed agricultural watersheds.

Study Area

The study sites used for this research project included four deltas located along the NBSR in the Ridge and Valley Province of Pennsylvania's anthracite coal mining region. Temperatures in this area normally range from -3.6 to 21.6° C with precipitation averaging 1056 mm annually (Pennsylvania State Climatologist 2004).

Assessment of the variability in coal contaminated soil was provided by the usage of two deltas without coal mining in the watershed, as well as two that drain coal mined areas (Fig 1).

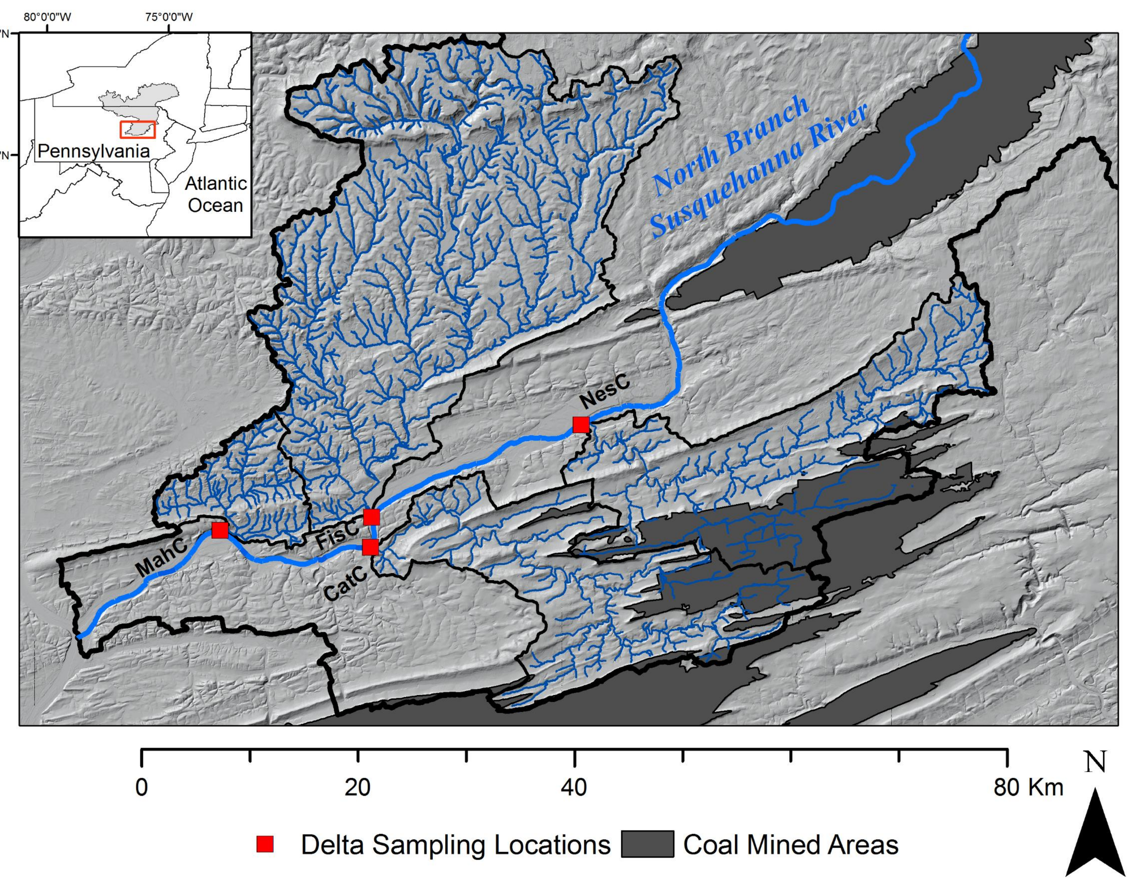

Fig. 1: Image showing delta sampling locations, total watershed area for each site, and previously coal mined areas are shown in dark gray (image created using ArcGIS, courtesy of Daniel Steinhauser).

Methods

Ten shallow soil samples (0-10 cm) were collected from the surface of each delta (n = 4), as well as deep core samples (>100 cm) from each location (n=1-2). Surface soil samples were collected with trowels using standard field procedures (Schoenberger et al. 2012) and GPS points were recorded at each sample location. Deep core samples were retrieved using a soil auger and bulk density subsamples were collected by horizon using a 98.2 cm^3 aluminum cylinder.

Both surface and core samples were tested for pH (1:1 slurry, OAKTON pH 700) and then oven dried at 105°C. Samples were then sieved to a particle size of <2 mm to remove coarse fragments. Subsamples were used for soil texture analyses using the hydrometer method (Soil Survey Investigation Staff, 2004). Additional subsamples were washed using a 63 µm sieve to separate sand particles from clay and silt fractions. Sand samples were examined under a Meiji MX9200 microscope at 100x magnification. A total of 200 sand-sized grains were counted per sample with a proportion of quartz to coal for an estimate of contamination. Additional subsamples were homogenized using mortar and pestle for total elemental analysis via X-ray Fluorescence (XRF, Niton XL3t GOLDD). Trace metal concentrations from XRF were compared to Pennsylvania background soil levels (Pb-19.5 ppm, As-12.0 ppm, Zn-65.0 ppm from Vosnakis et al. 2009; Ciolkosz et al. 1998) and also to the percentage of coal in each sample to determine the connection between coal contamination and metal storage.

The GPS points from each surface sample were used to create a Regularized Spline model demonstrating the estimated percentage of coal contamination distributed throughout each delta (Figs. 2 and 3).

Results

Coal grain counts ranged from 1.0% to 50.5%, with higher concentrations on the downstream side of each delta.

On deltas draining coal regions (CatC, NesC), Pb ranged from 16.0–103, As from 7.0–28, and Zn from 35–171.0 parts per million (ppm). In deltas drainage agricultural lands (FisC, MahC), Pb ranged from 18.0–88, As from 5.0–21, and Zn from 50–131.0 ppm. Average metal concentrations to a depth >100 cm on coal region deltas were 50.5 ppm Pb, 13.0 ppm As, and 73.8 ppm Zn. Agricultural deltas showed averages of 39.4 ppm Pb, 10.9 ppm As, and 79.7 ppm Zn. All average concentrations were elevated above Pennsylvania background levels with the exception of As in the agricultural deltas (Vosnakis et al. 2009, Ciolkosz et al. 1998).

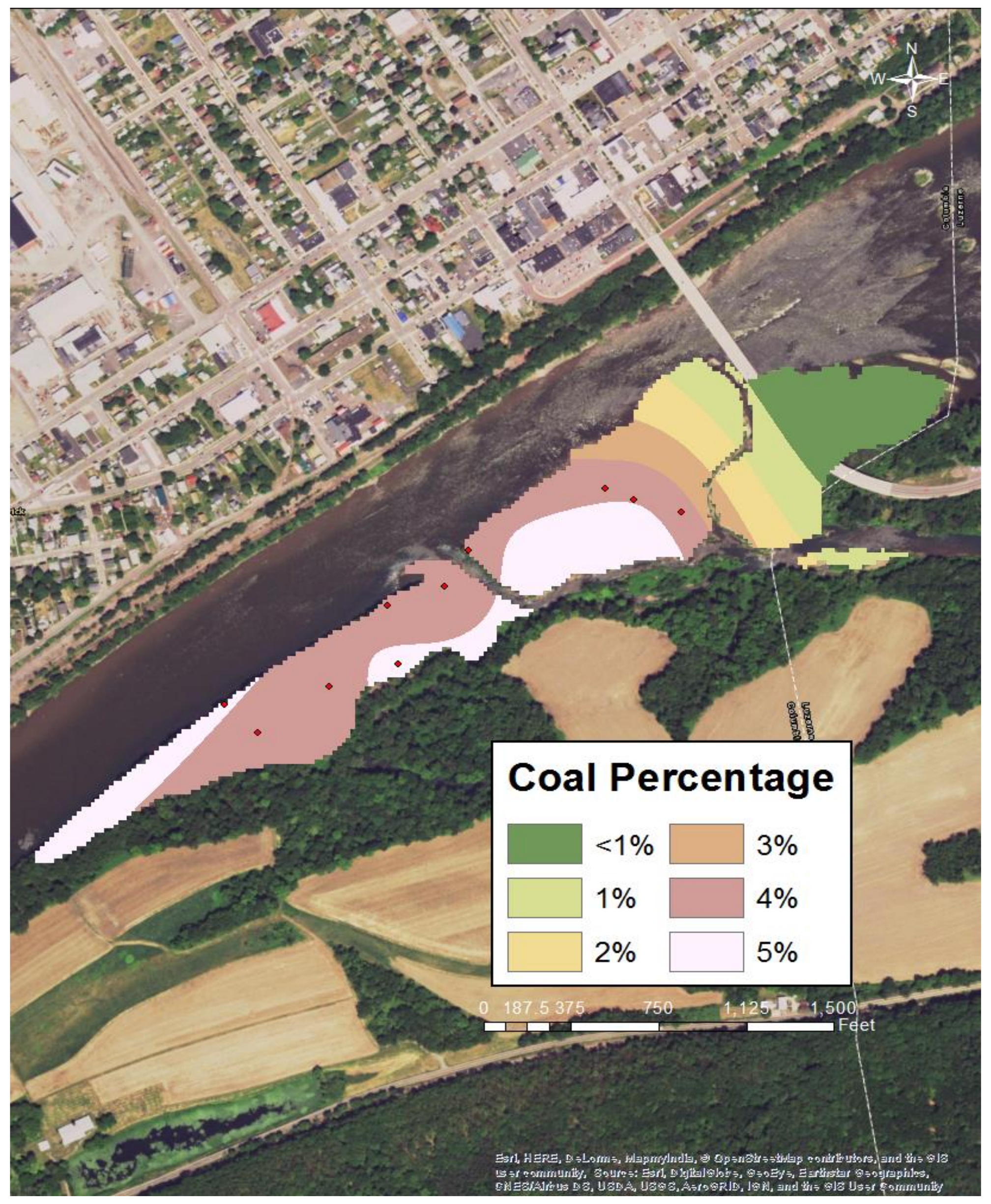

Fig. 2: Map displaying Nescopeck Creek (NesC) delta interpolated alluvial coal sand concentrations based on surface sample grain counts.

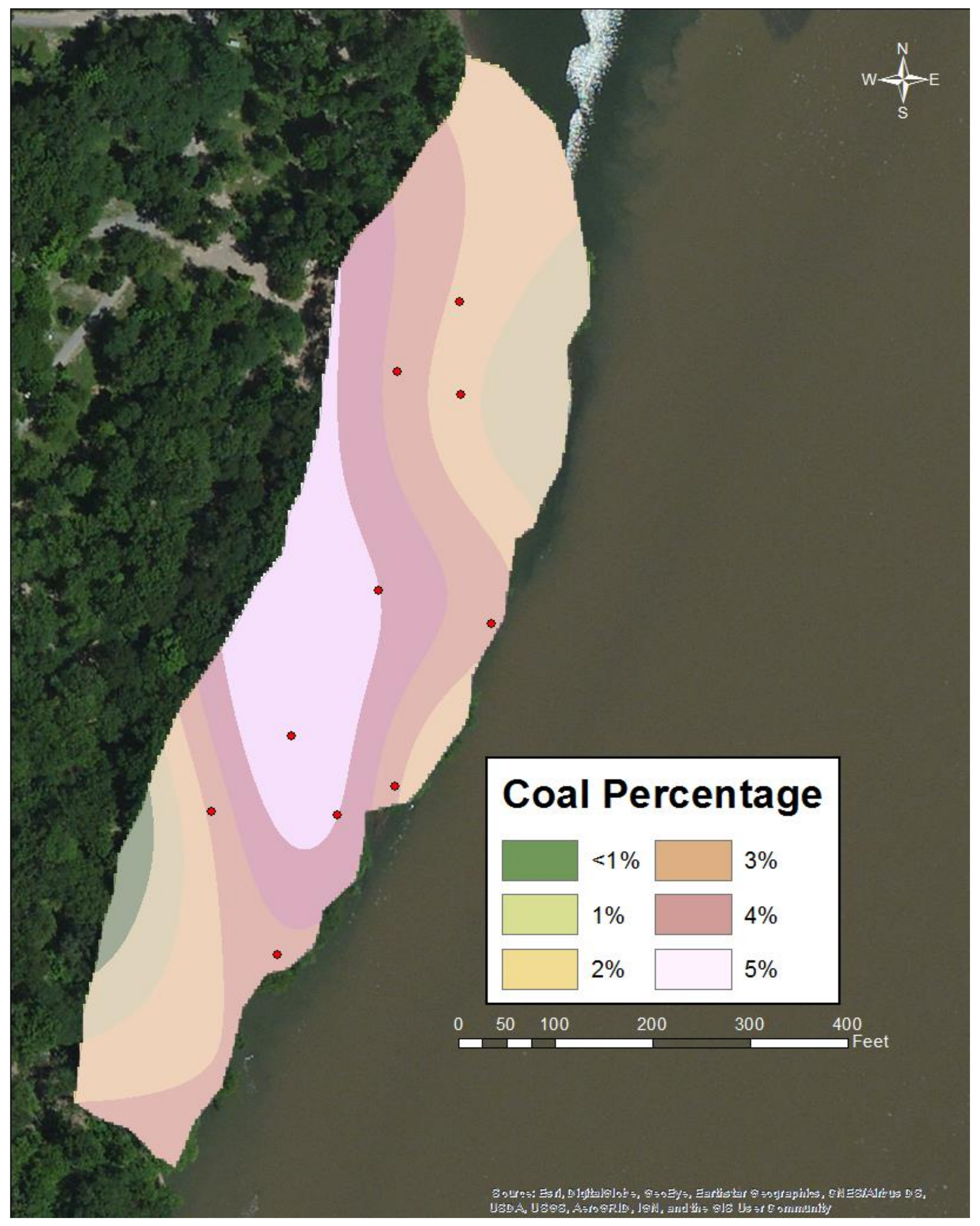

Fig. 3: Map displaying Fishing Creek (FisC) delta interpolated alluvial coal sand concentrations based on surface sample grain counts.

Delta	Delta Area (ha)	Watershed Area (ha)	Trees/ha	Mean Coal % to 100 cm	Mean Pb (ppm) in upper 100 cm	Mean As (ppm) in upper 100 cm
Fishing Creek Core1/Core2	2.34	99802	233	4.3	26.5	8.0
				7.9	36.2	10
Mahoning Creek Core1/Core2	2.79	10276	133	8.1	34.0	9.2
				6.9	51.2	14
Nescopeck Creek	16.7	45049	500	22	48.8	13
Catawissa Creek	4.03	39546	233	19	44.5	12

Table 1: Table showing sample sites with corresponding area in hectares, watershed area in hectares, trees/hectare, mean coal percentage to 100 cm, and mean lead/arsenic in parts per million to 100 cm.

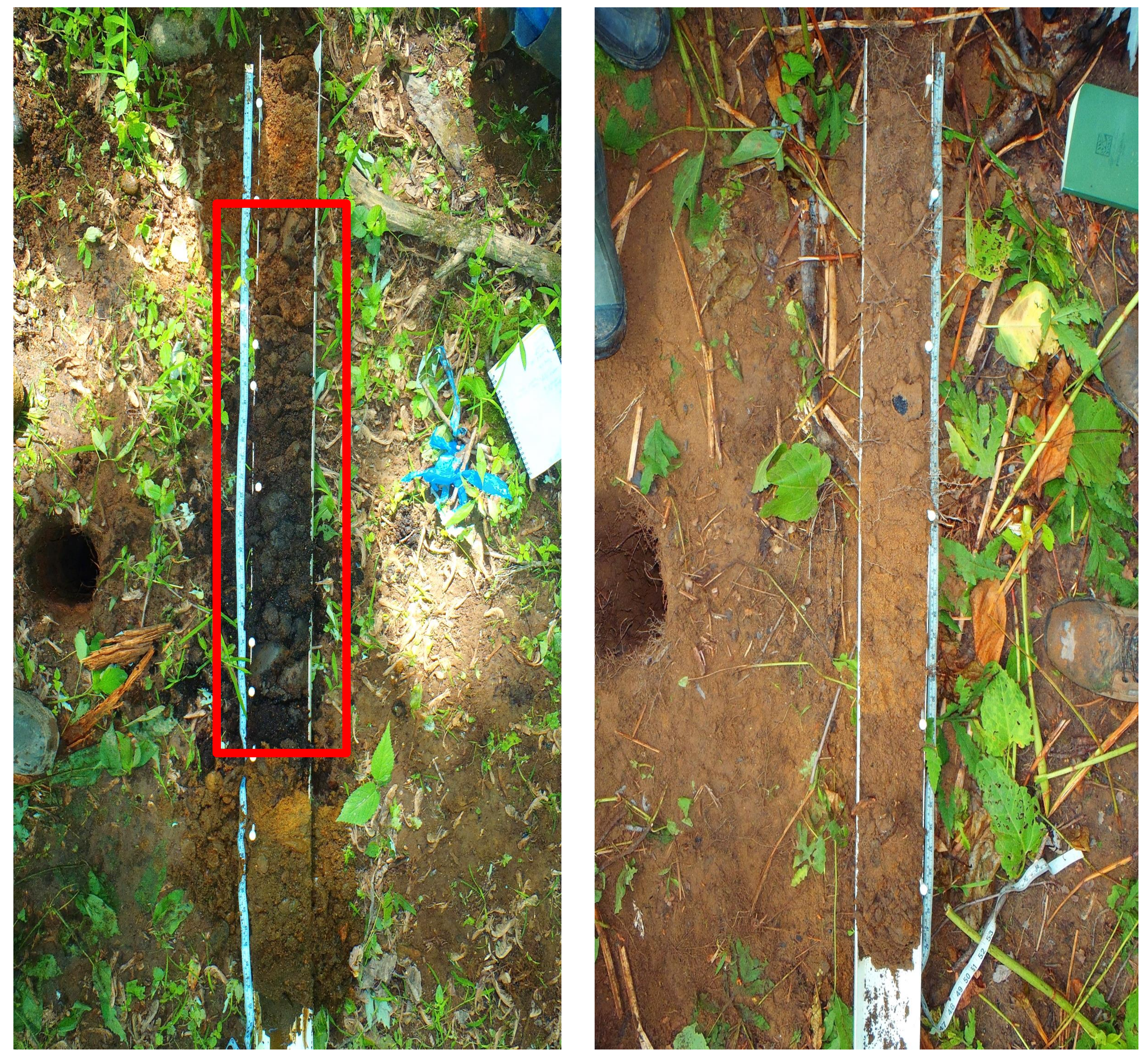

Fig. 4: A representative core sample from Nescopeck Creek delta (left) and Fishing Creek delta (right, Core 1). Notice the alluvial coal deposit in the Nescopeck sample outlined in red.

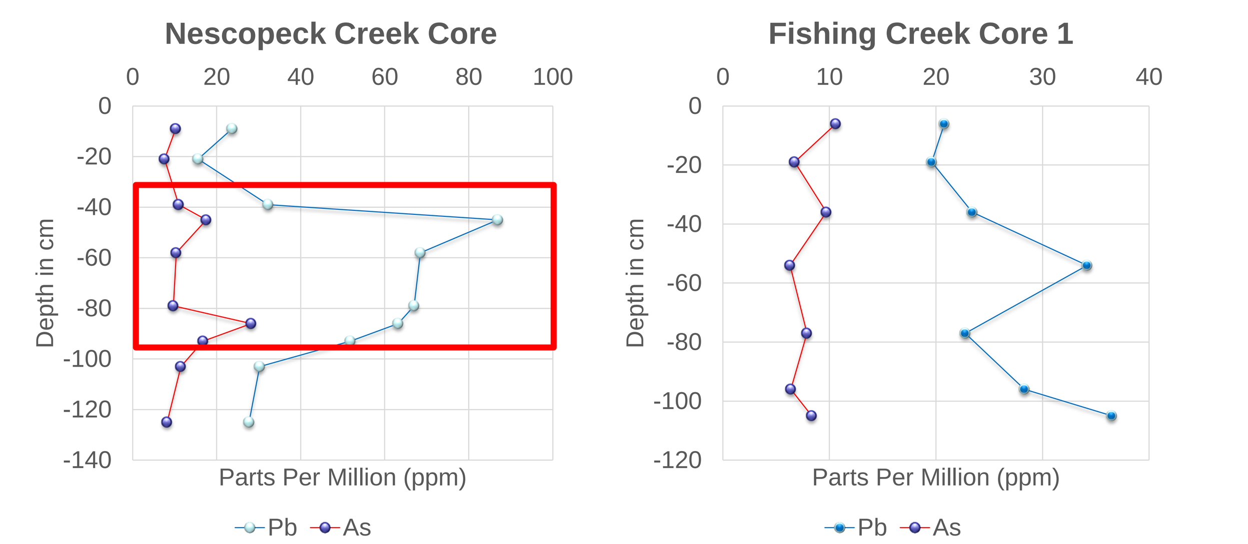

Fig. 5 and 6: Vertical profile of lead and arsenic values (ppm) with depth in both the Nescopeck Core and Fishing Creek Core 1 samples. Note difference in x-axis scales.

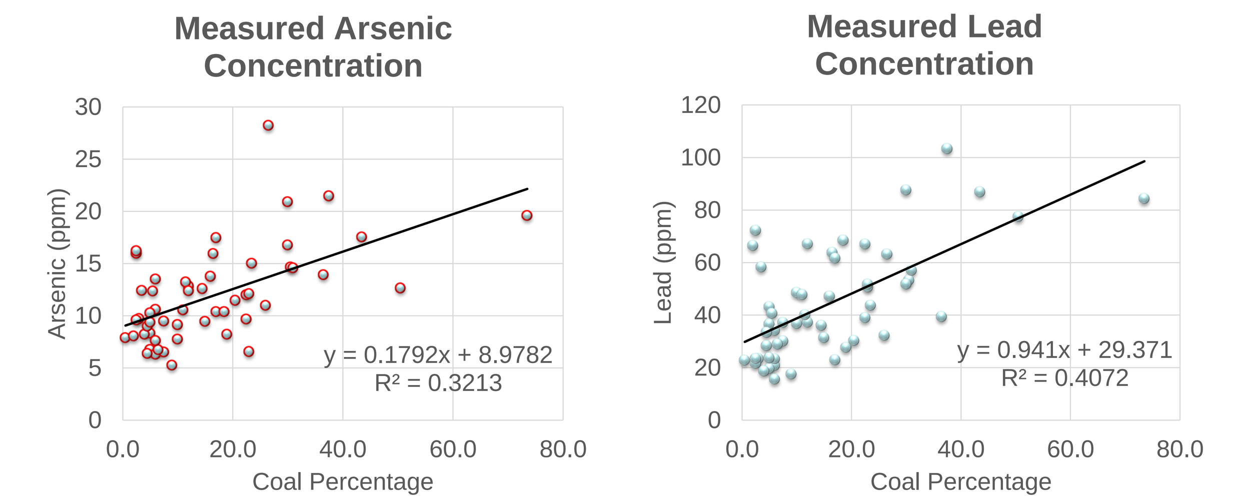

Fig. 7 and 8: Correlation between coal percentages and metal concentrations for **all deltas**. Notice the linear increase with both lead and arsenic concentrations as coal percentage increases.

Discussion

- Coal contamination was found at all depths regardless of the delta.
- Forested deltas continue to provide crucial ecosystem services.

Acknowledgments

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