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EFFECTIVE USE OF CONSTRUCTION, RENOVATION AND DEMOLITION WASTE IN THE TREATMENT OF ACID MINE DRAINAGE

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ABSTRACT: *The growth of the global population and the implementation of extensive urban development programs are responsible for the generation of millions of tons of construction, renovation and demolition waste (CR&DW). While wood and metal are typically recycled, concrete, bricks, and mortar are typically disposed of in landfills. The primary environmental concerns associated with CR&DW in landfills pertain to leachate, H2S gas emissions, and the presence of heavy metals, including Pb, Cu, Cr, and As, which may have originated from paints or treated wood. In addition to the aforementioned waste problems, acid mine drainage (AMD) represents an unavoidable consequence of the mining industry. The AMD is notably acidic and contains elevated levels of toxic metal ions, including iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), and cadmium (Cd). These ions contribute to long-term contamination of the environment. In light of these considerations, the present study investigated the potential of plaster, concrete, drywall, autoclaved aerated concrete and brick for the removal of Fe, Mn and Zn ions from AMD. The findings indicated that a solid/liquid ratio of 5/50 (g/mL) of concrete was sufficient to reduce the concentration of Fe, Mn and Zn below the limits set by Romanian legislation after 60 minutes.*
Keywords: *waste; heavy metals; wastewater treatment; acid mine drainage;*

1. Introduction

Acid mine drainage is a significant environmental concern due to its adverse impact on water bodies and surrounding ecosystems. These wastewaters are strongly acidic and have high concentrations of metal ions (e.g. iron, zinc, manganese, cadmium, etc.) which are not biodegradable and tend to accumulate in living organisms. Heavy metal pollution of the environment in general and of surface waters in particular leads to damage to the health of aquatic flora and fauna as well as to the health of the entire ecosystem, including humans Moreover, the phenomenon of acid mine water generation is difficult to stop due to its natural character [1].

As a result, a number of acid mine drainage treatment methods have been developed to date. The conventional technologies employed for the removal of heavy metals from acid mine drainage, including active (characterised by frequent input of chemicals and energy) and passive (based on reduction or oxidation) methods, have proven ineffective in addressing the issue of environmental pollution. This is largely attributed to their suboptimal performance, high cost and generation of toxic and hazardous waste (sludge) that could potentially lead to secondary pollution [2]. Other techniques, like precipitation [3], electrocoagulation [4], constructed wetlands [5] and adsorption [6] have also been recommended as alternative treatments for the removal of heavy metals from AMD.

The treatment of AMD is crucial to mitigate its harmful effects, and research is actively underway to explore efficient and environmentally friendly methods for this purpose. In recent years, the global scientific community has concentrated its efforts on identifying efficient and cost-effective methods that utilise materials that are readily accessible and as natural as possible, or waste or by-products from other industries for which no clear use has been identified or which are generated in large quantities. Consequently, the potential of waste materials from diverse sources, including those from the agricultural and food industries, for the removal of heavy metals from wastewater has been investigated [7]. Recently, alternative applications for construction, renovation and demolition waste have been identified, including the utilisation of these materials as sorbents for the removal of pollutants from wastewater [8].

Construction, renovation and demolition waste represents between 30 and 40 per cent of all solid waste [9]. In Romania, in 2017, the quantity of waste generated from construction and demolition activities was 1.33 million tons, with a recovery rate of 67% [10]. It contains materials that can be reused or recycled such as wood and metal. Unfortunately, a low percentage of CR&DW is reused or recycled as it requires extensive and costly sorting operations and after a volume reduction often ends up in uncontrolled landfills or landfills or incinerated, causing environmental pollution. The landfilling of construction and demolition waste is associated with the release of heavy metals into the environment via leachates [11]. Furthermore, the disposal of construction and demolition waste in landfills can also result in the formation of hydrogen sulphide. This is due to the high gypsum content of the waste and the action of sulphate-reducing bacteria present in the anaerobic environment characteristic of landfills. The emission of H2S can result in the production of unpleasant odours and the onset of health issues for both workers and local residents [9].

Therefore, this research aimed to investigate the possibility of using construction, renovation and demolition wastes (plaster, concrete, drywall, autoclaved aerated concrete and brick) to correct the acidity and to remove heavy metal ions (Fe3+, Mn2+ and Zn2+) from AMD generated at the "Hane " mining gallery located in Alma u Mare, Zlatna, Alba County.

Materials and methods

2.1. Study area and AMD sampling

The Hane mining perimeter is located within the Apuseni Mountains, in the western region of Zlatna, Alba County. The exploitation of non-ferrous and gold-silver ores within the Apuseni Mountains is well documented, with evidence of mining activities dating back over two millennia [12]. The presence of numerous mining galleries and extensive deposits of waste material within this area has resulted in significant contamination [13] of the soil, surface water and groundwater, and the surrounding ecosystem (Figure 1).

Fig.1. AMD generated at the Hane mine

In order to determine the extent of contamination in the Hane mine area, two water samples (AMD) were collected from the mine's drainage system. The sampling points were situated at a distance of 1.5 metres and 30 metres from the mouth of the gallery, respectively. The pH of the acid mine drainage was immediately determined using a laboratory pH meter (Hanna HI 5221).

The chemical composition of the acidic water collected from the Hane mine was determined in the laboratory by X-ray fluorescence spectrometry using an ARL Quant'X spectrometer (Thermo

Fisher Scientific, Waltham, USA).

All analyses were performed in duplicate, and the reported values represent the mean of the duplicate analyses.

2.2. AMD treatment using CR&DW

In order to determine the efficacy of the use of CR&DW in the removal of metal ions present in the AMD collected from the Hane mine, a series of static experiments ("Batch Technique") were conducted. A quantity of 5 g of CR&DW, namely plaster, concrete, aerated concrete, drywall and brick, were placed in contact with 50 ml of acid mine drainage under continuous stirring at 500 rpm for 24 hours in order to determine their preliminary effectiveness. In the process of removing metal ions from AMD, the investigated CR&DW was subjected to crushing, and the resulting particle size fraction of less than 1 mm was used without any further treatment.

In the second stage of the experiment, the influence of the dosage of CR&DW on the removal of metal ions from the Hane mine water was tested for a duration of 8h in the case of the most effective of the investigated wastes. For this purpose, 10 g and 20 g of the most effective waste, respectively, were brought into contact with 200 ml of AMD collected from the Hane mine under continuous stirring at 500 rpm.

At different time intervals samples were collected, filtered and analysed by X-ray fluorescence spectrometry. The pH was also monitored during the experiments.

$$Removal\ efficiency\ (\%) = \frac{C_0 - C_f}{C_0} \cdot 100$$

The efficiency of heavy metal removal was determined quantitatively using the following equation [14]:

-where; C_0 is the initial metal concentration in the AMD (mg L-1);

C_f is the final concentration of metals in the AMD (mg L-1).

3. Results and discussion

The chemical composition of the AMD is illustrated in Figure 2, which depicts the results of X-ray fluorescence (XRF) analysis. As can be observed, the water sampled from the Hane mine contains notable concen-trations of metal ions, including Fe^{3+}, Zn^{2+}, and Mn^{2+}. Additionally, the water exhibits a high degree of acidity, with a pH value of 3.

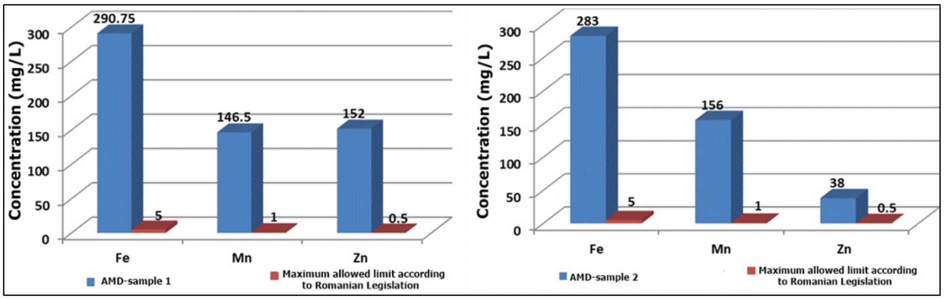

Fig. 2. Concentration of heavy metals identified in AMD samples collected from the "Haneş" mining perimeter

As can be seen from Figure 2, the concentration of Fe^{3+}, Zn^{2+}, and Mn^{2+} ions in the water sampled from the Hane mine exceeds by 58 to 76 times the maximum allowed limit established by the Romanian legislation [15].

It is thus imperative to impede or restrict the generation of acidic water at its point of origin. In the event that this is unfeasible, an alternative solution to this issue could be to subject the AMD to a process of treatment to ensure that it complies with the stipulated regulations for its discharge into the environment.

In order to treat the acid water from the Hane mine, the potential of different types of CR&DW for the removal of Fe^{3+}, Zn^{2+} and Mn^{2+} ions fromthe water was investigated at the laboratory scale. Figure 3 illustrates the variation in the concentration of Fe^{3+}, Zn^{2+} and Mn^{2+} ions in the acidic water sampled from the Hane mine during its contact with 5 g of CR&DW with a grain size of less than 1 mm.

As illustrated in Figure 3, a notable decline was observed in the concentration of Fe^{3+}, Zn^{2+}, and Mn^{2+} ions in the acidic mine wastewater shortly following the interaction of the AMD with

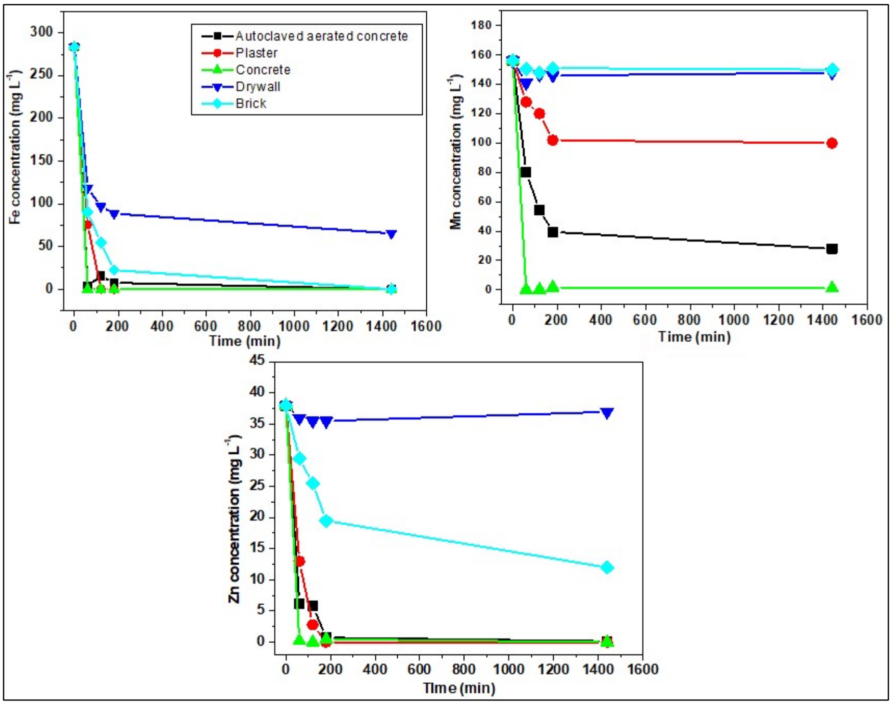

Fig. 3. Variation in the concentration of Fe^{3+}, Zn^{2+} and Mn^{2+} ions in AMD sampled from the Hane mine during its contact with 5 g of CR&DW (grain size < 1 mm)

the tested CR&DW. A notable reduction was observed in the concentration of Fe^{3+} ions across all five waste samples under investigation.

Thus, the concentration of Fe^{3+} ions exhibited a notable decline over the 120-minute observation period, reaching values with 267.75 mgL-1, 283.05 mgL-1 and 283.25 mgL-1 lower than the initial value when autoclaved aerated concrete, plaster and concrete waste were employed in the water treatment process, respectively. The application of drywall and brick waste resulted in a reduction of the Fe^{3+} concentration in mine water, with a decrease of 186.25 mg/L and 228.75 mg/L, respectively, in comparison to the initial value.

The utilization of autoclaved aerated concrete, plaster and concrete waste led to a significant decrease in Zn^{2+} ions. In contrast, the effectiveness of drywall and brick waste in the removal of Zn^{2+} ions from the Hanes mine water was observed to be less pronounced, particularly at low contact times.

The concentration of Mn^{2+} ions in AMD decreased by 156 mg/l after 60 min of contact with 5 g of concrete waste and by 101.5 mg/l after 120 min of contact with the same amount of autoclaved aerated concrete waste. The utilization of drywall waste and brick waste in the AMD treatment process resulted in an insignificant reduction in the concentration of Mn^{2+} ions in the wastewater. The preliminary results indicated that the highest removal efficiencies were achieved through the utilization of concrete waste for the treatment of acid mine drainage (AMD).

Figure 4 illustrates the influence of concrete waste dosage on the removal efficiency of Fe^{3+}, Zn^{2+} and Mn^{2+} metal ions from the acidic water sampled from the Hane mine. It can be observed that at contact times up to 120 minutes, the removal efficiency of Mn^{2} from the mine water increases with an increase in concrete waste dosage.

Instead, this fact is not applicable in the case of Fe^{3+} and Zn^{2+} ions, indicating that a dosage of 10 g of concrete waste to a volume of 200 ml of AMD is sufficient to achieve 100% removal efficiency.

Moreover, an examination of the pH values of the water during its contact with 10 g and 20 g of concrete waste, respectively, reveals a range of 6.4–8.1 and 11.1–11.5, respectively.

Thus, the utilization of 10 g of concrete waste

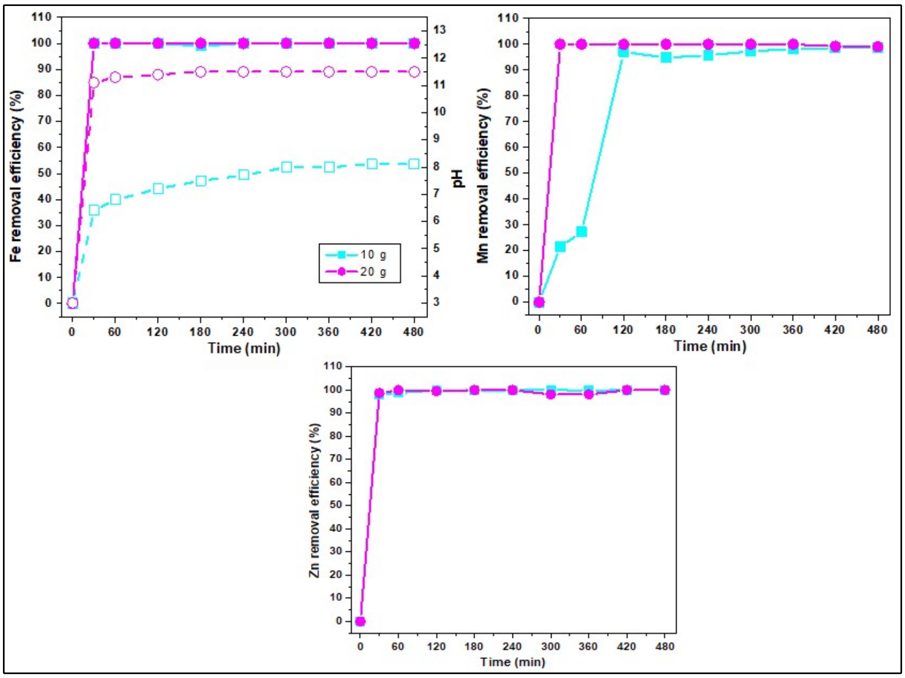

Fig. 4. Removal efficiency of Fe^{3+}, Zn^{2+} and Mn^{2+} ions from AMD sampled from the Hane mine at different concrete waste dosages (grain size < 1 mm)

ensures removal efficiencies of Fe^{3+}, Zn^{2+} and Mn^{2+} ions comparable to those obtained using a 20 g dose of concrete waste. However, it should be noted that these efficiencies are achieved at water pH values that are rather close to neutral, which is desirable in a water treatment process, particularly in the context of AMD. This is because it avoids the destruction of fish fauna and the disturbance of aquatic plant development. It was reported that river water with a sodium hydroxide concentration exceeding 25 mg/L has a detrimental impact on fish fauna and impedes the growth of aquatic plants [16].

4. Conclusions

The findings of the present study demonstrate the efficacy and potential applicability of CR&DW in the treatment of AMD generated at Hane mine. The concentration of Fe, Mn and Zn ions in the mine water was found to decrease significantly during the investigated contact time when using autoclaved concrete waste, plaster waste and aerated autoclaved concrete waste.

A dosage of 10 grams of concrete to a volume of 200 milliliters of mine water is sufficient to achieve 100% efficiency.

It was observed during the experiments that the reduction in the concentration of Fe^{3+}, Zn^{2+} and Mn^{2+} ions in the AMD was closely correlated with the capacity of the CR&DW to elevate the pH of the solution with which they were in contact. As a result, the notable increase in the pH of the AMD to alkaline values leads to the precipitation of metal ions in the form of hydroxides. It can thus be proposed that precipitation represents the primary mechanism by which heavy metals are removed from AMD, although it is also possible that other mechanisms may be involved in this process. To gain further insight into the mechanisms by which heavy metals are removed from AMD by CR&DW, further investigation is required.

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