Leachability Determination of Elements in Fly Ash as a Potential Fertilizer

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Objective:

To determine the leachable recoveries of zinc (Zn), lead (Pb), chromium (Cr), copper (Cu), nickel (Ni), cobalt (Co), manganese (Mn), iron (Fe) and magnesium (Mg) from fly ash samples using flame atomic absorption spectrometry (FAAS).

Background:

- Thousands of tons of ash being produced from burning coal each year is only adding to the increasing problem of environmental degradation.
- The ash produced is known as fly ash and has recently become popular in research due to the potential beneficial applications it has for the environment. The alternative uses of fly ash belong mostly to the construction industry, where they are used as additives to cement and concrete, while also being used in restoration, reclamation and road construction.[1]
- In the research setting, fly ash is being employed as a potential fertilizer in an effort to replace certain commercial fertilizers that can harm soils and crops because of the compounds they contain.[2]
- Due to the applications fly ash can have for the environment, it is important to determine the leachability of certain elements to see if either the toxic or beneficial elements maintain their concentrations after a duration of time.
- In this research, FAAS is used to determine the concentrations of elements in fly ash samples after 1 to 4 weeks of leaching. The results from this research contribute to determining whether fly ash has the ability to act as a fertilizer and can offer a perspective into how fly ash landfills should be maintained in relation to protecting the environment.

Methodology:

- Approximately 2.0000 grams of four types of fly ash was used, and then 400.00 mL of 18 MΩ water was poured using a graduated cylinder into beakers with the ash. For the fly ash sample, Type D, an exception was made and instead of using 400.00 mL of 18 MΩ water, 300.00 mL was used.
- Beakers were then shaken constantly for two minutes and left to sit for a certain duration of time, such as one, two, three or four weeks.
- Once the beakers had reached a certain time duration, approximately 50.00 mL of the ash solution was taken, and filtered using gravity filtration into tubes.
- These tubes were then analyzed using FAAS in triplicate, and the concentrations were determined using calibration equations.
- This process was then repeated for each time duration.

Type of fly ash	Low pH	High pH	Type C	Type D
Mass used (g)	2.0247	2.0980	2.0258	2.0726
Volume used for beaker (mL)	400.10	400.31	400.22	300.53

Table 1. Mass and volumes used of each fly ash type.

Element	Equation	R^2	LOD (µg/mL)	LOQ (µg/mL)
Cr	y= 0.0216x + 0.0064	0.9968	0.2788	0.9295
Co	y= 0.0380x + 0.0243	0.9746	0.0261	0.0869
Cu	y= 0.0516x – 0.0058	0.9979	0.0027	0.0091
Pb	y= 0.0201x + 0.0280	0.9844	0.1218	0.4060
Mg	y= 0.0340x + 0.0249	0.9975	0.1351	0.4504
Mn	y= 0.0586x – 0.0126	0.9964	0.0278	0.0928
Zn	y= 0.1950x + 0.0121	0.9916	0.0148	0.0494
Ni	y= 0.0085x + 0.0064	0.9983	0.1578	0.5261

Table 2. Calibration equations, R^2 values and LOD and LOQ of elements analyzed.

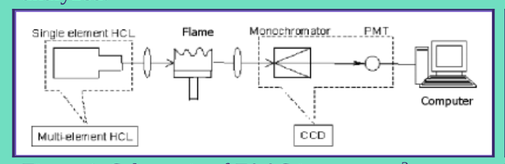

Figure 1. Schematic of FAAS instrument.[3]

Figure 2. Picture of FAAS (left) and lamps (right).

Results:

Fly Ash Type	Element	Average Diluted Concentration of Element in µg/mL (n=3)	Average Original Concentration of Element in µg/mL (n=3)
Low pH Week 1	Cu	0.1318	1.055
High pH Week 1	Cu	0.1318	1.055
Type C Week 1	Cu	0.1318	1.055
Type D Week 1	Cu	0.1124	0.676
Low pH Week 2	Cu	0.1124	0.899
High pH Week 2	Cu	0.1124	0.900
Type C Week 2	Cu	0.1124	0.951
Type D Week 2	Cu	0.1318	0.753
Low pH Week 3	Cu	0.1124	1.003
High pH Week 3	Cu	0.1124	1.003
Type C Week 3	Cu	0.1318	1.055
Type D Week 3	Cu	0.1318	0.792
Low pH Week 4	Cu	0.1318	1.055
High pH Week 4	Cu	0.1318	1.055
Type C Week 4	Cu	0.1318	1.055
Type D Week 4	Cu	0.1318	0.792

Table 3. Average concentrations of Cu in fly ash samples.

Fly Ash Type	Element	Average Diluted Concentration of Element in µg/mL (n=3)	Average Original Concentration of Element in µg/mL (n=3)
Low pH Week 1	Mn	0.2036	1.630
High pH Week 1	Mn	0.1923	1.540
Type C Week 1	Mn	0.1980	1.584
Type D Week 1	Mn	0.1923	1.156
Low pH Week 2	Mn	0.1923	1.538
High pH Week 2	Mn	0.1980	1.585
Type C Week 2	Mn	0.1809	1.448
Type D Week 2	Mn	0.1923	1.156
Low pH Week 3	Mn	0.1809	1.447
High pH Week 3	Mn	0.1809	1.448
Type C Week 3	Mn	0.1809	1.448
Type D Week 3	Mn	0.1809	1.087
Low pH Week 4	Mn	0.1752	1.402
High pH Week 4	Mn	0.1695	1.357
Type C Week 4	Mn	0.1695	1.357
Type D Week 4	Mn	0.1695	1.019

Table 4. Average concentrations of Mn in fly ash samples.

Fly Ash Type	Element	Average Diluted Concentration of Element in µg/mL (n=3)	Average Original Concentration of Element in µg/mL (n=3)
Low pH Week 1	Mg	19.47	155.8
High pH Week 1	Mg	27.33	218.8
Type C Week 1	Mg	31.10	248.7
Type D Week 1	Mg	27.31	164.1
Low pH Week 2	Mg	22.97	183.8
High pH Week 2	Mg	28.59	228.9
Type C Week 2	Mg	32.27	258.3
Type D Week 2	Mg	28.93	173.9
Low pH Week 3	Mg	22.70	181.7
High pH Week 3	Mg	28.99	232.1
Type C Week 3	Mg	32.18	257.6
Type D Week 3	Mg	29.80	179.1
Low pH Week 4	Mg	24.42	195.4
High pH Week 4	Mg	28.88	231.2
Type C Week 4	Mg	32.68	261.6
Type D Week 4	Mg	30.34	182.4

Table 5. Average concentrations of Mg in fly ash samples.

Conclusions:

- FAAS provided absorbances for Cu, Mn and Mg, as the other elements were not within the detection limits of the FAAS, thus, they were not determined.
- Based off the concentration values of Mg remaining relatively high after the leaching periods, fly ash as a potential fertilizer would provide benefits to crops and soil by promoting their growth.
- Elements that were not detected also support fly ash as a fertilizer since they do not remain in high concentrations after 1 week of leaching, therefore, not harming the environment and soil quality.

Future Work:

- Analyze remaining elements such as As and Cd to provide leachability information.
- Use a more sensitive instrument such as ICP-MS to analyze the elements that were not detected by FAAS.

References:

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3. Zheng, C., He, Y., Wei, S., Hou, X. Compact flame atomic absorption spectrometer based on handheld CCD for simultaneous determination of calcium and magnesium in water. *J. Anal. Atom. Spec.*, **2004**, *20* (1), 60-62.