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The impacts of pH on trace contaminant leaching and toxicity of coal ash in Planorbella duryi

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The Impacts of pH on Trace Contaminant Leaching and Toxicity of Coal Ash in *Planorbella duryi*

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Introduction

Coal ash is a major form of industrial waste produced by coal-burning power plants. Ash contains a variety of toxic substances such as sulfur and trace metals at ppm or ppb concentrations. Under the EPA's NPDES discharge permit, coal-burning power plants can discharge their treated coal ash waste into nearby water ways (NPDES Permit Basics, 2019). Once mixed with water the associated trace metals have the ability to leach into solution and enter aquatic environments (Lokeshappa and Dikshit, 2012). Coal ash has also been released into waterways through accidental spills, such as the Kingston coal ash event which resulted in the release of 4.1-million cubic meters of fly ash into the Clinch, Emory, and Tennessee Rivers (Rivera et al., 2017; Harkness et al., 2016). Previous studies have mainly focused on 1) the ability of trace metals to leach from coal ash, 2) specific trace metals that are commonly found within coal ash, and 3) the bioaccumulation of trace metals within aquatic organisms. Few studies have been conducted on the ability of trace metals to leach due to varying levels of pH as a result of acid rain in the environment.

Objectives

Coal Ash Leachates

- Assess the levels of trace metal contamination in 7 coal ash leachate solutions (CALs) prepared at various pH's. After conducting two exposure assays, complete mortality was observed in all treatment levels. New CALs containing varying concentrations of coal ash at a set pH of 7 were prepared in order to determine the appropriate concentration of coal ash for this study.

Laboratory Exposures

- Assess the effects of coal ash and trace metals on the mobility, coloration, hatching time, and mortality of a freshwater snail species *Planorbella duryi*.

Field Sampling

- Assess the spatial and temporal distribution of trace metal contamination in sediment and water samples collected from around a coal-burning power plant located within the Chesapeake Bay region: Chesterfield Power Station.

Hypotheses

Coal Ash Leachates

- Trace metals were expected to leach the highest in the lower pH solutions compared to the higher pH solutions.

Laboratory Exposures

- Low mobility, slow hatching time, and high mortality of *P. duryi* was expected for egg clusters exposed to all pH treatment levels.

Field Sampling

- In water column samples, trace metals were expected to be found in higher quantities closer to the sediment than samples closer to the surface. In sediment samples, trace metals were expected to be found in higher quantities in samples collected adjacent to and downstream of the power station.

Materials and Methods

Coal Ash Leachates

- 6 glass vessels filled with 500mL synthetic water were each adjusted to a pH of 7.00 using diluted hydrochloric acid (HCl).
- One of six concentrations of coal ash (0 g/L, 1 g/L, 10 g/L, 25 g/L, 50 g/L, and 100 g/L) was added to each glass vessel, vigorously mixed, and allowed to settle for 48 hrs.
- Each leachate was filtered using a Vacuubrand ME-1 Vacuum Pump to remove any particulate matter, and an aliquot analyzed for trace metal contamination using ICP-OES (Table 1).

Laboratory Exposures

- Six egg clusters were exposed to CALs prepared at various concentrations of coal ash for 10 days.
- Embryonic *P. duryi* were photographed every 24 hrs to assess differences in viability, development and hatching success.

Field Sampling

- Sediment and water samples were collected along the James River, Virginia, USA (Chester, VA) (Figure 1). Grab samples were collected using a Wildco Petite Ponar Grab sampler and sediment cores were collected using a manual push coring device. Water column samples were collected using a Wildco water sampler and dip sampling.
- Sediment samples were digested in 3:3:1 ratio of aqua regia (43 mL of nanopore H_2O: 43 mL of HCl: 14 mL of HNO_3).
- Water samples were acidified using 10% HNO_3 to prevent the adherence of trace metals to the container.
- Water samples were analyzed for trace metal contamination using ICP-OES (Table 2).

Results

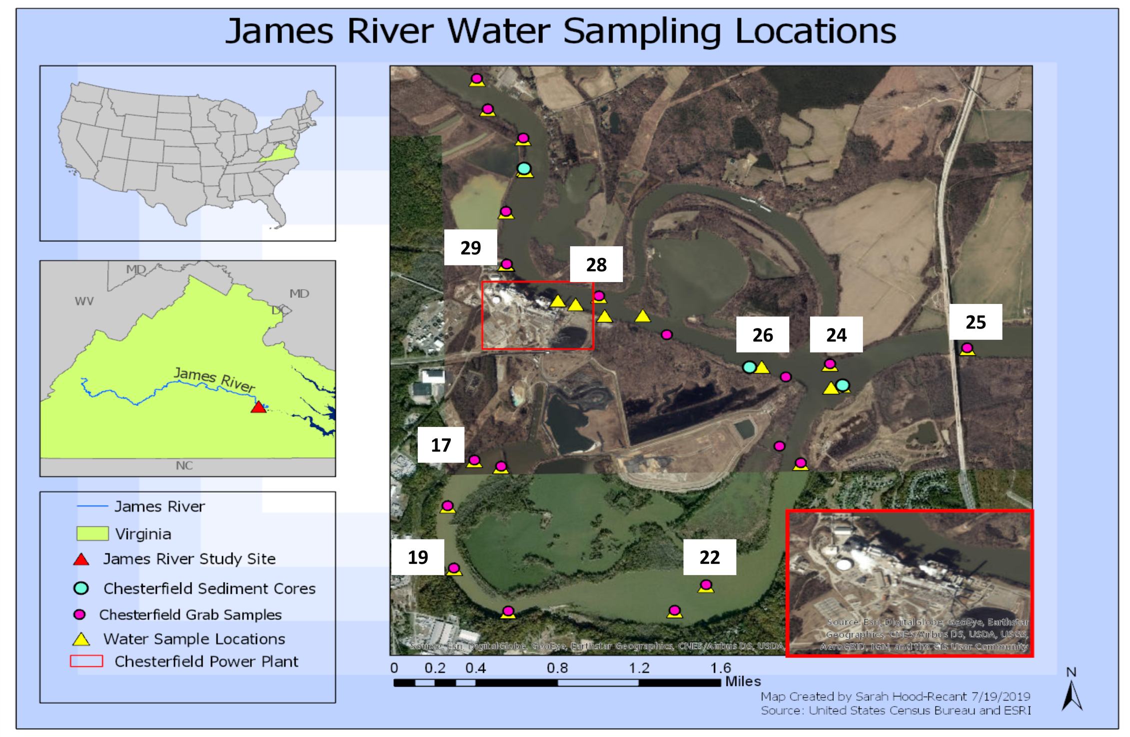

Figure 1 – GIS map displaying sampling locations at Chesterfield Power Station along the James River for sediment cores, grab, and water samples. Created by Sarah Hood-Recant.

Table 1: Trace metals detected in coal ash leachate solutions.

	Trace Metal	Conc (in ppm)									
Coal Ash Leachate Samples	**Al**	**As**	**Ca**	**Cd**	**Cu**	**Fe**	**Mg**	**Mn**	**Pb**	**Se**	**Zn**
0 g/L	0	0	25.170	0.007	0	0	11.340	0	0.002	0	0.384
1 g/L	0	0.007	30.990	0.023	0	0	11.420	0	0.003	0	0.382
10 g/L	0	0.006	72.630	0.017	0	0	13.250	0	0.003	0	0.390
25 g/L	0	0.007	121.900	0.021	0.023	0	15.830	0.021	0.004	0	0.414
50 g/L	7.939	0.005	183.800	0.027	0.181	0	19.430	0.280	0.012	0.003	0.558
100 g/L	0.210	0.014	170.400	0.015	0.103	0	27.400	0.595	0.005	0.017	0.487
MCLs	N/A	0.010	N/A	0.005	1.300	N/A	N/A	N/A	0.015	0.050	N/A

Table 2: Trace metals detected in water column samples collected from the James River near Chesterfield Power Station.

	Trace Metals	Conc (in ppm)									
Water Column Samples	**Al**	**As**	**Ca**	**Cd**	**Cu**	**Fe**	**Mg**	**Mn**	**Pb**	**Se**	**Zn**
Location #17 (Bottom)	0	0	21.278	0.008	0.001	0	4.203	0	0.001	0	0.431
Location #17 (Surface)	0	0	21.444	0	0.001	0	4.198	0	0	0.004	0.431
Location #19 (Bottom)	0	0	20.967	0.015	0.001	0	4.102	0	0.002	0	0.424
Location #19 (Mid-depth)	0	0	20.989	0	0	0	4.197	0	0.003	0	0.435
Location #19 (Surface)	0	0	20.478	0.014	0	0	4.077	0	0.002	0	0.410
Location #22 (Bottom)	0	0	20.800	0.015	0.001	0	4.120	0	0.001	0	0.434
Location #22 (Surface)	0	0	20.778	0	0.004	0	4.142	0	0.002	0	0.421
Location #24 (Bottom)	0	0	20.333	0.005	0.005	0	4.023	0	0.001	0	0.439
Location #24 (Mid-depth)	0	0	20.267	0	0.007	0	3.921	0	0.003	0	0.419
Location #24 (Surface)	0	0	20.111	0	0.009	0	3.888	0	0	0.004	0.436
Location #25 (Bottom)	0	0	19.967	0	0.010	0	4.090	0	0.002	0	0.432
Location #25 (Mid-depth)	0	0	19.789	0.001	0.008	0	3.801	0	0.003	0	0.434
Location #25 (Surface)	0	0	19.989	0.012	0.006	0	3.896	0	0.001	0	0.434
Location #26 (Bottom)	0	0	17.933	0.017	0.008	0	3.431	0	0	0	0.418
Location #26 (Mid-depth)	0	0	17.833	0.002	0.007	0	3.420	0	0	0	0.432
Location #28 (Bottom)	0	0	16.800	0.013	0	0	3.137	0	0.002	0	0.428
Location #28 (Mid-depth)	0	0	17.167	0.015	0.039	0	3.236	0	0.003	0	0.438
Location #29 (Bottom)	0	0	1.370	0	0	0	0	0	0.003	0.001	0.428
MCLs	N/A	0.010	N/A	0.005	1.300	N/A	N/A	N/A	0.015	0.050	N/A

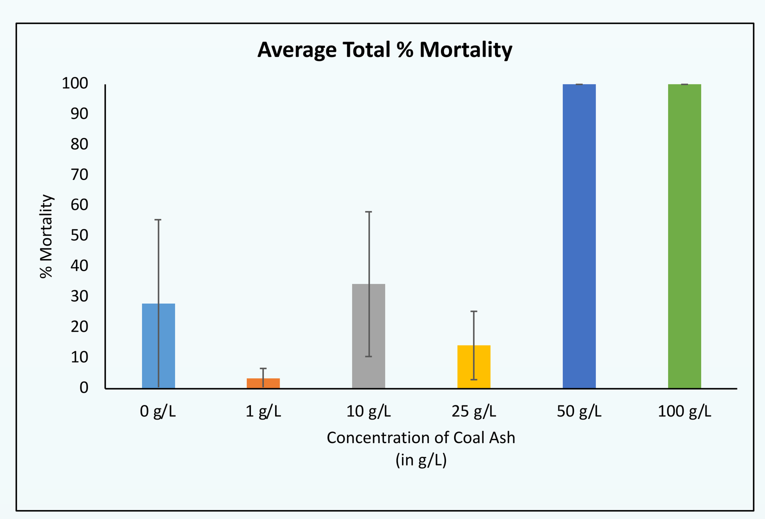

Figure 2 – Average total % of mortality after 10 days of exposure to varying concentrations of coal ash.

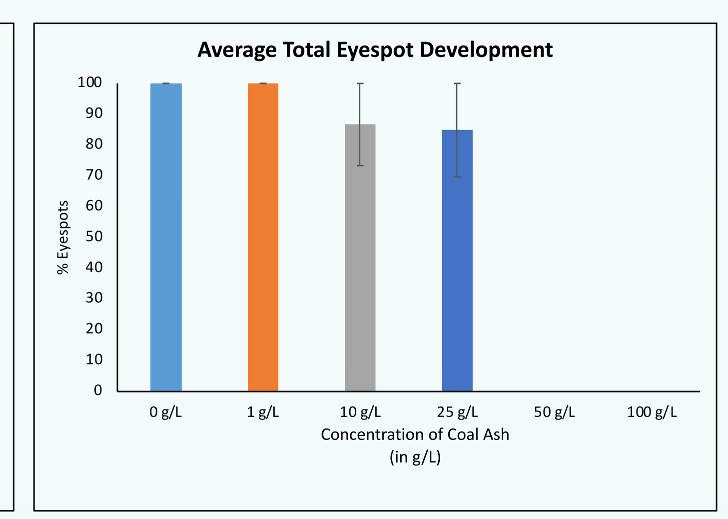

Figure 3 – Average total % of eyespot development after 10 days of exposure to varying concentrations of coal ash.

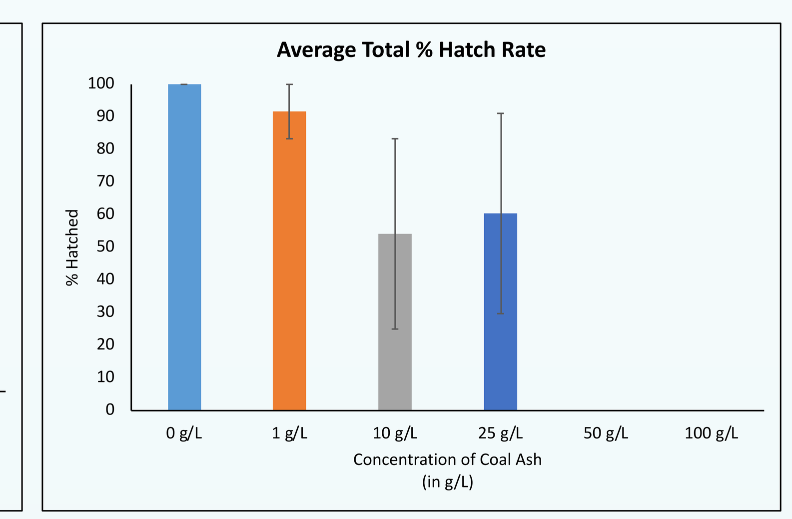

Figure 4 – Average total % of hatching rate after 10 days of exposure to varying concentrations of coal ash.

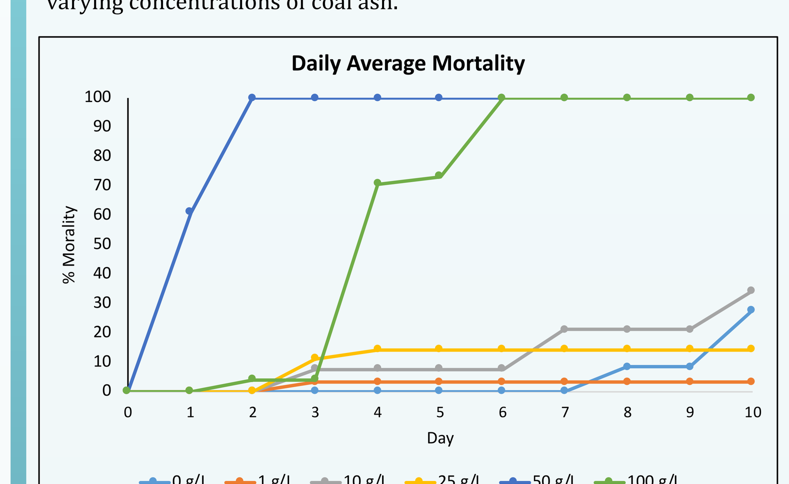

Figure 5 – Daily average % of mortality during 10 days of exposure to varying concentrations of coal ash.

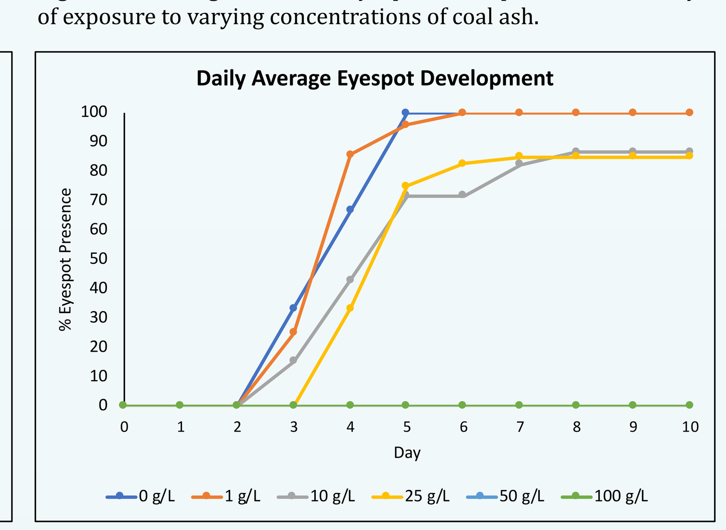

Figure 6 – Daily average % of eyespot development during 10 days of exposure to varying concentrations of coal ash.

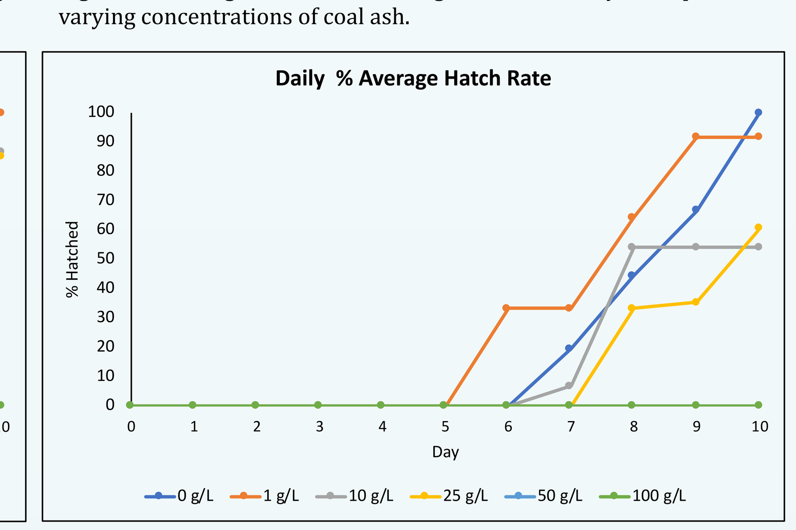

Figure 7 – Daily average % of hatching during 10 days of exposure to varying concentrations of coal ash.

Image 1– Snail embryo cluster at 0 days of exposure (control).

Image 2 – Snail embryo cluster at 4 days of development. Snails have begun to develop eyespots.

Image 3 – Snail embryo cluster at 9 days of development after 100% hatching.

Results (cont.)

Coal Ash Leachates

- Levels of arsenic (As), magnesium (Mg), manganese (Mn), and selenium (Se) were found at the highest concentration in the 100g/L leachate.
- Levels of aluminum (Al), calcium (Ca), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) were found at the highest concentration in the 50g/L leachate.
- No levels of iron (Fe) were detected in any of the leachates.

Laboratory Exposures

- Egg clusters exposed to the 0g/L, 1g/L, 10g/L, and 25 g/L leachates had quick hatching times and low mortality after 10 days of exposure (Figures 2-7).
- 100% mortality was found in egg clusters exposed to 50g/L or higher after 48 hrs. No hatching was observed in 50g/l treatment, and embryo coloration of egg clusters became yellow/brown. Few to no eggs within the clusters were visible after 48 hrs (Figures 2-7).

Field Sampling

- Levels of calcium (Ca), cadmium (Cd), copper (Cu), magnesium (Mg), and zinc (Zn) were found at the highest concentration in the water column samples collected from the bottom of the James River.
- No levels of aluminum (Al), arsenic (As), iron (Fe), or manganese (Mn) were detected in any of the water samples.

Conclusions

- The high quantities of trace metals found in the higher CALs show an effect on the ability of trace metals to leach into the surrounding solution. Levels of arsenic found in the 100g/L leachate, and levels of cadmium in all leachates were higher than the EPA's MCL's for Drinking Water (Table 1) (NPDWR, 2018).
- Results from 10 days of exposure indicate the lethality of coal ash on a freshwater snail species. The high mortality and slow development found in embryonic *P. duryi* after 2 days of exposure indicates that the leachates containing high concentrations of coal ash cause a delay in growth.
- Preliminary results show high quantities of trace metals detected in the water samples collected closest to the sediment (bottom). This indicates the possible presence of trace metals in surficial sediment found in the James River. Levels of cadmium (Cd) were higher than the EPA's MCL's for Drinking Water (Table 2) (NPDWR, 2018).

Future Studies

- The next phase of this study will examine sediment and remaining surficial water samples collected from Chesterfield Power Station. For both surface water and sediment samples, high quantities of trace metals are expected to be found in samples collected directly adjacent to and downstream of the power station.
- Examine sediment and water samples for trace metal contamination collected from Possum Point Power Station in Dumfries, Virginia.
- New coal ash leachates will be prepared at various pH's (4.5-7.5) prior to the addition of a specific concentration of coal ash (10g/L), in order to determine the potential effects of pH on the leaching of trace metals and the effects of pH-adjusted coal ash leachates on embryonic *P. duryi*.

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Acknowledgements

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