International Journal of Environment, Agriculture and Biotechnology
Vol-7, Issue-4; Jul-Aug, 2022

Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Peer Reviewed

Study on the Physico-Chemical Properties of Cement Dust and the Possibility of Application in Agriculture

Indira Šestan[1], Melisa Ahmetović[2], Besim Salkić[3], Emir Imširović[3], Nedžad Šeper[5]

[1]Department of Physical Chemistry and Electrochemistry, Faculty of Technology, University of Tuzla, Bosnia and Herzegovina
Email: indira.sestan@untz.ba
[2]Department of Physical chemistry and Electrochemistry, Faculty of Technology, University of Tuzla, Bosnia and Herzegovina
Email: melisa.ahmetovic@untz.ba
[3]Department of Plant production, Faculty of Technology, University of Tuzla, Bosnia and Herzegovina
Email: besim.salkic@untz.ba
[4]Department of Plant production, Faculty of Technology, University of Tuzla, Bosnia and Herzegovina
Email: emir.imsirovic@untz.ba
[5]Department of Plant production, Faculty of Technology, University of Tuzla, Bosnia and Herzegovina
Email: nedzad.seper99@gmail.com

Received: 27 Jul 2022; Received in revised form: 21 Aug 2022; Accepted: 25 Aug 2022; Available online: 31 Aug 2022

Abstract— *Cement dust is created as a by-product during the production of cement, and in its composition it contains high concentrations of calcium oxide (CaO), potassium oxide (K_2O) and other important micro and macro elements. Due to its composition, it is suitable for correcting the pH of the soil, as well as for the uptake of essential elements by plants. The ability to accumulate essential and non-essential heavy metals also depends on the cultivated plant species, and vegetables show the greatest affinity for these elements. The application of cement dust as a soil additive used to improve the physico-chemical soil properties is examined in the paper. After the addition, the soil was mechanically cultivated and planting of the vegetable crop tomato was carried out. The content of essential elements and heavy metals was determined in the soil, cement dust, and tomato fruits grown on soil with and without the addition of cement dust. Due to the high pH value, high conductivity as well as the high content of CaO, it is very important to examine in real conditions how the addition of cement dust to the soil affects the formation of micro and macro elements as well as the content of heavy metals when growing tomatoes. The results showed that the cement kiln dust is an effective addition to the soil because it is a source of calcium, potassium and other essential elements without affecting the loss of quality or contamination with heavy metals during production.*

Keywords— ***Physico-chemical characterization, cement dust, heavy metals, tomato.***

I. INTRODUCTION

With the increase in the number of the population in the world, the need for food production has also increased, which conditions the investment of great efforts in the field of agricultural sciences with the aim of achieving maximum yields. Each plant for its growth and development has certain requirements in the supply of plant elements that plants mainly use from the soil [1] The fact that chemical substances are present in the environment does not necessarily mean their availability for adoption by living organisms or incorporation into them, i.e. their bioavailability [2]. Plants need macronutrients and micronutrients for their growth. The main difference is in the amount of each biogenic element that plants need. If it is about a larger amount that the plant requires during its life cycle, it is about macronutrients, that is, if the plant requires biogenic elements in small amounts, it is about micronutrients. However, there is no difference in importance; both are necessary for the proper growth and development of the plant [3]. Plants have a highly specific mechanism of receiving and storing essential micronutrients from the environment, even at low ppm values. They also developed the mechanism of translocation and storage of micronutrients. These same mechanisms of receiving, translocation and storing also affect the absorption of toxic elements [4]. Heavy metals have multiple importance:

- they represent an important raw material for numerous industrial branches,
- some of them are essential for living organisms,
- they can have a favorable effect on agricultural productivity and
- most of them are often significant pollutants of the environment [5].

Heavy metals are characterized by different chemical, physical and physiological effects. Some of them are necessary for living organisms, such as: zinc (Zn), iron (Fe), molybdenum (Mo), manganese (Mn), cobalt (Co), selenium (Se), copper (Cu). Toxic metals are considered very dangerous pollutants and represent a great danger to all living organisms, humans, animals and plants [6]. Heavy metals are natural components of many food products, whether eaten fresh or processed [7]. The transfer of heavy metals from the soil to vegetables and fruits is the basis of the entry of heavy metals into the food chain [8]. The choice of the place of cultivation and the type of vegetables is very important because there can be too high a concentration (above MDK) in vegetables produced in gardens in urban areas. We can expect the lowest concentrations in fruit vegetables, and the highest in root vegetables [9]. It is considered that the toxicity of heavy metals is evident only if their concentration in pla[11],. nt tissue is increased above average values [10]. Disposal of cement dust is very difficult and causes danger to the environment. In order to minimize the adverse environmental impact of cement dust, many studies have been conducted to examine the beneficial commercial use of cement dust [11], [12]. Cement dust can be defined as a particulate material consisting of raw material, clinker particles and some calcined raw materials collected from the exhaust gas kilns of the Portland cement [13], [14], [15]. The use of cement dust in agriculture is useful and practical because it is a tool that improves soil properties and is a source of nutrients for plants. In many parts of the world, many researchers have proposed the use of cement dust to improve soil quality and increase yields [16]. X-ray diffraction analysis showed that the main components of cement dust are calcite ($CaCO_3$), quartz (SiO_2) and calcium sulfate ($CaSO_4$) [17].

The aim of the paper is to carry out the physico-chemical characterization of cement dust and examine the influence of its addition to the soil on the translocation of micro and macro elements as well as the content of heavy metals in tomato fruits in order to establish its positive agrochemical properties and the potential possibility of its use in agriculture.

II. METHODS

Material

The experimental study was conducted in the campus area of the University of Tuzla, on a land area of 500 m^2. A soil sample for analysis (about 2 kg) was taken from a depth of 0-30 cm, and after delivery to the laboratory, the pH value, conductivity, content of micro and macro elements and content of heavy metals were determined. After that, the physico-chemical characterization of the cement dust was carried out in order to determine the composition, pH value, content of micro and macro elements as well as the content of heavy metals. After the soil and cement dust analysis, cement dust was applied in the amount of 50 kg/100 m^2 per land surface, after which plowing was carried out. After 30 days, tomatoes were planted, where their growth and development were monitored in the period March-July, and after ripening, the fruits were delivered to the laboratory and analyzed.

Preparation of soil, cement dust and tomato fruits for analysis

Soil and cement dust samples were prepared by dry digestion [18]. The procedure consists in measuring a certain amount of the sample, which is then placed in a porcelain cup and burned by moderate heating for several hours, during which carbon, hydrogen, nitrogen and partially oxygen are converted into gases, while non-volatile oxides remain. The combustion process produces ash that is completely free of organic matter, which is a basic prerequisite for further analytical tests. The ash obtained by the combustion process is then dissolved in a mixture of acids, filtered and diluted to a certain volume, after which the solution is ready for analysis. Tomato fruit samples were prepared by wet crushing. The methods used for the analysis of heavy metals in food samples and environmental samples are based on different spectrometric analytical techniques: Atomic Absorption Spectrophotometry (AAS), Inductively Coupled Plasma Optical Emission Spectrophotometry (ICP-OES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [19].

-For the determination of heavy metals, the method of emission spectrophotometry was used, using the Optical emission spectrometer "Perkin Elmer" ICP Optima 2100 DV.

-The content of alkali and alkaline earth metals was determined by flame photometry using Jenway/PFP7 Flame Photometer.
-Nitrogen content was determined by the Kjeldahl method, and phosphorus and potassium content by UV/VIS spectrophotometry using a flame spectrophotometer.
-Soil pH was determined using a pH ion meter. Determination of the pH reaction of the samples is carried out by weighing 10 grams of the sample transferred into a 100 ml beaker. The samples are then poured with 25 ml of distilled water, i.e. 1 M KCl, and mixed well with a glass rod. After 30 minutes, the pH value in the sample suspension is measured with a pH-meter which is properly calibrated with standard buffer solutions of known pH value [20].
-The chemical composition of cement dust was determined using the XRF method (X-ray fluorescence spectroscopy).

III. RESULTS AND DISCUSSION

Determining chemical properties of the soil, the content of macro and micro elements as well as the content of heavy metals in the soil is a basic indicator for determining the degree of pollution and the suitability of the soil for crop production.

Table 1. Significant physico-chemical properties of soil

Soil chemical properties	**Content**
pH(H_2O)	6.92
pH(KCI)	5.71
Electrical conductivity, EC (μS/cm)	34
Total N (%)	0.2685
Accessible K_2O (mg/100 g of soil)	8,0
Accessible P_2O_5 (mg/100 g of soil)	1,735

Determination of the pH reaction of the soil in water and KCl solution is carried out to determine the pH reaction of the soil, which is an indicator of a number of the soil agrochemical properties, important for plant nutrition, and is expressed in pH units. Based on the pH value of the soil, it can be concluded that the analyzed soil sample belongs to carbonate to slightly acidic soils, with a very low supply of nitrogen, phosphorus and potassium. Table 2 shows the chemical analysis of cement dust. From the obtained results, it is evident that cement dust has an extremely alkaline reaction and high conductivity, which is correlated with a high content of calcium and potassium oxides.

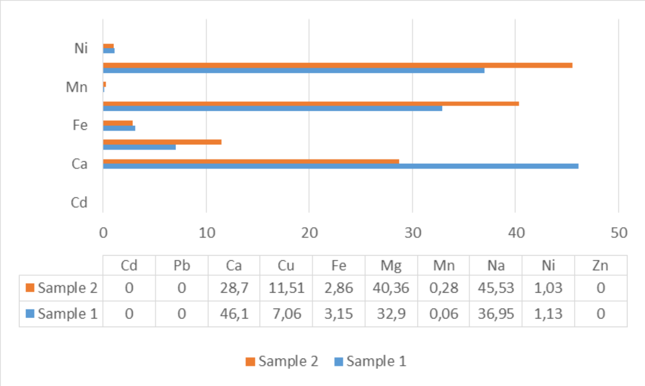
Table 2. Significant physico-chemical properties of cement dust

Cement dust chemical properties	**Content**
CaO (%)	65,40
Al_2O_3 (%)	3,55
K_2O (%)	8,68
Fe_2O_3 (%)	3,04
SiO_2 (%)	7,03
Cl (%)	4,54
SO_3	3,11
MgO	1,10
Na_2O	0,77
pH(H_2O)	12,76
pH(KCI)	12,70
Electrical conductivity (mS/cm)	5,31

Table 3. Content of essential and heavy metals in soil and cement dust (mg/kg, air-dried sample)

Sample	**Soil**	**Cement dust**
Cd	0.05	2.18
Pb	8.86	35.28
Ca	6456	18516
Cu	8.86	54.45
Fe	14133	6346.6
Mg	2761.6	2780
Mn	350	128.9
Na	332.8	1700
Ni	94.75	64.6
Zn	32.01	16.18

Based on the shown average values of essential and heavy metal content in Table 3, it can be concluded that the content of the tested elements in the soil and cement dust was within the maximum allowed values [21], except for the concentration of nickel in the soil, which was above the allowed values. The origin of nickel in the soil is explained as natural, given that the examined soil has not been cultivated for more than 10 years. Bioavailability and bioaccumulation of essential elements and heavy metals in plants is directly correlated with their content and mobility in the soil. Diagram 1 shows the values of the content of essential elements and heavy metals in tomato fruits in order to compare the obtained values with the regulations on the maximum allowed values [22].



	Cd	Pb	Ca	Cu	Fe	Mg	Mn	Na	Ni	Zn
Sample 2	0	0	28,7	11,51	2,86	40,36	0,28	45,53	1,03	0
Sample 1	0	0	46,1	7,06	3,15	32,9	0,06	36,95	1,13	0

Fig.1 Content of essential elements and heavy metals (data are expressed in mg/kg fresh weight)

Sample 1 – tomato fruits grown on soil with the addition of cement dust.

Sample 2 – tomato fruits grown on soil without the addition of cement dust.

Based on the average values of the analyzed elements (Ca, Fe, Mg, Mn, Na, Ni and Zn) in the tomato samples, the content was in accordance with the regulation on maximum allowed concentrations in vegetables (21). A higher uptake of calcium, iron and nickel was found in tomato fruits grown on soil with added cement dust, while the content of other elements was higher in pepper fruits grown on soil without cement dust. The determined values indicate a positive transfer of essential microelements from the soil to the vegetable fruit, although for a more accurate representation, the fraction of essential microelements accessible to the plant should also be analyzed. Namely, for plant nutrition, but also for food production and human health, the concentration available to plants is more important than the total amount. The content of highly toxic or non-essential metals (Pb, Cd) was not found in tomato fruits, which is very important from the point of view of safety. The content of Cu was above the value allowed by the regulations. A higher content of copper can be observed in samples of tomatoes grown on soil without added cement dust, which leads to the conclusion that the content of adopted copper is not limited only by its mobility from the soil, but also by other sources, of which copper-based vegetable protection agents are most often used. An excess of copper is thought to reduce the uptake and transfer of iron from the roots to the above-ground organs of plants, and suppresses other metals, especially iron, from physiologically significant centers. The use of calcium fertilizers or substrates that have a significant concentration of calcium in their composition (such as cement dust) aims to improve the quality of fruits in certain crops such as, for example, tomatoes [23].

IV. CONCLUSION

Cement dust is created as a by-product during the production of cement, it has a high pH value and is suitable for the soil pH correction.

Due to the high content of calcium, potassium as well as other micro and macro elements, it can be used as a soil additive at improving the fruit quality.

The content of the examined essential elements, as well as the content of heavy metals in the plant was within the permitted limits, except for the concentration of copper, whose concentration was above the permitted level. The assumed reason for the increase in copper concentration in tomato fruits is that a cooper-based vegetable protection agent is used.

In general, the results have shown that the cement kiln dust is an effective source of K and Ca for tomato production without short-term quality loss or soil metal contamination.

ACKNOWLEDGEMENTS

The authors acknowledge Lukavac Cement d.o.o. (Bosnia and Herzegovina) for their financial support of this research.

REFERENCES

[1] Vavetić Luka. (2016). Makroelementi u tlu i biljci, Završni rad, Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet abiotehničkih znanosti Osijek.

[2] Odobašić A., Šestan I., Ćatić S., Keran H.Bratovčić A., Šetsan A. (2013). Speciation of Zn in Water of Lake Modrac and Assessment of Toxicity of Water. Europan Journal of Scientific Research, Voleme 113, No.3.

[3] Kozina T. (2017). Određivanje teških metala u korabi (Brassica rupestris Raf.ssp.gongyloides (L.) Janch.), Završni rad, Sveučilište u Splitu, Kemijsko-Tehnološki fakultet.

[4] Radan A. (2020). Analitičke metode dokazivanja teških metala u biljnim materijalima. Završni rad, Sveučilište u Splitu, Kemijsko-Tehnološki fakultet, Split.

[5] Grozdić G. (2015). Određivanje sadržaja metala u biljnim vrstama Seseli rigidum I Seseli pallasii. Master rad, Univerzitet u Nišu, Prirodno-matematički fakultet, Department za Hemiju, Niš.

[6] Milanović M. (2017). Potencial tala istočne Hrvatske za proizvodnju povrća sa povišenim sadržajem esencjalnih elemenata, Završni rad, Fakultet Abiotehničkih znanosti Osjek.

[7] Keran H., Odobašić A., Ćatić S., Ahmetović N., Salkić M., Šetsan I. (2011). Lead and cadmium concentration in vegetables, the base for the calculation of their index and risk assessment. Journal on Environmental protection and Ecology 12, No.4, 1700-1706.

[8] Kebert, M.. (2014). Biochemical and physiological characterization of the poplar (Populus spp.) clones in the phytoextraction process of copper, nickel and cadmium. Doctoral dissertation, Novi Sad.

[9] Lončarić, Z, Gross Bošković A, Parađiković,N, Rozman V, Kralik Z, Baličević R, Bursić V, Miloš,S. (2015.). Utjecaj poljoprivrede na kakvoću hrane u pograničnome području, Priručnik IPA CBC Hrvatska-Srbija 2013.-2015., Poljoprivreni fakultet Osijek, Sveučilište Josipa Jurja Strossmayera.

[10] Maric´, M.J. (2014). The possibility of using some wild cultivated plants for soil remediation. Doctoral dissertation, Bor, Serbia.

[11] Abd El-Aleem, SA bd El-Aziz, M. A, Heikal, M and ElDiadmony, H. (2005). Effect of cement kiln dust substitution on chemical and physical properties and compressive strength of Portland and slag cements. The Arabian Journal for Science and Engineering, Vol. 30, No. 2B, pp. 263-273.

[12] Rahman M. K, Rehman S and Al-Amoudi, O. S. B. (2011). Literature review on cement kiln dust usage in soil and waste stabilization and experimental investigation. IJRRAS, Vol. 7, Issue 1, April 2011, pp. 77-87. Web Site: www.arpapress.com/Volumes/Vol7Issue1/IJJRAS_7_1_12.pdf.

[13] Kessler, G.R. Cement Kiln Dust (CKD) Methods for Reduction and Control. IEEE Trans. Ind. Appl. 1995, 31, 407–412. [CrossRef].

[14] Abdalla, A.A., Mohammed, A.S. (2022). Theoretical models to evaluate the effect of SiO2 and CaO contents on the long-term compressive
strength of cement mortar modified with cement kiln dust (CKD). Arch. Civ. Mech. Eng. 22, 1–21. [CrossRef].

[15] Adarmanabadi, H.R, Rasti, A, Razavi M. (2021). Long-term effects of Cement Kiln Dust (CKD) on erosion control of a soil slope. Int. J. Geotech. Eng. 16, 225–238. [CrossRef]

[16] Adaska, W. S. and Taubert, D. H. (2008). Beneficial uses of cement kiln dust. Presented at 2008, IEEE/PCA 50th Cement Industry Technical Conf., Miami, FL, May 19-22, pp. 1-19.

[17] A.M. Aboulfotoh, A.M. Dohdoh. (2017). Enhancement of thickening and dewatering characteristics of sewage sludge using cement kiln dust, Desalination and Water Treatment 81, 40-46, http://doi.org/10.5004/dwt.2017.21035

[18] Odobašić A., Šestan I., Bratovčić A. (2017). Handbook of Food Bioenergineering : Ingredients Extraction by Physicochemical Methods in Food, The Extraction of Heavy Metals From Vegetable Samples, Chapter 6, Volume 4.

[19] Perić–Grujić AA, Pocajt VV, Ristić MĐ. (2009). Određivanje sadržaja teških metala u čajevima sa tržišta u Beogradu. Hemijska Industrija, 2009; 63: 433-436.

[20] Lončarić, Z, Rastija, D, Karalić, K, Popović, B. (2007) Đurđević, B.; Engler, M. (2007). Mineralna gnojidba fosforom i kalcizacija: II. Promjene kemijskih osobina tla.

[21] Pravilnik o utvrđivanu dozvoljenih količina štetnih i opasnih materija u zemljištu i metode njihovog ispitivanja („Službene novine federacije BiH“, broj: 72/09).

[22] Pravilnik o maksimalno dozvoljenim količinama za određene kontaminante u hrani (Službeni glasnik BiH, broj 68).

[23] Bratovčić A., Šestan I. (2022): Agrohemija, Univerzitet u Tuzli, Tehnološki fakultet, Univerzitetski udžbenik.