

Georgian laumontite as an immobilizing agent for remediation of lead-contaminated soil

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Abstract

Heavy metals are a major source of environmental pollution, and the problem is becoming increasingly critical worldwide. Soil contamination by heavy metals is particularly hazardous because these elements are non-biodegradable, can accumulate in the soil for many years, and are readily taken up by plants. One of the major factors determining the solubility of heavy metals in soil is low soil pH. The addition of zeolite to soil significantly increases its pH, facilitates heavy metal adsorption on its surface, and ultimately reduces their solubility and bioavailability.

The presented work investigates commercially available Georgian natural zeolite laumontite to evaluate its feasibility as an immobilizing agent for Pb⁺² ions in lead-contaminated soils. The adsorption of lead ions (pb⁺²) was studied in pure soil and in the soil amended with different proportions (10, 20, 30%) of laumontite (Lmt). The addition of zeolite increased soil pH by 4.52% (soil+10% Lmt), 9.68% (soil+20% Lmt), and 13.95% (soil+30% Lmt) compared with the untreated soil, where no zeolite was added. Correspondingly, the amount of immobilized Pb⁺² ions in the soil samples increased, with the highest retention observed in the soil sample containing 30% laumontite. The results confirm the feasibility of the application of Georgian laumontite as an immobilizing agent for the remediation of lead-contaminated soil.

Keywords: Natural zeolite; Laumontite; Lead-Contaminated Soil; Immobilizing Agent

1. Introduction

Heavy metal pollution of soil caused by anthropogenic activities is a major concern worldwide in modern agriculture. Non-degradable heavy metals tend to accumulate in soil, threaten the ecosystem, and pose a potential risk to human health when they are readily released into soil solutions or otherwise become bioavailable to biological processes. However, if these metals are bound up in relatively inert and insoluble compounds, the associated environmental risk can be significantly reduced. The growing concern regarding soil quality and the need to restore soil to its original properties has encouraged the development of new remediation approaches. One promising technique for minimizing the risk of heavy metal contamination and restricting their bioavailability is the introduction of immobilizing agents into soil. Compared with other remediation techniques that mainly focus on reducing metal mobility, *in situ* chemical immobilization is relatively inexpensive, provides long-term remediation of contaminated soils through the formation of low-solubility compounds, and reduces environmental risk. Over the years, natural zeolites have been considered promising materials for this purpose due to their strong specific capacity to bind heavy metals in soils [1, 2, 3].

Zeolites are common minerals found in sedimentary rocks of various geological ages and environments. They are three-dimensional crystalline, porous, hydrated aluminosilicates consisting of systems of interconnected chambers and channels. They have a general formula $M_xD_y [Al_{(x+2y)} + 2_ySi_{n-(x+2y)} O_{2n}] mH_2O$, where x and y represent the number of

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mono- and bivalent cations, n represents their valence, and m represents the number of water molecules. The geometrical parameters and large cage-like cavities of zeolites are responsible for their high adsorption capacity and ability to act as sorbents for environmental pollutants. Due to their excellent ion-exchange properties, zeolites can selectively adsorb certain harmful or unwanted elements from soil and show a strong affinity for some heavy metals such as lead, chromium, nickel, and zinc, even at their trace concentrations. The important pathways of zeolite application are ecology, environmental protection, and agriculture, including soil amendment and heavy metal immobilization. Direct application of zeolites to the soil not only enhances the soil sorption capacity, but also reduces soil acidification, significantly increase soil pH and promotes precipitation of carbonates and formation of oxides that facilitates heavy metal adsorption on their surfaces. As a result, the solubility and bioavailability of heavy metals ultimately reduce, contributing to de-pollution of contaminated soils. An additional advantage is that ions and molecules already adsorbed within the zeolite structure can be removed or exchanged without destroying the aluminosilicate framework of zeolite. Therefore, further extensive research is required to identify the most effective natural zeolite and optimize its application methods for soil remediation [4, 5, 6, 7, 8].

Low soil pH is one of the key factors influencing the solubility of heavy metals. The addition of zeolite significantly increases soil pH, facilitating heavy metal adsorption on its surface and ultimately reducing their solubility and bioavailability [9].

In general, the solubility of heavy metals in soil solution is greater under acidic conditions, and this increased solubility enhances their uptake by plants. Since Heavy metals exhibit lower mobility under alkaline conditions, increasing soil pH is an effective approach for reducing heavy metal contamination in soil [10, 11].

2. Materials and methods

2.1. Experimental

The objective of this study was to investigate the feasibility of using commercially available Georgian natural zeolite laumontite for the immobilization of Pb^{+2} ions in lead-contaminated soils. Physical characteristics of Georgian laumontite are as follows: composition of the unit cell $[(Ca_4)(Al_8Si_{16}O_{48}) \cdot 16H_2O]$, porosity- 34%, channel dimensions- $4.6 \times 6.3 \text{ \AA}$, ion exchange capacity - 4.2 meq g^{-1} [11,12]. The object of the research was gray-cinnamomic soil (pH 6.31) collected from the 0-25 cm layer of agricultural soil in eastern Georgia. According to Georgian environmental regulations, the permissible concentration of lead in soil is 3.2 mg/kg [13].

To carry out the above investigation, the adsorption of lead ions (Pb^{+2}) was studied in pure soil, and in the soils amended with different percent composition (10, 20, and 30%) of laumontite (Lmt). X-ray analysis of laumontite rock showed 80% content of zeolite phase. Soil pH is a fundamental and essential factor significantly influencing the behavior and toxicity of heavy metals in soil, affecting their availability to plants both directly and indirectly [14].

Before the experiment, the pure soil was heated at $400\text{-}450 \text{ }^\circ\text{C}$ for 2 hours to destroy organic matter. A 25 g sample of crushed pure dry soil (sieved through a 1 mm mesh) was placed in a separate beaker. Soil samples containing laumontite were prepared by thoroughly mixing the above amounts of zeolite with pure soil and placing them in different beakers. Before use, the zeolite was heated at $300\text{-}350 \text{ }^\circ\text{C}$ for 2 hours and sieved through 0.2 mm mesh. To determine soil pH, suspensions of pure soil and soil + Lmt mixtures were prepared in distilled water at a 1:5 (w/v ratio, and the pH was measured using a Mettler Toledo pH and Conductivity Sensor LE703. Addition of zeolite increased pH by: 4.52% (soil+10% Lmt), 9.68% (soil+20% Lmt), and 13.95% (soil+30% Lmt).

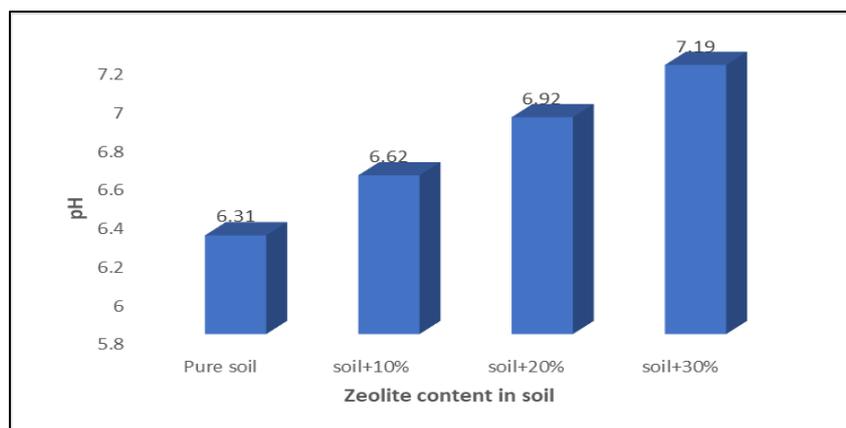


Figure 1 Effect of Zeolite (Lmt) amount on the soil pH change

25 ml of 0.001N $Pb(NO_3)_2$ solution was added to each sample [11, 12]. All the samples were incubated for 10 days to reach equilibrium under controlled conditions: 25°C and 60% humidity were maintained by adding the required amount of water every two days. The experiment comprised 4 treatments with three replicates. The treatments applied were the addition of different concentrations of zeolite (10, 20, and 30 %), as well as a control treatment where no zeolite was added. After 10 days, the samples were filtered through Whatman #42 filter paper, and the well-dried soil samples were analyzed. The results are represented in Fig. 2.

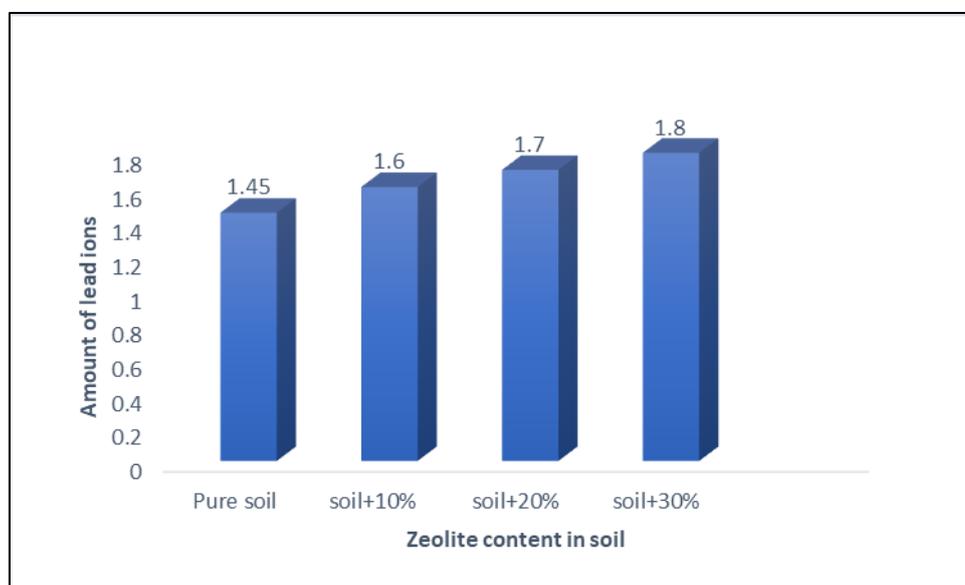


Figure 2 Amount of immobilized Pb^{+2} ion depending on the zeolite content of the soil samples (in ppm)

The samples were analyzed on the device (XRF)-SPECTROSCOUT, XEP-04 (firm SPECTRO Analytical Instruments GmbH) to determine the amount of immobilized Pb^{+2} ion in the soil samples.

3. Results and discussion

Georgian natural zeolite laumontite is an inexpensive material with high ion exchanged capacity and can act as an effective immobilizing agent for Pb^{+2} ions from lead-contaminated soil. Heavy metals are generally highly soluble at low soil pH and are therefore readily available for plant uptake from soil solution. The results of the experiment showed that the introduction of Georgian laumontite into the soil increased soil pH and consequently reduced the concentration of Pb^{+2} ions in the soil solution. This process limits the mobility of lead ions, preventing their migration in biological systems and their subsequent accumulation there. Ultimately, these effects reduce the risk of harmful impact of heavy metals on the environment and living organisms.

4. Conclusion

The obtained data proved that the Georgian natural zeolite Laumontite has a good ability to retain lead ions. A direct introduction of laumontite into the soil samples decreased the acidity of the soil and promoted lead ion adsorption on its surface from the soil. The higher the amount of the added zeolite (30%), the higher the concentration of immobilized lead ions in the soil, which in its turn lowers their bioavailability. All the above enable us to assume the feasibility of the application of Georgian Laumontite as an immobilizing agent for the remediation of lead-contaminated soil.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

References

- [1] L. Trakal, et.al. Dolomite limestone application as a chemical immobilization of metal-contaminated soil. *Plant, soil, and environment*. v.57, 2011 (4), 173-179, DOI:10.17221/408/2010-PSE
- [2] Wei-yu Shia, et.al. Progress in the remediation of hazardous heavy metal polluted soils by natural zeolite. *Journal of Hazardous Materials* 170 (2009) 1–6
- [3] Ponyadira Kabwadza-Corner, Erni Johan, Naoto Matsue. pH Dependence of Lead Adsorption on Zeolites. *Journal of Environmental Protection*. vol.6, No.1, January 2015. DOI: 10.4236/jep.2015.61006
- [4] Pitcher et al., 2004S.K. Pitcher, R.C.T. Slade, N.I. Ward. Heavy metal removal from motorway stormwater using zeolites. *Sci. Total Environ.*, 334–335 (2004), pp. 161-166, 10.1016/j.scitotenv.2004.04.0354.
- [5] Reháková, M., Čuvanová, S., Dzivák, M., Rimár, J., Gaval'ová, Z., 2004. Agricultural and agrochemical uses of natural zeolite of the clinoptilolite type. *Curr. Opin. Solid State Mater. Sci.* 8, 397–404. <https://doi.org/10.1016/j.cossms.2005.04.004>.
- [6] Ramesh, K.; Biswas, A.K.; Somasundaram, J.; Subbarao, A. Nanoporous zeolites in farming: Current status and issues ahead. *Curr. Sci.* 2010, 99, 760–765.
- [7] Pleśniak and Trzop, J. Pleśniak, W. TrzopCodzienność z zeolitami. *Analit*, 2 (2016), pp. 146-151
- [8] Renata Jarosz et.al. The use of zeolites as an addition to fertilizers – A review. *Catena*, v. 213 (2022) 106125. <https://doi.org/10.1016/j.catena.2022.106125>
- [9] Shia, W. et. al. Progress in the remediation of hazardous heavy metal-polluted soils by natural zeolite. *J. Hazard. Mater.* 2009, 170, 1–6.
- [10] Muhammed Moeen, Tian Qi, et. al. Use of Zeolite to Reduce the Bioavailability of Heavy Metals in a Contaminated Soil. *Journal of Ecological Engineering*, v.21 #7, 2020, p.186-196. <https://doi.org/10.12911/22998993/125547>
- [11] Tsitsishvili G.V., Andronikashvili T.G., et.al. *Natural Zeolites*. M.; Khimia, 1985, 224 p.
- [12] Mousumi Mondal, et.al. Zeolites Enhance Soil Health, Crop Productivity and
- [13] *Environmental Safety*. *Agronomy* 2021, 11, 448. <https://doi.org/10.3390/agronomy11030448>
- [14] Regulation #61 of the Minister of Environment and Natural Resources of Georgia, July 18, 2003, Tbilisi.
- [15] Radziemska M., Study of applying naturally occurring mineral sorbents of Piland (dolomite, halloysite, chalcadonite) for aided phytostabilization of soil polluted with heavy metals. *Catena* 163, 123-129