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RESEARCH ARTICLE

Heavy metals concentration and availability of serpentine soils in southwestern Turkey

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ABSTRACT

Soils developed on serpentine rocks have serious limitations for agriculture. Intensive agriculture and forestry activities are carried out in the lands developed on the serpentine rocks in the southwest of Turkey. Because of lack of information about heavy metal contents and some important soil physic-chemical properties of soils in this area some properties and especially heavy metal contents of the soils were aimed to be determined in this study. The results of the study showed that total Cd (5.4-6.8 mg kg^{-1}) concentrations with plant available fraction ranging from 0.52% to 0.90% of the total Cd were high. Total Ni (61%) and total Co (44%) concentrations of soil samples were found at high levels. Plant available Ni and Cr concentrations in soils were ranged between 0.08%-8.52% and 0.007%-0.56% of the total Ni and total Cr concentrations respectively. In addition, very high levels of the total Fe (17039-50883 mg kg^{-1}) and Mn (218-1790 mg kg^{-1}) concentrations were determined in the examined serpentine soils. Total Zn (33.0-87.5 mg kg^{-1}) and Cu (8.8-99.9 mg kg^{-1}) concentrations were ranged within the given limit values ($\leq$ 140 mg kg^{-1} for Cu and 300 mg kg^{-1} for Zn). With regard to macronutrients, 70% N, 61% P, 56% K and 87% Ca contents of soils were found to be at the adequate levels. The present study demonstrated that the first 10 principal components with an eigenvalue greater than 1 could explain 89.74% of the total variation in the population.

Key words: DTPA extraction, heavy metals, serpentine soils.

INTRODUCTION

Heavy metals accumulate in soils either from bedrock or from industrial pollution. Repeated soil amendment with industrial waste can affect the accumulation of chemical elements, mainly heavy metals, in plants (Silva et al., 2013). One of the most important heavy metal containing rocks is serpentine rocks. Serpentine rocks are ultramafic rocks and contain ferromagnesian minerals. Serpentine more appropriately describes a group of minerals found in hydrothermally altered ultramafic rocks, such as antigorite, chrysotile, and lizardite. Serpentine's weathering provides the soil with Mg, Fe, and heavy metals like Ni and Cd. Metals alter the physical and chemical characteristics of the soil, creating an environment that is unfavorable to plant growth. On the serpentine (ultramafic) soils covering 1% of the earth's surface, and some special plants are grown on these soils. The characteristic vegetation of Ni-containing serpentine soils in northern Europe is Caryophyllaceae, while it is Euphorbiaceae in tropical regions and Brassicaceae family in the temperate Mediterranean belt (Bani et al., 2013). Long-term accumulation of heavy metal elements causes serious damage to the ecological environment (Shi et al., 2022). It is thought that this situation results from the toxic impacts of high heavy metals like Ni, Cr, Mn and Co possessed by serpentine soils (Rajakaruna and Boyd, 2014). To determine if soil is contaminated, the total heavy metal concentration is often compared to any threshold limits and standard values. In addition to high concentrations of heavy metals, the lack of macronutrients such as N, P, and K and low Ca/Mg ratio limit the fertility of serpentine soils (Tomovic et al., 2013). Since Mg and Fe on the octahedral crystal lattices olivine and pyroxene in the peridotite and serpentine groups can easily replace Ni and Cr, toxic elements are easily transported to the soil and water environment, negatively affecting human, animal, and environmental health (Vithanage et al., 2014). Heavy metals also negatively affect the population of flora and beneficial fauna (bacteria, fungi, etc.) in serpentine soils due to weakening of vegetation and lack of nutrients (Ali et al., 2013).

Atalay (2017) classified the serpentine soils spreading in Turkey into two groups as ecologically well weathered and poorly weathered/decomposed. Well-weathered serpentines are clayey in texture, reddish in color, flat and nearly flat. Well-separated serpentines in inclination are suitable for use in agricultural production because of their high cation exchange capacity. Ultramafic soils which are poorly weathered/decomposed or under the restricted formation factors have weak horizon (A and C) development. These differences affect soil color, depth, element concentration, and plant growing ability. Poor soil development and a high concentration of potentially toxic elements prevent the growth of higher plants and thus the removal of metals from the soil by plants (Marescotti et al., 2019).

While the determination of the total heavy metal concentrations of the soils gives information about their chemical forms, it cannot provide sufficient information about their mobility and availability. Therefore, the available heavy metal concentrations of soil have to be determined (Lago-Vila et al., 2015).

The available heavy metal concentrations of soil vary depending on pH, organic C, and clay content and they affect plant growth, soil microorganism activities and human health.

The soils formed on the serpentine rock are widely distributed in Turkey. Although it is known that these soils have high heavy metal content, the available element concentrations and physical and chemical properties of the soil are very variable. For this reason, some soil properties and available heavy metal concentration of the soils on the serpentine rocks located in south-western Anatolia region in Turkey were determined in this study.

MATERIALS AND METHODS

One of the few countries in the world with ultramafic and serpentine soils in its geological formations is Turkey. The research area covers the Burdur and Gölhisar basins, which are located on the borders of the province of Burdur in the Mediterranean Region. The research area has large serpentine and calcareous main materials (Figure 1). The area is in the transition zone between the Mediterranean and continental climates. In the Burdur-Gölhisar basin, which is exposed to precipitation because it is surrounded by mountains, semiarid climatic conditions prevailing between Mediterranean and continental climates are effective. However, Spain and in Andalusian region, around Estepona and Marbella localities there is an important presence of serpentine lithologies.

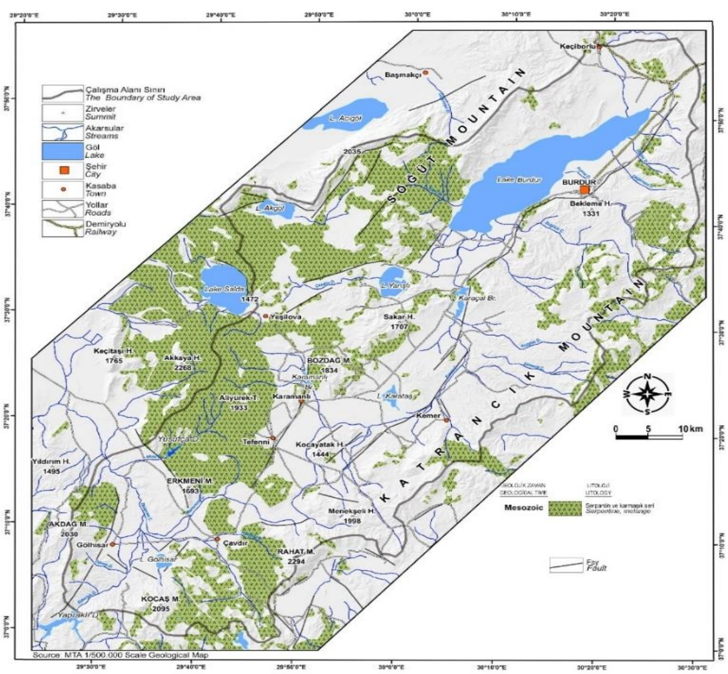

Figure 1. Geology of the study area.

Depending on these climatic conditions, in flat areas there are soils with high lime accumulation unit. In hilly areas, there are soils formed under intensive effect of the parent material. Due to the rainfall and temperature conditions affected by the relief, there are red pine forests, which are the climatic forest of the Mediterranean climate up to 1200 m, and the larch forests located in the forest of the Mediterranean mountain belt are located on it. The geomorphology of the research area is given in Figure 2. Peridotite serpentines are commonly seen on the basis of the Burdur-Gölhisar basin, around Gölhisar and in the southwest of the Burdur basin.

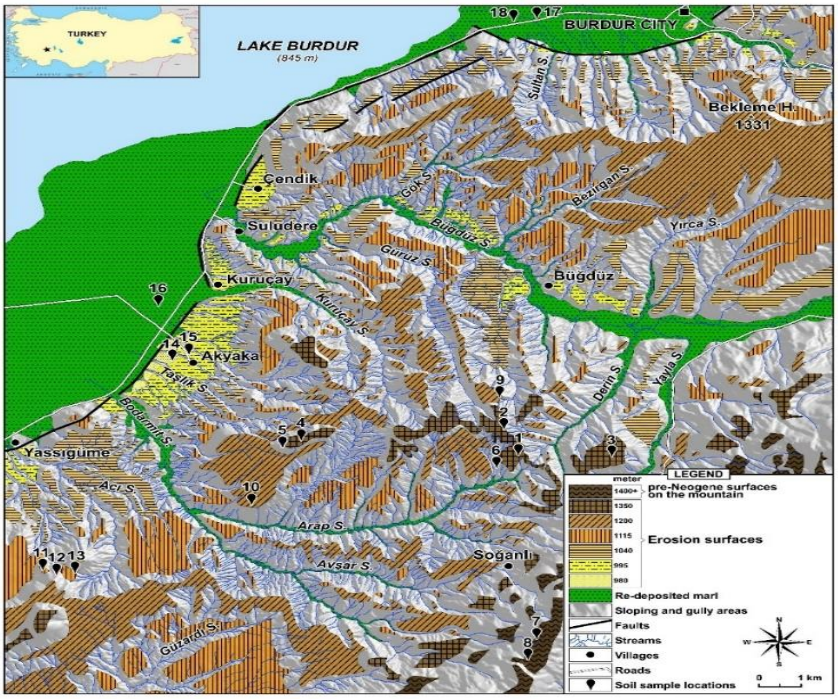

Figure 2. Geomorphology of the study area.

Sampling

Geological map of 1:100.000 scale prepared by Turkish State Mineral Research & Exploration was used to locate serpentinite and determine the survey routes. The coordinates and elevation of the sampling locations were determined using a handheld GPS receiver, with 3-6 m accuracy. Surface soil samples (0-20 cm) were collected from 23 different sites (such as agriculture and forest soils). The samples were transported to the laboratory in plastic bags.

Soil analysis methods

After mixing and homogenizing in the laboratory, soil samples were air dried at room temperature and passed through a 2 mm sieve. Standard soil analysis methods were used to determine physical and chemical characteristics of the soil; e.g., soil organic matter, cation exchange capacity (CEC), particle size, pH, electrical conductivity, calcium carbonate, total N, exchangeable K, Ca and Mg, available P, diethylenetriaminepentaacetic acid (DTPA) extractable and total Fe, Zn, Mn, Cu, Cd, Pb, Cr, Ni, Co.

Soil organic matter (SOM) was determined using the Walkley-Black method (Olsen and Sommers, 1982), particle size distribution was determined by the hydrometer (Day, 1982). The calcium carbonate content volumetrically by Scheibler calcimeter method, soil reaction (pH) and electrical conductivity (EC) were measured at a 1:2.5 soil/water aqueous extract (Jackson, 1967). Total N was determined using the Kjeldahl method (Kacar, 2016). Available P was determined by 0.5 M $NaHCO_3$ extraction (Olsen and Sommers, 1982). The exchangeable K, Ca and Mg were measured with 1 N ammonium acetate extraction (Kacar, 2016). Cation exchange capacity was assessed according to Kacar (2016). Available Fe, Zn, Mn, Cu, Cd, Ni, Pb, Cr and Co concentrations were determined using the DTPA (0.005 M DTPA+ 0.1 M triethanolamine (TEA) + 0.01 M $CaCl_2$) extraction method (Lindsay and Norwell, 1978). Total Fe, Zn, Mn, Cu, Cd, Ni, Pb, Cr, and Co concentrations of soil were measured with aqua regia (ultrapure mixture of concentrated HCl/HNO_3, 1/3 v/v) in microwave digestion apparatus (MarsX5, CEM Corporation, Matthews, North Carolina, USA). Standard soil (UME EnvCRM03) was used as a reference material for heavy metals. All analytical procedures were also performed using this reference sample.

Statistical analyses

Data statistical analyses were done in three steps: (i) Normality tests were applied (Shapiro-Wilks); (ii) distributions were described with classical statistics (arithmetic mean, standard deviation, maximum and minimum values, coefficient of variation), iii) correlation. The statistical analysis was made depending on the principles set of Yurtsever (1984). The JMP Statistical package program was used to examine all of the data, developed by SAS (SAS Institute, Cary, North Carolina, USA). Principle Component Analysis (PCA) done Jolliffe and Cadima (2016).

RESULTS AND DISCUSSION

Some physical and chemical properties of soils

The physical and chemical properties of serpentine soils can be changed by formation conditions. Soil reaction (pH), electrical conductivity (EC), texture and organic matter content are important parameters affecting heavy metal concentration. Minimum, maximum, average values, and some descriptive properties of serpentine soil are presented in (Table 1).

Table 1. Descriptive statistics of the soil physical and chemical properties. V: Variance; SD: standard deviation; CV: coefficient of variation; SC: skewness coefficient; K: kurtosis; EC: electrical conductivity; CEC: cation exchange capacity.

Parameters	Min.	Max.	Mean	V	SD	CV	SC	K
Clay	5.80	86.80	26.20	602.79	24.55	93.67	1.46	1.07
Silt	4.10	62.10	29.10	270.68	16.45	56.54	0.604	-0.371
Sand	9.00	86.80	44.70	660.50	25.70	57.51	-0.207	-1.797
pH	7.19	7.87	7.54	0.0019	0.14	1.85	-0.433	-0.584
EC	0.19	0.59	0.28	0.007	0.09	31.36	2.19	6.55
$CaCO_3$	1.55	49.38	18.84	314.65	17.74	94.16	0.81	-1.046
Organic matter	0.12	3.42	1.05	0.902	0.95	90.38	1.07	0.164
CEC	1.85	65.86	28.94	372.48	19.30	66.69	0.585	-0.679
Total N	0.03	0.294	0.149	0.007	0.086	64.47	0.658	-0.772
Available P	2.00	12.00	6.04	10.33	3.21	53.17	0.522	-0.937
Exchangeable K	0.10	6.00	1.026	1.580	1.257	122.51	3.033	11.359
Exchangeable Ca	4.10	110.80	49.27	649.61	25.48	51.73	0.372	0.600
Exchangeable Mg	1.90	89.40	17.64	397.77	19.94	113.04	2.419	6.984
Exchangeable Na	0.11	0.50	0.238	0.012	0.112	47.14	0.842	0.215

Soil reaction ranged from 7.19 to 7.87 (Table 1); 16% soil samples were neutral and 84% of them were slightly alkaline (Kacar, 2016). The total ion concentration of soil (EC) ranged from 0.19 to 0.59 dS m^{-1} and all of the samples were salt free. The kurtosis value (6.55) demonstrated that the total ion concentration of the soils varied very close range. Calcium carbonate content ranged from 1.55% to 49.38% and 74% of soil was with high lime content. The organic matter content of 78% of the soils examined was low (≤ 2%). The high amount of organic matter in the soil in some locations suggests that the properties of serpentine soils can be improved and they can be productive under suitable environmental conditions (Ünver et al., 2013). The percentages of sand, silt, and clay in the soil were between 9.0%-86.8%, 4.1%-62.1% and 5.8%-86.8% respectively; 70% of the serpentine soils had loamy texture. The cation exchange capacity (CEC) ranged from 1.85 to 65.86 meq 100 g^{-1}. The high standard deviation and coefficient of variation demonstrated that the percentage of sand, silt, and clay, lime contents, and CEC of the soils change over short distances (Table 1). The total N content of 48% of samples (0.030%-0.294%), exchangeable K in 56% of the samples (0.1-6.0 meq 100 g^{-1}), Ca concentration in 87% of the samples (4.1-110.8 meq 100 g^{-1}) and Mg concentration in 23% (1.9-89.4 meq 100 g^{-1}) of the samples were sufficient while available P concentration 86% of the samples was insufficient (Ünver, 2013; Özbek et al., 2014). The high standard error and coefficient of variation indicate that the exchangeable Ca and Mg concentrations of the soils change in short intervals (Table 1). The exchangeable Na concentration of the soils varied between 0.11-0.50 meq 100 g^{-1}. A high skewness coefficient value is the indicator of deviation from the normal distribution. The skewness in the organic matter content was thought to be due to the application of organic material in the field.

Total and DTPA-extractable essential and toxic heavy metals

Since this does not reflect how firmly the element is bonded to the surface of the soil constituents, the overall concentration of trace elements in soils only offers limited information on their bioavailability. The DTPA-extractable method was chosen as an estimate of soil trace elements' chemical availability (Bani et al., 2013). Serpentine soils were characterized by high heavy metal concentration, especially for Ni. Total Ni (12.76-1315.20 mg kg^{-1}) and Cr (8.03-291.16 mg kg^{-1}) concentrations were found to be wide range (Table 2).

Table 2. Descriptive statistics of the total and DTPA extractable heavy metals concentrations. V: Variance; SD: standard deviation; CV: coefficient of variation; SC: skewness coefficient; K: kurtosis.

Elements	Min.	Max.	Mean	V	SD	CV	SC	K
Total Cd	5.40	6.80	5.86	0.115	0.339	5.79	1.092	2.005
Total Co	18.38	67.89	33.97	170.89	13.07	38.47	1.086	1.272
Total Cr	8.03	291.16	109.19	11335.30	106.46	97.50	0.769	-0.838
Total Ni	12.76	1315.25	235.81	131204.50	362.22	153.60	2.374	5.197
Total Pb	7.03	62.70	39.32	272.00	16.49	41.94	-0.515	-0.655
Total Fe	17039	50883	32394.3	94093839	9700.20	29.94	0.0017	-0.993
Total Zn	33.00	87.50	64.56	282.61	16.81	26.04	-0.516	-0.803
Total Mn	218.00	1790.00	825.13	193042.47	439.36	53.25	1.124	0.697
Total Cu	8.80	99.90	46.72	607.45	24.64	52.72	0.578	-0.100
DTPA Cd	0.032	0.051	0.038	3.0221	0.005	14.35	1.015	-0.350
DTPA Co	0.187	0.351	0.277	0.001	0.032	11.72	-0.079	2.719
DTPA Cr	0.041	0.295	0.065	0.003	0.057	86.48	3.624	13.40
DTPA Ni	0.20	3.83	0.937	1.046	1.023	109.07	1.632	2.077
DTPA Pb	0.007	0.58	0.142	0.022	0.149	104.38	1.302	1.646
DTPA Fe	1.56	41.87	7.05	85.93	9.270	131.47	3.141	9.963
DTPA Zn	0.17	0.80	0.46	0.037	0.193	41.82	0.142	-0.931
DTPA Mn	0.34	11.15	3.66	9.861	3.14	85.77	1.442	1.091
DTPA Cu	0.32	2.68	1.24	0.448	0.669	53.99	0.372	-0.904

The high standard deviation and coefficient of variation indicated that total Ni and Cr concentrations of the soil changed at very close intervals (Table 2). This situation can be explained by the available Ni concentration being increased due to more soil decomposed (Ünver et al., 2013). The DTPA extractable Ni concentration of 65% of the soils was lower than 1 mg kg^{-1}, and 35% of them contain Ni between 1-5 mg kg^{-1}. There was a significant (r = 0.81***) relationship between total and available Ni (Figure 3). The DTPA extractable Ni concentration (0.20-3.83 mg kg^{-1}) constituted a very small part (0.08%-8.52%) of the total Ni concentration. The DTPA extractable Cr concentration (0.041 to 0.295 mg kg^{-1}) constituted 0.007%-0.56% of the total Cr. There was a weak (r = 0.50*) relationship between the available Cr and the total Cr concentrations of soils (Figure 4).

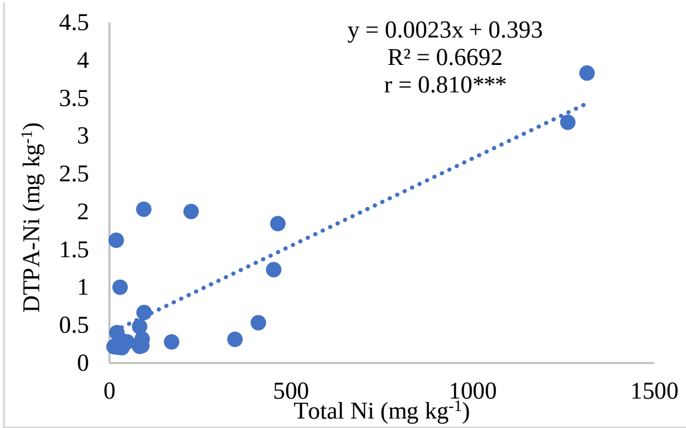

Figure 3. The relationship between total and DTPA extractable Ni concentrations of the serpentine soils.

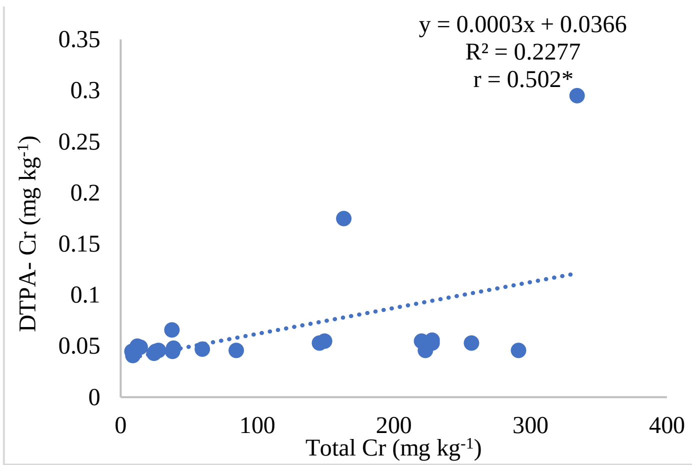

Figure 4. The relationship between total and DTPA extractable Cr concentrations of the serpentine soils.

The total Cd concentration of the soils (5.4-6.8 mg kg^{-1}) exceeded the limit value of 3 mg kg^{-1} reported in the National Soil Pollution Regulation (Anonymous, 2005). All of the samples DTPA extractable Cd concentrations (0.032-0.051 mg kg^{-1}) were below 1 mg kg^{-1} (Table 2). The DTPA extractable Cd to total Cd ratios ranged from 0.52% to 0.90%. There was a weak relationship (r = 0.26*) between available and total Cd. The total Pb concentration of the soils ranged from 7.03 to 62.70 mg kg^{-1} (all of the nontoxic for plants; < 200 mg kg^{-1}) and DTPA extractable Pb was between 0.007 and 0.580 mg kg^{-1}. The DTPA extractable Pb to total Pb ratios ranged from 0.03% to 4.43%, and Pb availability of serpentine soils generally was low. Total Co concentrations of serpentine soils varied between 18.38 and 67.89 mg kg^{-1} (74% soils contains 20-50 mg kg^{-1} Co). The DTPA extractable Co concentration was changed between 0.187 and 0.351 mg kg^{-1}. No relationship was found between total and DTPA-Co.

In addition to Ni, total Fe (17 039-50 883 mg kg^{-1}) and Mn (218-1790 mg kg^{-1}) concentrations were very high. Total Zn (33.0-87.5 mg kg^{-1}) and Cu (8.8-99.9 mg kg^{-1}) concentrations were ranged within the give limit values (Cu ≤ 140 mg kg^{-1} and Zn 300 mg kg^{-1}). The 87% of DTPA extractable Fe (1.56-41.87 mg kg^{-1}) and 61% of DTPA extractable Zn (0.17-0.80 mg kg^{-1}) concentrations were insufficient while all of the soil DTPA extractable Mn and Cu were sufficient according to Yurtsever (1984). There have been any relationships between soil organic matter content and DTPA extractable Ni and Cr concentrations. There were a negative and significant relationship between soil pH and DTPA extractable Ni (r = -0.445*) but no relationship has been found with DTPA extractable Cr concentration. The correlations between soil properties were listed in Tables 3 and 4.

Table3. Correlation coefficients DTPA-extractable heavy metals and some soil properties. EC: Electrical conductivity; CEC: cation exchange capacity.

	DTPA-Cr	DTPA-Ni	DTPA-Cd	DTPA-Mn	DTPA-Fe	DTPA-Cu
pH	0.609**	0.452*	-0.317	-0.441*	0.633**	-0.501*
EC	0.507*	0.460*	-0.290	-0.251	0.527**	-0.348
CEC	-0.401	-0.174	0.573**	0.427*	-0.394	0.030
P	-0.283	0.090	0.466*	0.282	-0.224	0.252
K	-0.207	-0.137	0.148	0.070	-0.217	0.183
Ca	-0.484*	-0.387	0.432*	0.295	-0.491*	-0.008
Mg	0.313	0.489**	0.029	0.09	0.350	-0.229
DTPA-Zn	0.360	0.300	0.360	0.517*	0.019	0.580**
DTPA-Cd	-0.295	0.157	1	0.580**	-0.230	0.414*
DTPA-Pb	-0.256	-0.059	0.417*	0.664**	-0.248	0.433*
DTPA-Ni	0.787***	1	0.157	0.131	0.848***	-0.132
DTPA-Cr	1	0.787***	-0.295	-0.282	0.965***	-0.382
Total Pb	0.149	-0.470	0.149	0.166	-0.468*	0.214
Total Ni	0.884***	0.818***	-0.183	-0.144	0.888***	-0.314
Total Cr	0.502*	0.559**	0.040	0.024	0.507*	0.150
Total Co	0.741***	0.784***	-0.066	-0.101	0.791***	-0.281

Table 4. Correlation coefficients total heavy metalsi and some soil properties. EC: Electrical conductivity; CEC: cation exchange capacity.

	Total Ni	Total Pb	Total Co	Total Zn	Total Cr
pH	0.686**	-0.373	0.560	-0.405	0.145
EC	0.626**	-0.445*	0.400	-0.303	0.127
CEC	-0.279	0.238	-0.163	0.378	-0.132
P	-0.387	-0.05	-0.294	0.419*	-0.294
K	-0.317	0.006	-0.447*	0.495*	-0.371*
Ca	-0.496*	0.454*	-0.433*	0.467*	-0.433*
Mg	0.643**	-0.492*	0.541**	0.467	-0.433*
DTPA-Zn	0.202	-0.189	0.208	-0.345	0.314
DTPA-Cd	-0.184	0.148	-0.066	0.385	0.040
DTPA-Pb	-0.216	-0.042	-0.322	0.168	-0.184
DTPA-Ni	0.818***	-0.470*	0.784***	-0.237	0.559**
DTPA-Cr	0.884**	-0.458*	0.740***	-0.476*	0.502*
Total Pb	-0.533**	1	-0.335	0.490*	-0.344
Total Ni	1	-0.534**	0.882***	-0.578**	0.671***
Total Cr	0.671**	-0.344	0.768***	-0.458*	1
Total Co	0.882***	-0.336	1	-0.391	0.768

Soil reaction at the research area was neutral and alkaline character and the range of these properties in serpentine soils was quite narrow. High soil reaction is generally characteristic of the regional soils and may be the result from low rainfall (Bani et al., 2013). Dominant soil texture classes were within medium ranges. This situation may have resulted from the existence of detrital parent material (Ünver et al., 2013). Serpentine soils were high with respect to calcium carbonate contents, this may due to past geological or anthropological mixtures with limestone formations. High soil pH and Ca content in serpentine soils were reported by different studies (Bani et al., 2013; Ünver et al., 2013; Atalay et al., 2019). A few numbers of the soils have relatively high organic matter content. These areas may be fertile under favorable conditions.

Due to the fact that a small amount of organic matter does not form a porous structure in the soil, it significantly prevents the leakage of water. Significant grass cover closure as a result of overgrazing lost and sloping places have also been found to gully erode.

The weathering process of serpentine-peridotite takes very long time due to ferro-magnesium-silicate composition. The CEC and/or plant nutrients are very low on the unweathered and low-weathered serpentine. The concentration of Ca and Mg in the study area was generally sufficient. While plant nutrient content especially clay, Mg and Ca cations and/or CEC capacity is higher on the deep and good weathered reddish serpentine than the yellowish and greenish serpentine. Alexander and DuShey (2011) reported that the serpentinization process leads to the loss of Ca in the parent material, found that serpentine soils have low Ca content.

Our research indicated that the Ca concentration of the serpentine soils was high contrary to other studies. The CEC, which is the expression of plant nutrition on serpentines, is significantly determined by the Ca and Mg ions released by the decomposition of the serpentines. In melange sites, the CEC has increased as the crushing of serpentines and the acquisition of cracked structures facilitate the progression of decomposition. The content of N and K was insufficient in half of the soil samples and nearly almost all of them had insufficient P. The same results were reported by Atalay et al. (2019). The plant nutrient elements released according to the different degrees of decomposition of serpentines directly affect the fertility of the soils and the main material formed on these rocks. In flat places where serpentines decompose deeply, agricultural plants and natural vegetation can usually grow on soils that are relatively rich in nutrients and have a clay structure. On the other hand, the sections where the serpentines come to the surface with the erosion of the soils on the sloping areas are in the form of areas where agriculture is unsuitable, yielding low, some forests are seen. The hard-massive, undecomposed serpentines in these areas prevent the roots from developing deeply, causing the trees to be shrub wood-tree-shaped.

According to the regulation reported by the Turkish Ministry of Agriculture and Forestry, 75 mg kg^{-1} total Ni and 100 mg kg^{-1} Cr can be allowed in agricultural soils (Anonymous, 2005). The Ni concentrations of 61% of the soils ($\geq$ 75 mg kg^{-1}) and Cr concentrations of 44% of the soils ($\geq$ 100 mg kg^{-1}) were above the limit values reported in the national soil pollution regulation. The geology and soil forming process strongly influence the Ni content. According to reported study results, available Ni concentration (75.32 mg kg^{-1}) in the rocky area was higher compared to under Ericaceae cover (32.98 mg kg^{-1}) in Marmaris Balan Mountain (Ünver et al., 2013). The total Ni concentration of serpentine soils in Western Anatolia varied between 2000-3000 mg kg^{-1}, and the DTPA-Ni concentration was below 5 mg kg^{-1} in 56.8% of the samples (Altinözlü et al., 2012). There is no doubt that numerous factors or soil properties such as depth, applied extraction and analysis methods, plant root depth, life, biological mass, Ni resistance, soil pH, organic matter content, structure, microbial biomass, etc., have an effect on the extractable Ni contents. Since Ni and Cr in serpentine soils are associated with Al, Mg, and Fe concentrations, they can cause negative effects on the biological system such as biological toxicity, inhibition of respiratory activities, and cancer. Toxic chromate ions in the soil cause skin irritations, weakening of the immune system, kidney, and cardiological diseases (Kumar and Maiti, 2013). The Ni and Cr concentrations of serpentine soils were changed between 2522-3800 and 177-354 mg kg^{-1} in the Isparta region (Saglam, 2013). Our results indicated that the slightly alkaline and alkaline pH of the soils prevented the penetration of Pb, Cd, and Co into the soil solution. Alkaline pH conditions may be led to the retention of trace metals which resulted in a decrease in plant uptake. There was a weak relationship between available and total Cd. This indicates that the release of extractable Cd salts was slow and difficult (Tran and Popova, 2013; Özbek et al., 2014).

In this context, principal component analysis (PCA) is recognized as one of the most widely used methods for reducing the number of variables by identifying those that are most significant in the data. Principal component analysis was performed for 26 qualities (variables) of 23 samples to reduce the dimensionality and facilitate interpretation. In PCA, components with an eigenvalue greater than 1 are accepted as principal components. The present study demonstrated that the first 10 principal components with an eigenvalue greater than 1 could explain 89.74% of the total variation in the population (Figure 5).

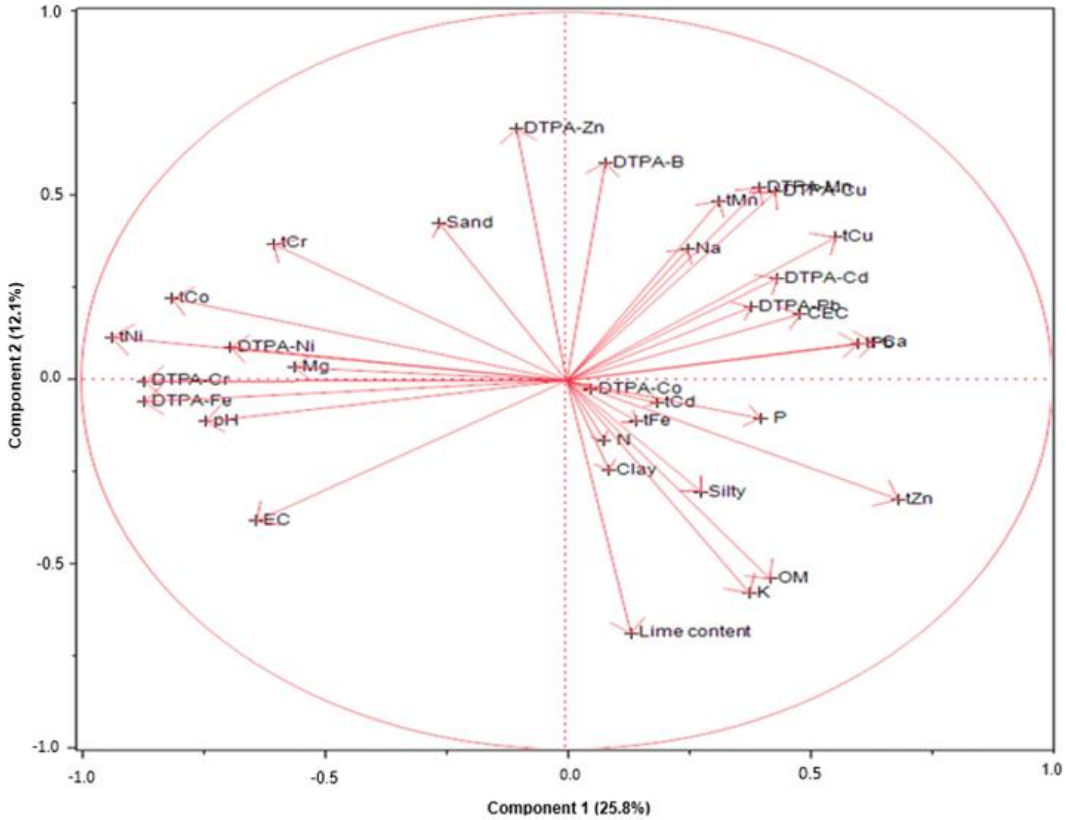

Figure 5. Principal Components PCA biplot.

CONCLUSIONS

In this study, the concentration of heavy metals (DTPA-extracted) has changed widely in relation to the climate conditions where the soil is formed, soil genetics, topographic components, geological and vegetative history. The extruded Ni concentration, considered to be available by plants, was found to be less than 1 mg kg^{-1} in most areas and the DTPA-Cr was low and formed a small portion of its total concentration. The DPTA-Ni and DPTA-Cr correlation with Cr and Ni totals is obvious. The present study demonstrated that the first 10 principal components with an eigenvalue greater than 1 could explain 89.74% of the total variation in the population. In our study, determination of the additive variance of the first three principal components as 25.7% enables accurate and effective interpretation. Variables of the first principal component such as DTPA-Cr, DTPA-Fe and total Ni were able to explain 25.7% of the total variation. DTPA-Zn, DTPA-B and calcium carbonate content were the second principal components, explaining 12.07% of the total variation. DTPA-Cd, DTPA-Ni, silty and DTPA-Mn were the third principal component, explaining 11.4% of the total variation. Total Fe, Na, clay and sand were the fourth principal, containing 9.8% of the total variation. Exchangeable Ca and cation exchange capacity (CEC) were the fifth principal component and were composed of 7.53% of the total variation. Total Mn and total Cd were sixth, DTPA-Pb was seventh, total Cd was the eighth principal component and explained 6.4%, 5.1%, and 5.0% of the variation, respectively. total Fe, CEC, organic matter and total Cu were ninth, total Cd, total Pb and P were tenth principal components and explained 3.4% and 3.0% of the variation, respectively.

The research area is under the influence of the temperate terrestrial and Mediterranean climate conditions. The low resolution of heavy metals has led to the healthy growth of many types of plants, especially grain plants, without showing signs of toxicity, especially in areas where the slope is low. It is thought that the conditions of the exposure of people or animals that consume plants that are cultivated in the land of the serpentine should be revealed by advanced studies.

The physical and chemical properties of the soil have been found to have changed in a very large range. It has been determined that this wide range of change is associated with the separation and formation of the soil; that the concentration of plant elements of the well segregated lands is sufficient and high, and that the under separated lands are inadequate.

Author contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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