

Predicting Total Dissolved Solids Release from Overburden in Appalachian Coal Fields



Jessica Odenheimer, Jeff Skousen, and Louis M. McDonald
West Virginia University, Division of Plant and Soil Sciences



Abstract

Historically, the Appalachian coal industry has been very successful in developing technologies to identify, handle, treat and isolate potentially acid-forming overburden materials at coal mines in the region. However, the techniques to predict acid mine drainage potential do not adequately predict the release of Total Dissolved Solids (TDS). This often leads to handling plans that actually increase TDS release due to the blending of net acid-forming and alkaline strata. As part of a larger project with a goal of developing methods to predict TDS release from overburden materials in the Appalachian region, our objective was to determine the effect of particle size on constituent release. Three overburden samples from a surface coal mining site in West Virginia were chosen to encompass the widest expected range of properties. A subsample was ground and sieved to 500 μm , 250 μm and 106 μm mesh sieves. The material remaining on the 250 μm and 106 μm mesh sieves were used for the weathering experiment. Two liters of 0.0159M HNO_3 were combined with 3.00 g of each size fraction in 2-L Nalgene bottles, in triplicate. Bottles were placed on a reciprocating shaker for 14 days. Aliquots were collected approximately every other day; pH, EC, major and micro elements were determined. Results showed that in general, the two particle sizes used in this weathering experiment were not significantly different from each other.

Introduction

- Coal contributes to more than 50% of the electricity generated nationwide.
- The coal industry has been at the forefront of controversy surrounding human and environmental health and safety.
- In order to extract coal, overburden material is blasted apart and moved.
- Overburden weathering can promote acid mine drainage, alkaline mine drainage (Berhardt et al., 2012), as well as release Total Dissolved Solids (TDS) and heavy metals into surrounding water sources.
- Since ion concentrations control Electrical Conductivity (EC) in water, EC can be used to estimate TDS with a conversion factor of 0.64 (Evangelou, 1998).

A quick laboratory or field technique for estimating constituent release potentials from coal overburden material would be helpful for mine planning, placement and abatement procedures for coal operators, but first we must determine the effect of particle size on constituent release.

Materials and Methods

- Three overburden samples were collected from a surface coal mine in West Virginia.
- Dilute nitric acid (HNO_3) of pH 2 was prepared in the lab by a 1/1000 dilution of 15.9M trace metal grade HNO_3 .
- Two liters of HNO_3 were combined with 3.00 g of overburden.
- Overburden samples were of two particle sizes:
 1. 250 μm mesh (> #60 sieve)
 2. 106 μm mesh (> #140 sieve)
- Six containers were placed on a reciprocating shaker for 14 days.
- 15-mL aliquots were extracted approximately every other day.
- EC, pH, and cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , P , Fe , Al^{3+} , Mn^{2+} , B , Sr^{2+} , Pb^{2+} , Cu^{2+} , Ni^{2+}) were measured by ICP-OES.
- All analyses were conducted in triplicate.

Results

Table 1. Acid-Base Account parameters for three overburden samples from West Virginia surface coal mining sites

Sample	Color	Rock Type	pH	S %	MPA	NP ----kg (1000 kg) ⁻¹ ----	NET
WV 2	2.5Y 6/1	Black Shale	6.0	0.15	30.0	30.0	0
WV 3	5Y 7/1	Gray Shale	8.1	0.001	0.25	60.0	59.75
WV 4	2.5Y 3/1	Sandstone	5.0	0.1	4.0	3.0	-1.0

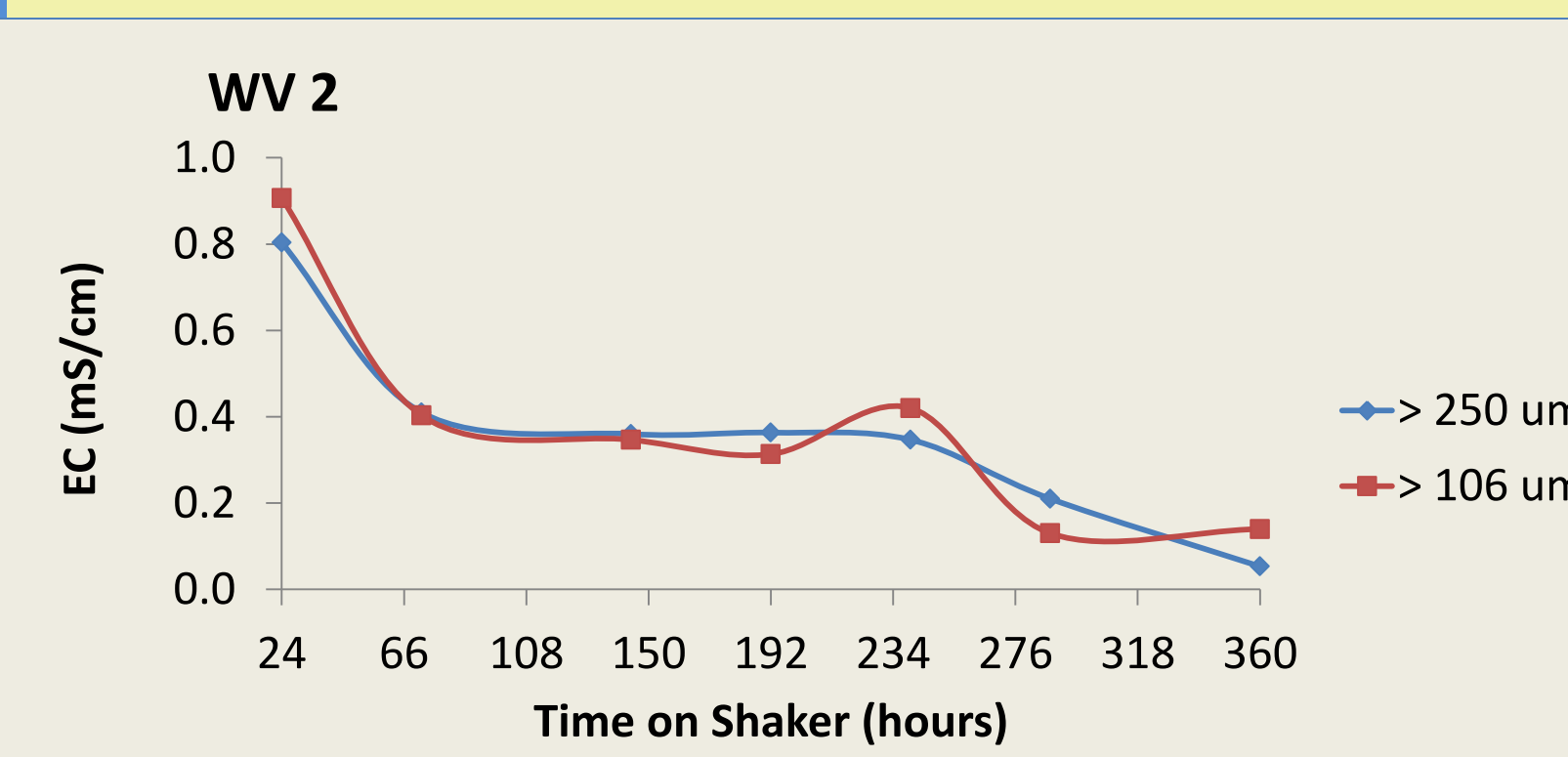


Figure 1. Comparison of Electrical Conductivity between two particle sizes from sample WV 2.

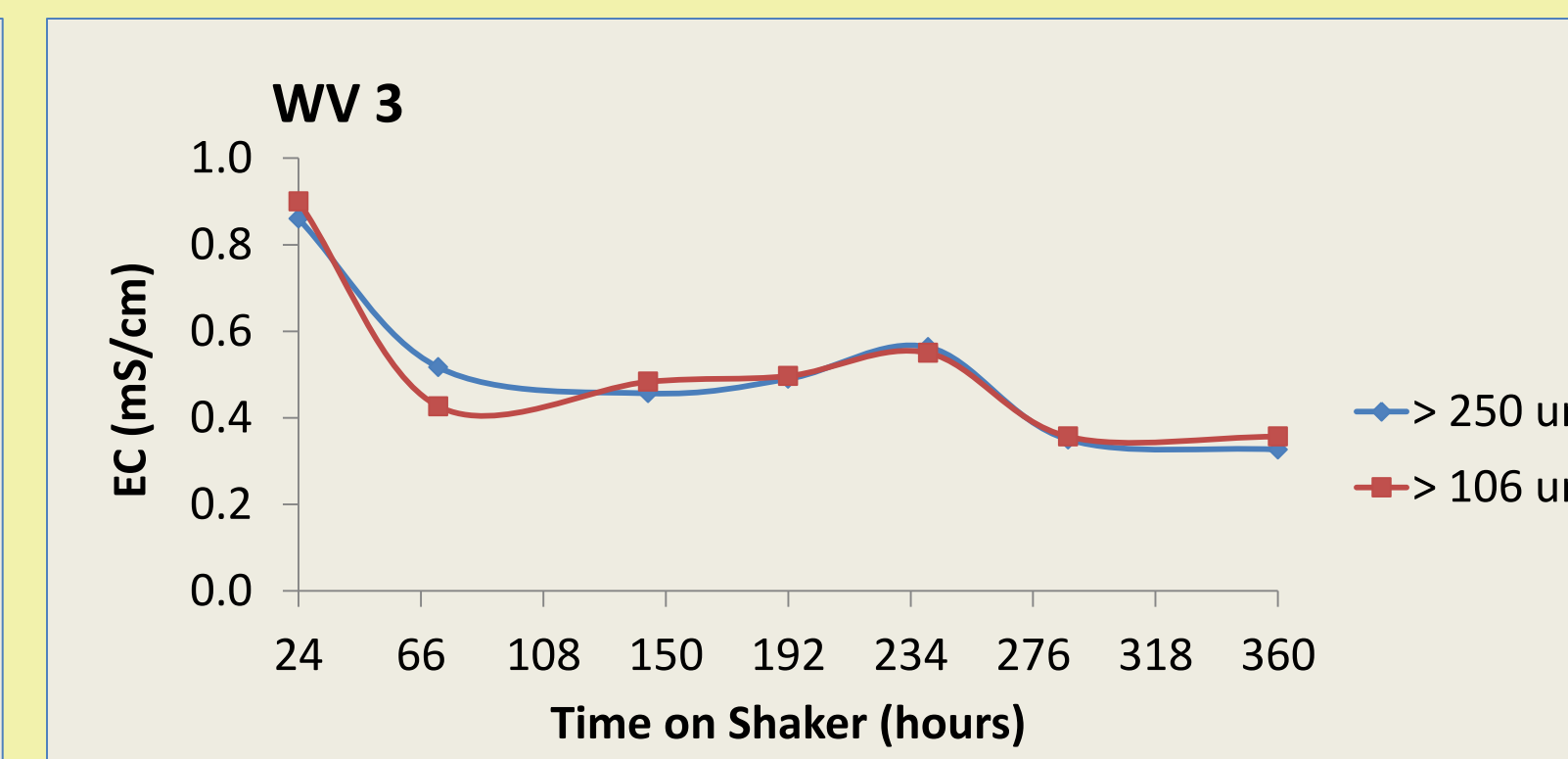


Figure 2. Comparison of Electrical Conductivity between two particle sizes from sample WV 3.

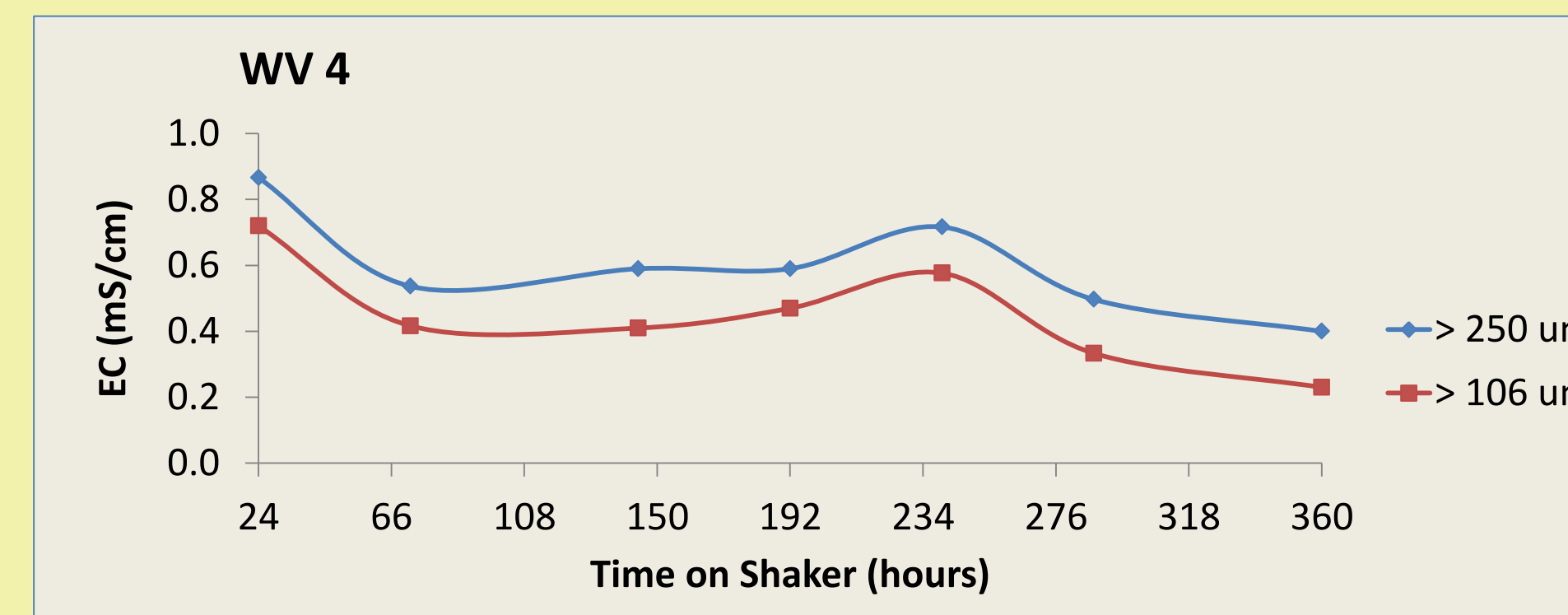


Figure 3. Comparison of Electrical Conductivity between two particle sizes from sample WV 4.

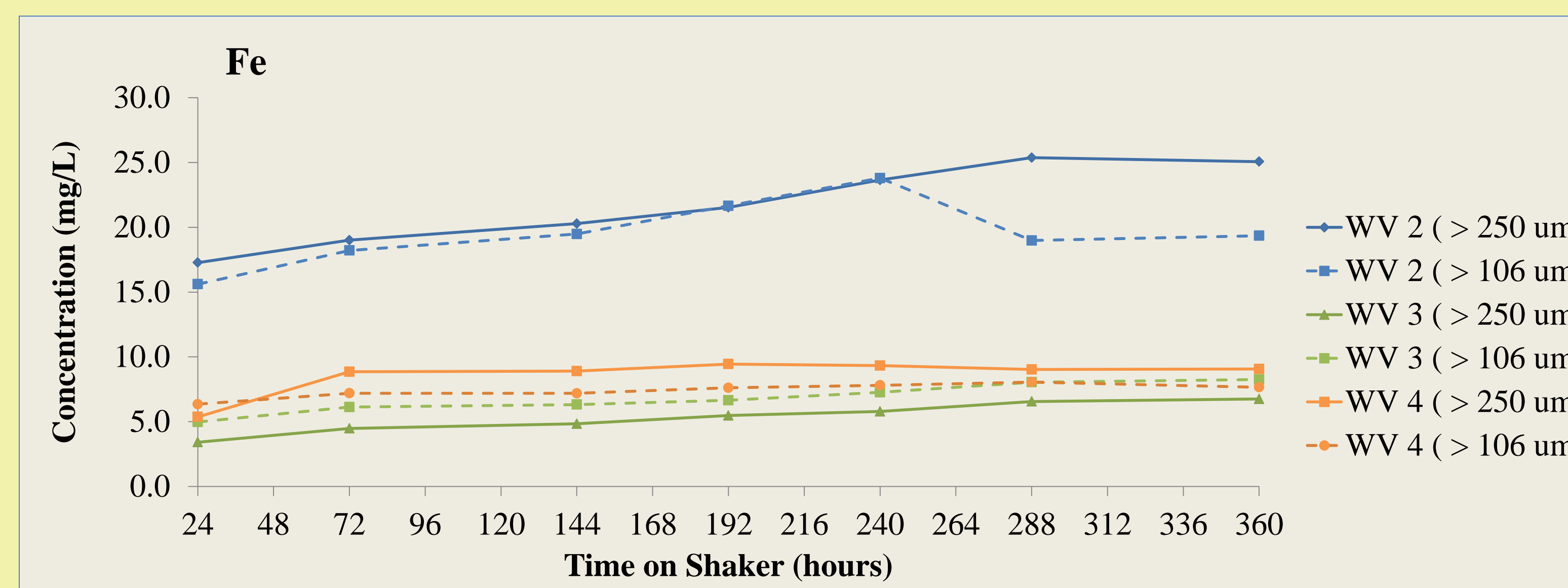


Figure 4. Iron concentrations released over time from three overburden samples and two different mesh sizes.

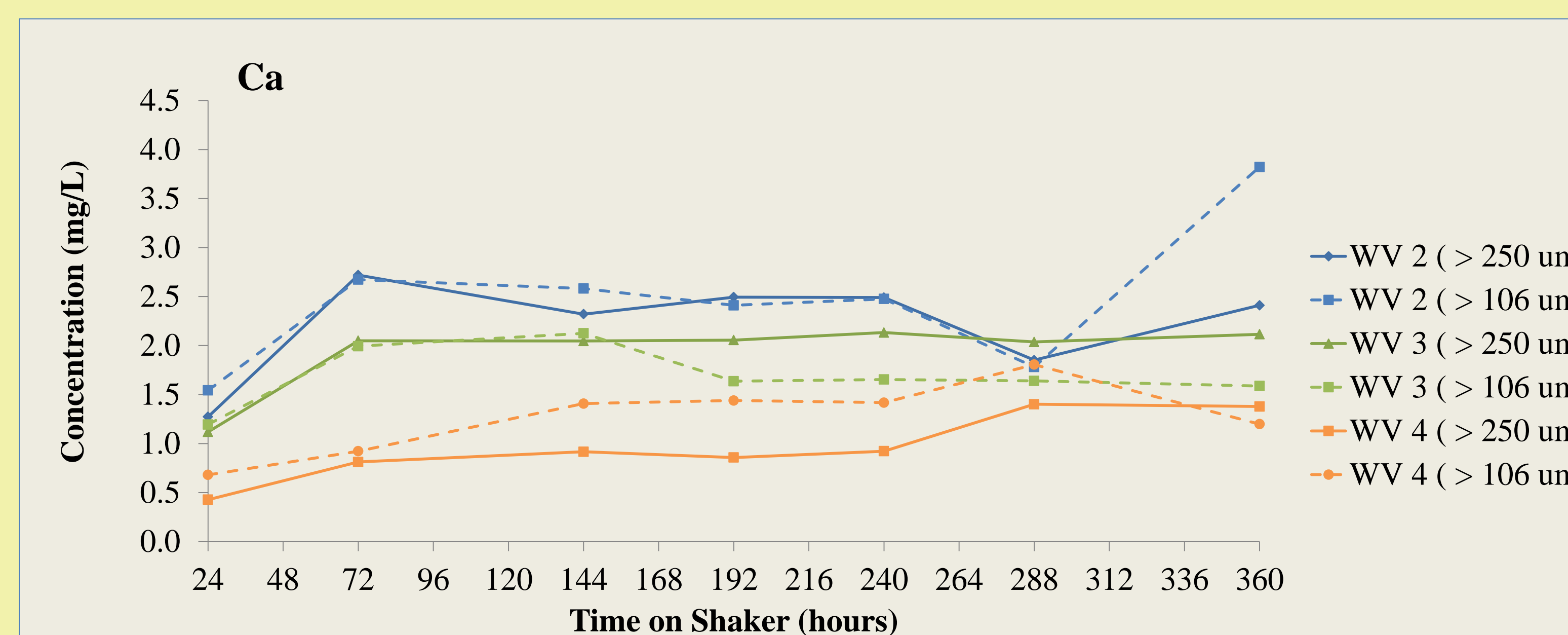


Figure 5. Calcium concentrations released over time from three overburden samples and two different mesh sizes.

Discussion

Table 1 shows Acid-Base Accounting parameters for our three rock samples. We expected differences in EC and other constituents among samples due to the differing amounts of sulfur (S) and neutralization potential (NP). In general, smaller particles have larger surface area and an increased likelihood of dissolution. EC did not significantly vary between the two particle sizes for Sample WV 2 (Figure 1) and WV 3 (Figure 2). However, EC was greater by about 0.2 mS cm^{-1} for the larger mesh size (250 μm) in sample WV 4 (Figure 2). Samples WV 2 and WV 3 were comprised of shale, which is a rock made up of thin, flat pieces of clay-sized particles. Sample WV 4 was made up of sandstone which is primarily comprised of sand-size particles. The difference in surface area between these two types of rock may explain why particle size did not affect EC from samples WV 2 and WV 3, but did for sample WV 4, but does not explain why the larger particle size (250 μm) had a greater EC than the smaller particle size (106 μm).

Statistical analyses were conducted by ANOVA using SAS. Samples WV 2, WV 3, and WV 4 were all statistically different from each other for all 12 elements. There were statistically significant interactions between particle size and sample for Cu and Fe ($p < 0.05$). However, there was no statistical evidence that particle size affected constituent release among the three samples for Al, B, Ca, K, Mg, Mn, Na, Ni, P, and Pb.

Figure 4 displays the cumulative release of Fe from three overburden samples. There was a significant interaction between the two particle sizes for at least one of the overburden samples. However, from looking at Fe concentrations released over time, the only apparent difference in particle size is from sample WV 2 after 240 hours on the shaker (Figure 4).

There was a significant difference among concentrations of Ca released from all three samples, but no significant difference between the two particle sizes. Although particle size did not affect Ca dissolution, we chose to display it because of its role in NP from the Acid-Base Account.

Conclusions

- In general, we found no significant difference in constituent release between our two particle sizes.
- Although ANOVA gave evidence that the concentrations of Cu and Fe were dependent on particle size, graphically we did not see this interaction.
- The next step of our research will be to repeat this shaking experiment on a greater number and variety of overburden samples with different extracting solutions.

Acknowledgments

This project is in collaboration with the Appalachian Research Initiative for Environmental Science (ARIES). Thank you to my advisors Dr. Jeff Skousen and Dr. Louis M. McDonald for providing useful comments and inputs during various stages of this work. Thank you to Joan Wright for spending many hours grinding overburden samples with me, and running the samples through the ICP-OES.

