

Bio-availability and Bio-accessibility of Lead and Zinc in Contaminated Soil from Cwymystwyth Lead Mine Site

Abstract

Pollution level of lead and zinc in contaminated soil of Cwymystwyth Lead Mine were studied in which the bio-availability and bio-accessibility were measured in the present research. The results were obtained using XRF and ICP methods. The percentage concentration of lead in the topsoil was 0.64 percent and in the bottom soil was 1.47 percent, with a total mean concentration of 1.06 percent in combined top and bottom soil. Zinc concentrations in the top and bottom soils were 0.22 and 0.45 percent, respectively, with a computed total mean of 0.34 percent. The findings revealed a highly significant difference between lead and zinc in both the top and bottom soil samples (LSD = P0.05). The average concentrations of lead and zinc extracted in both the stomach and intestinal stages were 15.98% and 1.23 percent, respectively. In both the stomach and intestinal stages, the total mean concentration of lead and zinc removed was 12.37 percent and 4.84 percent, respectively. In addition, lead extracted in the gastrointestinal phase has a greater mean value of 23.48 percent than zinc extracted in the gastric phase, which has a mean value of 8.48 percent. In the same way, lead taken from the gut has a slightly higher mean value (1.26%) than zinc (1.19 percent). Pb and Zn pollution at Cwymystwyth Lead Mines appears to be linked to anthropogenic activities on the study site, particularly lead mining.

Key words: Bio-availability, Bio-accessibility, Lead, Zinc, Cwymystwyth

Introduction

Soil from contaminated sites, particularly mining areas where Lead, Zinc, and other toxic or harmful elements have been explored for a long time, may have a higher availability of toxic metals pollutants because the soil has larger soil particles, allowing these elements to sink to ground water levels. Pb and Zn could be ingested by humans and other animals if they drink or consume plants that have these metals deposited on them. Ingestion of dust is the most significant route of exposure to environmental toxins. Children, in particular, can inhale soil and dust through willful hand-to-mouth motions or accidentally by consuming food that has fallen on a polluted floor (Bacigalupo and Hale, 2012). In addition to inhalation of suspended soil particles, Pb exposure to children living near Pb polluted areas includes related soil ingestion via hand-to-mouth actions (Mielke, Gonzales and Powell, 2011). Although children may be exposed to Pb as a result of their childlike behaviour of putting their hands in their mouths and eating Pb-

polluted toys and other items, it is unlikely that they will ingest it (ATSD,1999C). Due to the abundance of pollutants floating freely in the environment, breathing is the most common route of contamination.

Many inorganic compounds have the potential to be dangerous, thus it's important to understand/comprehend their sources, transport, and fate in nature, as well as the paths through which they might be transferred to people. Understanding the principal sources of Pb is crucial to risk assessment. Pb is transported via air, water, soil, and food channels, as well as contaminant fate consolidated with exposure pathway focus on the concentration of chemicals with which individuals may come into contact through oral, inhalation, or skin/eye contact (Reis, et al 2014).

All ingestion routes pass through the nasal and vocal cavities before reaching the systemic circulation. Because food is essential for the growth and development of the human body, the link between creatures in the food chain may result in the transfer of pb detrimental effects to people for those who live outside of mining zones. However, because pb impacts the neurological and circulatory systems, it may influence the growth rate of both sexes. It may also impair growth hormone-producing glands. Without proper protection measures, abandoned mine waste would quickly spread through the air, water, and precipitation, contaminating nearby agricultural lands (Boussen et al 2013). Chemicals released into the air, water, or farming land may also find their way into human bodies via a route sequence. Although various human activities, including fuel burning, agriculture, mining, and municipal waste incineration, have contributed to the increased Pb level in the environment (Palmer et al 2015). Pb in the soil, on the other hand, comes predominantly from mining, as well as from the refinement of parent rocks and, in general, from leaded petroleum additives. Because of its poor solubility, Pb can collect and become accessible in the soil for several years, and it is resistant to microbial destruction (Davies, 1995). As a result, Pb soil is important due to its toxicity to humans. Cardiovascular, neurological, gastrointestinal, reproductive, and haematological disorders have all been linked to pb toxicity in humans (ATSDR, 2005), and as a dangerous trace element, pb has been the topic of substantial human research (Palmer, et al 2015). Bioaccessibility studies have long been used as a means of determining the possibility for human exposure to ingested contaminants. It also denotes the maximum concentration of pollutant that is specifically accessible for absorption in the intestine (Wragg et al 2011). Bioavailability, on the other hand,

could refer to the proportion of pollutants in the small intestine after ingestion of soil to the gastro intestinal phase (Appleton, Cave and Wragg, 2012). However, Ruby et al. (1999) defined bio accessibility as the portion of a contaminant that is absorbed by the body through the gastro intestinal system and is assessable to the body by eating, oral inhalation, and skin contact.

Zinc is a vital trace element with a wide range of physiological and biochemical functions. It is found in essential metallo-enzymes, as well as major metabolic pathways and the creation of deoxyribonucleic acid (DNA). Furthermore, the human body requires a particular amount of zinc for growth and development (Prasad, 2009). Zinc is also said to be a common component of soil and is found in abundance in nature (Adriano, 2001, in Baker et al 2012). Zinc levels in the soil continue to rise as a result of quarrying, agricultural activities, sewage sludge application, fossil fuel burning, and industrial activities (Basta et al 2005 in Baker et al 2012). In comparison to other PHEs, zinc is readily soluble in soil and is both accessible and movable. Zinc associated to Fe, Mn oxides is the most available phase to plants in acidic low-concentration mineral soils (Norrish 1975). As a result, zinc absorption can also be obtained from cereals and legumes, which are the primary sources of food in underdeveloped nations, and are thus the primary sources of zinc for the majority of the population (Gibson et al 1998). Zinc is an essential nutrient for humans, with a recommended daily allowance (DRA) of 15mg/d for men and 12mg/d for women (USEPA, 2009). In humans, intense inhalation of anomalous zinc has resulted in dryness of the throat, coughing, and chest pain, whereas intense oral absorption of high zinc concentrations has resulted in gastrointestinal disturbance and pancreatic damage. Additional chronic oral intake has had negative effects on the blood, resulting in a drop in haemoglobin levels (ATSDR, 1994). However, unlike prior literatures that focused solely on the phytotoxicity of zinc to plants, an excess percentage of absorbed Zn in the human body has substantial impacts (Brown et al 2003).

Materials and Methods

Sample and Sampling

Sixteen (16) soil samples were taken at random sites around the mining regions with a soil auger and a hand trowel, with the results being analysed. The samples were labelled with the numbers 1 through 16. The moist samples were transported to a laboratory for further examination and analysis.

Sample Preparation

Using an oven set at a constant temperature of 400 degrees Celsius for 72 hours, the samples were dried to prevent any modification of the mineralogical properties of the samples (Ellis and Mellor, 1995). Wire mesh (250 microns) was used to sift the samples. To prepare the samples for examination, they were mashed in a pestle and mortar, then sieved and used as is.

Digestive fluids preparation

Wragg et al. 2011, Cave and Wragg 2012, and Wragg et al. 2012 developed a standard process for the preparation of digestive fluids, which was endorsed by the Bioaccessibility Research Group of Europe (BARGE). To conduct the unified barge method (UBM) test, a mixture of saliva, gastric, duodenal, and bile fluids was prepared. Four sets of solutions were prepared, with each fluid consisting of a combination of one inorganic solution, one organic solution, and specific enzymes. Each fluid is formed from the combination of one inorganic solution, one organic solution, and unique enzymes. 3 hours were spent agitating the solutions of each fluid on the magnetic agitation system. Checking the PH values of each fluid and adjusting the values to the correct tolerance using NaOH was done (1M). All fluids were placed in the rotator water bath for one hour at 370 degrees Celsius.

Bioavailability Extracts method

The soil samples were subjected to a bioavailability extraction test using the unified barge method (ubm) at 370 degrees Celsius. A three-stage mimic process was performed, starting with the mouth cavity and progressing to include the stomach and intestinal cavities, with a stomach PH of 1.20.5 and an intestine PH of 6.30.5. Using a pipette, 9.0 ml saliva fluid was added to each 0.6g of soil sample to obtain the results. The vessels containing the extracts were covered and vibrated for thirty seconds. Each experiment received 13.5 mL of stomach fluid, which was distributed evenly. It took one hour for the extraction vessels to be inserted in the extractor and incubated in the extractor with the ends turned over. After one hour of incubation, the gastric and intestinal extracts were removed from the incubation chamber and the pH was measured. The pH of the solution was adjusted using 1.0 mL of concentrated HCl. The extract from the "gastric phase" was centrifuged at 3600 rpm for 15 minutes, after which it was stored after being treated with 0.5 ml of HNO₃ for 15 minutes. The intestinal phase was formed by adding 27.0 ml of duodenal fluid and 9.0 ml of bile fluids to the mixture using a pipette to create the intestinal phase. The content was shaken for 30 seconds, after which the pH was measured. To modify the

pH, one milliliter of 37 percent concentrated HCl or one millilitre and ten millilitres of NaOH were added, depending on the necessity. The combination was incubated at 370°C and rotated for a further 4 hours, after which the contents were centrifuged at 3600rpm for 15 minutes to extract the protein. The pH was measured at the end of the intestinal incubation time after the addition of one millilitre of HNO₃.

Sample Analysis

Determine the bioavailability and bio accessibility of lead (Pb) and zinc (Zn) in humans (Zn) for the measurement of bioavailability and bio accessibility of the soil samples, the inductively coupled plasma-optical emission spectrophotometer (ICP-OES) method published by Wragg et al (2011) was used. We extracted two bioavailable extracts from each sample, one at the end of the gastric phase and another at the end of the gastrointestinal phase, and analysed them separately. Every batch of sixteen (16) samples was subjected to a reference material extraction process in both the gastric and gastrointestinal phases.

Results and Discussion

Results

The results of XRF analysis shows the concentrations of lead and zinc from the top and bottom samples collected from the soil.

Table 1 Concentration of heavy metals (Pb and Zn) in top and bottom sample of contaminated soil

Heavy metals	Concentration in soil profiles (%)		Mean (Heavy metals)
	Top soil	Sub soil	
Lead (Pb)	0.64	1.47	1.06
Zinc (Zn)	0.22	0.45	0.34
Mean (Soil profile)	0.43	0.96	
LSD ($P \leq 0.05$)			
Heavy metals		0.19**	
Soil profile		0.19**	
Heavy metals x Soil profile		Ns	

** : Highly significant

ns: Non-significant

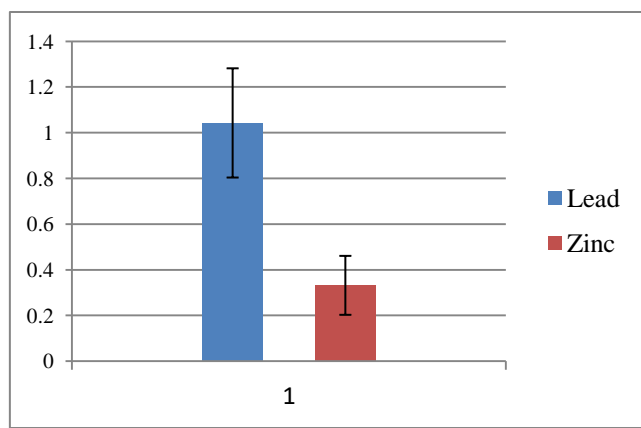


Figure1:Concentration of Lead (Pb) and Zinc (Zn) in the contaminated soil

Table 2 Concentration of Lead (Pb) and Zinc (Zn) in gastric and intestinal phase

Organs	Concentration (%)		Mean (Organs)
	Pb	Zn	
Gastric	23.48	8.48	15.98
Intestine	1.26	1.19	1.23
Mean (Heavy metals)	12.37	4.84	
LSD ($P \leq 0.05$)			
Heavy metals		2.58 **	
Organs		2.58 **	
Heavy metals x Organs		1.92 **	

** : Highly significant

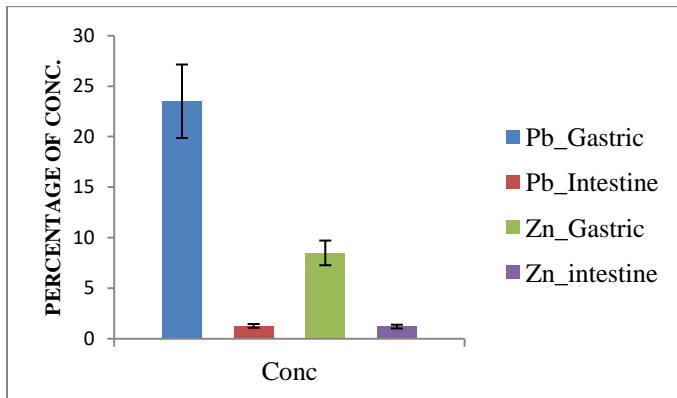


Fig. 2 the mean concentrations of lead and zinc extracted in both gastric and intestine

Discussion

The table below shows the mean percentages of lead and zinc in top soil and bottom soil samples, respectively. Overall, 1.06 percent of the total mean lead concentration was found in both top and bottom soil, with the top soil holding 0.64 percent and the bottom soil carrying 1.47 percent, respectively. However, the top soil had a zinc concentration of 0.22 percent, while the bottom soil had a zinc concentration of 0.45 percent, resulting in a total mean zinc concentration of 0.34 percent. Top soil contained 0.43 percent of the overall Mean concentration of the soil profile, while bottom soil had 0.96 percent of the total Mean concentration. Figure 1 shows the lead and zinc concentrations in the top and bottom soils, which may be found above. The mean

concentration of Lead in the sample was clearly higher than the mean concentration of Zinc in the sample. According to Fig. 1, lead and zinc had mean concentrations of 1.06 percent and 0.34 percent, respectively. Lead concentrations averaged 1.06 percent and 0.34 percent, respectively, while zinc concentrations averaged 0.34 percent. The results demonstrated a statistically significant difference between lead and zinc in both top and bottom soil samples, with $LSD = P < 0.05$ indicating a statistically significant difference.

The average concentrations of heavy metals eliminated during the stomach and intestinal stages, as well as the extraction results, are shown in Table 2. The average concentration of heavy metals (Pb and Zn) in the stomach phase was 15.98%, while the average percentage of lead and zinc retrieved from the intestine was 1.23 percent, according to the findings. According to the data, the total mean concentration of lead extracted in both the gastric and intestinal phases was 12.37 percent, while the total mean concentration of zinc removed in both phases was 4.84 percent. The data demonstrated that in both the gastric and intestinal phases, there is a statistically significant difference between lead and zinc removed in the stomach and intestinal stages, respectively. Another conclusion is that there is a considerable difference in the bioavailability of heavy metals in the organs compared to the extracted heavy metals. FIGURE 2 provides a graphical representation of the mean lead and zinc concentrations collected from stomach and intestinal tissues. The mean value of lead extracted during the gastrointestinal phase was found to be 23.48 percent higher than the mean value of zinc extracted during the gastric phase, which was 8.48 percent in this study. The mean value of Lead extracted in the digestive tract, on the other hand, was marginally higher at 1.26 percent, compared to a slightly lower mean value of Zinc extracted in the intestinal tract of 1.19 percent.

According to Palmer et al. (2015), the presence of lead in the environment can be attributed to a number of human activities, including fuel combustion, agriculture, mining, and waste incineration at municipal waste facilities, in addition to industrial processes. The majority of lead (Pb) in the soil, on the other hand, comes from mining, which supports the findings of this study. Davies and colleagues' studies show that Pb can build up in soil and become bioavailable (1995). It was determined that the soil samples and organs under scrutiny contained a significant level of lead. As a result, lead toxicity to the gastrointestinal system in humans is a significant risk, as indicated in the ATSDR (2005). This is in line with the findings of a large human investigation on harmful trace metals (Palmer, et al 2015). The results of a study on the bio-accessibility of

lead (Pb) and zinc (Zn) indicated that ingested pollutants can cause human exposure. It also found that the amount of heavy metals analysed had increased significantly, indicating that they were potentially accessible for intestinal absorption, which was in line with Wragg et al's findings (2011). According to Palmer et al. (2015), the presence of lead in the environment can be attributed to a number of human activities, including fuel combustion, agriculture, mining, and waste incineration at municipal waste facilities, in addition to industrial processes. The majority of lead (Pb) in the soil, on the other hand, comes from mining, which supports the findings of this study. Davies and colleagues' studies show that Pb can build up in soil and become bioavailable (1995). It was determined that the soil samples and organs under scrutiny contained a significant level of lead. As a result, lead toxicity to the gastrointestinal system in humans is a significant risk, as indicated in the ATSDR (2005). This is in line with the findings of a large human investigation on harmful trace metals (Palmer, et al 2015). The results of a study on the bio-accessibility of lead (Pb) and zinc (Zn) indicated that ingested pollutants can cause human exposure. It also found that the amount of heavy metals analysed had increased significantly, indicating that they were potentially accessible for intestinal absorption, which was in line with Wragg et al (2011) findings.

Conclusion

In conclusion, the hazardous heavy metals found in the contaminated soil samples analysed were shown to be present, and they may cause severe toxicity in humans if they are inhaled. According to the findings of the research, lead and zinc are abundant in the Cwmystwyth Lead Mine, and the considerable quantities of lead and zinc present are relatively damaging to the human body. Because the concentrations of lead and zinc in Cwmystwyth Lead Mines were highly significant, this demonstrated the high level of danger to human health posed by the mine.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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