Correlation of Electrical Resistivity Profiles and Soil Properties at Mine Waste Sites

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Introduction

Legacy mining in Zambia, South Central Africa has become a historically ecological, socioeconomical, and health issue in the country. Copper mining occurs in the Copperbelt Province, a region spanning between Zambia and the Democratic Republic of the Congo [1]. Ore composition in this subgroup is mostly commanded by pyrite, chalcopyrite, bornite, and chalcocite [1]. Kabwe, Zambia is one of the most polluted towns in the world, contaminated with lead as a result of copper mining. More than 70,000 people in Kabwe live in townships and villages contaminated with lead and more than half of the children living in these areas have significant lead levels in their blood [6]. Combined with the dry and dusty climate that Zambia has, it is extremely common for children to inhale and ingest significant amounts of dust and dirt, which is often contaminated with heavy metals. In Kabwe specifically, children can end up ingesting four to five times as many heavy metal contaminants as adults [6]. Specific medical implications from lead poisoning include learning disabilities, organ damage, birth defects, and more [6]. The mining of copper in Zambia is vital for the country's economic welfare and stability, and a significant percentage of Zambia's working population is employed in the mining industry.

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In this study, geophysical surveying methods were used to measure geologic materials in the subsurface. These results were used to contribute to the goal of remediating Cu and Pb contaminated soils through phytoremediation using hyperaccumulator plant species native to Zambia. Phytoremediation is the process of cleaning and restoring contaminated soil, water, or rock using hyperaccumulator plant species. Hyperaccumulators are plants with the ability to accumulate a significant concentration of metals or metalloids in their biomass [7].

Methodology

ERT (Electrical Resistivity Tomography) is a geophysical testing and measurement method that shows the resistivity and conductivity of materials in the subsurface. ERT provides significant insight into subsurface characteristics, and can often measure several variables at once – such as soil salinity and

ionization, fracture zones, and soil and groundwater contamination. In this study, 2-dimensional and 3-dimensional surveys were generated through measurement in order to create a digital image of the subsurface. These surveys were analyzed alongside the collection of several soil samples taken at each site, collected at multiple depths and locations within the site. These soil samples then underwent moisture content and density tests to examine physical properties within the soil.

Kabwe

Sites examined in Kabwe included Kampai and Mine School sites. Kampai is a private piece of land used by The University of Zambia specifically for field work. The site is rectangular in shape, spanning approximately 191 meters long and 91 meters wide. Kampai site trended dry soil and less vegetation toward the Northeast end of the site and increased in moisture and vegetation moving toward the Southwest end of the site. While the NE end of the site kept relative consistency in flatness, the SE end of the site had points of significant topographic relief. Mine School site is a small primary school containing lead contaminated soil. It is a relatively small site, rectangular in shape and spanning approximately 110 meters in length and 95 meters in width. Mine School contains a courtyard with contaminated soil, half of which is tilled and half being un-tilled, which was performed in previous project years for geophysical research purposes. This site is dry, has small amounts of vegetation, and is in close proximity to local power lines – making geophysical measuring methods especially difficult.

Figure 2 *Mine School Site Satellite View.*

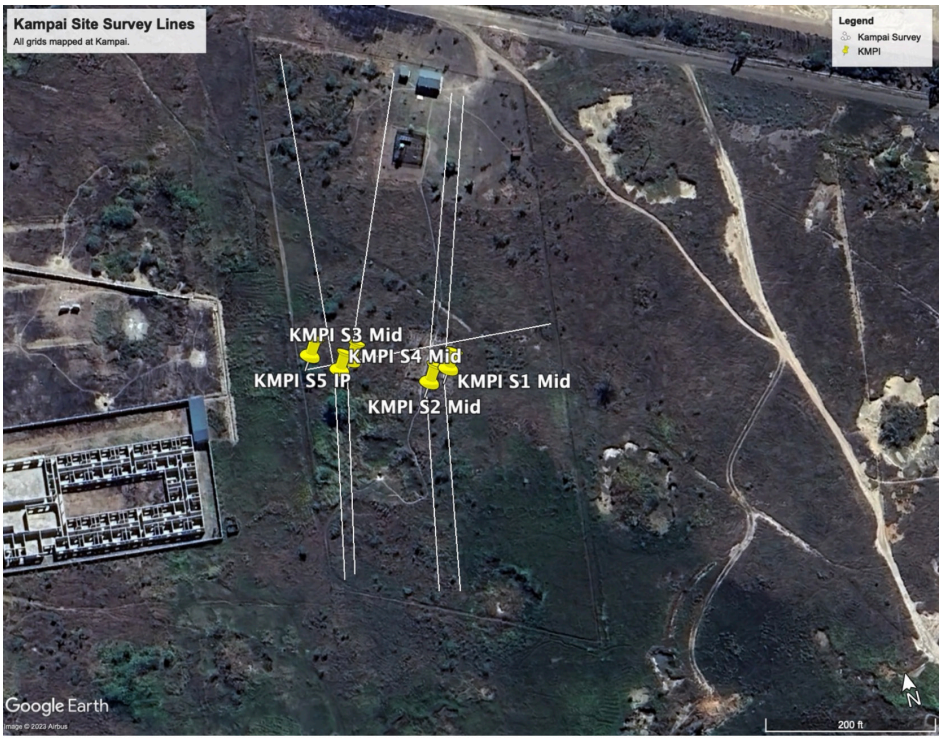

Figure 1 *Kampai Site Satellite View.*

Kitwe

The examined in Kitwe was Uchi Tailings Dam. Uchi Tailings Dam is a waste rock dumping site, now used as a park/training area for youth sports. The site itself is rectangular in shape and quite large, spanning approximately 1,500 meters in length and 600 meters in length. The section of the site surveyed spanned approximately 115 meters in length and 75 meters in width. Uchi is sandy and dry in several areas, and in others wet sand and clay will accumulate near the surface

Figure 3 *TD 10 Satellite View.*

and can be detected in topsoil and shallow soil samples. A young to middle-aged stream runs through the perimeter of the site, Significant halite accumulation on the surface of moisture patches was also noted.

Mufulira

Tailings Dump 10 (TD 10) is a large and remote area used to dump mine waste. This site is relatively rectangular in shape, spanning around 4,000 meters in length and 1,000 meters in length. The surveyed section of the land spanned around 300 meters by 300 meters. TD 10 resembles sand dunes, as this site is extremely dry and sandy, with small amounts of vegetation accumulation on the south end of the site and slight accumulations around the general perimeter of the site. When running seismic cables, action was taken to ensure a sufficient number of electrodes were placed within vegetative areas.

Results

After soil and inversion analysis, immediate results show no correlation of any sorts between soil properties and geophysical data. A correlation is seen, however, between moisture and organic matter, as expected. Results have shown that as organic matter increased across each site, moisture increased by about 70%. Although the immediate results do not suggest correlation at this time, it should be noted that this work is ongoing – further analysis currently taking place includes comparing physical data with ERT profiles, increasing resolution of data in order to decrease coarse readings, and determining the concentration of specific contaminants within each site. Currently, the relationship between Pb (lead) and Zn (zinc) contaminants is being compared in order to deduce which contaminants are most abundant at each site.

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Frances LeDuke is a sophomore studying Geological Engineering. She joined a research lab in her first year at Mines and opened the door to global research with a global impact. She is a member of a lab at Colorado School of Mines funded by a National Science Foundation research program called IRES, or International Research Experience for Students. Dr. Rennie Kaunda, a Mining Engineering Associate Professor at Colorado School of Mines, leads the project in partnership with colleagues at Georgia College. Alongside her research team, LeDuke is studying possible avenues for remediation of contamination from legacy mining in Zambia. She was awarded a Travel Grant to poster presentation at the Geological Society of America (GSA) Connects conference in Pittsburg, PA in October 2023.

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