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Using marble wastes as a soil amendment for acidic soil neutralization

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ABSTRACT

One of the most important factors limiting plant growth is soil pH. The objective of this study is to determine the effectiveness of marble waste applications on neutralization of soil acidity. Marble quarry waste (MQW) and marble cutting waste (MCW) were applied to an acid soil at different rates and their effectiveness on neutralization was evaluated by a laboratory incubation test. The results showed that soil pH increased from 4.71 to 6.36 and 6.84 by applications of MCW and MQW, respectively. It was suggested that MQW and MCW could be used as soil amendments for the neutralization of acid soils and thus the negative impact of marble wastes on the environment could be reduced.

1. Introduction

Liming is a common method to increase the pH of acid soils. The liming material reacts with carbon dioxide and water in the soil to yield HCO_3^-, which removes the H^+ and Al^{3+} from the solution, raising the soil pH (Safari and Bidhendi, 2007; Muthukrishnan and Oleske, 2008). Naturally occurring minerals such as lime (predominantly $CaCO_3$) are commonly used to reclaim acid soils (Wang et al., 2011).

Marble is a crystalline metamorphic limestone, basically containing calcite ($CaCO_3$) and maybe dolomite ($CaMg(CO_3)_2$) (Segadães et al., 2005). Turkey has approximately 3872 million m^3 of valuable marble reserve (Celik and Sabah, 2008). On the other hand, as a result of the marble production activities, marble-manufacturing industry produces high amount of waste. Waste generation continues from mining process to final product and is about 50% of mineral mined; the dried slurry product is quite fine. 90% of the particles are below 200 μm. The waste of marble can cause environmental problem and economic loss if it is not used. However, waste marble can be used as a neutralization material for acid soil (Aruntas et al., 2010).

Marble wastes are generated by quarries (marble quarry waste-MQW) and processing plants (marble cutting waste-MCW). The proportion of marble discharged as waste during block production at the quarries is equal to 40–60% of the overall production volume. The waste generation rate at marble processing plants is around 30–35% and this varies according to shape and kind of blocks being cut (Celik and Sabah, 2008). The large amount of marble wastes is a serious problem for the industry and the environment because of being discarded into rivers and lagoons without any treatment. This type of waste has a good potential to be used as an amendment for the neutralization of acid soils (Xenidis et al., 2002; Karasahin and Terzi, 2007; Bilgin et al., 2012).

The objective of this incubation study is to determine the effectiveness of marble waste applications on neutralization of soil acidity. More specifically, this study aimed to investigate how soil pH changes resulting from MQW and MCW amendments varied with incubation time and thereby determine an optimum incubation period and optimum amendment ratios for the neutralization of acid soils.

2. Materials and methods

2.1. Soil and liming materials

A composite surface soil sample (0–20 cm) was taken from the Kelali garden, Inece village, Bulancak town, Giresun, Turkey (38°14′60″E, 40°51′54″N). They were air-dried, passed through a 2-mm sieve and thoroughly mixed. Some chemical and physical properties of the soil samples are shown in Table 1. Particle size

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Table 1
Some physical and chemical properties of the studied soil. CEC; cation exchange capacity.

Texture				Field capacity (%)	Bulk density ($g\ cm^{-3}$)	pH 1:2.5 (v/v)	Exchangeable cations ($cmol_c\ kg^{-1}$)				CEC ($cmol_c\ kg^{-1}$)	H saturation (%)
Clay (%)	Silt (%)	Sand (%)	Textural class				Ca	Mg	Na	K		
21.0	34.8	44.2	Loam	37.0	1.3	4.71	6.95	1.79	0.70	0.70	23.1	56.0

distribution was determined using the Bouyoucos hydrometer method (Gee and Bauder, 1986). Field capacity was determined in 0.033 MPa pressure using a membrane extractor (Cassel and Nielsen, 1986). Bulk density was determined as described by Blake and Hartge (1986) and pH measured in soil suspensions with a soil to water ratio of 1:2.5 (v/v). The exchangeable cations were determined to be the difference between the soluble salts extracted with deionized water using the fixed-ratio extract method (Rhoades, 1982) and the total extractable cations extracted using the ammonium acetate method (Thomas, 1982). The cation exchange capacity was determined with a flame photometer using sodium acetate-ammonium acetate buffered at pH 7 (Rhoades, 1982).

The materials used as soil amendment, marble quarry wastes (MQW) and marble cutting wastes (MCW), were taken from Afyonkarahisar region of Turkey. Moreover, agricultural lime (AL) produced by Niksar AS was applied to soil in order to compare the effectiveness of marble waste applications for the neutralization of soil acidity. The pH and $CaCO_3$ contents of the liming materials are given in Table 2.

The chemical compositions of the AL, MQW and MCW were determined using the X-ray fluorescence (XRF-Philips PW 1400) technique. The X-ray diffraction method (XRD-Rigaku Geigerflex D/max-series) was used to determine the mineralogical compositions and the laser diffraction technique (Coulter LS 230) was used for the definition of the particle size distribution.

2.2. Soil incubation

A column (Φ10 cm × 35 cm) test was conducted for evaluating the effectiveness of the liming materials on neutralization of acid soil under laboratory conditions. The total amount of marble waste applied was calculated as described by Brady and Weil (2004). As each molecule of $CaCO_3$ neutralizes two H^+ ions through the following reaction:

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$$

Table 2
The pH and $CaCO_3$ (%) contents of the liming materials.

	Agricultural lime (AL)	Marble quarry waste (MQW)	Marble cutting waste (MCW)
pH	13.03	8.44	8.08
$CaCO_3$ (%)	100.00	99.24	94.12

Table 3
Chemical composition of the AL, MQW and MCW materials determined by XRF (wt %). LoI: Loss on ignition (CO_2).

Oxide compound (%)	AL	MQW	MCW
CaO	55.86	55.04	50.80
Na_2O	0.04	1.87	0.68
MgO	0.58	2.01	9.84
Al_2O_3	0.70	0.63	0.76
Fe_2O_3	0.29	0.22	0.48
K_2O	0.08	0.05	0.04
LoI	42.60	35.20	37.20

the mass of lime needed was 5 g $CaCO_3$ per kilogram of soil, a bulk density of 1.3 g cm^{-3} for the surface soil to a depth of 20 cm. Considering the purity of MQW (99.24% $CaCO_3$) and MCW (94.12% $CaCO_3$) and taking into account that not all the $CaCO_3$ in the amendment completely reacts with the soil, the amount of lime required was adjusted with three additional rates for MQW and MCW (0, 100% (1:1), 150% (1.5:1) and 200% (2:1)) each with three replications. A non-amended control treatment was also conducted.

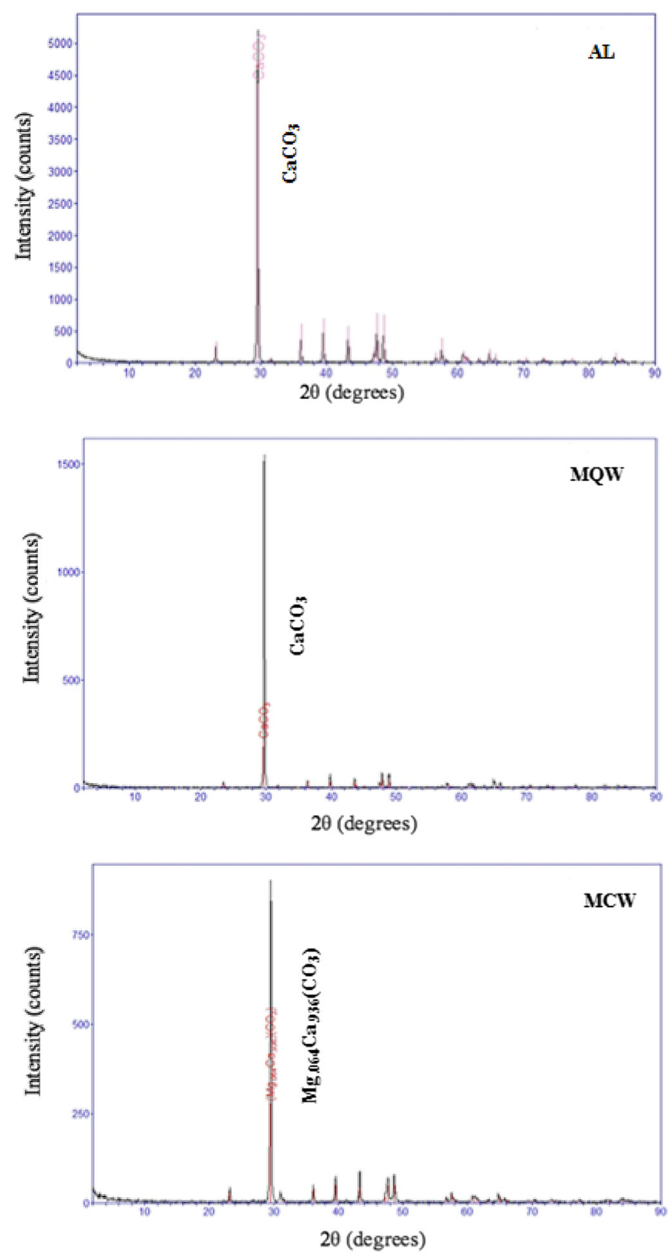

Fig. 1. X-ray diffraction patterns of the AL, MQW and MCW materials.