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Chemical characterization, nano-particle mineralogy and particle size distribution of basalt dust wastes

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HIGHLIGHTS

- Expansion in Brazilian basalt mining studies will increase human health information in this area.
- Several samples were advanced nano-particles techniques.
- The compounds showed strong sorption ability to hazardous elements.
- The advanced methodology has been applied to investigate elements occurrence and ultra-fine/nano-particles properties.

GRAPHICAL ABSTRACT

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ABSTRACT

Understanding the geochemistry of basalt alteration is central to the study of agriculture systems. Various nano-minerals play an important role in the mobilization of contaminants and their subsequent uptake by plants. We present a new analytical experimental approach in combination with an integrated analytical protocol designed to study basalt alteration processes. Recently, throughout the world, ultra-fine and nano-particles derived from basalt dust wastes (BDW) during "stonemeal" soil fertilizer application have been of great concern for their possible adverse effects on human health and environmental pollution. Samples of BDW utilized were obtained from companies in the Nova Prata mining district in southern Brazil for chemical characterization and nano-mineralogy investigation, using an integrated application of advanced characterization techniques such as X-ray diffraction (XRD), High Resolution-Transmission Electron microscopy (HR-TEM)/Energy Dispersive Spectroscopy (EDS)/(selected-area diffraction pattern) SAED, Field Emission-Scanning Electron Microscopy (FE-SEM/

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Detailed waste geochemistry
XRD, HRTEM/EDS/SAED, and FE-SEM/EDS
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EDS), and granulometric distribution analysis. The investigation has revealed that BDW materials are dominated by SiO_2, Al_2O_3, and Fe_2O_3, with a complex micromineralogy including alkali feldspar, augite, barite, labradorite, hematite, heulandrite, gypsum, kaolinite, quartz, and smectite. In addition, we have identified a number of trace metals such as Cd, Cu, Cr, and Zn, that are preferentially concentrated into the finer, inhalable, dust fraction and, thus, could present a health hazard in the urban areas around the basalt mining zone. The implication of this observation is that use of these nanometric-sized particulates as soil fertilizer may present different health challenges to those of conventional fertilizers, inviting future work regarding the relative toxicities of these materials. Our investigation on the particle size distribution, nano-particle mineralogy and chemical composition in typical BDW samples highlights the need to develop cleaning procedures to minimize exposure to these natural fertilizing basalt dust wastes and is, thus, of direct relevance to both the industrial sector of basalt mining and to agriculture in the region.

1. Introduction

Alteration of basalt is a common process in geosciences and agricultural tests. However, the current scientific understanding of the kinetic laws controlling such processes is very limited. Natural silicates, oxides, sulphates, and carbonates represent important sinks for metals/metalloids in soils through different immobilization mechanisms including sorption, surface complexation or co-precipitation. Rock waste application as agricultural fertilizer has a long history. For example, Leonardos et al. (1976a) reported centuries-old cases of the implementation of rock fragments in soil in Brazil. In recent years, many studies have been developed in recent years with the aim of applying rock reject material to soils, with positive results for productivity (da Silva et al., 2011; Lourenço, 2011; Prates et al., 1998; Plewka et al., 2009). This application of mineral particles as soil fertilizers, also known as the stonemeal technique, can provide important macronutrients such as Ca, K, Mg, N, P, Si, and S, as well as micronutrients such as Cr, Cu, Fe, Mn, Zn, and Na, to the plant, water, soil, and interfaces of the biosphere (Ramos et al., 2014).

In general, agricultural practises, especially in tropical regions, mostly rely on acid soils with low productivity without technology intervention. A great challenge in using basalt dust for agricultural activities is to obtain natural materials with a special ability to restore productivity. In Brazil, in the current years, increased construction and building activities have promoted an exploitation growth of basaltic, which are widely applied as ornamental rocks (Nunes et al., 2014). Silva et al., 2009a (Silva et al., 2010) investigated the productive processes of 110 basalt mining companies in Nova Prata, Rio Grande do Sul State, Brazil (Fig. 1) and revealed the existence of 647,000m^3 of basalt waste disposed in piles along with a monthly production of 7000m^3. Later studies (Lourenço, 2011; Ramos et al., 2014) have further demonstrated the growth of this sector, estimating a generation of 17,000 t of waste per month from 256 companies in the same region during 2011. The Basalt Dust Waste (BDW) use for stonemeal application as a fertilizer material is increasing in Brazilian agricultural production, being applied, for example, in soil amendment, cattle feeders, and soil stabilization. New or combined processes are manufacturing high grade and expensive materials for multiple specialized applications, although so far there remains little information with regard to the nanomineralogy of the basalt dusts involved, especially with regard to their utilization, handling, storage, and disposal. In an industrial context,

Fig. 1. Location of basalt mining are where samples for this study were obtained (Nova Prata).