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Evaluation of the natural fertilizing potential of basalt dust wastes from the mining district of Nova Prata (Brazil)

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ABSTRACT

This work studies the physical, physical-chemical, chemical and mineralogical properties of basalt dust waste from mining activities by measuring the availability of nutrients in an aqueous medium to evaluate the potential use of this type of waste as a natural fertilizer. The samples used in this study were obtained from companies in the mining district of Nova Prata in southern Brazil. The moisture, density, particle size classification, surface area, zeta potential, cation exchange capacity and chemical and mineralogical composition of the waste, as well as the availability of macronutrients and micronutrients (Al, Ca, Mg, Mn, P, K, B, S, Cu, Fe, Na and Zn), were studied. The wastes were combined with a crystalline phase of labradorite and quartz, and the primary oxides were SiO_2, Al_2O_3, Fe_2O_3, CaO, K_2O and Na_2O. Several important nutrients were transferred into the aqueous medium, indicating the significant potential of these particles in developing and facilitating plant metabolism and demonstrating the feasibility of the application of these dust wastes as a natural fertilizer. This work is an initial study, and more results are expected with the practical application of the waste, thereby contributing to a series of studies in this area. This research is of great importance to both the industrial sector of basalt mining and to agriculture in the region because it can create an alternative disposal treatment for tailings and improve the viability and sustainability of local farms, thereby avoiding excessive mineral fertilizer consumption.

1. Introduction

Several efforts have been made in recent years to mitigate the different environmental impacts related to agricultural activities. In particular, the use of conventional synthetic fertilizers consisting of nitrogen, phosphorus and potassium, namely NPK, has drawn significant attention due to the adverse environmental impacts caused by the excessive application of these products. The excess fertilizer is carried by rainwater from the soil surface to other water resources, causing pollution, algae proliferation and the eutrophication of aquatic ecosystems (Almeida et al., 2006; Hodges and Crozier, 1996; Santucci, 2012).

Several studies (Knapik, 2005; Nunes, 2012; Theodoro and Leonardos, 2006) have intensified the use of mineral particles as a soil fertilizer or pH corrective as alternatives to reduce agricultural costs and decrease the dependence on imported raw materials while avoiding environmental impacts (Fyfe et al., 2006). According to Almeida et al. (2006), the negative environmental impacts of these fertilizers are also a long-term concern. Almeida emphasized that the numerous differences between modern and traditional methods of managing soil fertility were related to the fact that nutrients must be made readily available in a form that was easy for the plants to absorb. However, readily available nutrients are easily lost through leaching or erosion and can also become unavailable by being fixed to soil particles. Both methods of soil fertility management therefore depend on the continual replacement of nutrients to support crop production. Ensuring the maintenance of soil fertility in the long term is one of the principal objectives of managing agricultural ecosystems.

The use of mineral particles as soil fertilizers, also known as a stone meal technique, can provide important macronutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as micronutrients such as iron, manganese, copper, zinc and sodium, to the plant/water/soil interface.

Approximately 60% of the small farmers in Brazil do not use any fertilizer on their properties, and approximately 50% of the fertilizers consumed in this country are imported, creating high costs for this sector (Loureiro et al., 2009).

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In recent years, increased construction and building activities have promoted an increase in the exploration of basalt minerals, which are widely applied as ornamental rock. While this development in the mineral sector is very important, the generation of waste has also increased, causing detrimental environmental problems that must be addressed. Toscan et al. (2007) investigated the productive processes of 110 basalt mining companies in Nova Prata Rio Grande do Sul, Brazil in 2005. The authors showed the existence of 647,000 m^3 of basalt waste disposed in piles along with a monthly production of 7000 m^3. In addition, Kautzmann (2011) showed the growth of this sector, estimating a generation of 17,000 tons of waste per month from 256 companies in the same region during 2011.

Numerous authors (Bailey, 1967; Graham, 1941; Hamaker and Weaver, 1982; Hensel, 1894; Keller, 1948, 1950; Lacroix, 1952; Lewis and Eisenmenger, 1948; Russel, 1961; Theodoro and Leonardos, 2006; van Straaten, 2002; Villiers and De, 1949) have shown that the addition of crushed rock to agricultural soil dates back to antiquity.

Basalt particles are among the major mineral fertilizers studied, researched and discussed in existing literature (Bezerra, 2010; Knapik, 2005; Nunes, 2012; Santucci, 2012; Toscan et al., 2007). In Brazil, interest in this mineral is because basalt mineral processing generates a significant amount of rock powder waste, which is composed of important mineral elements that can be used for plant metabolism. These particles are emitted in dust form from comminution operations or discarded in the solid/solid separation in screening units and thus constitute an adverse environmental impact for mineral industries. Brazilian environmental laws and inspections have been improved to improve the minimization of these wastes. Thus, new applications for these basalt mineral particles are an issue of concern. Leonardos et al. (2000) discussed the problem of sustainable tropical agriculture from a Brazilian viewpoint and reported on research related to the use of native rocks (stone meal) as an alternative or support for chemical fertilizers, emphasizing this practice as an important step towards sustainable development. According to the authors, stone meal must be included in quality of life strategies such as a cleaner environment and a partial return to multiple crop family farming, allowing that the use of rock fertilizers does not exclude other environmentally friendly alternatives. In addition, this technique may promote the re-establishment of soil fertility, thus reducing the application of NPK fertilizers.

Wang et al. (2000) investigated the ability of plant types to release K from slightly weathered gneiss of differing particle sizes; the different size fractions were compared in pot experiments with maize, pak choi and two alfalfa cultivars. The authors showed that the plant species influenced the potassium release, with maize and ryegrass demonstrating superior performance. In addition, the smaller particles (1 mm $<$ particle diameter $<$ 2 mm) were more efficient than particles with sizes in the range of 2 mm $<$ particle diameter $<$ 5 mm.

In addition, Theodoro and Leonardos (2006) evaluated and suggested alternatives to fertilization that used natural rocks in agricultural lands cultivated by small farmers, with the goal of achieving sustainable development. They emphasized that these rocks were sources of phosphorus, potassium, calcium, magnesium and several micronutrients indispensable to vegetable nutrition. This work initially reviewed the history of the Brazilian Agricultural sector, aiming to understand the causes that led the country to a widespread situation of economic, social, land division and ecological instability. They also outlined the use of the stone meal method in an analysis and identification of characteristics of the rural environment. In addition, they characterized dust waste particles and their *in situ* application in the "Brazilian Cerrado" region, gaining perspective on the region's agricultural sector to consider the premises associated with sustainable development.

Hinsinger et al. (2001) also studied the influence of distinct plant species on the weathering of basaltic rock, determining the amounts of Si, Fe, Ca, Mg, and Na released from basalt under leaching conditions. Based on their results, the authors determined that although the plant mechanisms were not fully elucidated in their experiments, the results supported the conclusion that larger plants can play a significant role in rock weathering, indicating that land plants need to be taken into account in the geochemical mass balance of elements, particularly for those elements that are absorbed by the plants.

In addition, Knapik (2005) evaluated the viability of basalt dust as fertilizer for *Mimosa scabrella Benth* and *Prunus sellowii Koehne*, showing that this mineral provided larger seedlings and observed superior results when the particles were mixed with horse dung. The author noted that this mixture provided seedlings with development despite the lack of ground aeration.

Zuba et al. (2011) also evaluated the yield, nutrition and fruit qualities of tomatoes by using different alternative sources of nutrients composed of conventional fertilizers, organic composts and rocks that were applied in seven combinations, thus resulting in different mixtures. The author showed that the highest production levels were obtained with chemical fertilizers but also showed that the use of mineral and organic fertilizers significantly reduced the incidence of soft rot and pests in comparison to the use of chemical fertilizers.

Therefore, this study asserts that global mining impacts can be minimized with the total utilization of the exploited resource, the recycling of the generated byproducts and innovative usage of the environmentally impacted areas. In this context, the study of the mining wastes as potential fertilizers is a practice that should be developed to further contribute to sustainability. The focus on the use of natural fertilizers is very important for the development of more sustainable farming and mining activities, thus providing several advantages to a significant portion of our society. This study examines a comprehensive characterization of basalt dust wastes from four ore deposits, examining the potential of available nutrients from both solid to liquid phases to incorporate these particles as fertilizer in southern Brazil.

2. Experiments

The samples were taken from four ore deposits from four different basalt mining organizations. These ore deposits were located in the mining district of Nova Prata in Rio Grande do Sul, Southtern Brazil. The wastes were classified as W-I from Basel Indústria e Comércio de Minerais (latitude: 28°36'39,38″S, longitude: 51°51'33,56'W), W-II from Concresul Britagem (latitude: 29°07′39,30″S, longitude: 51°29′37,50′W, W-III from Sindicato da Indústria de Extração de Pedreiras de Nova Prata (latitude: 28°46′27,37″S, longitude: 51°38′16,61′W) and W-IV from Zilli Basalto e Britagem (latitude: 28°45′09,20″S, longitude: 51°38′38,16′W).

Five random increments (4 kg) of basalt waste were collected from each ore deposit. These increments were then mixed, resulting in a primary sample of 20 kg that was then submitted to homogenization and subsequent quartering procedures according to standard methods for mineral particles (Oliveira and Aquino, 2007), resulting in two portions of 10 kg each. One portion (10 kg) was reprocessed by quartering, resulting in ten samples of approximately 1 kg that were stored in plastic bags and randomly selected to use in this study. Thus, the particle characterization results were an average of values of three aliquots of each bag chosen and related to the samples entitled W-I, W-II, W-III and W-IV.

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