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Araştırma Makalesi

Determination of Cu, Pb, and Zn Contents of Soils Formed on Different Parent Materials (Çanakkale, Türkiye)

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ABSTRACT

This study was carried out to determine the heavy metal (Cu, Pb, and Zn) contents and their differences in soils formed on three different parent materials (basalt, clastic and carbonate rocks and granite) in the Ezine district of Çanakkale province. For this purpose, surface sampling was conducted in soils formed under natural conditions on different geological materials. Heavy metal contents of the soil samples were determined using flame atomic absorption spectrometry using the wet digestion *Aqua regia* method. Analysis of variance (ANOVA) was used to determine the elemental differences in soil samples. Pearson correlation analysis was applied to reveal the relationship between heavy metals and the physicochemical properties of soils taken from different parent materials. As a result of the evaluation, the mean Cu concentrations in the samples ranged from soils formed on basalt (40.8 ± 3.8 µg/g)> soils formed on clastic and carbonate rocks (24.8 ± 1.5 µg/g)> soils formed on granite (22.5 ± 2. 8 µg/g); mean Pb concentrations followed the order of soils formed on granite (37.50 ± 3.30 µg/g)> soils formed on clastic and carbonate rocks (35.67 ± 2.74 µg/g)> soils formed on basalt (21.6 ± 6.7 µg/g). The mean Zn concentrations of the soil samples were as follows: soils formed on basalt (80.9 ± 8.7 µg/g)> soils formed on clastic and carbonate rocks (44.1 ± 3.7 µg/g)> soils formed on granite (37.0 ± 9.4 µg/g). Pb concentrations of all soil samples were found to be higher than the average of the earth's crust.

Key words: Heavy metals, clastic and carbonate rocks, granite, basalt

Farklı Anamateryaller Üzerinde Oluşmuş Toprakların Cu, Pb ve Zn İçeriklerinin Belirlenmesi (Çanakkale, Türkiye)

ÖZ

Bu çalışma, Çanakkale ili Ezine ilçesinde üç farklı anamateryal (bazalt, kireçli ve karbonatlı kayaçlar ve granit) üzerinde oluşan topraklardaki ağır metal (Cu, Pb ve Zn) içeriklerini ve bunların farklılıklarını ortaya koymak için yapılmıştır. Bu amaçla, farklı jeolojik materyaller üzerinde doğal ortam koşullarında oluşmuş topraklarda yüzey örneklemesi yapılmıştır. Örneklerin ağır metal içerikleri *Aqua regia* yaş yakma yöntemi kullanılarak alevli atomik absorpsiyon spektrometresi ile belirlenmiştir Toprak örneklerinde elementler arası farklılaşmayı belirlemek için varyans analizi (ANOVA) kullanılmıştır. Farklı anamateryaller üzerinde oluşmuş topraklardan alınan örneklerin ağır metal ve fiziko-kimyasal özellikleri arasındaki ilişkiyi ortaya koymak için Pearson korelasyon analizi uygulanmıştır. Değerlendirme neticesinde, örneklerdeki ortalama Cu konsantrasyonları bazalt üzerinde oluşmuş topraklar (40.8 ± 3.8 µg/g)> kireçli ve karbonatlı kayaçlar üzerinde oluşmuş topraklar (24.8 ± 1.5 µg/g)> granit üzerinde oluşmuş topraklar (22.5 ± 2.8 µg/g) sıralamasını; ortalama Pb konsantrasyonları granit üzerinde oluşmuş topraklar (37.50 ± 3.30 µg/g)> kireçli ve karbonatlı kayaçlar üzerinde oluşmuş topraklar (35.67 ± 2.74 µg/g)> bazalt üzerinde oluşmuş topraklar (21.6 ± 6.7 µg/g) sıralamasını izlemiştir. Toprak örneklerinin ortalama Zn konsantrasyonları ise bazalt üzerinde oluşmuş topraklar

(80.9 ± 8.7 µg/g)> kireçli ve karbonatlı kayaçlar üzerinde oluşmuş topraklar (44.1 ± 3.7 µg/g)> granit üzerinde oluşmuş topraklar (37.0 ± 9.4 µg/g) olarak belirlenmiştir. Tüm toprak örneklerinin Pb konsantrasyonlarının, yer kabuğu ortalamasından daha yüksek olduğu tespit edilmiştir.

Anahtar kelimeler: Ağır metal, kireçli ve karbonatlı kayaçlar, granit, bazalt

INTRODUCTION

Parent materials are the primary geological materials consisting of consolidated or unconsolidated materials that influence soil formation through mineralogical composition, texture, and stratification (Okoli et al., 2021). Parent material is a soil-forming factor that has a strong influence on different characteristics such as soil geochemistry, nutrient content, clay mineralogy, the composition of Fe/Al oxides, textural properties, and physicochemical properties of soils (Spinola et al., 2022). Due to the different mineralogical compositions of parent materials, soil formation processes result in different heavy metal contents and types in soils composed of different parent materials (Fei et al., 2023). Therefore, this situation affects the elemental and mineralogical contents of the soils. For example, basaltic volcanic rocks are generally rich in heavy metals such as Cu, Cd, Ni, and Co, while shales contain high amounts of Pb, Cu, Zn, Mn, and Cd (Li et al., 2019).

Soil formation is a process that occurs with the weathering of the bedrock. While soil is the largest and most important component of terrestrial ecosystems, it serves as both a source and a reservoir for heavy metals (Sungur et al., 2023). Heavy metals enter the soil ecosystem through natural processes and anthropogenic activities (Peng et al., 2019). The primary source of heavy metals in soil is the parent material. This effect is mainly due to heavy metals in primary minerals in parent materials or after weathering and deposition in sediments and soils (Zinn et al., 2020).

In the literature review, numerous studies reveal the heavy metal contents of soils formed on different parent materials. Mendoza-Grimón et al (2014), in their research on basaltic ash soils, found the average Zn content of soils as 85.2 ± 12.2 µg/g and Cu content as 43.7 ± 12.7 µg/g. Afu et al (2020), found Cu concentrations of 1.19 µg/g and Zn concentrations of 28.3 µg/g in soils formed on granitic gneiss. Tuğyan and Sungur (2020), determined the mean Cu, Pb, and Zn concentrations of soils formed on granite as 90.25 ± 22.09 µg/g, 25.12 ± 7.05, 50.45 ± 4.84 µg/g, respectively, in a study on different parent materials. However, such a study has not been found in the Ezine district of Çanakkale province, which was chosen as the study area. The primary purpose of this study is to determine the physicochemical properties and Cu, Pb, and Zn concentrations of the soils formed on different parent materials (basalt, clastic and carbonate rocks, and granite) in very close locations in Çanakkale and to reveal the differences based on parent material.

MATERIAL and METHOD

Study area and soil sampling

The study was carried out in the Ezine district of Çanakkale province, located between 39° 55′ 13′′ - 39° 44′ 6′ latitude and 26° 12′ 54′′ – 26 19′ 10′ longitude (Fig 1). The climate under the influence of the Marmara and Aegean seas, is very similar to the Mediterranean climate type (Atalay, 1991) in the study area. The annual average temperature is 15.1 °C, and the annual average precipitation is 616.7 mm (MGM, 2022). Geological formations of the study area and its vicinity are shale, marble, calcareous rocks, claystone, sandstone, igneous rocks, quaternary sediment, and volcanic ash ranging from Paleozoic to Quaternary (Özcan et al., 2011; Everest et al., 2021). The morphology and micro-surface relief of the study areas was very different. The topography of the surface ranges from flat to local depressions due to the land use (pasture) in all sampling areas. All samples were taken from pastures, and these areas have very shallow soil depths. Therefore, samples were taken from the surface (0-20 cm depth) formed on three different parent materials (basalt, clastic and carbonate rocks, and granite) under the same climate and land cover (Fig 2). At each parent material, seven soil samples were taken from the surface with a 0-20cm depth at 200m intervals. Non-metallic tools were used while sampling in the field. The samples were brought to the laboratory under safe conditions to be prepared for analysis.

Preparation of soil samples and analysis

Soil samples were air-dried in plastic containers at room temperature. Air-dried soil samples were ground with the wooden mallet and passed through a 2.0 mm sieve. In addition, some of the ground soil samples were re-grind in a mortar and then sieved through 0.5 mm to use for organic matter (OM), $CaCO_3$, and heavy metal (Cu, Pb, and Zn) analyses. The pH and EC values of the samples were measured in a 1:2.5 (soil: water) suspension with a pH/EC meter (Thomas, 1996). Soil texture was determined using the hydrometer method (Gee and Or, 2002). The calcium carbonate ($CaCO_3$) content of the soils was measured as a percentage

(%) with a calcimeter based on measuring the CO_2 produced by the acidification of the soil sample (Nelson, 1982). The organic matter content of the samples was determined using the dichromate oxidation method (Nelson and Sommers, 1982).

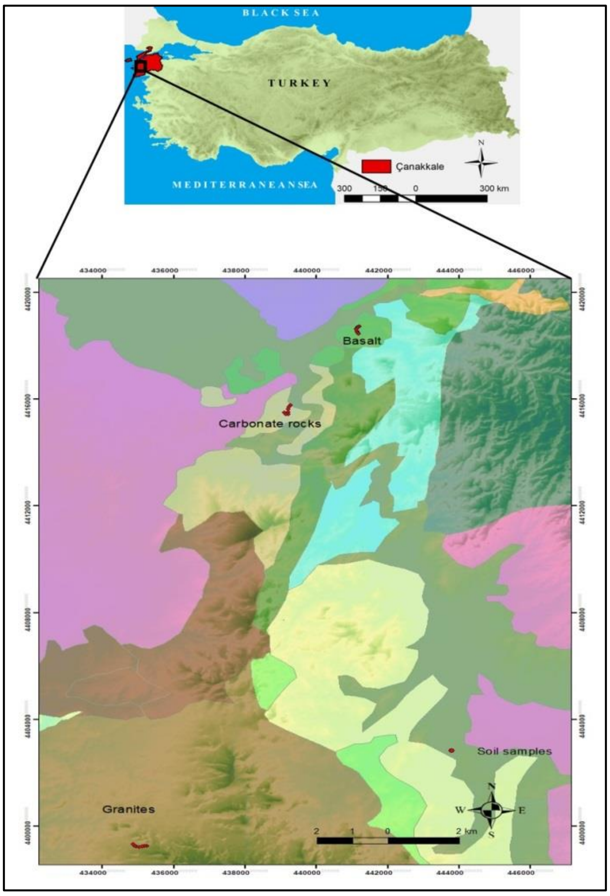

Figure 1. Geology of the study area and soil sampling locations

Heavy metal analysis and Accuracy Testing

The soil samples were extracted with Aqua regia (1:3 ratio HNO_3: HCl) by wet digestion method (Tuzen et al., 2004). Flame atomic absorption spectrometry (FAAS) was used for detection. In the flame atomic device, Cu, Pb, and Zn were detected at wavelengths of 324.8 nm, 283.3 nm, and 213.9 nm, respectively. In addition, purchased stock solution (SCP SCIENCE, 1000 µg/ml, AA standard) used each element for the standard series preparation stage. For the determination of heavy metals in the soil samples, approximately 5 g of re-grounded soil samples were kept in an oven at 85 °C for one night to remove humidity. After dehumidification, 1 g of each sample was weighed with a balance with an accuracy of 0.001. The weighed samples were poured into beakers with a volume of 100 mL and 20 mL of *Aqua regia* was added and covered with a watch glass. Afterward, the samples taken on the hot plate were evaporated to near dryness with a gradual temperature increase and after passing through a 0.45 µm blue-band filter it was made up to 50 mL with ultrapure water. The accuracy of the wet digestion method used in the study was tested with the Certified Reference Material, ERM-CC141. Obtained recoveries are given in Table 1. As shown in Table 1, the recoveries were between 94.2% and 100.6%, and these results were satisfactory.

Table 1. Certificate values and recovery rates obtained of ERM CC-141certified reference material (de Vos et al., 2012) extracted with *Aqua regia*, n = 3

Metals	Certificate Values (µg/g)	Determined (µg/g)	Recovery (%)
Cu	12.4 ± 0.9	12.2 ± 0.2	98.4
Pb	32.2 ± 1.4	32.4 ± 3.3	100.6
Zn	50.0 ± 4.0	47.1 ± 2.4	94.2

Statistical analysis

In this study, analysis of variance (ANOVA) was applied to determine the differences between heavy metal (Cu, Pb, and Zn) concentrations in soils formed on different parent materials ($p<0.05$). The averages of heavy metal variables were compared with the Tukey multiple range test. In addition, Pearson correlation analysis was performed to determine the relationship between the heavy metal contents and the physicochemical properties of soils (pH, EC, $CaCO_3$, organic matter, clay, silt, and sand content). MINITAB-21 program was used for statistical analysis.

RESULT AND DISCUSSIONS

Physicochemical properties of the soil samples

Some physicochemical properties of soil samples are presented in Table 2. The average pH value of the soil samples formed on basalt was nearly neutral at 7.1 ± 0.5, the formed on clastic and carbonate rocks were slightly alkaline at 7.7 ± 0.2 and the formed on granite was slightly acidic at 6.2 ± 0.3 (Soil Survey Division Staff, 1993). The mean EC values of the soil samples formed on basalt, clastic and carbonate rocks, and granite were 124.6 ± 84.7 µS/cm, 130.0 ± 8.3 µS/cm, and 44.3 ± 11.3 µS/cm, respectively. These results show that there are no salinity problems in soil samples.

Table 2. Some physicochemical properties of soil samples

Parent material	Sample	pH	EC (µS/cm)	$CaCO_3$ (%)	OM (%)	Clay (%)	Silt (%)	Sand (%)
Basalt	1	8.0	105.1	3.6	4.0	33.3	31.4	35.3
	2	7.2	82.7	0.5	6.4	34.7	26.6	38.7
	3	6.6	61.3	0.2	5.2	35.9	21.6	42.6
	4	6.7	313.0	0.2	7.6	34.1	28.0	37.9
	5	7.1	110.0	1.9	7.4	35.8	22.3	42.0
	6	7.1	98.1	0.6	4.6	36.7	31.2	32.1
	7	7.1	102.1	0.5	5.7	36.0	30.1	33.9
	Mean	7.1	124.6	1.1	5.8	35.2	27.3	37.5
	Sd[a]	0.5	84.7	1.3	1.3	1.2	4.1	4.0
Clastic and carbonate rocks	1	7.9	117.4	31.3	4.0	25.8	29.5	44.7
	2	7.5	132.1	25.2	5.8	13.8	32.6	53.5
	3	7.5	141.6	40.2	6.0	23.3	29.3	47.4
	4	8.0	127.8	37.3	5.3	13.8	30.3	55.9
	5	7.6	128.5	20.7	5.4	12.1	31.7	56.2
	6	7.8	138.3	12.1	6.3	19.9	42.8	37.4
	7	7.5	124.0	23.3	5.7	12.5	28.0	59.5
	Mean	7.7	130.0	27.2	5.5	17.3	32.0	50.7
	Sd[a]	0.2	8.3	9.8	0.8	5.6	5.0	7.8
Granite	1	6.0	54.0	0.4	6.2	13.2	10.4	76.3
	2	5.8	30.7	0.6	5.9	7.0	14.7	78.3
	3	6.4	48.9	0.7	1.8	8.9	12.2	78.9
	4	6.3	44.0	1.4	2.4	10.9	12.2	76.9
	5	6.8	61.5	0.5	2.6	9.0	12.3	78.7
	6	6.1	37.4	1.0	4.4	11.2	14.6	74.3
	7	6.2	33.5	1.1	4.3	6.8	14.3	78.9
	Mean	6.2	44.3	0.8	3.9	9.6	13.0	77.5
	Sd[a]	0.3	11.3	0.4	1.7	2.3	1.6	1.7

a Standard Deviation

The average organic matter contents of the soils formed on basalt, clastic and carbonate rocks, and granite were 5.8 ± 1.3%, 5.5 ± 0.8%, and 3.9 ± 1.7%, respectively. The land use types are very effective on organic matter contents. According to the classification by Nelson and Sommers (1982), the organic matter content of the soils in the study area is high. Soils formed on granite were found to be less calcareous; however, soils formed on basalt were found to be calcareous, and clastic and carbonate rocks were found to be highly calcareous (Nelson, 1982).

Heavy metal contents of the soil samples

Heavy metal (Cu, Pb, and Zn) concentrations of soil samples are given in Table 3. The average Cu concentrations of soils formed on basalt, clastic and carbonate rocks and granite were 40.8 µg/g, 24.8 µg/g and 22.5 µg/g, respectively. These results are lower than the crustal average (55 µg/g). Considering the world soil average (38.9 µg/g), the soils formed on the basalt (40.8 µg/g) parent material are equal; it has been determined that the soils formed clastic and carbonate rocks (24.8 µg/g) and granite (22.5 µg/g) are lower.

Table 3. Heavy metal (Cu, Pb, and Zn) concentrations (µg/g) of soil samples.

Parent Material	Sample	Cu	Pb	Zn
Basalt	1	35.6	16.9	62.7
	2	40.1	17.0	89.5
	3	39.0	19.1	86.5
	4	42.0	35.2	82.0
	5	48.0	25.2	80.2
	6	41.1	21.5	84.2
	7	39.9	16.5	81.2
	Mean	40.8	21.6	80.9
	Sd[a]	3.8	6.7	8.7
Clastic and carbonate rocks	1	22.9	29.8	39.6
	2	27.7	31.9	44.5
	3	24.2	35.7	42.7
	4	24.8	34.9	42.7
	5	24.6	30.6	45.4
	6	25.2	32.3	51.4
	7	24.1	27.9	42.5
	Mean	24.8	31.9	44.1
	Sd[a]	1.5	2.7	3.7
Granite	1	19.5	38.3	33,4
	2	23.9	37.6	29,1
	3	17.5	44.6	36.5
	4	25.1	37.8	34.7
	5	24.5	35.2	59.4
	6	25.4	33.5	34.0
	7	21.9	35.5	32.0
	Mean	22.5	37.5	37.0
	Sd[a]	2.8	3.3	9.4
Earth's crust*		55.0	15.0	70.0
World soil average**		38.9	27.0	70.0

*Kabata-Pendias,2011 **Alloway, 1990.
[a] Standard Deviation

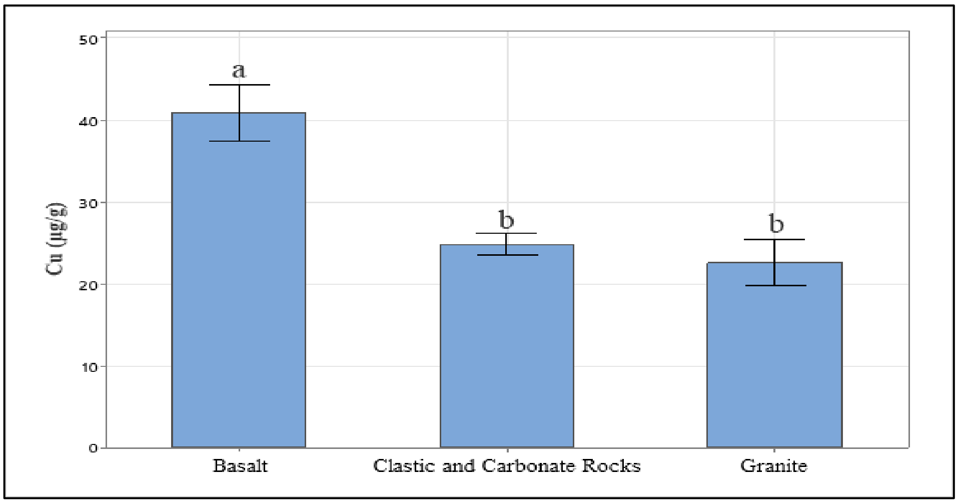

Figure 2. Cu concentrations of Basalt, Clastic and carbonate rocks, and Granite (The differences between the averages indicated with different letters are significant at $p \leq 0.05$).

It was found that the Cu concentrations of the soils formed on basalt were statistically significantly higher ($p \leq 0.05$) compared to the soils formed on granite and clastic and carbonate rocks (Fig 2). The results obtained in previous studies support the results of this study (Rodríguez et al., 2008; Dantu., 2009; Mendoza-Grimón et al., 2014).

When the Pb concentrations were evaluated, the concentrations of the soils formed on parent materials were found to be higher than the average of the earth's crust (15 µg/g). Based on the world soil averages (27 µg/g), the average of the soils formed on granite and clastic and carbonate rocks was found to be high, while it was found to be low in the soils formed on basalt. When the mean Pb concentrations of soil samples were evaluated, Pb concentrations were found in the order of soils formed on granite (37.5 ± 3.3 µg/g) > soils formed on clastic and carbonate rocks (31.9 ± 2.7 µg/g) > soils formed on basalt (21.6 ± 6.7 µg/g). It was found that the Pb concentrations of the soils formed on granite and clastic and carbonate rocks were significantly higher ($p \leq 0.05$) than in soils formed on basalt (Fig 3). The results obtained in previous studies support the results of this study (Dantu., 2009; Bi et al., 2020; Fei et al., 2023). A quarry and a cement factory are near the soils formed on clastic and carbonate rocks. Mining carbonate rock to provide raw materials for the factory is thought to increase atmospheric dust emission in and around the sampling location. Additionally, in the granite locations, there are some granite quarries. A large amount of dust is emitted from the granite quarry into the atmosphere. These dusts can contain lead, affecting the lead concentration in the study area. As a result of the environmental assessment, it is thought that mining activities in the area could be the reason for these high values.

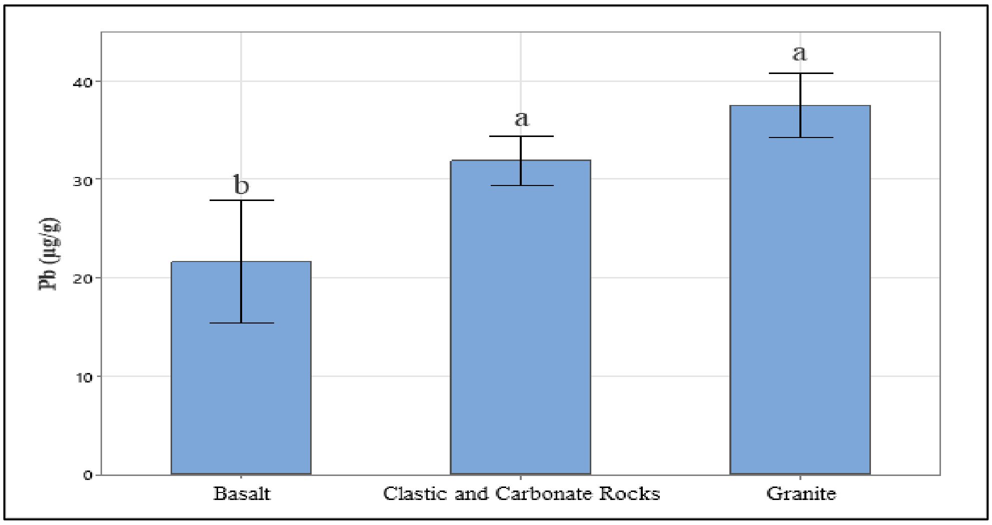

Figure 3. Pb concentrations of Basalt, Clastic and carbonate rocks, and Granite (The differences between the averages indicated with different letters are significant at $p \leq 0.05$).

Comparing the Zn concentrations to the earth's crust and the world soil average, the soils formed on the basalt are higher (70 µg/g), on granite and clastic and carbonate rocks were found to be lower. The Zn content of the soils largely depends on the nature of the parent rocks, organic matter, texture, and pH levels. Basalt is rich in Zn, whereas granite is poor (Adriano, 1986). The Zn concentration of rocks is highly variable. Basic igneous rocks such as basalt are rich in Zn due to the isomorphic substitution of Zn for Fe^{2+} or Mg^{2+} in ferromagnesian minerals (eg augite, hornblende, biotite). In contrast, silica-rich igneous rocks (granite) or metamorphic rocks (gneiss) are extremely low in Zn (Alloway, 2013). The average Zn concentrations were as follows: soils formed on basalt (80.9 ± 8.7 µg/g)> soils formed on clastic and carbonate rocks (44.1 ± 3.7 µg/g)> granite (37.0 ± 9.4 µg/g). The results obtained in previous studies support the results of this study (Rodríguez et al., 2008; Mendoza-Grimón et al., 2014; Bi et al. 2020). It was found that the Zn concentrations of the soils formed on basalt were significantly higher ($p \leq 0.05$) than in soils formed on granite and clastic and carbonate rocks (Fig 4).

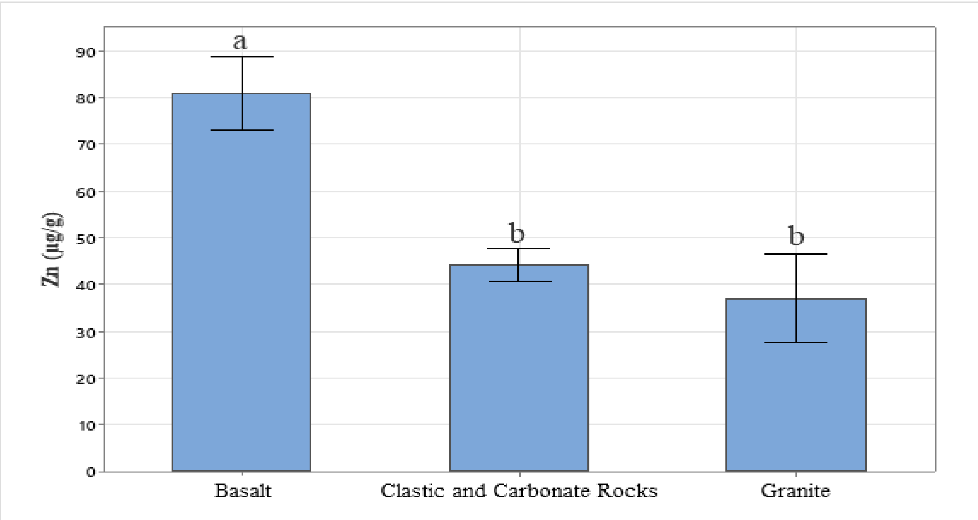

Figure 4. Zn concentrations of Basalt, Clastic and carbonate rocks, and Granite (The differences between the averages indicated with different letters are significant at $p \leq 0.05$).

Correlation of heavy metals and soil properties

Pearson correlation analysis was performed to determine the relationships between the physicochemical properties (pH, organic matter, $CaCO_3$, clay, silt, and sand contents) of the soils taken in this study and the heavy metal contents of each parent material, and the results are given in Table 4. A statistically positive correlation at $p \leq 0.05$ was determined between Cu and organic matter in soil samples formed on basalt parent material (r = 0.763). Since basalt provides plants with essential micronutrients (Conceição et al., 2022; Swaboda et al., 2022), plants can grow better in basalt soils. This is expected to increase the amount of organic matter in these soils. Cu^{+2} has a stronger affinity for soil organic matter than other divalent cations. Therefore, Cu is adsorbed by soil organic matter (Mengel et al., 2001). A positive correlation was determined between the Pb and EC content of the soils at the $p \leq 0.05$ level (r = 0.896). These results are consistent with previous studies (Peris et al., 2008; Pandey et al., 2016). While there is a negative correlation at $p \leq 0.05$ between the Zn concentrations and pH contents of the soils; A negative correlation was observed between $CaCO_3$ contents at $p \leq 0.01$ (r = -0.813 for pH, r = -0.907 for $CaCO_3$). These results are consistent with previous studies (Roca et al., 2008). There was no linear relationship between Cu and Pb metals and the physicochemical properties of the soils in the soil samples formed on the granite parent material. A positive correlation was determined between the Zn concentrations of the soils and their pH levels at $p \leq 0.05$ (r = 0.863). This correlation was deemed to reflect the quartz content in soils formed on granite. The zinc concentration and quartz concentration in the soil parent material are the main determinants influencing the zinc concentration in the soil. Research indicates that the quantity of quartz in soil reduces soil's zinc concentration (Helmke et al. 1977; Brehler and Wedepohl, 1978; Barak and Helmke 1993). As it is widely accepted, soil pH decreases with increased quartz content (Gray et al., 2016). Consequently, it is believed that the rise in quartz content reduces both soil pH and Zn concentration. A positive correlation was determined between the Zn concentrations of the soils and their EC contents at $p \leq 0.05$ (r = 0.774 for EC). EC results are consistent with previous studies

(Katyal and Sharma, 1991; Saranghtem et al., 2019). There was no linear relationship between Cu and Pb metals and the physicochemical properties of the soils in the samples taken from the soils formed on the calcite and carbonate rocks. A negative correlation was determined between the soils' Zn concentrations and $CaCO_3$ contents at $p \leq 0.05$ (r =- 0.755 for $CaCO_3$). Zn deficiency is common in soils with high lime content. Previous studies have also reported this situation (Adriano, 1968; Sungur et al., 2012; Everest and Özcan, 2018). In addition, a positive correlation was found between the Zn concentrations of the soils and the silt contents at $p \leq 0.01$. These results are consistent with previous studies (Roca et al.,2008; Yan et al.,2018; Andrea et al., 2019).

Table 4. Correlation of heavy metals and properties of soils taken from basalt, clastic and carbonate rocks, and granite parent material.

Parent Material	Heavy Metals	pH	EC (µS/cm)	$CaCO_3$ (%)	OM (%)	Clay (%)	Silt (%)	Sand (%)
Basalt	Cu (µg/g)	-0.382	0.198	-0.194	0.763*	0.416	-0.510	0.394
	Pb (µg/g)	-0.427	0.896**	-0.236	0.690	-0,163	-0.142	0.196
	Zn (µg/g)	-0.813*	-0.052	-0.907**	0.442	0.600	-0.451	0.276
Clastic and carbonate rocks	Cu (µg/g)	-0.409	0.431	-0.266	0.575	-0.493	0.342	0.136
	Pb (µg/g)	0.147	0.686	0.545	0.347	0.229	0.134	-0.250
	Zn (µg/g)	-0.054	0.612	-0.755*	0.720	-0.187	0.927**	-0.456
Granite	Cu (µg/g)	0.059	-0.251	0.381	0.048	-0.063	0.495	-0.367
	Pb (µg/g)	0.027	0.204	-0.153	-0.372	-0.027	-0.437	0.435
	Zn (µg/g)	0.863*	0.774*	-0.318	-0.485	-0.005	-0.282	0.264

*p<0.05, correlation is significant at 95 % confidence level; **p<0.01, correlation is significant at 99 % confidence level.

CONCLUSION

The parent material is an essential factor in soil formation. Different parent materials affect soils' chemical composition and mineralogical content under the same conditions. Differences in soil's physical, chemical, and mineralogical properties are primarily related to the parent material. This study revealed the differences between the physicochemical properties and heavy metal contents of soils formed on different base materials. Considering the results, the average concentrations of Cu and Zn metals in the soils formed on the basalt base material were higher than the other base materials, and this situation was found to be statistically significant. When the average of the world soils and the averages of the earth's crust were compared, Pb concentrations were found to be high in all the parent materials. Our country and the Biga peninsula, chosen as the study area, are very rich in terms of geological diversity. For this reason, future studies considering these different geological materials should be planned in more profound and detailed studies. With the knowledge to be created in this way, the heavy metal levels of the soils developed on different geological materials can be determined and the necessary substrate materials will be provided for the management of these soils. With the knowledge to be created in this way, the heavy metal levels of the soils developed on different geological materials can be determined and the necessary substrate materials will be provided for the management of these soils.

Conflict of Interest Statement: The authors declare there is no conflict of interest.

Contribution Rate Statement Summary of Researchers: The authors declare that they have contributed equally to the article.

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