International Journal of Environment and Geoinformatics 11(4):001-009 (2024)
DOI: 10.26650/ijegeo.1571546

Research Article

Ecological Risks Caused by Heavy Metal Accumulation in Umurbey Plain (NW Türkiye)

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Received 22.10.2024
Accepted 04.12.2024

Abstract

This study aims to assess the ecological risks in the agricultural soils of the Umurbey Plain in Çanakkale, NW Türkiye. To evaluate the anthropogenic impact on the studied soil samples, various indices and statistical analyses were employed. Our results revealed that the elements Cu, Cr, and Ni exhibited very high contamination levels at all stations. As showed high contamination at nearly all other stations, with a strong positive correlation to $CaCO_3$. Ni, Cd, Cr, and As demonstrated moderate to significant enrichment at these stations. Cu displayed very high to significant enrichment, likely associated with the use of bordeaux mixture in fruit orchards. The calculated average mEri values indicated that Ni, As, Cu, and Cd posed significant potential ecological risks at many stations, while other elements, including Hg and Tl, also presented risks. The Spearman correlation analysis among the variables revealed that the sources of the metals Pb, Zn, Mn, Fe, V, and Cd differed from those of Ni, As, and Cr.

Keywords: Ecological risk, Pollution, Heavy metal, Umurbey Stream, Çanakkale

Introduction

Agricultural lands are crucial in meeting the food needs of the growing human population. They provide the space and resources necessary for cultivating fruits, vegetables, grains, and other products essential for sustaining the global population. Beyond this, they significantly contribute to economic growth and development in many countries. In addition to being vital for food production, they are key in maintaining rural communities and preserving cultural heritage through traditional farming practices. Moreover, agricultural lands help mitigate the impacts of climate change by sequestering carbon and promoting sustainable practices that enhance soil health and water conservation. It is known that traditional agricultural practices significantly contribute to global annual CO2 emissions and that conservation agriculture helps offset part of the emissions resulting from unscientific agricultural practices (Patle et al., 2013). Furthermore, they serve as buffers against natural disasters, stabilize local economies, and provide essential resources during crises. On the other hand, when agricultural practices are intensified, biodiversity can decline in both agricultural areas and adjacent natural habitats, which necessitates the careful monitoring of biodiversity responses to these practices (Zhao et al., 2024).

The economic and social crises, along with global pandemics, have frequently reminded us of the importance of secure access to food. Agricultural lands, critical to the future and survival of humanity, face a serious pollution problem due to anthropogenic pressure. Soil pollution is defined as the introduction of physical, biological, and chemical substances into the soil, which eventually affects the life cycles of animals, plants, and humans, leading to adverse consequences for living organisms (Velayatzadeh, 2023). Metals pose a risk to soil safety in agricultural lands (Wu et al., 2016). Heavy metal contamination in agricultural soils has become a hidden threat to global food security, and understanding this issue while mitigating its negative impacts will be increasingly important in the future to protect food safety (Nde et al., 2024). The problem is exacerbated by factors such as rapid urbanization, industrial activities, and agricultural practices, and it is often not taken seriously enough, especially in developing countries, due to a lack of awareness about the toxic effects of pollution on both human and crop health (Rashid et al., 2023). Toxic elements pose long-term health risks, including increased cancer rates, nervous system injuries, and genetic disorders, primarily resulting from the consumption of contaminated water and food (Gazioğlu, 2018; Guzmán-Morales et al., 2019). This lack of awareness stems from the fact that soil is not as directly associated with human health as air and water (Velayatzadeh, 2023). Since metals cannot degrade, they persist in the environment, and many have physiological effects on living organisms, even at very low concentrations. These elements pose a risk to the food chain in the ecosystem due to their toxicity, abundance, persistence without degradation, and accumulation characteristics (Bessa et al., 2018). Toxic elements also disrupt the normal structure and function of cellular components, thereby impairing various metabolic and developmental processes, which in turn affects plant health and reduces crop yields (Angon et al., 2024).

The Umurbey Plain is an area where agricultural activities are very intense (Eren et al., 2021), where vegetables and fruits are cultivated, and holds significant economic value for the region (Yiğini and Ekinci, 2007). However, it is under pressure from various pollutants, including fertilizers used to increase yield, pesticides for pest control, waste from mining storage sites, residential areas, ship traffic, and industrial waste. This study aims to i) determine the metal content in soil samples collected from agricultural lands in the Umurbey Plain, ii) reveal the existence and levels of anthropogenic enrichment, iii) calculate the potential ecological risk levels, and iv) identify the possible sources, transportation processes, and interrelationships of the elements.

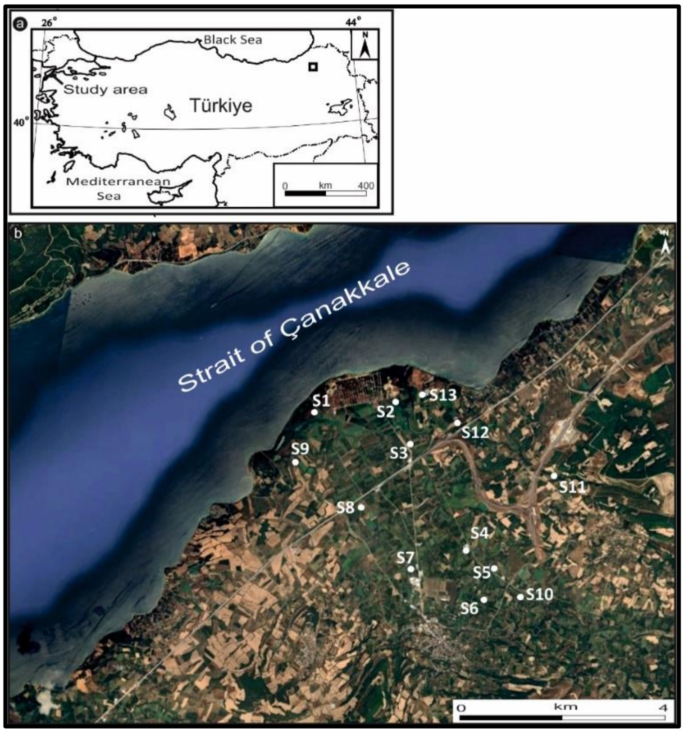


Fig. 1: Location map of the Umurbey Plain (a) and sampling sites (b).

Materials and Methods

Study Area

The Umurbey delta plain is located in the northwestern part of the Biga Peninsula, south of the Marmara Region, approximately 15 km northwest of Çanakkale province and lies between 40° 20′ N latitude and 26° 42′ E longitude (Fig. 1). It is formed by the Umurbey Stream, which is 57 km long. The upper reaches of its basin are characterized by Paleozoic granites and metamorphic rocks, while the lower reaches are dominated by limestones formed during the Miocene and Pliocene periods (Erdal, 2019).

Sampling and analytical procedures

A total of 13 samples (S1-S13, herein) were collected from the agricultural soils of Umurbey Plain. Additionally, 4 bedrock samples were collected from the Umurbey basin for background analyses (Fig. 1). Since the carbonate level plays a significant role in the transportation of metals to wetland areas, and the pH levels of soils and sediments are influenced by calcium carbonate, the $CaCO_3$ levels of each sample were therefore determined using a Schibler Calcimeter (Schlichting and Blume, 1966) to understand the transportation processes of metals and identify potential sources. Total organic carbon was determined using the Walkley-Black titration method (Walkley and Black, 1934). The total nitrogen (TN) was determined using Dumas procedure (Bremner, 1965).

Since the pH levels of sediments and soils affect the absorption rates and availability of metals, a decrease in pH levels leads to increased metal absorption and more rapid chemical processes. The soil pH affects the accessibility and mobility of heavy metals (HMs) within the soil and has effects on microorganisms (Angon et al., 2024). Thus, the pH was measured using a Thermo Scientific Orion brand electrode. A 1 g sample of soil and sediment was weighed using a precision balance, placed in tubes, and 2.5 ml of distilled water was added. The tubes were capped and shaken for 1 minute (Thomas, 1996). The pH meter was then calibrated with distilled water. After calibration, the pH electrode was immersed in the tubes, and the pH values were recorded. A spectrophotometric method was selected for the analysis of chlorophyll degradation products, and the analyses were conducted on fresh sediment samples following the acetone extraction method (Lorenzen, 1971). The metal levels in the samples were determined using ICP-MS. These analyses were conducted at the Bureau Veritas laboratories in Canada. We utilized Spearman's correlation, Principal Component (PCA), and Cluster analyses for statistical interpretations.

Pollution indices

Contamination factor (CF)

CF indicates the degree of anthropogenic pollution in the environment and is calculated by dividing the concentration of the element under study by its background concentration. According to Hakanson (1980), the results are interpreted as follows: CF < 1 indicates low contamination, CF = 1-3 indicates moderate contamination, CF = 3-6 indicates high contamination, and CF > 6 indicates very high contamination. Hakanson's (1980) formula is as follows:

$$CF = \frac{C_{heavy\,metal}}{C_{background}} \qquad \text{(Eq.1)}$$

Enrichment factor (EF)

EF is a commonly used index for identifying anthropogenic pollution in sediments and agricultural soils and is calculated by dividing the measured metal/reference element ratio by the background metal/reference element ratio (Abrahim and Parker, 2006; Barbieri, 2016; Loska et al., 2005). In studies of heavy metals in sediments and soils, conservative elements like Mn, Al, Fe, Ti, and Ca from lithogenic sources are commonly used as references. In this study, aluminum (Al), the most abundant element on Earth's surface, was used. Four bedrock samples were collected in the study area to determine the background calculation.

The enrichment factor (EF) is calculated using the following formula:

$$EF = G\ (Metal/Al)/\ A\ (Metal/Al) \qquad \text{(Eq.2)}$$

where, G represents the current element levels, while A denotes the background element levels. The obtained values have been assessed according to Sutherland (2000). The evaluation criteria are as follows: EF < 2, no enrichment/minimal enrichment; EF = 2–5, moderate level enrichment; EF = 5–20, significant enrichment; EF = 20–40, very high enrichment, and EF > 40, extremely high enrichment.

Geo-accumulation index (Igeo)

The Igeo index was proposed by Müller (1969) and is another method used to identify anthropogenic pollution in soils and sediments. The Geo-Accumulation Index is calculated using the following formula:

$$I_{geo} = \log C_n/(1{,}5 \times B_n) \qquad \text{(Eq.3)}$$

where, Cn represents the current element level, and Bn denotes the background element level. The classification of the Igeo Index are as follows: Igeo < 0, uncontaminated; Igeo = 0 ≤ Igeo ≤ 1, uncontaminated to moderately contaminated; Igeo = 1 ≤ Igeo ≤ 2, moderately contaminated; Igeo2 ≤ Igeo ≤ 3, moderate to strongly contaminated; Igeo= 3 ≤ Igeo ≤ 4, strongly contaminated; and Igeo= 4 ≤ Igeo ≤ 5, strongly to extremely contaminated.

Potential ecological risk (PER)

To determine the potential ecological risks that metals can pose to ecosystems, the Potential Ecological Risk Index (PERI) developed by Hakanson (1980) has been calculated. The modified risk factor (Eri) for each element is computed using the formula below. It is obtained by multiplying the enrichment factor values by the toxic responsibility coefficient and summing the resulting products.

$$mEri = E_f \times T^i f \qquad \text{(Eq.4)}$$

In the formula, mEri is an index calculated separately for each metal, while EF represents the Enrichment Factor and Ti denotes the toxic responsibility coefficient for the target element. The risk factors (PER) that are calculated for all metals collectively are evaluated as follows: Eri < 40, low potential ecological risk; 40 ≤ Eri ≤ 80, moderate potential ecological risk; 80 ≤ Eri ≤ 160, considerable potential ecological risk; 160 ≤ Eri ≤ 320, high potential ecological risk; Eri ≥ 320: very high potential ecological risk; and Eri≥320, very high potential ecological risk.

Ecological risk assessment at the station level is performed by summing the potential ecological risk index levels of the elements:

$$PERI = \sum MRI \qquad \text{(Eq.5)}$$

In this formula, PERI represents the ecological risk assessment at the station level, while MRI refers to the calculations made for each metal. Based on the results, the ecological risk levels are classified as follows: PERI<150, low ecological risk; 150≤PERI<300, moderate ecological risk; 300≤PERI<600, considerable ecological risk; and PERI≥600, very high ecological risk.

Results and Discussion

pH, TOC, $CaCO_3$, and TN

The pH levels of agricultural soils in Umurbey Plain are shown in Table 1. The measurements revealed that the pH levels ranged from 7.7 to 8.6, similar to the pH of the Umurbey sediments, which ranged between 7.18 and 8.04 (Eren et al., 2021). According to the pH classification scale, the agricultural soils were found to be in the range of mildly alkaline, moderately alkaline, and strongly alkaline. The presence of lime and high pH in the studied soil samples is important for alleviating metal toxicity for plants (Gatiboni and Hardy, 2022). TN levels ranged from 0.019% to 0.086%. It was found to be low at S1, while at all other stations, it was classified as very low.

TOC levels in agricultural soils ranged from 0.64% to 1.54%. Among the stations, the lowest carbon level was observed at S13 with 0.64%, while the highest carbon level was found at S10 with 1.54%. Stations 2, 8, and 10 were identified to have relatively higher organic carbon levels compared to the other stations. According to the organic carbon scale established by Ülgen and Yurtsever (1995), the agricultural soils of Umurbey Plain showed very low organic matter levels at stations 3, 4, 5, 11, 12, and 13, while low levels were recorded at S1, 2, 8, and 10. The $CaCO_3$ levels of the soil samples are also varied, with those at S1 and 12 being below the detection limits. The levels ranged from 0.08% to 45.3%. The lowest

$CaCO_3$ content was observed at Stations 2, 3, 8, 9, and 13, while the highest was found at S10, 6, 11, and 7. These values are quite high compared to the average calcium carbonate content of 6.15% reported by (Eren et al., 2021).

Table 1: pH, TOC, $CaCO_3$, and TN values of soils from the Umurbey Plain.

	pH	OC (%)	$CaCO_3$ (%)	TN
S1	8,5	1,03	0	0,09
S2	8,6	1,49	0,83	0,02
S3	8,3	0,94	0,08	0,03
S4	8,8	0,67	14,13	0,03
S5	9,1	0,68	16,67	0,04
S6	9	0,92	39,98	0,03
S7	8,7	0,97	33,43	0,04
S8	8,5	1,49	4,18	0,04
S9	9	0,87	2,66	0,04
S10	8,6	1,54	45,55	0,02
S11	8,4	0,74	36,85	0,02
S12	9,2	0,68	0	0,02
S13	8	0,64	1,5	0,02

Metal distributions

The average concentrations of heavy metals in agricultural soils of Umurbey Plain are ranked as follows: Mn > Cu > Zn > V > Ni > Pb > Cr > As > Co > Fe > Al > Cd > Tl > Hg. The concentrations were found to be: Mn 743-1302 ppm, Cu 29.7-85.3 ppm, Zn 32.1-111 ppm, V 24-118 ppm, Ni 24.5-74.4 ppm, Pb 12.5-43.8 ppm, Cr 21.6-50.8 ppm, As 12.3-41.3 ppm, Co 9.1-18.3 ppm, Fe 1.6-3.5%, Al 1.2-2.8%, Cd 0.1-0.6 ppm, Tl 0.1-0.3 ppm, and Hg 0.01-0.05 ppm (Table 2). Minimum values for Pb, Zn, Co, Mn, Fe, Cd, V, Tl, Hg, and Al were detected at S11, while Ni and Cr were found at S1, Cu at S10, and As at S8. Maximum values for Zn, Co, Mn, and Cd were detected at S13, while Ni, Cr, and Al were highest at S9. Pb and Hg were found at S5, Cu at S6, Fe at S2, As at S11, V at S1, and Tl at S7. The levels of Pb, Zn, Mn, and Fe in soil samples from Umurbey Plain were found to be below background levels, with Hg at the threshold level, while all other elements were above background levels. According to the World Health Organization's permissible heavy metal levels, only the level of As was found to exceed the threshold.

Pollution indices

CF distributions

The CF values of soil samples taken from Umurbey Plain agricultural soils are illustrated in a box and whisker plot (Fig. 2). As a result of the calculations, the CF values of the elements are ranked as follows: Cu > Ni > Cr > Cd > As > Tl > Co > Al > V > Hg > Fe > Mn > Pb > Zn. The Pb and Zn elements exhibited low contamination across all stations, while the Cu, Cr, and Ni elements showed very high contamination at all stations. Despite the prevalence of polymetallic mineralizations such as Pb, Zn, Cu, Mo, Au, and Ag around the study area (Demirela et al., 2014), and the presence of areas containing metals like Pb, Cu, and Zn in the Umurbey Stream and its surroundings (Özdemir, 2011), these metals were found at low contamination levels in the studied soils. The Fe and V elements demonstrated low contamination at stations 6, 7, 10, and 11, while the Al and Co elements showed low contamination only at stations 10 and 11; all other stations exhibited moderate contamination. The As element showed moderate contamination only at station 8, while high contamination was observed at all other stations. Based on the average CF values for each station, high contamination was noted at stations 4 and 6, while moderate contamination was found at all other stations.

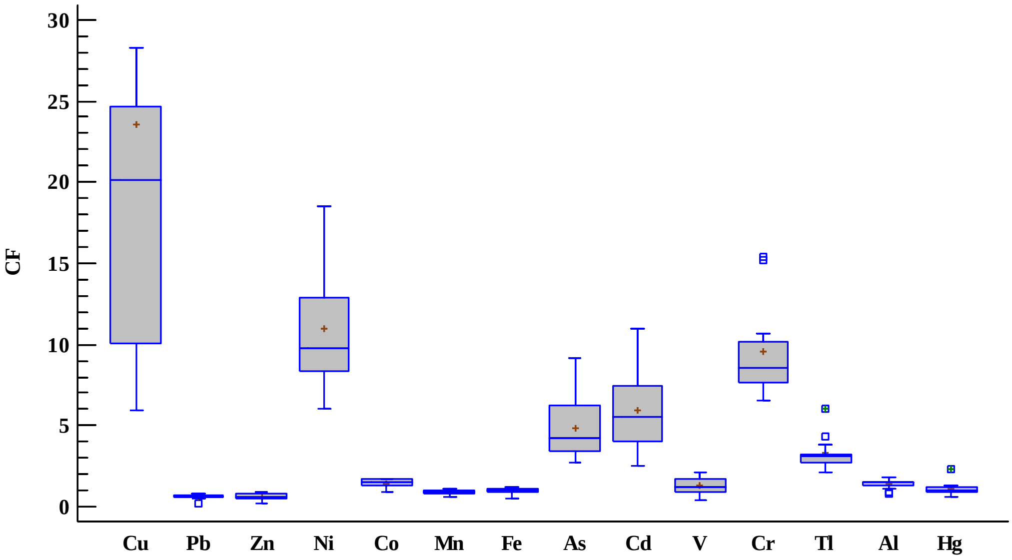


Fig. 2: Box and Whisker Plot of CF values.

Table 2: The distribution of metals* in the soils of Umurbey Plain.

Site	Cu	Pb	Zn	Ni	Co	Mn	Fe	As	Cd	V	Na	Mg	Cr	Tl	Al	Hg	K	P
S1	57,3	34,9	79,2	24,5	16,1	1019	34200	13,7	0,33	118	0,092	0,76	21,6	0,17	22100	0,017	0,24	0,048
S2	72,2	43,6	103,5	29,9	17,9	1295	35400	15,5	0,5	112	0,065	0,87	22,9	0,2	25100	0,026	0,33	0,076
S3	99,9	39,4	100,2	31,7	17,5	1213	34100	15,7	0,5	106	0,065	0,85	25,1	0,21	24900	0,023	0,25	0,063
S4	222,1	32,6	78,7	52,7	16,5	1051	27300	23,2	0,38	68	0,035	0,9	33,4	0,28	21400	0,017	0,41	0,09
S5	77,1	43,9	99,2	34,1	15,1	1125	29600	21,8	0,38	79	0,048	1,2	25,8	0,2	24900	0,046	0,38	0,115
S6	229	28,4	62,1	51,2	11,3	1016	19200	32,8	0,22	34	0,016	0,97	35,3	0,18	17800	0,026	0,35	0,108
S7	33,7	30,7	63	72,9	15,1	861	26600	28,4	0,3	50	0,025	0,84	50,3	0,39	24000	0,02	0,43	0,057
S8	45,4	36,4	90,2	44,8	13,7	840	27700	12,3	0,24	68	0,039	1,04	33,4	0,21	24200	0,017	0,44	0,156
S9	30,7	32,8	77,4	75,4	17,8	951	32400	19,1	0,3	70	0,021	3,2	50,8	0,25	28600	0,018	0,33	0,056
S10	21	30,3	46,6	39,9	9,6	915	17300	30,1	0,19	29	0,024	1,02	28,2	0,16	14700	0,02	0,32	0,117
S11	35,8	12,5	32,1	53,9	9,1	743	16400	41,3	0,15	24	0,024	1,02	32,3	0,14	12700	0,012	0,25	0,07
S12	71,4	36,8	89,7	34,9	16,7	1149	33800	15,9	0,45	99	0,082	0,82	25,1	0,19	26100	0,017	0,26	0,057
S13	87,3	42,4	111	34,1	18,3	1302	33200	15,8	0,66	98	0,08	0,55	24,9	0,2	26900	0,02	0,25	0,072

[*] *The results are presented in ppm.*

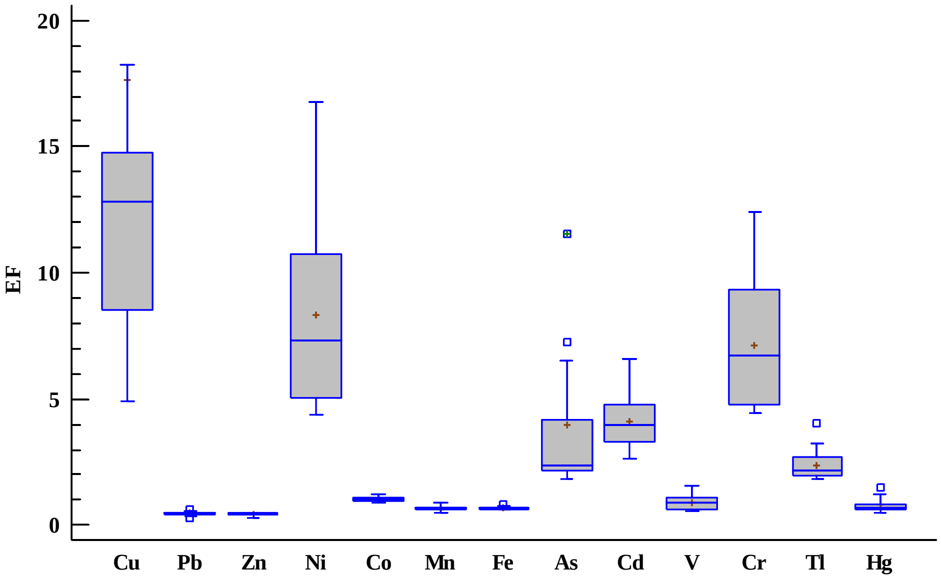


Fig. 3: Box and Whisker Plot of EF values.

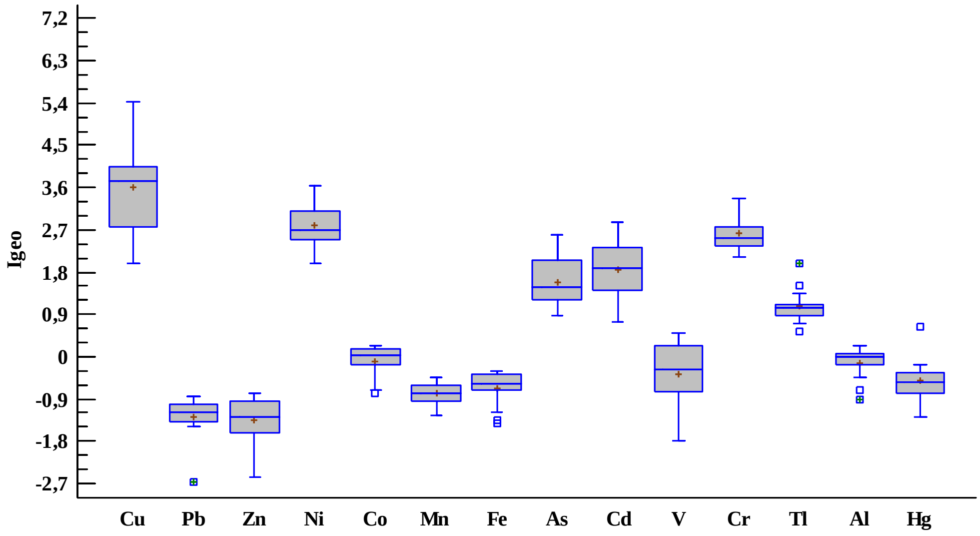


Fig. 4: Box and Whisker Plot of Geo-Accumulation Index (Igeo) values.

EF distributions

The EF values of trace elements analyzed in soil samples from Umurbey Plain are presented as box and whisker plots (Fig. 3). The calculated average EF values of the trace elements are ranked in decreasing order as follows: Cu, Ni, Cr, Cd, As, Tl, Co, V, Hg, Fe, Mn, Pb, and Zn.

For the elements Pb, Zn, Co, Mn, Fe, V, and Hg, no enrichment or minimal enrichment was found at all stations. For the Tl element, no enrichment or minimal enrichment was found at stations 1, 2, 5, 12, and 13, while moderate enrichment was observed at all other stations. Ni showed moderate enrichment at stations 1 and 2, while significant enrichment was found at all other stations. As exhibited significant enrichment at stations 6, 10, and 11, while moderate enrichment was observed at all other stations. For the Cd element, significant enrichment was noted at stations 2, 3, and 13, while moderate enrichment was found at all other stations. Cr also showed moderate enrichment at stations 1, 2, 3, 12, and 13, while significant enrichment was observed at all other stations. The Cu element exhibited very high enrichment at stations 4 and 6, with significant enrichment at all other stations. Based on the average EF values at the stations, significant enrichment was found at stations 4 and 6, while moderate enrichment was observed at all other stations.

Geo-Accumulation Index (Igeo)

The average element levels obtained from the measurements of soil samples taken from Umurbey Plain agricultural soils are presented in a box and whisker plot (Fig. 4). The average ranking of the studied elements is as follows: Cu > Ni > Cr > Cd > As > Tl > Co > Al > V > Hg > Fe > Mn > Pb > Zn. The Cu and Ni elements were found to be at very polluted levels at stations 4 and 6, while the Cr element was at a very polluted level at S7. It was determined that the Pb, Zn, Mn, Fe, and Hg elements were not polluted at all stations. According to the average Igeo values based on each station, S11 was found to be unpolluted, while all other stations were either unpolluted or moderately polluted.

Potential ecological risk (PER)

The mEri values obtained for each element in the agricultural soils of Umurbey are shown in a box and whisker plot (Fig. 5). The calculated average mEri values are ranked as follows: Cd > Cu > Ni > As > Hg > Tl > Cr > Co > Pb > V > Mn > Zn. According to the element-based potential ecological risk assessment scale, Ni and As were found to pose 'significant potential ecological risk' levels at S11, while Cu was identified at S3, and Cd was significant at all stations except stations 2, 3, and 13. Other elements posing a risk include Cu, Cd, Hg, and Tl.

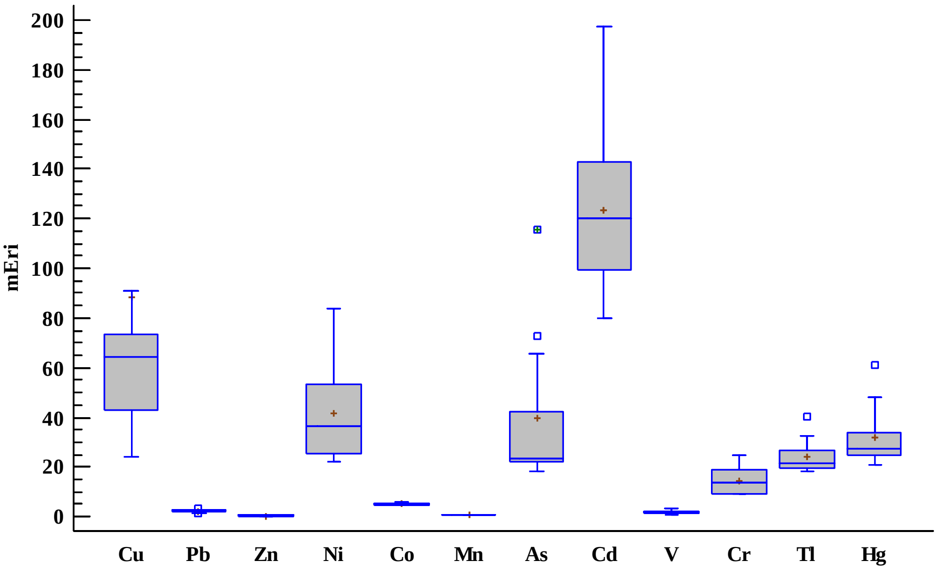


Fig. 5: Box and Whisker Plot of the Potential Ecological Risk Index for Agricultural Soils of Umurbey Plain.

Statistical Implications

Statistical analyses and measurements conducted on samples taken from the agricultural soils of Umurbey Plain have revealed that some metals exhibit strong positive correlations with each other (Table 3). The metals Pb, Zn, Co, Mn, Fe, V, and Cd showed strong positive correlations among themselves. In contrast, there was an inverse relationship between the metals Pb, Zn, Co, Mn, Fe, V, and Cd with Ni, As, and Cr. In other words, it can be seen that the sources of the metals Pb, Zn, Mn, Fe, V, and Cd are different from those of Ni, As, and Cr.

The TOC, P, and TN parameters showed no correlation with the metals Hg and Tl during the analysis process. The $CaCO_3$ parameter exhibited a strong positive correlation with the As metal, while V, Cd, Na, Fe, and Co displayed negative correlations. According to the enrichment, contamination factor, and geo-accumulation index data, Cu, Zn, Cd, Ni, and As metals were found to be at high levels, indicating an ecological risk. The results suggest that there is an anthropogenic effect on the levels of Cu, Zn, Cd, Ni, and As metals.

The PCA results are presented in Table 4. The analysis identified five components, which explain 88.4% of the total variation. The first component consists of the metals Pb, Zn, Co, Mn, Fe, Cd, V, Na, and Al, explaining 45.6% of the total variation. In the principal component analysis, these metals showed strong positive correlations. However, in all ecological risk index calculations conducted, the Cd metal was found to be at very high levels, indicating a significant potential ecological risk among the metals studied. The agricultural soils of Umurbey Plain are irrigated with waters from the Umurbey River. Thus, the potential source of the metals Pb, Zn, Co, Fe, V, Al, Na, Mn, and Cd is believed to be the Pb-Zn mine located in the upper part of the Umurbey Dam. The second component consists of the metals Ni, Co, Mg, Cr, Al, and Tl, explaining 16.9% of the variation. Similar results were obtained in the Spearman analysis, which corroborates the findings from the principal component analysis. The metals constituting the second component are thought to originate from synthetic fertilizers. The third component includes the metals Cu, Pb, Al, Hg, along with the parameters K and P, explaining 11.3% of the total variation. The fourth component consists of the metals Cu, Mn, As, and Cd, as well as the TOC parameter, explaining 8.7% of the total variation.

The fifth component consists of the metals Cu, Mg, and Tl, along with the TN parameter, explaining 5.6% of the total variation. In components 3, 4, and 5, the Cu metal has shown associations with many metals and parameters. This situation indicates that the source of Cu metal may be multifaceted. In the peach orchards located in the Umurbey Plain, a fungicide known as Bordeaux mixture is used intensively. It is believed that the most significant source of the identified Cu metal in the soils is the Bordeaux mixture.

A cluster analysis was conducted to determine the sources and transport processes of metals and parameters present in the agricultural soils of Umurbey Plain. The analysis revealed that Pb, Zn, Co, Fe, V, Al, Na, Mn, and Cd share common sources and transport processes (Fig. 6). The agricultural soils of Umurbey Plain are irrigated with the waters of the Umurbey River. Therefore, the metals found in the sediments of the Umurbey River are also present in the agricultural soils of Umurbey Plain. Thus, the probable sources of Pb, Zn, Co, Fe, V, Al, Na, Mn, Hg, and Cd are thought to be the Pb-Zn mine located in the upper section of the Umurbey Dam. These findings support the results of the Spearman correlation analysis. It has been determined that Ni, Cr, Tl, Mg, K, P, As, TOC, and TN also share common sources and transport processes.

The probable sources of these metals and parameters are believed to be the synthetic fertilizers used in agricultural processes. According to the Principal Component Analysis, Cu has shown associations with multiple metals and parameters. However, the most significant source of Cu is thought to be the Bordeaux mixture used in fruit orchards. The results of the cluster analysis substantiate the findings of the Principal Component Analysis.

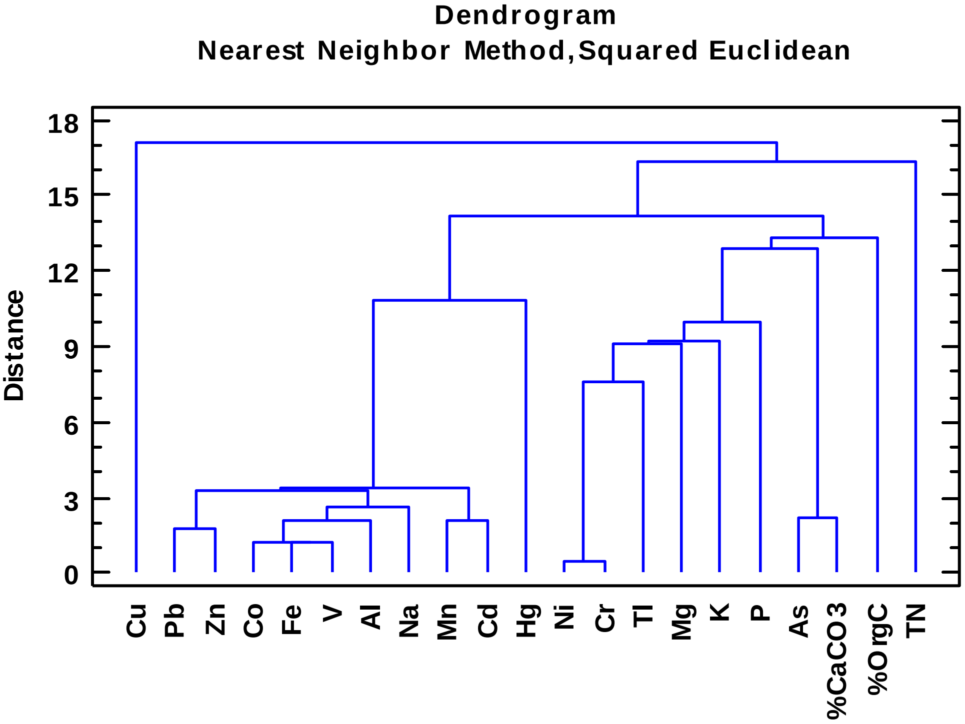
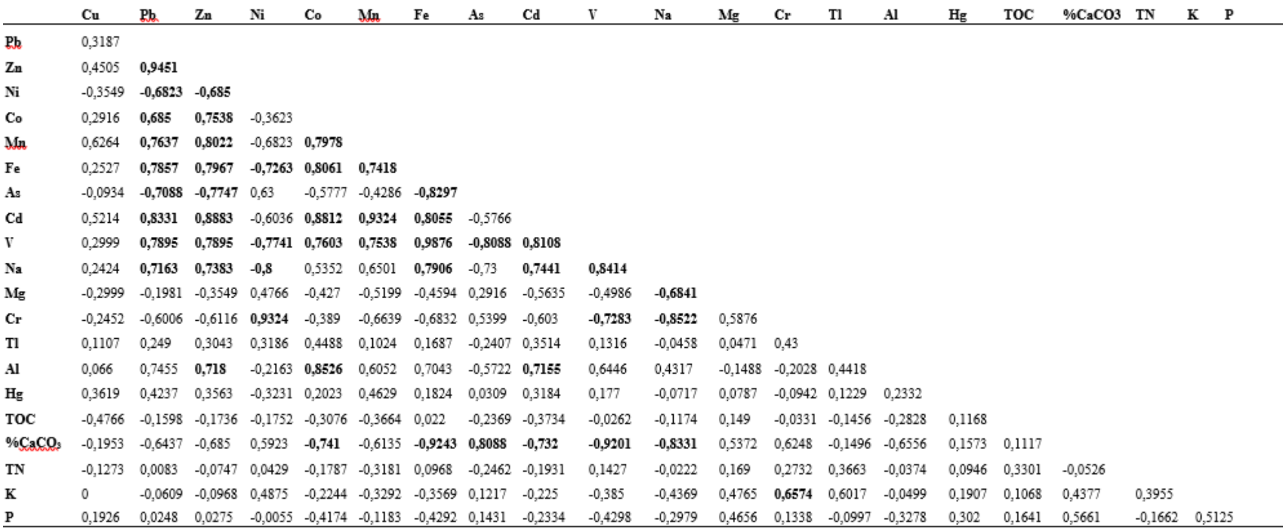


Fig. 6: Cluster Diagram of Agricultural Soils in Umurbey Plain.

Table 3: Spearman Correlation Among Variables in Agricultural Soils of Umurbey Plain.



	Cu	**Pb**	**Zn**	**Ni**	**Co**	**Mn**	**Fe**	**As**	**Cd**	**V**	**Na**	**Mg**	**Cr**	**Tl**	**Al**	**Hg**	**TOC**	**%CaCO3**	**TN**	**K**	**P**
Pb	0,3187																				
Zn	0,4505	**0,9451**																			
Ni	-0,3549	**-0,6823**	**-0,685**																		
Co	0,2916	**0,685**	**0,7538**	-0,3623																	
Mn	0,6264	**0,7637**	**0,8022**	-0,6823	**0,7978**																
Fe	0,2527	**0,7857**	**0,7967**	**-0,7263**	**0,8061**	**0,7418**															
As	-0,0934	**-0,7088**	**-0,7747**	0,63	-0,5777	-0,4286	**-0,8297**														
Cd	0,5214	**0,8331**	**0,8883**	-0,6036	**0,8812**	**0,9324**	**0,8055**	-0,5766													
V	0,2999	**0,7895**	**0,7895**	**-0,7741**	**0,7603**	**0,7538**	**0,9876**	**-0,8088**	**0,8108**												
Na	0,2424	**0,7163**	**0,7383**	**-0,8**	0,5352	0,6501	**0,7906**	-0,73	**0,7441**	**0,8414**											
Mg	-0,2999	-0,1981	-0,3549	0,4766	-0,427	-0,5199	-0,4594	0,2916	-0,5635	-0,4986	**-0,6841**										
Cr	-0,2452	-0,6006	-0,6116	**0,9324**	-0,389	-0,6639	-0,6832	0,5399	-0,603	**-0,7283**	**-0,8522**	0,5876									
Tl	0,1107	0,249	0,3043	0,3186	0,4488	0,1024	0,1687	-0,2407	0,3514	0,1316	-0,0458	0,0471	0,43								
Al	0,066	0,7455	**0,718**	-0,2163	**0,8526**	0,6052	0,7043	-0,5722	**0,7155**	0,6446	0,4317	-0,1488	-0,2028	0,4418							
Hg	0,3619	0,4237	0,3563	-0,3231	0,2023	0,4629	0,1824	0,0309	0,3184	0,177	-0,0717	0,0787	-0,0942	0,1229	0,2332						
TOC	-0,4766	-0,1598	-0,1736	-0,1752	-0,3076	-0,3664	0,022	-0,2369	-0,3734	-0,0262	-0,1174	0,149	-0,0331	-0,1456	-0,2828	0,1168					
%CaCO$_3$	-0,1953	-0,6437	-0,685	0,5923	**-0,741**	-0,6135	**-0,9243**	**0,8088**	**-0,732**	**-0,9201**	**-0,8331**	0,5372	0,6248	-0,1496	-0,6556	0,1573	0,1117				
TN	-0,1273	0,0083	-0,0747	0,0429	-0,1787	-0,3181	0,0968	-0,2462	-0,1931	0,1427	-0,0222	0,169	0,2732	0,3663	-0,0374	0,0946	0,3301	-0,0526			
K	0	-0,0609	-0,0968	0,4875	-0,2244	-0,3292	-0,3569	0,1217	-0,225	-0,385	-0,4369	0,4765	**0,6574**	0,6017	-0,0499	0,1907	0,1068	0,4377	0,3955		
P	0,1926	0,0248	0,0275	-0,0055	-0,4174	-0,1183	-0,4292	0,1431	-0,2334	-0,4298	-0,2979	0,4656	0,1338	-0,0997	-0,3278	0,302	0,1641	0,5661	-0,1662	0,5125	

Bold black values: Correlation is significant at the 0.1 level. Black values: No correlation.

Conclusions

The agricultural soils of the Umurbey Plain in Çanakkale, NW Türkiye, are very highly to highly contaminated with Cu, Cr, Ni, and As, and they exhibit moderate to very high enrichment of Ni, Cd, Cr, As, and especially Cu, likely due to the widespread use of fungicides. It has been determined that Ni, As and Cr metals, which are correlated with each other in statistical analyses and at a level that will pose a risk in ecological index calculations, come from artificial fertilizers used to increase production in agricultural activities due to their correlation with TOC, TN and K parameters. Ni, As, Cu, and Cd, along with Hg and Tl to a lesser extent, pose a significant potential ecological risk in the agricultural soils of the Umurbey delta plain. In particular, Ni, As, and Cr share a common anthropogenic source. Additionally It has been determined that the Umurbey Plain agricultural soils have a low capacity to retain heavy metals due to their organic matter content varying from high to low.

Acknowledgements

This research was supported by the Scientific Research Projects Unit of Çanakkale Onsekiz Mart University (Project No: SYL-2020-3451).

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