Chromium Concentrations Achieved Through Atomic Absorption Readings and Abiotic Factors of Soil and Water Samples from 8 Locations on the Dan River

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Abstract:

This experiment aimed to determine whether water and soil quality differed above the site of the February 2014 Dan River coal ash spill, at the spill site, and downstream of the spill site, as well as determining if the chromium levels (mg/kg) differed among these sites as a result of the coal ash deposit. Because coal ash is known to contain heavy metals and toxins, the parameters chosen for this study including pH levels for both soil and water are expected to appear lower downstream of the spill and at the spill site compared to upstream of the spill. The chromium and nitrate concentrations are expected to be higher downstream and at the site of the spill than upstream of the spill. The parameters chosen to measure water and soil quality were pH, nitrate levels, total dissolved oxygen, total dissolved solids, turbidity and chromium concentration measured using Atomic Absorption Spectrophotometry. Chromium concentrations were positively correlated, increasing with subsequent locations after the spill. The pH and nitrate levels in both soil and water samples were lowest at Location 5, directly downstream of the spill, and then increased to levels similar to upstream data values, possibly due to the topography of the area and exposure to deposits. Since all organisms depend on soil and water to survive, understanding the changes in water and soil quality above and below a coal ash spill provides a baseline for interpreting all other changes in the environment.

Introduction:

The US Environmental Protection Agency estimates that there were more than 735 surface impoundments of coal ash across the United States in 2012 (EPA 2014). On February 2, 2014, one of those failed when a storm water pipe broke below the coal ash pond of the closed Duke Energy Power Plant on the Dan River near Eden, NC. The spill released 39,000 tons of coal ash into the river(Miller 2014). The longer-term effects of the coal ash spill on water and soil quality have not been explored in depth. In this experiment, soil and water samples from 8 locations along the Dan River were collected almost a year after the spill in order to determine what effects, if any, the coal ash had on water and soil quality surrounding the Dan River coal ash spill site.

In controlled laboratory experiments on water, an increase in coal ash has been correlated with a decrease in pH, and one study attributed the lowered water pH to the sulfate ions present in coal ash (Webster 1986, Guthrie 1982). An increase in nitrate content in soil is also correlated significantly with an increase in coal fly ash (Ciecko 2010). The EPA has found that higher concentrations of coal ash are correlated with higher levels of the toxic Chromium VI, sometimes pushing above levels deemed safe for drinking ((Kosson 2009). These are the parameters that were chosen to assess water and soil quality.

Test Performed:

Water samples were tested for temperature, pH, dissolved oxygen, nitrate concentration, and total dissolved solids. Soils were tested for temperature, pH, nitrate concentration and chromium concentration.

Results:

On the banks, we found that chromium concentration was highest in Location 5 (112.5 ± 51.92308) (Figure 1, n=3). Channel Location 8 (33.17308 ± 60.57692) had chromium levels significantly different from chromium levels of nearly all other locations (Table 1, n=3, t-test). On the bank, there was a significant difference between chromium content upstream of the spill site (0.01 ± 0.002), at the spill site (0.021 ± 0.001), and below the spill site (0.054021 ± 0.013631) (Table 2, n=3, t-test, p>0.05). At the channel, there was no significant difference between chromium content in the spill site and the upstream or downstream area. There was a significant difference in chromium levels in the channels upstream of the spill site (Table 2 0.002 ± 0.001) and downstream of the spill site (0.037 ± 0.008) (n=3, t-test, p>0.05).

The pH of soil, which remained primarily acidic, did change between a few locations. While there was no significant difference between soil pH on the banks upstream of the spill site, the spill site, and downstream of the spill site, there was a significant difference between the pH of the soil in the channel upstream (5.626 ± 0.070) and downstream (5.239 ± 0.099) of the spill site (Table 3, n=3, t-test p=0.002). However, there was no significant difference between upstream and spill site or downstream and spill site.

The nitrate levels in the soils collected from the banks show a statistical trend with two-sample t-tests, specifically when location 8 is compared to the other locations (table the one I put together summarizing the results of the t-tests). Locations 1,2,4,5, and 6 are significantly different from location 8 (p<0.05). which help to support this trend. No definitive trend was found for the channel samples (Table 4). Additional two-sample t-tests were performed, comparing the upstream locations (L1,L2, and L3), the downstream locations (L5, L6, L7, and L8), and the spill site (L4) for both the bank and the channel soil samples. No statistical significance was found. The differences for locations 3 and 7 approach statistical significance (0.05<p<0.10), both of which help to support this trend. No definitive trend was found for the channel samples (Table 4). Additional two-sample t-tests were performed, comparing the upstream locations (L1,L2, and L3), the downstream locations (L5, L6, L7, and L8), and the spill site (L4) for both the bank and the channel soil samples. No statistical significance was found.

Results:

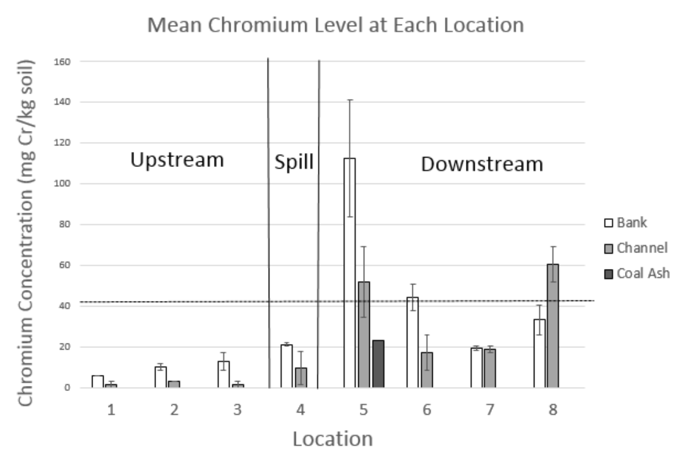


Figure 1: Mean (+/- 1 se) soil chromium concentration at each sampling location (3 samples per location) for samples collected on the Dan River near Eden, NC on 1/13 and 1/20/15. Horizontal line indicates EPA Ecological Risk Screening Levels (ERSLs) for chromium concentration (43.4 mg/kg).

P-values from Two-tailed T-test of Bank Soil Chromium Samples

	l1	l2	l3	l4	l5	l6	l7	l8
L1		ns	ns	0.004	ns	0.029	0.005	ns
L2			ns	0.024	ns	0.038	0.034	ns
L3				ns	ns	0.030	ns	ns
L4					0.034	0.027	ns	ns
L5						ns	0.032	ns
L6							0.021	ns
L7								ns
L8								

P-values from Two-tailed T-test of Channel Soil Chromium Samples

	L1	L12	L3	L4	L5	L6	L7	L8
L1		ns	ns	ns	ns	ns	0.014	0.021
L2			ns	ns	ns	ns	0.008	0.022
L3				ns	ns	ns	0.014	0.021
L4					ns	ns	ns	0.024
L5						ns	ns	ns
L6							ns	0.072
L7								0.041
L8								

Table 1: P values of soil pH between sampling locations on Dan River near Eden, NC on 1/13 and 1/20/15 (p<0.05). "ns" signifies non-significance.

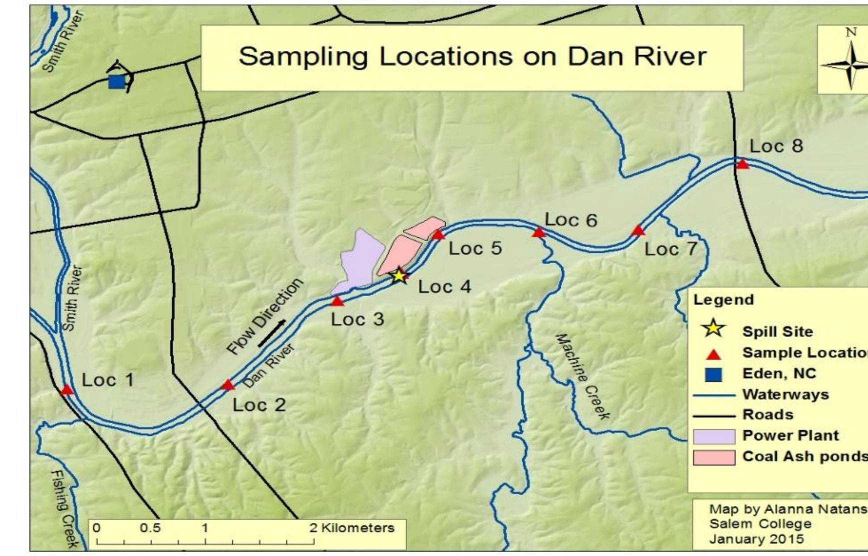
P-values from Two-tailed T-test of Bank Soil Nitrate

C		L2	L3	L4	L5	L6	L7	L8
L1		ns	ns	ns	ns	ns	0.082	0.004
L2			ns	ns	ns	ns	ns	0.037
L3				ns	ns	ns	ns	0.092
L4					ns	ns	ns	0.04
L5						ns	ns	0.004
L6							ns	0.028
L7								0.066
L8								

P-values from Two-tailed T-test of Channel Soil Nitrate

C		L2	L3	L4	L5	L6	L7	L8
L1		0.07	ns	0.065	ns	0.093	0.009	0.003
L2			ns	ns	ns	ns	0.092	ns
L3				ns	ns	ns	ns	0.092
L4					ns	ns	ns	0.096
L5						ns	ns	ns
L6							0.048	0.01
L7								<0.0001
L8								

Table 4: P values of soil nitrate between sampling locations on Dan River near Eden, NC on 1/13 and 1/20/15 (p<0.05). "ns" signifies non-significance.



Map 1: Map of sample locations along Dan River. Water samples and soil samples (both from the banks and rivers) were taken via canoe on the Dan River near Eden, NC, on 1/13 and 1/20/15. Samples were taken in triplicate in bank, duplicate in channel and triplicate in water, but samples were not collected from Locations 6 and 7 on 1/13.

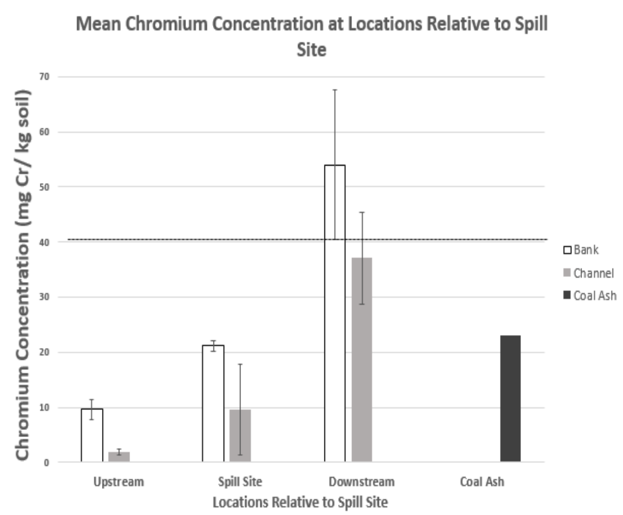


Figure 2: Mean (+/- 1 se) soil pH at each sampling location (3 samples per location) for samples collected on the Dan River near Eden, NC on 1/13 and 1/20/15.

P-values from Two-tailed T-test of Bank Soil Chromium Samples in Relation to Spill Site

	Upstream	Downstream	Spill Site
Upstream		0.009	0.001
Downstream			0.037
Spill Site			

P-values from Two-tailed T-test of Channel Soil Chromium Samples in Relation to Spill Site

	Upstream	Downstream	Spill Site
Upstream		0.004	ns
Downstream			0.057
Spill site			

Table 2: P values of soil chromium concentrations between sampling locations on Dan River near Eden, NC on 1/13 and 1/20/15. (p<0.05). "ns" signifies non-significance.

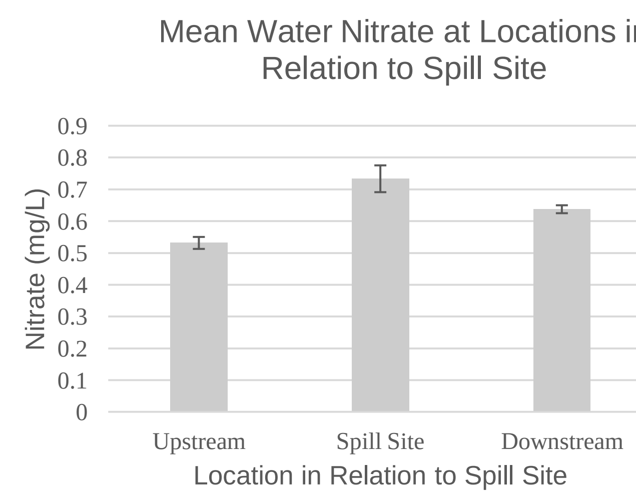


Figure 3: Mean (+/- 1 se) water nitrate concentration at each sampling location (3 samples per location) for samples collected on the Dan River near Eden, NC on 1/13 and 1/20/15. On 1/20/14, there was a significant difference between nitrate levels upstream of the spill site and downstream of the spill site (p=0.004).

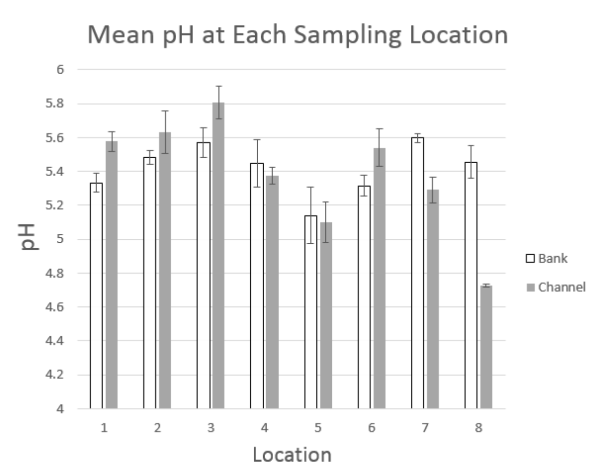


Figure 3: Mean (+/- 1 se) soil pH at each sampling location (3 samples per location) for samples collected on the Dan River near Eden, NC on 1/13 and 1/20/15.

P-values from Two-tailed T-test of Bank Soil pH Samples

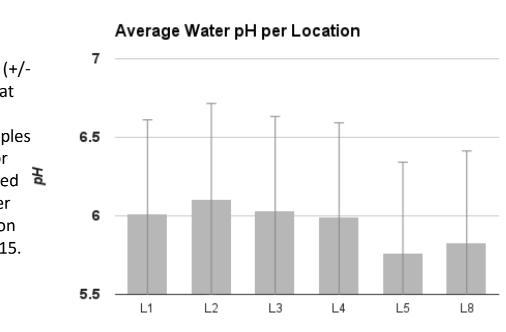
Colu	L1	L2	L3	L4	L5	L6	L7	L8
L1		ns	ns	ns	ns	**0.026**	**0.026**	ns
L2			ns	ns	ns	ns	ns	ns
L3				ns	ns	ns	ns	ns
L4					ns	ns	ns	ns
L5						ns	ns	ns
L6							**0.006**	ns
L7								ns
L8								

P-values from Two-tailed T-test of Channel Soil pH Samples

Colu	L1	L2	L3	L4	L5	L6	L7	L8
L1		ns	ns	ns	**0.025**	ns	**0.042**	**0.0001**
L2			ns	ns	**0.040**	ns	ns	**0.002**
L3				ns	**0.028**	ns	ns	ns
L4					ns	ns	ns	**0.0002**
L5						ns	ns	**0.038**
L6							ns	**0.002**
L7								**0.002**
L8								

Table 3: P values of soil pH between sampling locations on Dan River near Eden, NC on 1/13 and 1/20/15 (p<0.05). "ns" signifies non-significance.

Figure 4: Mean (+/- 1 se) water pH at each sampling location (3 samples per location) for samples collected on the Dan River near Eden, NC on 1/13 and 1/20/15.



P-values from two-tailed T-test of Turbidity

	L1	L2	L3	L4	L5	L6	L7	L8
L1		0.001	ns	ns	ns	0.001	ns	ns
L2			0.04	ns	ns	**	ns	**
L3				ns	ns	0.007	ns	ns
L4					ns	ns	ns	ns
L5						0.037	ns	ns
L6							0.027	**
L7							^	ns
L8								

Table 5: P values for turbidity between sampling locations on Dan River near Eden, NC on 1/13 and 1/20/15. (p<0.05). "ns" signifies non-significance. ^ signifies same location, ** indicates where both locations had a variance of 0.

Results (cont.):

The turbidity did show a significant difference at a few locations. Location 1 (1.625 ± 0.072) was significantly different in turbidity compared to Location 2 (1.25 ± 0) and Location 6 (0.75 ± 0). Turbidity was also significantly different between Location 2 and Locations 3 (1.563 ± 0.120), 6, and 8 (1.75 ± 0). Besides varying significantly from Locations 1 and 2, Location 6 varied significantly from Location 3, Location 5 (2.188 ± 0.400), Location 7 (2.25 ± 0.25), and Location 8 (n=4, Figure 5 and Table X, t-test, p=0.05). There was no significant difference between the turbidity of the water upstream of the spill site, at the spill site, or below the spill site (n=4, t-test, p>0.05). In total, average turbidity was 1.61 ± 0.107.

Discussion:

Our hypothesis that there would be a significant difference between Cr concentrations (except at L7), water and soil nitrates, water and soil pH, and turbidity upstream and downstream of the spill site was supported by the results. Our Cr results are similar to Cr concentrations measured by the EPA near our L6, legitimizing the high levels of Cr at L5 even though they are more than double the levels the EPA says pose a risk to aquatic life (UCWR 2014). The low pH of soil at the spill site in this study disagreed with our hypothesis and earlier studies that suggest basic coal ash can neutralize acidic soils, and the EPA found slightly higher water pH levels at Draper Landing than we did for our sample (Pan 2011, UCSR 2014). The curve in the river at Location 5 could be a collection point for any acids washing down the river. Water nitrates levels were shown to be significantly higher downstream than upstream of the coal ash site, showing similar results to those received through test run to determine the influence of a coal ash spill on aquatic invertebrates in Aiken, South Carolina (Cherry, Guthrie, Sherberger, Larrick 1979). Previous studies have found that increasing levels of coal fly ash correlates to higher levels of nitrates (Ciecko 2010); however, we found that to hold true only for the bank soil samples while the opposite held true for the channel. We must account for the fact that upstream sites may also have faced contamination or pollution and may not be a good demonstration for the effects of coal ash on unpolluted soils. In the future, further studies could increase the sample size, conduct a controlled experiment testing concentrations of coal ash and resulting Cr to further correlate increasing coal ash with increasing Cr, and examine whether the water and soil qualities tested vary more significantly within sediments or within soils.

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