Journal of Earth Science and Engineering 9 (2021) 7-12
doi: 10.17265/2159-581X/2021.01.002

Ornamental Rock Waste Application for Soil Remineralization

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Abstract: This study consists in the investigation of the application of ornamental rock tailings applied in remineralization in the Brazilian soil through the rocking technique. Due to the Brazilian dependence on the importation of agricultural inputs, the use of the method aims beyond improving the physical and chemical properties of the soil, supplying the demand for such data, and in return to give an adequate end to pollutant tailings. The tailings have chemical characteristics that are of great importance for soil composition. The methodology employed was divided into three stages, the first one was the physicochemical characterization of the rock dust, followed by the characterization of the soil experimented and the cultivation of the plant species Phaseolus Vulgari. The results obtained so far showed favorable results since the characteristics obtained through the physicochemical analyses were compatible with those suitable for the soil, after the application of the powder, which had its high pH and which proved that the tailings corrected the soil acidity of the sample in question, placing it at an ideal level for the cultivation of new species.

Key words: Ornamental rocks, agriculture, soil, remineralization.

1. Introduction

The demand for a healthier and better quality of life food in Brazil has been growing, as the country has its economy supported by agriculture, representing 21% of GDP in 2016. For this to occur, it would be necessary to adapt the agricultural bases. If they were available to the development of these food demands, whose most usual way found by her was through industrialized sources of nutrients, with the mass application of soluble and chemical fertilizers [1]. In the case of fertilizers, while highly advantageous because of the rapid availability of nutrients to plants, they have raised important questions about the depletion of non-renewable resources when mass applied and the environmental consequences of traditional farming techniques used in fragile ecosystems [1, 2].

According to the National Fertilizer Diffusion Association (2018), fertilizer deliveries to the market ended in June 2018 with 2992,000 tonnes, up 3.8% from June 2017, when 2883 thousand tons were delivered. While Brazil is the largest food producer in the world, it is also highly dependent on imports of raw materials for fertilizer formulation [3].

In this context, other fertilizer production techniques should be thought through, tested, and used, associated with rational land use and methods that have less impact on the environment [2]. The rocking technique is an exciting way to make nutrients available to plants, as well as soluble fertilizers. The technology has also contributed to the reduction of the Brazilian n dependence on resource imports and decrease the accumulation of ornamental waste deposited in the open, maintaining soil fertility and not generating social and environmental problems. The agronomic and economic viability of regional sources of nutrients may decrease the occurrence of migratory agriculture, being a good option for small farmers, as they are more accessible and cheaper.

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With the consolidation of the technique and the structuring of the production and consumption chains, macrominerals can even become a local economic alternative, replacing part of the fertilizer importation. The rocking technology enables interaction between two sectors of the economy: rock processing and agriculture, which currently operate with environmental degradation processes. This technique still meets the need to discard the tailings of ornamental products companies, the method of rocking would enable the interaction between two sectors of the economy: the beneficiation of rocks and agriculture, which currently operate with environmental degradation processes. One, due to inadequate waste disposal, the other due to the high demand for agro-polluting inputs [4].

The subject of the study is related to the application of industrial ornamental tailings in poor soils by the technique of sedimentation. The study aims to investigate the interaction between the residues and the soil to conclude if the application of these composites has been satisfactory compared to the results obtained by chemical fertilizers. Also, the objectives are to apply ornamental tailings to the soil and to evaluate their behavior over time, as well as to characterize the tailings in a physical-chemical context and to investigate the soil used for the experimentation. The justification for this is, as already mentioned, the existence of concern for the depletion of non-renewable resources (by the application of archaic techniques), the Brazilian dependence on the foreign market in the purchase and use of chemical fertilizers and the decrease in the amount of waste generated by beneficiation of ornamental rocks. The beneficiation of these rocks made the equivalent of 1.8 million tons in 2007 [2].

Ornamental rocks are lithological types that have a high content of quartz, mica, and feldspar, and have in their composition elements such as iron, magnesium, titanium, calcium, sodium, potassium and silicon [5]. These rocks classified according to their structure, mineralogical composition, texture, granulometry, and divided into slate, quartzites, granite, serpentinite steatites, and marble. In Brazil, the ornamental stone sector is very prominent, and in 2006 the country was the world's fourth-largest producer and exporter of decorative and cladding stones, surpassing several European countries and distinguished by the geodiversity of its raw materials. Today the sector represents 90% of commercial transactions, and marble shops represent 65% of the universe of companies in the sector with the support of the Marble and Granite Technological Center (CETEMAG), integrated with the Ministry of Science, Technology, and Innovation (MCTI) (Ministry data). It is possible that by 2020, the Brazilian sheet sawing capacity could exceed 100 million square meters per year [6].

Due to their textural, compositional, mineralogical features, and aesthetic (ornamental) beauty, these rocks are used in processing companies for the manufacture of furniture, paving, and walls. The most commonly used rock cutting process by companies in the industry is the diamond wire method, as well as the diamond, saw approach. In the diamond wire method, firstly drill holes in the plate to then insert the diamond wire, with the spliced ends, forming a closed circuit and placing over the drive pulley of the cutting equipment. During the cutting process, there are translational movements of the tensioned wire in contact with the plate, and water is added for cooling and cleaning of the cutting particles. After cutting, the plate goes through the polishing, which, besides giving better finishing, ensures higher resistance to weathering and chemical attacks [6].

The cutting process generates a series of residues such as debris, dust, and abrasive sludge. Among these wastes, the most worrying environmental sector is rock dust, which represents about 50,000 tons/year per company and is characterized by the presence of water used in the process and sand coming from the whole range of rocks cut in the company [7]. Abrasive sludge preserves the chemical properties resulting from the composition of ornamental rocks and is classified according to NBR 10004/2004 [5] as Class IIB waste - inert and has no toxicity [8].

Soils are composed of three phases, which are solid (organic and inorganic matter), liquid (soil solution or its presence of water), and gaseous (soil air). Minerals (inorganic matter) from rock weathering represent about 61% of its composition and are classified as primary (quartz, apatites, micas, limestone, biotites, plagioclase), secondary (kaolinite, halloysite, montmorillonite, vermiculite, illite) and clay fraction (minerals smaller than 0.002 mm). The ores present in the soil give it a range of elements, including oxygen, silicon, aluminum, iron, calcium, potassium, sodium, and magnesium, with oxygen prevailing, representing about 47% of its volume.

The soil, due to weathering, salt crystallization, and biological activities, in addition to its use for planting and breeding, ends up losing critical chemical elements for plant nutrition, such as calcium, magnesium, and potassium, weakly retained by soils.

The lack of minerals gives the soil great weakness and, besides generating harmful acidity for cultivation, causes a series of adverse effects for agriculture that can be easily noticed visually in plants. Lack of nitrogen, phosphorus, potassium, copper, and iron can cause growth retardation of the seedling and its plant development, which inhibits the proper nutrient distribution and triggers plant necrosis, besides causing diseases such as chlorosis [9]. To combat this problem, the soil needs to be remineralized or corrected.

Among the various segments of agricultural practice, there is the growing demand and exercise of urban and periurban agriculture, characterized by the use of small areas within cities or in their respective regions for agricultural production, livestock, and conservation of natural resources.

Agriculture is a well-developed sector in the country. However, it has excellent vulnerability since most come from dependence on inputs that make up the formulations of soluble fertilizers (N, P, and K). This dependence on fertilizers occurs due to the current production pattern, which becomes indispensable in the supply of nutrients to intensely leached soils [10]. According to the Ministry of Agriculture, Livestock, and Supply (MAPA), Brazil is a major importer of agricultural inputs, because even being the fourth largest consumer of fertilizers in the world, it only accounts for 2% of world production. In recent years there have been slight variations in fertilizer imports ranging around 70% of consumption. In 2007, there were 2.8 million tons of nitrogen (75% imported), 3.7 million tons of phosphorus (51% imported), and 4.2 million tons of potassium (91% foreign), according to the Association. Fertilizer Diffusion (Associação Nacional para a Difusão de Adubos (ANDA)).

The ground rocks used are registered with the Ministry of Agriculture, Livestock, and Supply (MAPA) according to Law 12.890/2013 [11]. Instructions 5 and 6 set out the specifications and warranties, tolerances, registration, packaging, labeling, and advertising of remineralizes intended for agricultural activity. These normative instructions establish two criteria for remineralizes regarding specifications and warranties. They are proven by geochemical and mineralogical analyses, such as minimum percentages of the sum of bases and maximum rates of potentially toxic elements, pH indication, and particle size. Also, agronomic efficiency needs classification by public research institutions or entities accredited by MAPA.

2. Methods and Materials

The ornamental tailings to be used in the soil as rock dust come from a company located in São Leopoldo in Brazil. The samples were collected at three different times, with a period of 7 days between collections, since the company's tailings were part of the total amount produced by the company, and there was no separation of residues by the beneficiation process or the characteristics of the rock used.

From the three samples collected, a composite sample was made. Thus, the tailings used for the research had the composition of all rocks used by the company, which are part of the characteristics of granite, marble, quartz, slate, and basalt. All the stones used by the company come from the region of Cachoeiro de Itapemirim - Espirito Santo and only went through the process of cutting the diamond saw, without the addition of grit or other abrasive blasting material. With the three collections of ornamental tailings made, they were placed in aluminum molds to evaporate the water at room temperature, since they would be used later as a powder. Characterization occurred through differential thermal analysis and thermogravimetry, electrical conductivity, X-ray diffraction, and X-ray fluorescence.

Also, dry granulometry, specific mass, scanning electron microscopy, pH by solution, neutralizing power, total neutralizing relative power, and moisture were characterization stages.

After the physicochemical characterization of the three rock dust collections, the researchers collected a quantity of soil necessary for the incubation experiment. The soil collected was taken from a small farm located in the municipality of Dois Irmãos and was obtained from the 0-20 cm layer of the horizon. For the experiments, the researchers transferred the soil to study bucket, which received five holes in the bottom surface, allowing water to flow during preparation. They also received 2 cm of gravel 1 (8 to 12 mm) and 10 cm of soil collected. The dosages used for the experiments were 1.5 ton/ha and 3.0 ton/ha, and because it was quantitative experimentation, it occurred in quintuplicate study buckets.

The application of rock dust in experimental buckets occurred based on the surface area of the bucket used. As three collections were performed by sampling the ornamental tailing, it was necessary to mix the collections before applying to the homogenized soil manually. After the use of the rock dust to the test buckets, they were prepared for 36 days with irrigation of 90 ml of water every 48 hours and left in an environment exposed to weather and calm. The technique of sedimentation consists first of the fertilization of the soil and then the planting of some species. The experimentation produced 15 buckets, according to Fig. 1.

The authors analyzed powdered ornamental tailings, pure soil, and soils from the experimentation buckets for qualification and comparison. For the analysis, the authors used electrical conductivity, X-ray fluorescence, particle size, macro and micronutrients, specific mass, organic matter, pH, and humidity. The authors also monitored the planting of the species Phaseolus Vulgari, to identify which dosage presented the highest application potential index.

All management conditions except rock dust content were the same for the study buckets and exposure to climatic variation from the external environment. The researchers planted two seeds in each bucket and then monitored and analyzed by forming leaf area and plant height.

3. Results and Discussion

The pH measured for ornamental tailings, for fresh soil and applications of formulations of 1.5 ton/ha and 3.0 ton/ha of rock dust according to Table 1.

Rock dust behaves as a soil corrective, raising the soil pH from 5.39 to 6.40 and 6.64 when the addition takes place at 1.5 ton/ha and 3.0 ton/ha. The presence of calcium in high levels corroborates this result according to Table 1.

Fig. 1 Simplified scheme of the experimental procedure for adding rock dust to the soil.

Fig. 2 Experimentation.

Table 1 pH of the Samples in $CaCl_2$ solution.

Sample	Measure 1	Measure 2	Measure 3
Tailings 1st Collection	8.15	7.98	-
Tailings 2nd Collection	8.19	8.35	-
Tailings 3nd Collection	8.14	8.19	-
Fresh soil	5.39	5.40	5.40
Soil 1.5 tons/ha	6.40	6.34	6.34
Soil 3.0 tons/ha	6.64	6.69	6.70

Table 2 Electrical conductivity at 25°C (μs/cm).

Sample	Measure 1	Measure 2	Measure 3
Tailings 1st Collection	1808.0	1796.2	-
Tailings 2nd Collection	1761.7	1837.0	-
Tailings 3nd Collection	1758.9	1743.1	-
Fresh soil	1742.6	1761.1	1724.6
Soil 1.5 tons/ha	2040.0	2090.0	2040.0
Soil 3.0 tons/ha	2060.0	2000.0	2060.0

The electrical conductivity found for all samples involved in the experiment can be found in Table 2.

Qualitative X-ray fluorescence identified essential elements in the chemical composition of rock dust and soil, according to Table 3.

The authors found the specific mass of the three rock dust collections and the soil sample used for the experiments, according to Table 4.

The thinner the material, the higher its reactivity potential. This aspect is relevant because it can influence the chemical properties of the soil, namely its nutrient adsorption capacity, according to Table 5.

4. Conclusions

After the physicochemical characterization and application of rock dust in the soil, as well as the monitoring of the cultivation of Phaseolus Vulgari species, it is possible to conclude some important

Table 3 Results of qualitative X-ray fluorescence.

Sample	5% < x < 50%	x < 5%
Tailings 1st Collection	Si, Ca, Fe, Al, K	Ti, Ba, Sr, S, Mn, Zr, Rb, Zn, Y
Tailings 2nd Collection	Si, Ca, Fe, Al, K	Mg, Ti, P, Sr, Mn, S, Zr, Cu, Rb, Zn, Y
Tailings 3nd Collection	Si, Ca, Fe, Al, K	Mg, Ti, Sr, Mn, Zr, S, V, Rb, Zn, Y
Fresh Soil	Fe, Si e Al	Ba, Ca, Cr, Cu, K, Mg, Mn, Ni, S, Sr,Ti, Zn e Zr

Table 4 Especific mass.

Sample	5% < x < 50%
Tailings 1st Collection	2.6920
Tailings 2nd Collection	2.6715
Tailings 3nd Collection	2.6543
Fresh Soil	2.4245

Table 5 Surface area

Sample	Surface area (m²/g)
Tailings 1st Collection	2.7917
Tailings 2nd Collection	2.5467
Tailings 3nd Collection	2.7917

Table 6 Laser grain size Average grain Ø (µm)

Sample	Average grain Ø (µm)
Tailings 1st Collection	23.64
Tailings 2nd Collection	21.35
Tailings 3nd Collection	22.61
Fresh Soil	13.02

Table 7 Neutralizing Power (NP).

Sample	% neutralization in $CaCO_3$
Tailings 1st Collection	29.0899
Tailings 2nd Collection	26.9688
Tailings 3nd Collection	27.6967

Table 8 Sieve Size: Particle Size.

Sieve	1st Collection		2nd Collection		3nd Collection	
mm	Mass (g)	% Retained	Mass (g)	% Retained	Mass (g)	% Retained
0.15	0.80	1.98	1.23	3.09	1.33	2.68
0.07	4.30	10.62	2.54	6.35	3.95	7.91
Bottom	35.40	87.41	36.20	90.56	44.71	89.41
Total	40.50	100.0	39.98	100.0	50.00	100.0

aspects about the application of industrial ornamental tailings by the rocking technique. The three collections by ornamental rock tailings sampling presented similar results and behaviors, whether in the granulometry, the qualitative X-ray fluorescence, the acidity, the specific mass, the surface area, and the neutralizing power. The tailings produced have uniform characteristics, without significant variations and alterations. Also, the chemical composition of the collected ornamental residues, used under the rock powder physiognomy, has essential constituents for the return of minerals to the soil, with the presence of potassium, calcium, magnesium, sulfur, manganese, zinc and iron. They are part of the macronutrients and micronutrients essential for the excellent development of seedlings in fertile soils.

The authors verified the application of rock dust to the soil in the 1.5 ton/ha and 3.0 ton/ha formulations that had high acidity and electrical conductivity. As the application resulted in an increase in pH, and both formulations showed a difference, the researchers concluded that for more significant correction of soil acidity, when there is a case of intensely poor soil, the amount of 3.0 tons should be used. Based on the results, the authors preliminarily conclude that the studied ground had its fertility recovered since soils with pH between 6 and 7 are ideal for the cultivation of new species.

Although the authors performed tests and obtained favorable results, research in this field requires continuity applied in diversified agricultural production to observe the response in a greater diversity of species. Therefore, the continuity of the study will be in the monitoring of new seedlings and the monitoring of the macronutrients and micronutrients of the crops, to conclude if the rock dusting technique with the application of rock dust in the soil continues to show positive results.

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