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Determination of molybdenum content of soils in Arsuz region of Hatay Province and relationships with some heavy metals in soil

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Abstract: In this study, it was aimed to determine the molybdenum content of the soils of Arsuz region of Hatay province and to determine their relationship with some heavy metals in the soil. For this purpose, a total of 70 soil samples were taken from 0-30 cm depth and 70 points to represent the soils of Arsuz district. According to the results of the research; Cd content of the soils was found between 0.01-0.03 µg/kg; Co content between 0.02-2.96 µg/kg; Cr content between 0.01-0.85 µg/kg; Ni content between 0.35-17.60 mg/kg; Fe content between 1.65-18.72 mg/kg and Mo content between 0.01-0.18 µg/kg. Positive significant relationships were determined between Mo and Cd, Co and Fe contents of soils. At the same time, positive significant relationships were determined between Cd and Co, Ni, Fe and Co and Ni and Fe. When the heavy metal contents of the soils of the region were compared with the limit values, no heavy metal pollution was found.

Keywords: molybdenum content; Arsuz district; heavy metals

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1 Introduction

Soil is an active and essential natural part of the lithosphere, which includes many different types of organisms from very small organisms to very large trees. Soil is also a living entity that contains macro and micronutrients, which are an important source of nutrients for biological activity to take place, and helps to maintain the continuity of many different biodiversity and habitats (Küçük and Karaoğlu 2021). In general, metals with a specific gravity above 5 g cm^{-3} and an atomic mass above 20 are more commonly referred to as heavy metals. Both high and low concentrations of heavy metals in soils are toxic to soil organisms. At the same time, very low concentrations of some heavy metals (Fe, Cu, Zn, Mo and Ni) are necessary for plants in the soil. Some of them (Cd, Pb, Hg, As, etc.) show toxic effects on plants because they do not have a known physiological function in plants in the soil. However, heavy metals in nature pose a very important threat to human, animal and plant health at high concentrations. The development of industry and anthropogenic effects are the most important factors in the increase of heavy metal-induced environmental pollution (Yurdakul et al. 2023). Heavy metal pollution in soils in nature can be caused by human-induced practices such as the combustion of fossil fuels, thermal power plants, the use of waste or polluted water, fertilisers and pesticides in agricultural soils, mining wastes and landfill filtration, as well as the natural weathering process of minerals, erosion, forest fires and volcanic activities (Özyiğit 2021). Among sustainable agricultural inputs, one of the most important sources of pollution, especially in agricultural lands, is heavy metal pollution. The most important factors in the formation of heavy metal pollution are the uncontrolled application of urban wastes and sewage sludge to lands, the use of solid and liquid wastes from industry in agricultural environments, and the improper use of pesticides and fertilizers (Saltalı et al. 2018). In sustainable agricultural activities, plant products grown in soils contaminated with heavy metals negatively affect all life systems when they are added to the food chain. For this reason, heavy metal pollution in soil, which occurs naturally or artificially, is one of the very important issues that need to be controlled and monitored, especially in agricultural areas (Dedeoğlu and Başyiğit 2018). Depending on their amounts in the soil, heavy metals can potentially determine toxicity for plants in the soil and those who consume them. In general, toxic metals accumulate in the upper layer of the soil and enter the food chain through plants. With their entry into the food chain, bioaccumulation events occur and pose a significant risk to all living species (Çolak et al. 2021). In addition to the effect of heavy metal contents in the soil ecosystem, heavy metals in soils can cause acute or chronic diseases as a result of consumption in humans through the food chain. Due to these known damages, it is not desirable to have heavy metal concentrations above critical levels in soils. Along with the aforementioned effects the removal of heavy metal pollution in the soil from the environment is one of the most important issues for the continuation of biological vitality in the soil, the protection of soil health and quality, and the continuation of agricultural sustainability (Taciroğlu et al. 2016). Heavy metals as pollution factors pose a danger and risk to all living organisms and human life worldwide. They cause various diseases, especially cancer, in humans depending on factors such as exposure dose, genetics, immune resistance and general health status, age, nutritional level. Urgent measures should be taken to minimise soil pollution caused by heavy metals, which are a problem in the world and in our country. Plant products grown unhealthily in soils contaminated with heavy metals directly affect human and animal life negatively (Seven et al. 2018).Many studies on heavy metals have been carried out in our country. In a study carried out in the same region, Yalçın (2024) aimed to determine the molybdenum content of the soils of Kırıkhan-Kumlu region and to determine their relationship with some heavy metals in the soil. As a result of the study; Cd content of soils was found between 0.01-0.06 µg kg^{-1}; Co content between 0.02-0.22 µg kg^{-1}; Cr content between 0.03-0.77 µg kg^{-1}; Ni content between 0.70-6.56 mg kg^{-1}; Fe content between 4.04-13.09 mg kg^{-1} and Mo content between 0.01-0.23 µg kg^{-1}. Negative significant relationships were determined between Mo and Cr contents of soils. At the same time, positive significant relationships were determined between Cd and Ni, Co and Cr and Ni and Ni and Fe. When the heavy metal contents of the soils of the region were compared with the limit values, no heavy metal pollution was found. Yalçın (2023) aimed to determine the molybdenum content of agricultural soils in the Kırıkhan-Reyhanlı region and its relation with some heavy metals. According to the results of the study, Cd content of soils varied between 0.009-0.041 µg kg^{-1}, Co content between 0.011-0.317 µg kg^{-1}, Cr content between 0.008-0.187 µg kg^{-1}, Ni content between 0.787-6.211 mg kg^{-1}, Cu content between 1.11-3.77 mg kg^{-1}, Fe content between 2.80-15.09 mg kg^{-1} and Mo content between 0.006-0.101 µg kg^{-1}. Positive significant relationships were determined between Mo and Co and Ni contents of soils, but negative significant relationships were determined with Cr content. In addition, positive significant relationships were found between Cd and Co and Ni, between Co and Ni and Cu, and between Cu and Fe. When the heavy metal contents of the soils in the region were compared with the limit values, no heavy metal pollution was found. The study aimed to determine the relationships between the molybdenum level of soils in the Arsuz region of Hatay province and some heavy metals in these soils and to contribute this information to the productivity and quality of agricultural soils.

2 Materials and Method

2.1. Materials

In this study, surface soil samples (0-30 cm) were duly taken from 70 different locations in parsley cultivated agricultural fields in Arsuz district of Hatay province (Figure 1; Table 1). The soil samples were brought to the laboratory on the same day, air-dried in the shade and sieved through a 2 mm sieve to prepare them for analysis. The pH of the soils of the study area was determined as 8.07 in the range of 7.65-8.42 and the pH of the soil samples was slightly alkaline throughout the study area. While the lowest % salt content of Arsuz district soils was 0.013, the highest % salt content was 0.033. The average % salt content of the study area was 0.020. The lowest clay, sand and silt contents of the soils of Arsuz district of Hatay province were 18.88 %, 3.68 % and 18.00 %, respectively, while the highest clay, sand and silt contents were 60.32 %, 51.12 % and 64.00 %, respectively. The average clay, sand and silt contents of the 0-30 cm depth samples of the soils were found as 43.16 %, 19.09 % and 37.84 %, respectively. The lime contents of the soils of the research area were found to be between 0.62-28.04 %, with an average of 14.69 %, and they were commonly determined as medium to very calcareous soils. While the lowest organic matter content of Arsuz district soils was 1.68 %, the highest organic matter content was 4.09 %. The average organic matter content of the samples of the soils at 0-30 cm depth was found to be 2.50 % and commonly low to high organic matter (Yalçın and Çimrin 2021).

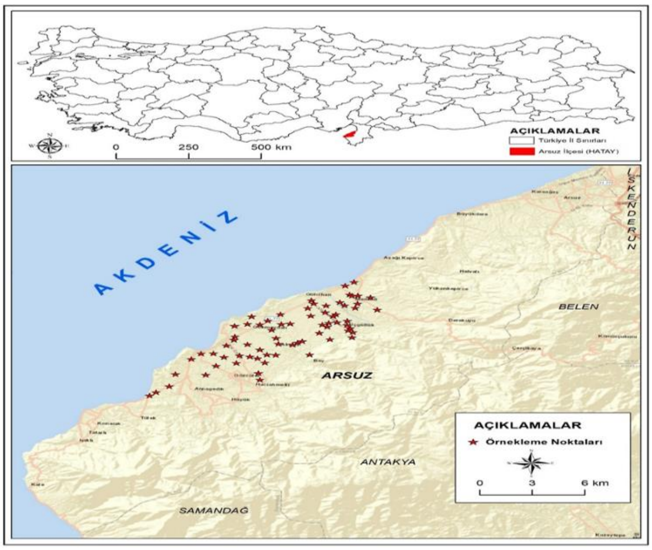

Figure 1. Representation of the soil samples on the map

2.2. Method

Soils were analysed for cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni), copper (Cu), iron (Fe) and molybdenum (Mo) according to Lindsay and Norvell (1978) in 0.005 M DTPA+0.01 M CaCI$_2$+0.1 M TEA (pH 7.3). Correlation and regression analyses between soil properties and nutrients were performed using SPSS 17 statistical software (Düzgüneş et al. 1987).

Table 1. Locations where soil samples were taken

Soil Number	Sample Place	N/E Coordinates with GPS	Soil Number	Sample Place	N/E Coordinates with GPS
1	Madenli 1	(36.4718 - 35.9798)	36	Akçalı 8	(36.4113 - 35.9595)
2	Madenli 2	(36.4751 - 35.9852)	37	Akçalı 9	(36.4202 - 35.9392)
3	Madenli 3	(36.4641 - 35.9828)	38	Akçalı 10	(36.4251 - 35.9376)
4	Madenli 4	(36.4515 - 36.0009)	39	Akçalı 11	(36.4374 - 35.9404)
5	Madenli 5	(36.4620 - 35.9962)	40	Akçalı 12	(36.4459 - 35.9396)
6	Madenli 6	(36.4564 - 35.9883)	41	Akçalı 13	(36.4401 - 35.9318)
7	Madenli 7	(36.4631 - 35.9845)	42	Akçalı 14	(36.4258 - 35.9113)
8	Madenli 8	(36.4633 - 35.9881)	43	Akçalı 15	(36.4230 - 35.9109)
9	Madenli 9	(36.4547 - 35.9801)	44	Akçalı 16	(36.4192 - 35.9197)
10	Madenli 10	(36.4573 - 35.9770)	45	Akçalı 17	(36.4149 - 35.9276)
11	Üçgüllük 1	(36.4543 - 35.9683)	46	Akçalı 18	(36.4073 - 35.9264)
12	Üçgüllük 2	(36.4468 - 35.9747)	47	Akçalı 19	(36.4107 - 35.9323)
13	Üçgüllük 3	(36.4451 - 35.9731)	48	Akçalı 20	(36,4105 - 35,9379)
14	Üçgüllük 4	(36.4399 - 35.9758)	49	Gökmeydan 1	(36,4322 - 35,9345)
15	Üçgüllük 5	(36.4391 - 35.9705)	50	Gökmeydan 2	(36,4367 - 35,9268)
16	Üçgüllük 6	(36.4375 - 35.9664)	51	Gökmeydan 3	(36,4369 - 35,9189)
17	Üçgüllük 7	(36.4360 - 35.9697)	52	Gökmeydan 4	(36,4435 - 35,9214)
18	Üçgüllük 8	(36.4349 - 35.9844)	53	Gökmeydan 5	(36,4350 - 35,9107)
19	Üçgüllük 9	(36.4413 - 35.9822)	54	Çetellik 1	(36,4037 - 35,9313)
20	Üçgüllük 10	(36.4377 - 35.9822)	55	Çetellik 2	(36,3945 - 35,9276)
21	Üçgüllük 11	(36.4451 - 35.9567)	56	Çetellik 3	(36,3887 - 35,9287)
22	Üçgüllük 12	(36.4559 - 35.9588)	57	Çetellik 4	(36,4029 - 35,9132)
23	Üçgüllük 13	(36.4559 - 35.9603)	58	Çetellik 5	(36,4078 - 35,9051)
24	Üçgüllük 14	(36.4484 - 35.9679)	59	Çetellik 6	(36.4108 - 35.8982)
25	Üçgüllük 15	(36.4330 - 35.9831)	60	Çetellik 7	(36.4104 - 35.8905)
26	Üçgüllük 16	(36.4527 - 35.9868)	61	Çetellik 8	(36.4056 - 35.8844)
27	Üçgüllük 17	(36.4316 - 35.9861)	62	Çetellik 9	(36.3921 - 35.8941)
28	Üçgüllük 18	(36.4270 - 35.9859)	63	Çetellik 10	(36.3922 - 35.8749)
29	Akçalı 1	(36.4586 - 35.9587)	64	Çetellik 11	(36.3816 - 35.8713)
30	Akçalı 2	(36.4379 - 35.9461)	65	Çetellik 12	(36.3762 - 35.8631)
31	Akçalı 3	(36.4215 - 35.9513)	66	Çetellik 13	(36.3732 - 35.8592)
32	Akçalı 4	(36.4197 - 35.9482)	67	Çetellik 14	(36.4180 - 35.9062)
33	Akçalı 5	(36.4229 - 35.9544)	68	Çetellik 15	(36.4095 - 35.9149)
34	Akçalı 6	(36.4304 - 35.9658)	69	Çetellik 16	(36.4087 - 35.9216)
35	Akçalı 7	(36.4249 - 35.9719)	70	Çetellik 17	(36.4002 - 35.9004)

3. Findings and discussion

3.1. Some Heavy Metal Content of Soil Samples

The results of some heavy metal properties of the soil properties used in the study are given in Table 3.

Cadmium

The lowest cadmium content of the research soils was 0.01 µg kg^{-1} and the highest cadmium content was 0.03 µg kg^{-1}. The average Cd content of the soils was 0.01 µg kg^{-1} (Table 2.). Özkan and Demir (2023), who studied the heavy metal contents tea soils of Rize province, reported that the Cd content of the soils of the study area was much lower than the known limit values and presented similar results.

Cobalt

The lowest cobalt content of the Arsuz region soils was 0.02 µg kg^{-1} and the highest was 2.96 µg kg^{-1}. The average Co content of the soils was 0.49 µg kg^{-1} (Table 2.). Özkan and Demir (2023) reported similar results by determining the Co contents of the soils between 0-0.09 µg kg^{-1} in their study in which they aimed to determine the heavy metal contents of the soils cultivated in Rize province.

Table 2. Cd, Co, Cr, Ni, Fe, Mo contents of soils of Arsuz region of Hatay province

Soil Number	Depth	Cd µg kg^{-1}	Co µg kg^{-1}	Cr µg kg^{-1}	Ni mg kg^{-1}	Fe mg kg^{-1}	Mo µg kg^{-1}	Texture Class
1	0-30	0.01	0.03	0.04	0.82	4.30	0.01	C
2	0-30	0.01	0.03	0.04	0.60	2.96	0.02	SiC
3	0-30	0.01	0.04	0.06	0.57	4.00	0.01	SiC
4	0-30	0.01	0.04	0.79	1.44	3.68	0.02	C
5	0-30	0.01	0.04	0.07	1.42	1.65	0.01	CL
6	0-30	0.01	0.04	0.08	0.58	2.85	0.02	SiC
7	0-30	0.01	0.04	0.21	0.55	3.63	0.01	SiC
8	0-30	0.01	0.04	0.17	1.17	2.73	0.01	C
9	0-30	0.01	0.03	0.12	0.57	3.06	0.00	SC
10	0-30	0.01	0.03	0.17	0.95	2.50	0.01	C
11	0-30	0.01	0.02	0.08	1.80	3.25	0.01	L
12	0-30	0.01	0.05	0.52	0.98	4.15	0.01	SiCL
13	0-30	0.02	0.02	0.12	0.56	5.28	0.01	C
14	0-30	0.02	0.02	0.06	0.74	4.84	0.02	SiC
15	0-30	0.01	0.04	0.07	0.84	6.01	0.02	SiC
16	0-30	0.01	0.04	0.05	0.57	7.15	0.04	SiC
17	0-30	0.01	0.03	0.03	0.56	4.97	0.02	SiC
18	0-30	0.02	0.02	0.08	0.60	7.42	0.02	SiC
19	0-30	0.01	0.03	0.08	0.43	4.05	0.03	SiC
20	0-30	0.02	0.02	0.11	0.35	6.35	0.01	SiC
21	0-30	0.01	0.03	0.07	0.54	4.72	0.01	C
22	0-30	0.01	0.02	0.07	0.58	7.67	0.03	C
23	0-30	0.00	0.02	0.11	0.63	2.54	0.01	C
24	0-30	0.02	0.03	0.08	0.92	4.36	0.01	C
25	0-30	0.01	0.04	0.15	0.68	4.70	0.03	SiC
26	0-30	0.01	0.14	0.06	0.81	5.03	0.04	SiCL
27	0-30	0.02	0.05	0.10	0.86	3.86	0.03	SiCL
28	0-30	0.01	0.13	0.04	0.80	3.42	0.04	SiCL
29	0-30	0.02	0.03	0.12	0.70	5.23	0.01	C
30	0-30	0.01	0.03	0.04	0.66	6.07	0.02	SiC
31	0-30	0.01	0.04	0.06	0.58	4.08	0.02	SiL
32	0-30	0.01	0.03	0.04	0.94	4.47	0.01	CL
33	0-30	0.01	0.08	0.06	0.67	6.39	0.02	SiC
34	0-30	0.01	0.05	0.09	0.60	4.79	0.02	SiCL
35	0-30	0.01	0.05	0.11	0.66	5.17	0.01	CL
36	0-30	0.01	0.35	0.01	1.21	9.43	0.03	SiCL
37	0-30	0.02	0.49	0.01	2.40	6.84	0.02	CL
38	0-30	0.02	0.59	0.03	2.11	10.27	0.04	SiC
39	0-30	0.01	0.35	0.03	1.36	6.48	0.02	C
40	0-30	0.01	0.51	0.02	2.76	9.04	0.02	C

Table 2. (Continued)

Soil Number	Depth	Cd µg kg^{-1}	Co µg kg^{-1}	Cr µg kg^{-1}	Ni mg kg^{-1}	Fe mg kg^{-1}	Mo µg kg^{-1}	Texture Class
41	0-30	0.02	0.79	0.02	4.48	11.83	0.03	C
42	0-30	0.02	1.17	0.01	2.47	12.97	0.05	C
43	0-30	0.01	0.33	0.02	1.58	14.63	0.03	SiCL
44	0-30	0.02	1.77	0.02	5.99	9.51	0.03	C
45	0-30	0.02	1.08	0.01	3.00	9.59	0.05	CL
46	0-30	0.01	0.81	0.02	1.98	11.17	0.06	C
47	0-30	0.02	0.42	0.02	1.36	7.65	0.03	SiC
48	0-30	0.02	1.05	0.01	3.42	7.83	0.03	C
49	0-30	0.02	0.41	0.02	3.04	8.23	0.02	SiC
50	0-30	0.02	0.36	0.03	2.65	10.17	0.03	SiC
51	0-30	0.01	1.27	0.01	6.12	10.44	0.02	C
52	0-30	0.02	0.63	0.01	4.31	6.05	0.01	SC
53	0-30	0.01	1.04	0.04	10.41	9.20	0.03	C
54	0-30	0.03	1.32	0.02	2.31	9.44	0.04	CL
55	0-30	0.02	0.40	0.85	1.45	18.72	0.11	SiC
56	0-30	0.02	1.95	0.01	2.46	14.64	0.07	SiCL
57	0-30	0.02	0.30	0.01	1.59	12.57	0.04	C
58	0-30	0.03	1.27	0.18	3.19	17.35	0.08	C
59	0-30	0.02	0.59	0.57	2.37	16.43	0.02	C
60	0-30	0.02	0.94	0.63	5.50	10.90	0.03	C
61	0-30	0.02	1.70	0.01	13.56	6.04	0.02	CL
62	0-30	0.02	2.17	0.02	17.60	7.48	0.02	C
63	0-30	0.02	1.94	0.01	9.73	5.69	0.02	C
64	0-30	0.01	2.96	0.02	11.52	6.75	0.02	C
65	0-30	0.02	0.83	0.02	6.84	5.22	0.05	CL
66	0-30	0.01	0.07	0.02	1.41	3.35	0.01	CL
67	0-30	0.02	0.08	0.01	1.09	11.54	0.02	C
68	0-30	0.01	0.20	0.02	1.46	5.12	0.02	C
69	0-30	0.01	0.13	0.02	0.95	12.15	0.02	CL
70	0-30	0.02	0.24	0.01	7.18	7.26	0.01	L
Min.		**0.01**	**0.02**	**0.01**	**0.35**	**1.65**	**0.01**	
Max.		**0.03**	**2.96**	**0.85**	**17.60**	**18.72**	**0.11**	
Aver		**0.01**	**0.49**	**0.11**	**2.72**	**7.22**	**0.03**	

Chrome

The lowest chromium content of the soils was 0.01 µg kg^{-1} and the highest chromium was 0.85 µg kg^{-1}. The average Cr content of the soils was found to be 0.11 µg kg^{-1} (Table 2). In a study conducted in a different region, Taş and Demir (2022), who aimed to determine the heavy metal contents of the central districts of Van province, found similar results in terms of Cr content of soils.

Nickel

The lowest exchangeable nickel content of all agricultural soils in the study area was 0.35 mg kg^{-1} and the highest was 17.60 mg kg^{-1}. The average nickel content of the soils was found to be 2.72 mg kg^{-1} (Table 2.). In a study carried out in a different region, Taş and Demir (2022) determined that the Ni content of the soils was between 2.47-14.95 mg/kg as a result of the study in which they aimed to determine the fertility level and some heavy metal contents of the agricultural soils of Bingöl plain and presented similar results.

Iron

The minimum iron content of the soils of the study area was 1.65 mg kg^{-1}, the highest iron content was 18.72 mg kg^{-1} and the average iron content was 7.22 mg kg^{-1}. When the soil iron contents were classified according to the limit values of Lindsay and Norvel (1978), 1.43 % of the samples were found to be iron deficient (<2.5 mg kg^{-1}), 27.14% were found to be adequate (2.5-4.5 mg kg-1) and 71.43 % were found to be iron surplus (>4.5 mg kg^{-1}) (Table 2.). Bayram et al. (2023), who studied the fertility status of pistachio orchards in Adıyaman province, determined that 85 % of the Fe content of the soils was adequate and high and presented similar results.

Molybdenum

The lowest molybdenum content of Arsuz region soils was 0.01 µg kg^{-1}, while the highest molybdenum content was 0.11 µg kg^{-1}. The average molybdenum content of the soils was found as 0.03 µg kg^{-1}. The available molybdenum contents of all of the agricultural soils of Arsuz region were found to be sufficient (>1 ppm) according to Viets and Lindsay (1973) (Table 2.). Shaheen et al. (2021), who aimed to determine the heavy metal contents of the agricultural soils of Kafr El-Zayat city of Egypt, reported that the Mo content in Egyptian soils was very low and the Mo content in the soils was below the limit values.

3.2. Relationships between available Molybdenum Content and Some Other Soil Heavy Metal Properties

The relationships between heavy metal contents of the soils under investigation and available molybdenum are given in Table 3. As can be seen from the table, positive significant relationships were determined between Mo and Cd (r: 0.39***; Figure 2), Co (r: 0.34***; Figure 3) and Fe (r: 0.69***; Figure 4) contents of soils. In a study conducted by Yu et al. (2018) in which heavy metal contents of soils were determined, similar results were obtained for Mo content of soils. In addition, significant positive relationships were determined between Cd content and Co (r: 0.42***), Ni (r: 0.29*) and Fe (r: 0.51***) contents of soils. Similar results were obtained in a study conducted by Arıkan et al. (2019). A significant positive relationship was determined between Co content of soils and Ni (r: 0.80***) and Fe (r: 0.42***) contents. A study by Shaheen et al. (2021) showed similar results between Co and Ni in agricultural soils in Egypt.

Table 3. Correlation coefficients (r) between molybdenum and some soil heavy metal contents of soils of Arsuz region of Hatay province

	Mo µg kg^{-1}	Cd µg kg^{-1}	Co µg kg^{-1}	Cr µg kg^{-1}	Ni mg kg^{-1}
Cd µg kg^{-1}	0.39***				
Co µg kg^{-1}	0.34***	0.42***			
Cr µg kg^{-1}	0.22	0.02	-0.14		
Ni mg kg^{-1}	0.06	0.29*	0.80***	-0.12	
Fe mg kg^{-1}	0.69***	0.51***	0.42***	0.18	0.17

* 0.05 düzeyinde önemli, *** 0.001 düzeyinde önemli

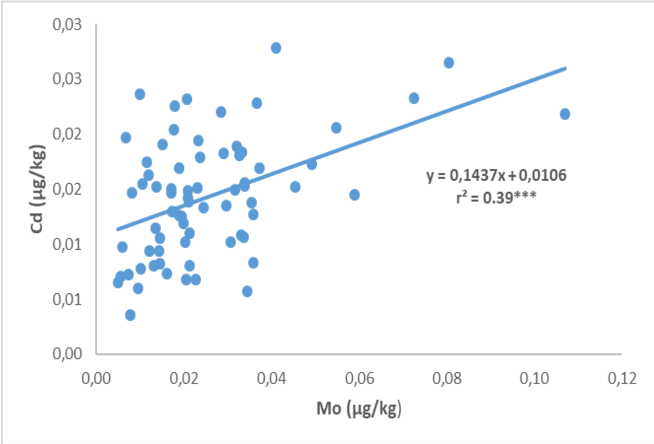

Figure 2. Relationship between useful Mo and Cd contents of soil prefixes

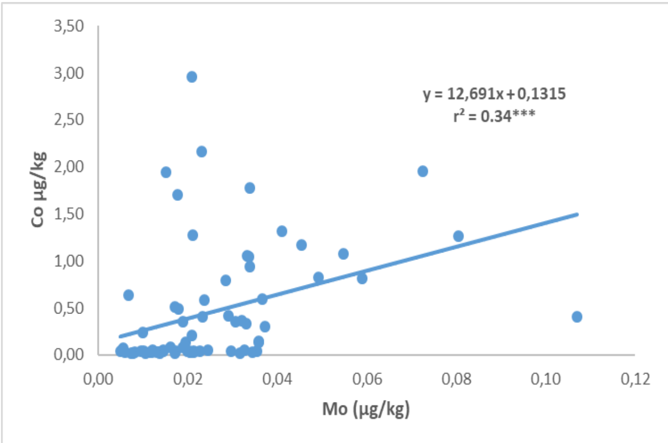

Figure 3. Relationship between Mo and Co contents of soil prefixes

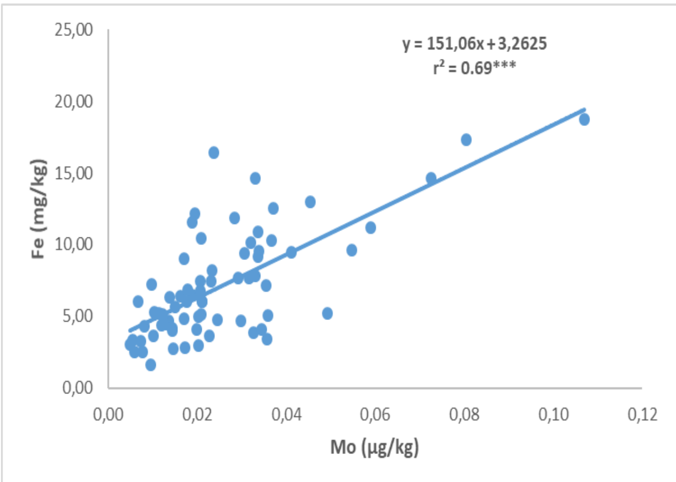

Figure 4. Relationship between Mo and Fe contents of soil prefixes

4. Discussion

Molybdenum content of soils in Arsuz region of Hatay province was analysed and its relationship with some heavy metal concentrations was investigated. The data obtained in this direction were compared with the permissible heavy metal limit values in soils determined in Turkey and worldwide. The results show that heavy metal accumulation in soils in the study area is within acceptable limits. This study reveals that the potential harm of heavy metal pollution caused by agricultural and industrial activities to human health is minimal. It is important to take necessary precautions to prevent the heavy metal contents in the agricultural soils in the study area, which do not reach harmful levels for human and animal health, from exceeding the specified limit values. In particular, it is necessary to carry out strict inspections of enterprises and factories in industrial and industrial zones located close to the study area.

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