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Leaching properties of fly ash from Duvha power station in South Africa

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Abstract

Fly ash and phosphogypsum are abundantly available in South Africa. However, landfilled industrial waste materials interact with the environment leading to groundwater, air, and soil pollution. This study aims to determine and quantify the heavy metal concentrations in fly ash from the Duvha power station and compare the results with US EPA regulatory limits. The TCLP and ICP-MS methods are used for leachate measurements. The results showed that the fly ash can be considered non-hazardous since the amounts of toxic elements such as Hg, Pb, Cu, Cd, Zn, Ni, As, P, Co, Se, and Mn are below the US EPA limits. The study findings can help policymakers manage fly ash disposal and/or management thereby reducing the environmental impact.

Keywords: Heavy metals, waste management, supplementary cementitious materials

1. Introduction

South Africa is among the highest coal-consuming countries in the world after China, India, USA, Russia, and Japan [1]. Currently, the South African annual production amounts of fly ash stand at 40 million tonnes [2]. Globally, around 1 billion tonnes of fly ash are produced annually but only around 30% is reused by industries [3], [4]. The remaining 70 % of FA is usually disposed of in landfills leading to ecosystem disturbance. The need for its eco-friendly disposal and/or recycling has attracted global attention and requires further research to advance circularity in accordance with sustainable development goals [5], [6]. But to ensure that the fly ash is fully utilized in construction, it is imperative to examine its leaching properties. Leachate is the liquid produced when water percolates through any permeable material. Ugurlu [7] observed that leaching studies are crucial in predicting the impact of fly ash disposal on the environment. Mashifana et al. [11] demonstrated that treating phosphogypsum with citric acid and stabilizing the material with fly ash, lime, and slag reduces the heavy metal concentration in the leachate. Gitari [12] found that the amounts of toxic trace elements e.g., Se, Pb, As, Cr, and Cd leached out of the fly ashes from Sekunda and Tutuka power stations (DIN-S4 test) were below the Target Water Quality Range (TWQR) of South Africa.

However, no research has been done to examine the leaching properties of fly ash at the Duvha power station. Proper disposal and management of FA can help address environmental pollution from landfills and provide alternative construction materials for circular economy advancement. Therefore, this study aims to determine and quantify the heavy metal concentrations in fly ash from the Duvha power station and compare the results with regulatory limits. The key research question to be addressed is whether the FA is compliant with international regulatory limits for consideration as non-hazardous material.

2. Materials and Methods

Bulk quantities of fly ash (FA) were collected from Eskom Duvha Power Station in Mpumalanga, South Africa. A riffle splitter was used to obtain a representative sample for testing in accordance with ASTM D6913 [13]. The FA samples were dried in an oven at 105°C as per ASTM C311 [14]. The toxicity characteristic leaching procedure [15]–[18] was carried out to obtain the leachate which was further analyzed using the inductively coupled plasma-mass spectrometer (PerkinElmer NexION ICP-MS), shown in Figure 1, to determine the concentration of leached heavy metals.

Fig. 1. PerkinElmer NexION ICP-MS

The ICP-MS instrument ionizes the sample with inductively coupled plasma and then the ionized sample is passed through a mass spectrometer to separate and quantify the metal/nonmetal ions [19], [20]. A similar technique of TCLP and ICP-MS was used by Anastasiadou et al. [21] and Mashifana et al. [22], to evaluate the environmental impact of industrial solid waste leachate in comparison to the US EPA regulatory limits.

3. Results and Discussion

Table 1 and Figure 2 show the TCLP and ICP-MS findings for FA compared to the toxicity characteristic regulatory limits. The measured concentrations of heavy metals and phosphorus in the FA comply with the US EPA TC limits [23]. For instance, the levels of Hg, Pb, Cd, and Se in the FA satisfy all the international regulatory limits. Since the measured concentrations are within the international and local limits, the FA used in the present study can be considered non-hazardous. The US EPA issued a final ruling in 2014 that coal fly ash does not have to be classified as hazardous waste but advised the importance of monitoring the heavy metal concentrations to comply with the US EPA regulatory limits [24], [25]. The major potential impacts of disposing of fly ash in ash dams or landfills lead to the leaching of potentially toxic substances into soils, surface water, and groundwater [16].

Table 1. TCLP results compared to different regulatory limits (mg/l)

Element	Hg	Pb	Cu	Cd	Zn	Ni	As	P	Co	Se	Mn
FA	0.008	0.134	0.0676	0.01	0.0492	0.364	0.0159	0.4223	0.0105	0.074	0.03306
US EPA TC [23]	0.2	5.0		1.0	2.0		5.0			1.0	

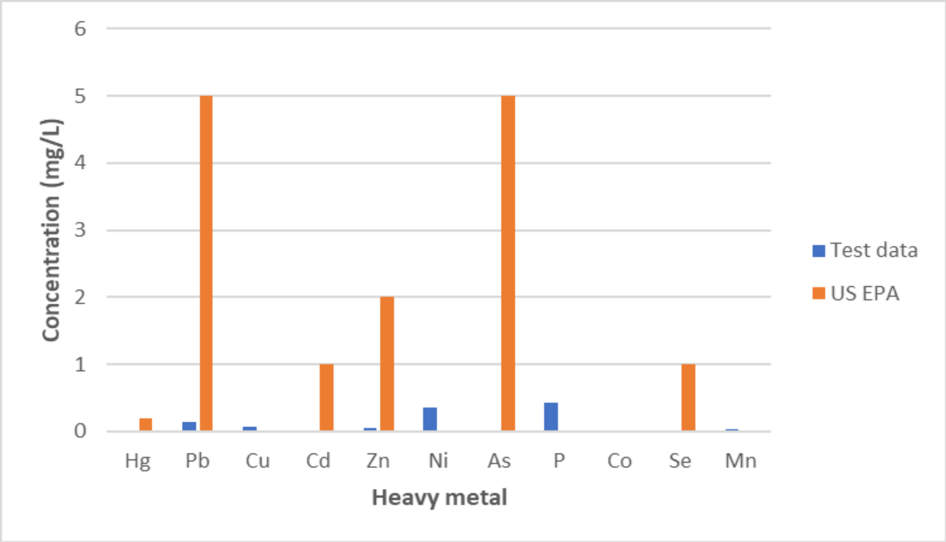

Fig. 2. Heavy metal concentration in FA leachates

4. Future Research Trends

Future research should compare the leaching properties of FA from different sources at a local/global scale and develop sustainable cost-effective management methods.

5. Limitations

FA used was collected from one source only.

6. Conclusions

This study sought to determine and quantify the heavy metal concentrations in fly ash from the Duvha power station and compare the results with US EPA regulatory limits. The FA complies with all regulatory limits and is thus considered non-hazardous and suitable for use in the built environment. However, continued monitoring of the heavy metal concentrations in the stockpiled FA is recommended to ascertain long-term compliance with the US EPA regulatory limits. Reusing and recycling the FA can help mitigate continuous stockpiling and disturbance to the ecosystem.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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