Potential Legacy of Heavy Metal Contamination in the Sediments of Former Sewage Holding Ponds at Otter Point Creek, MD

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Abstract:

Sewage and wastewater inputs are a major contributor of contaminants and pollutants to waterways, especially those near heavily urbanized areas. Some of the more hazardous pollutants introduced through sewage and wastewater include reactive heavy metals such as copper, lead, and zinc. Reactive metals introduced into aquatic systems can be adsorbed on particles and deposited in the sediments, where they can be buried or remobilized back into the water column. In August 2013, as part of a U.S. Naval Academy (USNA) Summer Internship at the Anita C. Leight Estuary Center (ACLEC) in Edgewood, MD, two sediment cores were collected from two man-made lagoons formerly used as sewage holding ponds at Otter Point Creek (OPC). An additional core was collected from outside the lagoons to serve as a control. Cores were analyzed for water content, porosity, grain size and for bulk elemental composition. There were noticeable differences in the composition and heavy metal profiles between the lagoon and the control cores but no clear indication of a legacy of heavy metal contamination. In order to identify or rule out any potential heavy metal contaminant legacy related to wastewater or sewage inputs in these lagoons, further research is required.

Study Area and Methods:

Figure 1. Google Earth view of study area showing sediment core sampling locations for Lagoon 1, Lagoon 2, and Control. Also shown is the location for the Anita C. Leight Estuary Center (ACLEC), located on Otter Point Creek off the Chesapeake Bay (inset).

Figure 1 shows the study area at OPC. Shallow sediment core samples were collected using a Multi-Use Core Collection Kit (MUCK) from Lagoon 1 and the Control site on 25 JUL 2013 and from Lagoon 2 on 05 AUG 2014. The MUCK is a handheld, messenger-actuated gravity coring device (**Fig. 2**). Core lengths for Lagoon 1, 2 and the Control were 18 cm, 16 cm, and 18 cm, respectively. After collection, cores were vertically sectioned (2 cm intervals) and transported to the Hendrix Oceanography Laboratory at USNA for analysis. Core sections were weighed wet, then dried at 60ºC for 48-72 hours and weighed again dry to determined water content and porosity. Dried samples were then mechanically homogenized, and sieved into > 250 µm (gravel and coarse sand), < 250 µm and > 63 µm (fine sand), and < 63 µm size (mud or fines) fractions. Subsamples (~5 g) of the fines from each core section were then sent to Spectro Analytical Instrument, Inc., Mahwah, NJ for bulk elemental analysis using a XEPOS HE Energy-Dispersive X-Ray Fluorescence (ED-XRF) Spectrometer.

Figure 2. MIDN 1/C Ben Ziemski operating the Multi-Use Core Collection Kit (MUCK) similar to the one used at Otter Point Creek.

SPECTRO

Results:

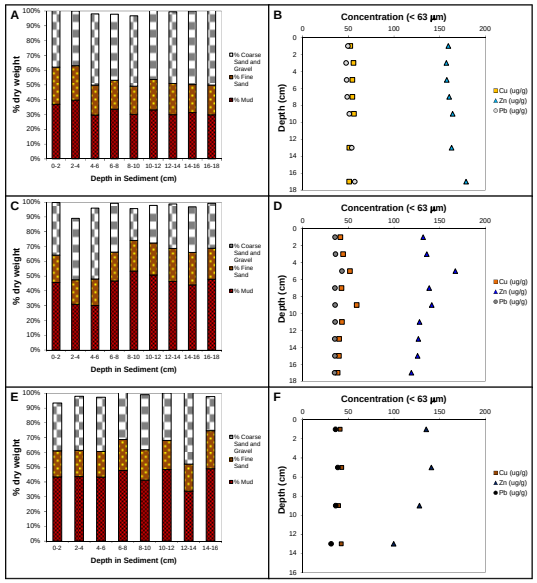

Figure 3. Results of grain-size analysis (**A, C, E**) and bulk Cu, Zn , Pb concentrations vs. depth for: (**A, B**) Control; (**C, D**) Lagoon 1; and (**E, F**) Lagoon 2. The bulk elemental composition shown is based on ED-XRF analysis of the < 63 µm (mud/fine) fraction.

Figure 3 shows the results of grain-size analysis and bulk elemental analysis of Cu, Zn, Pb concentrations vs. depth for the fine fraction for each core. Results show a clear difference in grain-size (% muds/fines) between the Control core (**Fig. 3A**) and the two lagoons (**Fig. 3C, E**). Sediments in the Control core were consistently comprised of < 40% fines while Lagoon 1 and 2 were consistently > 40% fines. Certain sections of the lagoon cores (2-4 cm, and 4-6 cm in Lagoon 1 and 12-14 cm in Lagoon 2) had a grain-size distribution similar to the control. Measured Cu, Zn, and Pb concentrations of the fine fraction of sediments in the Control core (**Fig. 3B**) were fairly consistent with depth and generally higher than those measured in either lagoon (**Fig. 3D, F**). Notable exceptions can be seen in measured Cu, Zn, Pb concentrations in the fine fraction of the 4-6 cm and 8-10 cm sections of Lagoon 1 (**Fig. 3D**).

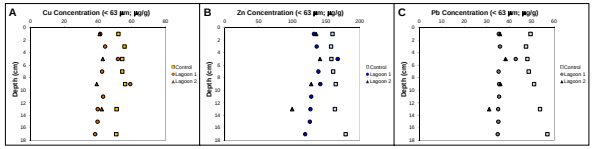

Figure 4. Side-by-side comparison of bulk (**A**) Cu, (**B**) Zn, and (**C**) Pb concentrations for Control, Lagoon 1 and Lagoon 2 cores vs. depth. The bulk elemental composition shown is based on ED-XRF analysis of the < 63 µm (mud/fine) fraction.

Figure 4 shows a side-by-side comparison of bulk Cu, Zn, and Pb concentrations for the fine fraction which clearly shows the differences between bulk heavy metal concentrations vs. depth between the control core and the lagoon cores.

Discussion:

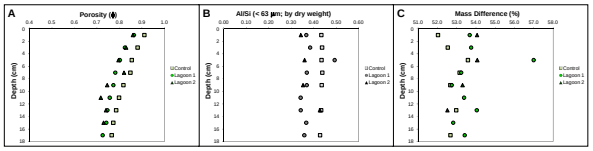

Figure 5. Side-by-side comparison of (**A**) porosity, (**B**) Al/Si, and (**C**) Mass Difference for Control, Lagoon 1 and Lagoon 2 cores vs. depth. Mass Difference (%) was calculated as the ratio of the difference of total dry mass minus the total elemental mass (Na to U) measured by ED-XRF analysis of the < 63 µm (mud/fine) fraction to the total dry mass for each sediment sample.

Figure 5 shows porosity, Al/Si, and mass difference (%) values vs. depth for each core. Porosity in all cores is similar, implying that water content has little to do with the observed differences in heavy metal concentration between cores (**Fig. 5A**). There is a difference, however, in Al/Si with depth between the Control and lagoon cores (**Fig. 5B**). The 4-6 cm section (Lagoon 1) and the 12-14 cm section (Lagoon 2) are different as compared to each background profile. This suggests a difference in sediment composition in these sections. Whether this represents a transport of material in or out of the lagoons is unclear. There is variability in the estimated mass differences of discrete sections in the cores (**Fig. 5C**), which suggests that material differences (such as organic C) may influence the heavy metal concentration profiles observed.

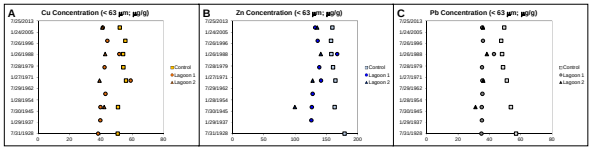

Figure 6. Comparison of sediment geochronologies for (**A**) Cu, (**B**) Zn, and (**C**) Pb in Control and lagoon cores. Geochronologies were developed using an estimated constant sediment accumulation rate of 0.2 cm/yr for Chesapeake Bay (Brush et al., 2007)

Figure 6 shows estimated Cu, Zn, and Pb geochronologies for each core. The noted differences in heavy metal concentrations correspond to dates in the late 1980's for the 4-6 cm section and the late 1960's for the 8-10 cm section of Lagoon 1. The estimated dates for the use of these lagoons as sewage holding ponds was from 1968-1972 (ACLEC, unpublished). The correlation of these dates suggests there may be some lasting anthropogenic impact on the sediments of these lagoons, however, the results of this study are inconclusive and more research is required to determine whether this may be the case.

Conclusions:

- ***There is no clear evidence of heavy metal contamination in the sediments of Lagoon 1 or 2 due to their use as sewage holding ponds.***
- ***Deeper cores and additional geochemical analysis (organic C, radioisotopes, stable isotopes) would be required to draw any definite conclusions.***
- ***Other factors such as storm events, physical alteration, material and sediment mixing, changes in sediment chemistry, and remobilization may account for the differences observed between cores.***

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