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Comprehensive utilization of lead–zinc tailings, part 1: Pollution characteristics and resource recovery of sulfur

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ABSTRACT

According to the pollution characteristics and current situation of sulfur resources in lead–zinc tailings, the mineral composition, risk assessment and oxidation reaction characteristics of lead–zinc tailings were investigated. The results showed that the main mineral in the lead–zinc tailings was pyrite and the contents of Fe and S were 23.4% and 24.9%, respectively. The heavy metals Pb, Zn, Cu, Cr and Cd were mainly present in the residual fraction, but the Pb, Zn and Cd in the non-residual fraction were 28.21%, 37.49% and 42.92%, respectively. Additionally, the lead–zinc tailings potentially form acid, which poses a potential heavy metals pollution risk to the environment. The reaction characteristics of tailings, including the roasting temperature, filling rate and air–solid ratio, were investigated in a rotary furnace under different conditions. The results showed that the desulfurization rate was 99.0% and the concentration of SO_2 was 5.58–5.07% when the roasting temperature was 400 °C, the filling rate was 4.29%, the air–solid ratio was 1.7 L/g and the residence time was 20 min. After roasting in the rotary furnace, the cinder became non-acid forming and the SO_2 in the flue gas can be recovered by producing sulfuric acid. Meanwhile, the roasting procedure concentrates metals such as Fe, Ag and Ga, which assists further recovering the resources in the cinder. All of these results provide a new approach for eliminating the pollution of acid mine drainage and recovering the sulfur from lead–zinc tailings.

Introduction

In China, the total lead–zinc tailings are approximately 160–200 million tonnes and increase at a rate of 2.5% per year with the rapidly increasing demand of lead and zinc. Lead–zinc tailings mainly contain sulfide with a sulfur content reaching 9.88–26.6% [1], which will stimulate acid mine drainage (AMD) and cause serious pollution in the environment [2–4]. Measures have been taken to prevent the production of AMD. Demers et al. [5] found that the use of desulfurized tailings as a cover material combined with water table elevation was able to prevent the production of AMD by reducing the oxygen diffusion rate and thereby preventing sulfide oxidation. Bussière [6] reported that the synthetic materials (such as geomembranes and bentonite geocomposites) can control the production of AMD by limiting the water flow though reactive mine wastes. However, these methods are difficult to implement and display a security risk over the long term. Therefore, to remove the sulfur in the tailings is considered the most effective method to address the problem of the acidification of tailings [7,8].

As a common method, flotation separation is used to separate the sulfides from the tailings. However, the low sulfur content of tailings produces little economic benefit and secondary pollution is easily generated because of the large number of flotation reagents added during the process of flotation [9]. Roasting is another feasible method for removing sulfur from the tailings. During roasting, the sulfur in the tailings is removed and transformed to sulfur dioxide in the flue gas and then collected to produce sulfuric acid. To produce sulfuric acid, the concentration of SO_2 in the flue gas must be sufficiently high. However, two stumbling blocks complicate the ability of roasting lead–zinc tailings to satisfy the requirements of the SO_2 concentration. One drawback is that the sulfur content of lead–zinc tailings is 10–26%, significantly less than the sulfur content (34–48%) of pyrite that is the common raw material used in sulfuric acid production [10]. The other hindrance

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is that the roasting equipment used is commonly the traditional fluidized bed furnace [11], in which the high excess air coefficient produces a concentration of SO_2 in the flue gas below the minimum amount required for industrial production of sulfuric acid. Additionally, because of the low sulfur content in the lead–zinc tailings, the heat balance of the traditional fluidized bed furnace cannot be guaranteed, which hinders continuous and stable operation. Therefore, the use of the traditional fluidized bed furnace for lead–zinc tailings desulfurizing roasting is rare. As an alternative, a rotary furnace is more effective for lead–zinc tailings desulfurizing roasting because of the flexible control of air and the countercurrent between tailings and air. This design can take full advantage of heat and improves the concentration of SO_2. However, this research is rarely reported.

Based on the pollution characteristics and the resources of lead–zinc tailings, we systematically studied the recovery of sulfur, iron and rare metals such as Ag and Ga in the lead–zinc tailings by different processes including roasting, magnetic separation, leaching and solvent extraction. In this paper, the mineral composition of lead–zinc tailings was studied and the acid production potential was analyzed to assess the environmental risk of lead–zinc tailings. Meanwhile, the recovery of sulfur in lead–zinc tailings was studied through roasting in a rotary furnace, which will lay the foundation for the recovery of low-grade sulfur in lead–zinc tailings.

Materials and methods

Study area and sample collection

The Fankou lead and zinc mine is located in Renhua, 48 km north of Shaoguan, Guangdong, China (Fig. 1). This mine is the largest production base of lead and zinc in China. Approximately 5500 tonnes of lead–zinc ore containing rich metals such as copper, silver, gold and some rare metal minerals are processed daily. The quantity of the tailings produced every year has increased from 200,000 to 600,000 tonnes since the mine was put into production in 1968. The total tailings reach 10 million tonnes and are mainly stored in a tailing reservoir, except for a small portion that was utilized for underground filling. Fankou lead–zinc tailings are mainly sulfides that are easily oxidized and produce a large amount of acid mine drainage contaminating water and soil. Moreover, the process of oxidation will release a large amount of heavy metals from tailings, which is a serious risk to surrounding rivers and groundwater. The samples used in this study were collected from Fankou lead–zinc tailings. These samples were pulverized and sieved through 200 mesh after drying at room temperature. The sample was further dried at $105 \pm 2\,^{\circ}C$ to a constant weight. The reserves were then sealed for use.

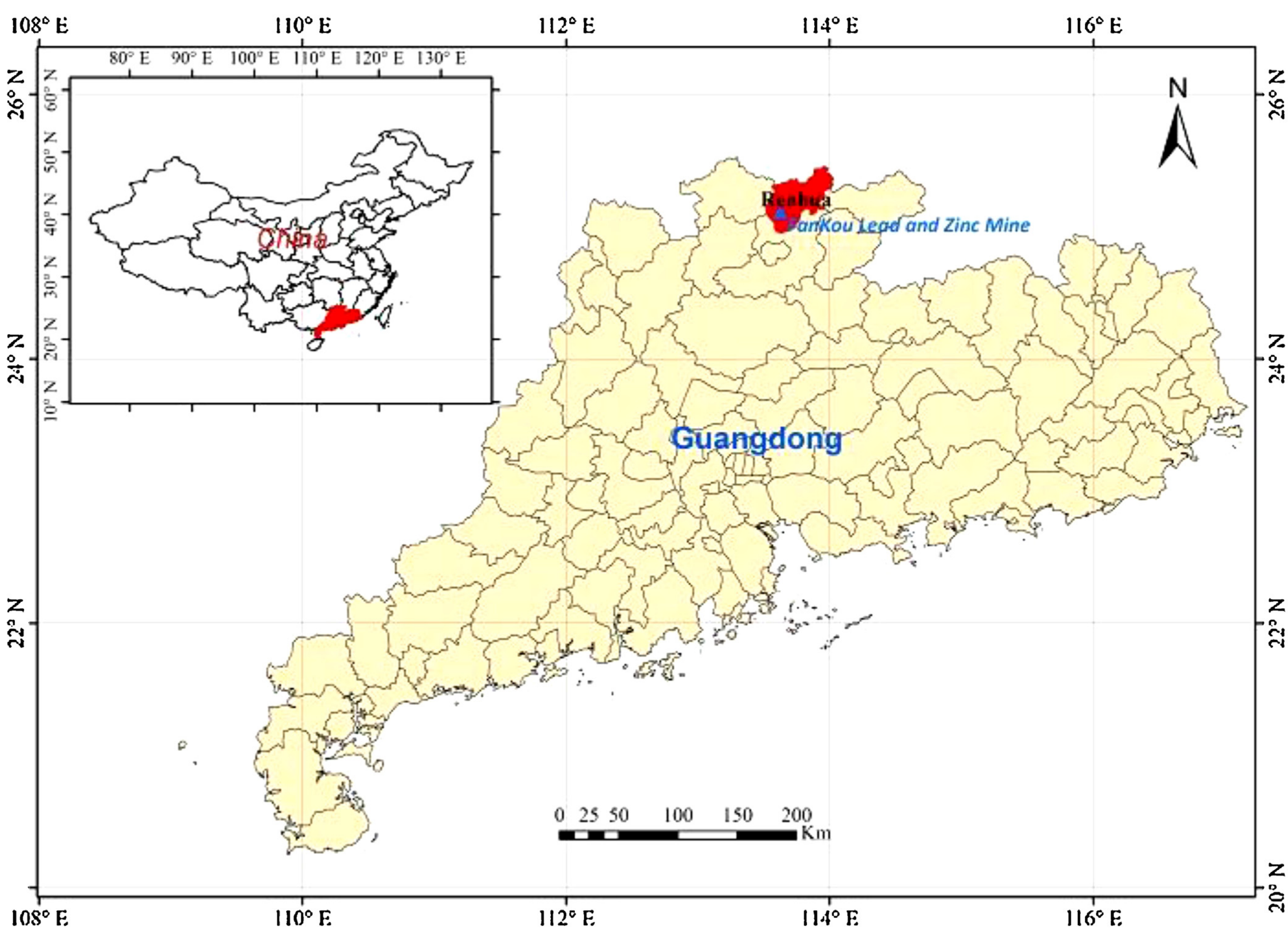

Fig. 1. The location of the Fankou lead and zinc mine.