Microwave-assisted leaching technique as a novel technique for metal recovery from municipal solid waste (bottom and fly ashes)

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Introduction

Municipal solid waste (MSW) is the second largest waste contributor in Qatar. The principal method of MSW disposal in Qatar is landfilling. Umm Al-Afai, Rawda Rashed, and Al-Krana are the main landfills in Qatar for bulky and domestic wastes, construction and demolition wastes, and sewage waste, respectively. Approximately, more than 2.8 million tons of MSW are produced every year (domestic and bulky), which reads to 1.7 kg per person per day. According to recent studies, Qatar produces up to 8,100 tons of MSW every day. The majority of the MSW in Qatar is made up of organic materials (between 55% and 70%), with the remainder being made up of paper, glass, plastics, and metals. In countries, such as Qatar, where land is limited and environmental legislations are constricted, environmental regulations attempt to diminish landfilling as much as possible. Therefore, the development of alternative methods to reduce MSW production is one of the greatest challenges faced by Qatar in view of economic expansion and high population, industrial, and urbanization growth rates.

In the incineration of MSW, two types of residues are produced, the bottom ash (BA-MSW) and the fly ash (FA-MSW). Figure 1A shows the results of the metal concentration in BA-MSW and FA-MSW. Consequently, to reduce the environmental burden and to save mineral resources, recovery of these valuable metals from the solution of the detoxified BA-MSW and FA-MSW can be an attractive and potential way. Numerous studies have looked into the viability of recovering and extracting different metals from MSW ashes recently (Pérez-Martnez et al., 2019; Abramov et al., 2018; Arain et al., 2008). Using an acid-extracting agent would be necessary for enhancing metal solubility. But because the MSW ash is alkaline, as was mentioned in our preliminary research, a lot of acids are required. This motivates scientists to create an alternate technique that can recover needed metals from the ash without using a lot of acids, inexpensive, simple to use, and successful. When a solvent or acid is subjected to microwave radiation, the temperature rises fast. Fast temperature increases caused by the penetration of microwave radiation into solvents or acids increase container internal pressure.

Microwave-assisted leaching technique (MAE) can apply different time duration and power levels, and the energy produced by microwaves is distributed equally throughout the entire mass. This would increase internal pressure while heating a complex reactant, such as MSW ash, in a closed vessel (Al-Ghouti et al., 2021; Wang et al., 2016; Chan et al. 2015). In addition, the acid's viscosity and surface tension can be reduced by these high temperatures, which enhances its ability to penetrate into the ash's matrix and causes the solutes to transfer faster.

Material and methods

The extraction of metals from the ashes was investigated using microwave-assisted extraction. The metals obtained from the ashes before and after extraction were quantified using ICP-MS. In this study, water was used as a safe and environmentally friendly solvent in addition to a combination of different types of extractants such as H_3PO_4, HCl, and HNO_3. Here, several key parameters – time, power, sample mass, and temperature, which can be designated as a ratio between microwave and the sample were studied. A standard microwave oven (Panasonic Dimension NN-CD997s) was employed for metal extraction.

Results and discussion

Beneficiation of BA-MSW and FA-MSW should necessitate; ensuring the extraction of metals to diminish the effect of hazardous impact on our environment and can fill the demand for resources such as valuable metals. Figure 1 illustrates the selected initial metal concentration of the MSW-BA and MSW-FA before any treatment. The ceramic and glass industries frequently use rare metals such as Sr (Ryu et al., 2020), and vanadium (V) is essential for the high-tech sector (Zhang et al., 2022). Therefore, it has become crucial in the scientific community to secure Sr and V resources that can satisfy both current and future industrial demand. Multiple metals could be recovered from MSW-BA and MSW-FA using microwave-assisted heating, as shown in Figures 1B and 1C, respectively. Using 2M of HCl and 3M of H_3PO_4 from MSW-BA, 2.32 % of Zn and 4.8% of V were removed in 5 minutes using 22% of the power. Strontium was extracted to a degree of 38%. However, a 4.8% recovery was seen for V at a 5M concentration of HCl and HNO_3. In contrast, Sr's 18.53% recovery took 5 minutes and 22% power using 2M HCl and 3M H_3PO_4. The extraction of 2.32% of Zn and 12.32% of the strontium, on the other hand, required 5M HCl and 5M HNO_3 to be applied at 22% power for 5 minutes. While 5.24% of V was extracted in 5 minutes with 22% power using 2M HCl and 3M H_3PO_4. According to our early findings, MAE and conventional solvent extraction are equivalent (Al-Ghouti et al., 2021). In contrast to the solvent extraction

technique, the MAE has a high extraction efficiency. As the sample preparation is done in a closed microwave system, which reduces cross-contamination and loss of volatile pollutants, the MAE is a quick, effective, and economical method.

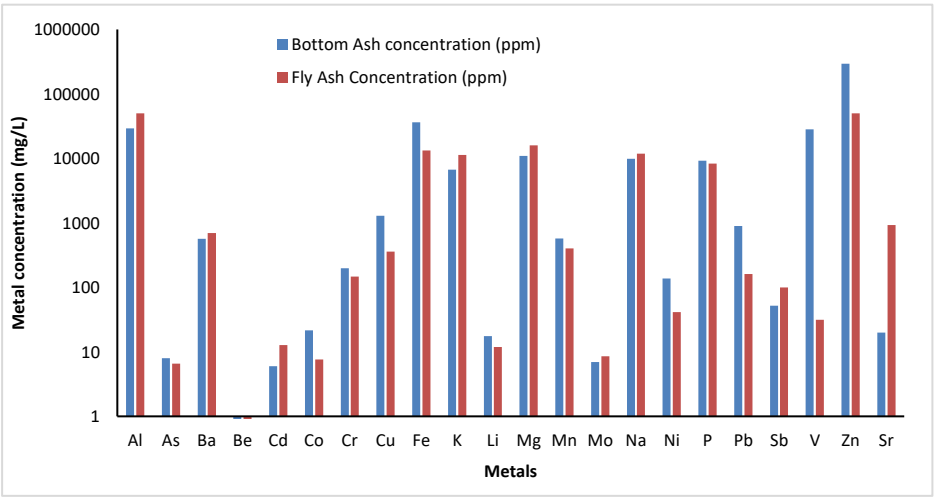

Figure 1. Metal concentration profile for MSW-BA and MSW-FA.

Conclusion

The approach used in this work produced very high metal extraction efficiencies in a short period of time - 5–10 min—and only needed tiny volumes of acid-extracting agents. The current work provides a potential approach for extracting metals from municipal solid waste incinerator ashes that is easy to use, affordable, and poses no environmental danger.

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