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THE ROLE OF *Chenopodium album* L. ON THE ON-SITE RECLAMATION OF SEWAGE SLUDGE LAGOONS

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ABSTRACT

In this study, the contribution of *Chenopodium album* L. to the reclamation of sewage sludge lagoons in Bursa East Municipal Wastewater Treatment Plants (Bursa-EWWTP), Turkey through their uptake of heavy metal/ element and their bioaccumulation factor (BAF) and translocation factor (TF) were investigated and assessed. It is important to determine of role of plant species that were already naturally established in lagoons before preparing an experiment design belong to on-site phyto-reclamation of sludges. *Chenopodium album* L. are a plant community that occur naturally in the sewage sludge lagoons in Bursa East WWTP (Bursa-EWWTP), Turkey.

Firstly, plant materials from all lagoons were collected for chemical analysis. A total of 15 elements including heavy metals (Cr, Cd, Pb, Ag, Sb, Al, As, Sn) and trace elements (Mn, Se, Cu, Zn, Fe, Ni, B) were measured using ICP-OES emission spectrometer. 7 metals / elements [arsenic (As), cadmium (Cd), lead (Pb), antimony (Sb), silver (Ag), tin (Sn) and selenium (Se)] was below the limit value. The concentrations of Aluminum (Al), Boron (B), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni) and Zinc (Zn) in leaves, stems and roots of *Chenopodium album* were determined. The metals deposition in the *C. album'* tissues (roots, stems and leaves) was significant high level. Cu accumulation in *Chenopodium album* was lower than other examined elements and metals, while Fe, Zn, Cr and Mn deposition were quite high generally in all lagoons. This data was consistent with BAF values of Fe, Zn and Mn in *Chenopodium album*. The high TF value supported that *Chenopodium album* is a fast growing species characterized by high biomass production. At the same time, these results gave us insight into the mobility of metals and elements in lagoons via bioaccumulation capacity of *C. album*. Our findings made a significant contribution to the experimental design to be formed in the improvement of these sewage sludge lagoons.

KEYWORDS:
Phytoremediation, sewage sludge, bioaccumulation, heavy metals, trace elements, *Chenopodium album*

INTRODUCTION

Fast economic growth, urbanization and industrialization, in the other side improvement of quality of life, the protection of natural resources and the natural environment are two conflicting areas on the agenda of countries in the 21st century. Maintaining balance between these areas are an essential for the future of human beings. Thus, our living conditions according to policies and practices that encourage the recycling and reuse of waste or its minimization, are rearrange in nowadays.

Sewage sludge is a by-product of municipal wastewater treatment plants (WWTP) [1] and its production is increasing day by day due to urbanization. A lot of methods for its disposal or remediation like landfilling in lagoons, sludge incineration, composting and agricultural use are being developed in many countries [2, 3, 4]. Sewage sludge contains heavy metals, hydrocarbons and other pollutants which can potentially cause soil pollution and toxic effect on plant growth as much as macronutrients and micronutrients that is needs of plants [4, 5, 6, 7, 8, 9, 10, 11, 12]. Thus, agricultural use of sewage sludge can be emerging different problems due to ecotoxicological risks [13, 14]. Other side, the sludge in landfills will fill up after a while and will lead the search for new landfills. The incorporation of a vegetal cover of landfills at the WWTP can alleviate the treatment facilities by returning them in to the ecosystem [15]. Because this practice has many useful affects such as control soil erosion and to minimize the infiltration of rainwater [16, 17]. Phytoremediation studies come into prominence in these method called as the on-site reclamation of sludge.

Phytoremediation is offering a sustainable treatment option for metal-contaminated sites utilizing the inherent potential of plants to reduce environmental risk [18, 19]. It is especially ideal method for reclamation of sewage sludge landfills due to it is an ecological, low-cost and cost-effective, lead to establish long-term green cover in the contaminated area [20]. Fast growing plant species characterized by high biomass production is use in this method [21, 22, 23, 24]. However, choosing the right plants are an important factor in this situation. Selected plants should have the appropriate characteristics to allow them to growing in site-specific conditions such as

waste characteristics and to meet the objectives of phytoremediation. This situation will bring up the development of specific approaches to the sludge that will attract high attention in many developed countries in the future [25, 26, 27]. The consideration of native plants already growing at the site is hot point for this process [28]. Many researchers in recent years point out investigation of plants which have established themselves naturally at this kind of the sites and determination of their contribution on the reclamation of the site [7, 29, 30].

Therefore, the present study is designed to determine the accumulation of elements and heavy metals in *Chenopodium album* L., which were already naturally established on the sewage sludge lagoons of Bursa East WWTP (Bursa-EWWTP), Turkey in order to create a useful model for reclamation of sludge lagoons in the future. In the area of the Bursa East WWTP (Bursa-EWWTP), there are seven sewage sludge lagoons. In these lagoons, it is requested to be on-site reclamation studies. Before preparing an experiment design belong to on-site phyto-reclamation of sludges, it is investigated *Chenopodium album* that were already naturally established in lagoons.

MATERIALS AND METHODS

Site description. The experimental site is sewage sludge lagoons at the biggest municipal Wastewater Treatment Plant (WWTP) in east of Bursa, Turkey (coordinates 40°13'45.4"N 29°05'11.3"E, Figure 1). It receives around 240,000 m^3 of domestic wastewater daily from urban area in east of city via the central sewage system. The mechanical treatment of the Bursa East Wastewater Treatment Plant (Bursa-EWWTP) have enhanced by a biological treatment stage including activated sludge tanks, clarifiers, rapid sand filtration, mechanical excess sludge thickening (DAF), two digesters, sludge dewatering and stabilization with lime. The sludge is anaerobically digested, thickened, and gave a product of about 23% in solids (Table 1). The sewage sludge is stored in lagoons. There are seven sewage sludge lagoons in the Bursa-EWWTP (Figure 1). Physicochemical parameters of lagoons were given in Table 1. The area of the sewage sludge lagoons in the Bursa-EWWTP are with average minimum and maximum monthly temperatures of +2.6◦C (January) and +22.4◦C (July), respectively.

TABLE 1
Physicochemical parameters of sewage sludge lagoons in the EWWTP of Bursa.

Physicochemical parameters	
pH	6.68
Total Solid Content, %	22.71
Moisture content, %	77.29
Inorganic matter, %	6.54
Organic matter, %	16.17
Oil and Grease, mg/L	1533 (%0.15)
Total Nitrogen, mg/L	10
Total Phosphorus, mg/L	3
Total Organic Carbon (TOC), mg/kg	259135 (%25,91)



FIGURE 1
Sewage sludge lagoons and their coordinates in the Bursa-EWWTP, Turkey. The image was obtained using the Google Earth program.

TABLE 2

Total accumulation and concentrations of heavy metals (Al and Cr) and trace element (B, Cu, Mn, Ni, Zn) in leaves, stems and roots of *Chenopodium album* growing natively in sewage sludge lagoons (mg/kg DW). The total metal deposition order is also given for each lagoon (Mean values ± SE, n=5)

		Al	B	Cr	Cu	Fe	Mn	Ni	Zn
Lagoon 1	Roots	292.50 ±34.37	93.75 ±10.24	1871.25 ±201.12	127.50 ±14.12	7556.25 ±614.45	506.25 ±81.07	457.50 ±113.58	652.50 ±110.26
	Stems	404.61 ±40.36	323.68 ±76.82	2038.82 ±464.74	120.39 ±34.27	7762.50 ±489.11	611.84 ±121.18	690.79 ±107.46	2096.05 ±461.58
	Leaves	183.75 ±48.08	313.13 ±58.62	3013.13 ±404.37	131.25 ±38.85	1105.63 ±178.29	2700.00 ±678.92	935.63 ±132.17	1014.38 ±80.45
	Total accumulation	**880.86 ±38.87**	**730.56 ±48.56**	**6923.19 ±383.68**	**379.14 ±29.97**	**16424.38 ±447.35**	**3818.09 ±287.52**	**2083.91 ±132.20**	**3762.93 ±210.42**
Total metal accumulation order		**Fe > Cr > Mn = Zn > Ni > Al > B > Cu**							
Lagoon 2	Roots	487.50 ±48.49	183.75 ±40.12	2212.50 ±208.69	120.00 ±11.04	8801.25 ±390.78	405.00 ±90.15	723.75 ±133.65	907.50 ±122.45
	Stems	236.84 ±40.36	128.29 ±15.38	921.71 ±161.99	57.24 ±36.71	3726.32 ±478.16	307.89 ±78.21	301.97 ±76.18	1766.45 ±61.14
	Leaves	243.75 ±41.88	215.63 ±50.12	622.50 ±110.55	80.63 ±30.23	2677.50 ±459.41	1777.50 ±459.12	206.25 ±20.53	1186.88 ±76.55
	Total accumulation	**968.09 ±43.52**	**527.66 ±38.58**	**3756.71 ±155.27**	**257.86 ±26.37**	**15205.07 ±442.78**	**2490.39 ±280.93**	**1231.97 ±76.78**	**3860.82 ±84.09**
Total metal accumulation order		**Fe > Cr = Zn > Mn > Ni > Al > B > Cu**							
Lagoon 3	Roots	1128.75 ±401.34	236.25 ±41.78	330.00 ±108.52	300.00 ±16.67	8891.25 ±674.40	607.50 ±86.44	187.50 ±23.18	2066.25 ±52.31
	Stems	303.95 ±24.18	144.08 ±15.38	560.53 ±126.17	71.05 ±30.12	2400.00 ±360.35	625.66 ±121.18	244.74 ±71.85	1985.53 ±58.72
	Leaves	573.75 ±108.00	918.75 ±63.28	3585.00 ±404.38	161.25 ±40.75	1396.25 ±272.54	3123.75 ±78.92	1151.25 ±152.47	1072.50 ±80.05
	Total accumulation	**2006.45 ±183.27**	**1299.08 ±40.15**	**4475.53 ±219.82**	**532.30 ±29.50**	**12687.50 ±435.78**	**4356.91 ±95.26**	**1583.49 ±83.82**	**5124.28 ±64.77**
Total metal accumulation order		**Fe > Zn > Mn =Cr > Al > Ni > B > Cu**							
Lagoon 4	Roots	360.00 ±34.37	93.75 ±10.04	408.75 ±102.12	60.00 ±11.25	2373.75 ±417.89	345.00 ±80.02	142.50 ±22.81	798.75 ±102.04
	Stems	98.68 ±16.74	80.92 ±08.37	373.03 ±46.56	37.50 ±01.14	1527.63 ±185.75	463.82 ±68.10	132.24 ±46.85	787.50 ±18.69
	Leaves	393.75 ±55.10	253.13 ±48.12	418.13 ±110.20	56.25 ±09.62	1938.75 ±379.64	1438.13 ±68.27	146.25 ±20.50	800.63 ±64.16
	Total accumulation	**852.43 ±36.37**	**427.80 ±25.74**	**1199.90 ±88.54**	**153.75 ±07.34**	**5840.13 ±327.76**	**2246.94 ±80.93**	**420.99 ±39.83**	**2386.88 ±69.80**
Total metal accumulation order		**Fe > Zn = Mn > Cr > Al > Ni = B > Cu**							
Lagoon 5	Roots	1545.00 ±41.34	95.75 ±10.21	345.00 ±58.52	101.25 ±10.45	3877.50 ±446.27	551.25 ±75.14	97.50 ±22.10	1143.75 ±52.31
	Stems	191.45 ±20.06	122.37 ±15.38	2696.05 ±64.74	146.05 ±38.12	9868.42 ±421.18	860.53 ±121.18	842.76 ±107.46	1067.76 ±58.73

	Leaves	352.50 ±58.01	405.00 ±55.14	243.75 ±10.55	50.63 ±08.27	1321.85 ±138.92	2210.63 ±178.92	101.25 ±21.35	1164.38 ±82.05
	Total accumulation	**2088.95 ±46.57**	**621.12 ±29.63**	**3284.80 ±44.60**	**297.93 ±19.59**	**15067.77 ±335.46**	**3622.40 ±128.59**	**1041.51 ±50.26**	**3375.89 ±50.48**
Total metal accumulation order		**Fe > Mn = Zn = Cr > Al > Ni > B > Cu**							
Lagoon 6	Roots	697.50 ±108.49	90.75 ±08.14	168.75 ±48.52	71.25 ±10.25	2058.75 ±385.38	318.75 ±85.68	56.25 ±12.24	873.75 ±110.26
	Stems	75.00 ±16.75	69.08 ±08.37	525.00 ±146.56	39.47 ±03.48	2113.81 ±310.34	617.76 ±110.48	169.74 ±72.18	815.13 ±48.89
	Leaves	163.13 ±41.88	305.63 ±58.02	198.75 ±40.12	71.25 ±40.23	1235.62 ±145.47	1511.25 ±145.24	84.38 ±12.25	871.88 ±62.85
	Total accumulation	**935.63 ±55.70**	**468.45 ±25.74**	**892.50 ±78.54**	**181.97 ±17.54**	**5408.18 ±280.39**	**2447.76 ±120.09**	**310.36 ±.32.22**	**2560.76 ±74.00**
Total metal accumulation order		**Fe > Zn = Mn > Al = Cr > B > Ni > Cu**							
Lagoon 7	Roots	337.50 ±34.06	92.15 ±10.86	172.50 ±74.67	48.75 ±06.45	1136.25 ±174.45	97.50 ±12.44	60.00 ±15.43	648.75 ±110.25
	Stems	215.13 ±22.64	136.18 ±18.40	234.87 ±41.33	35.46 ±05.72	1160.52 ±175.21	396.71 ±78.21	80.92 ±20.65	789.47 ±18.68
	Leaves	341.25 ±60.03	163.13 ±30.18	172.50 ±27.86	37.50 ±09.62	1050.63 ±155.12	470.63 ±55.68	60.00 ±14.34	515.63 ±57.45
	Total accumulation	**893.88 ±38.91**	**393.06 ±20.60**	**579.87 ±47.85**	**125.72 ±05.77**	**3347.40 ±168.26**	**964.84 ±48.78**	**200.92 ±16.80**	**1953.85 ±63.79**
Total metal accumulation order		**Fe > Zn > Mn = Al > Cr > B > Ni > Cu**							



FIGURE 2
***Chenopodium album* L. plants natively growing in sewage sludge lagoons in the Bursa-EWWTP, Turkey.**

Sampling and analysis. The samples of plant material natively growing in lagoons is belong to *Chenopodium album* L. (Figure 2). Plant individuals were collected from all lagoons during early September 2019. Five individuals were collected from all areas forming a plant community on lagoons. All samples were put into plastic packages and were labeled. Then, the plant samples (with replications) were washed thoroughly with de-ionized water. They separated plant organs such as roots, stems and leaves. Each plant organ was air-dried in a paper bag for 24 hours and stored them at +4°C until the laboratory process.

To avoid contamination from outside, all materials (the plastic ware and glassware etc.) were soaked in a dilute nitric acid solution (10% v/v) overnight, and then rinsed several times with ultrapure water and dried in an oven at 40◦C.

The plant samples were dried in an oven at 70◦C for 24 h and homogenized in a sterile porcelain mortar. The powdered samples weighed as 0.0080 g for leaves, 0.0080 g for stems and 0.0035 g for roots. Then, they were digested with a proportion of HNO_3 (3 mL) and H_2O_2 (2 mL) in a 50 mL borosilicate glass vessel with a triplicate digestion procedure ap-

plied for each sample. After cooling to room temperature, the solutions were transferred to polypropylene centrifuge tubes and diluted to 15 mL with 0.3% v/v nitric acid. The contents of 15 elements including heavy metals (Cr, Cd, Pb, Ag, Sb, Al, As, Sn) and trace elements (Mn, Se, Cu, Zn, Fe, Ni, B) were determined using an ICP-OES emission spectrometer in Wastewater Laboratory, Directorate of Treatment Plants, Bursa Metropolitan Municipality.

Evaluation of metal accumulation capacity. The bioaccumulation factor (BAF) and translocation factor (TF) indicators as widely applied to evaluate the metal accumulation were calculated. For these factors, calculations were made for Aluminum (Al), Boron (B), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni) and Zinc (Zn) due to analyzes of 7 metals/elements [arsenic (As), cadmium (Cd), lead (Pb), antimony (Sb), silver (Ag), tin (Sn) and selenium (Se)] was below the limit value. The bioaccumulation factor (BAF) refers to the ratio of metal concentration in stems (C_{stems}) to metal concentration of soil ($C_{sewagesludge}$) [31, 32]:$C_{stems}/C_{sewagesludge}$. The translocation factor (TF) refers to the ratio of total metal concentration of leaves and stems ($C_{leaves+shoots}$) and metal concentration of roots (C_{roots})[33, 34, 35]: $C_{leaves+shoots}/C_{roots}$.

Statistical analyses. Analyzes of 7 metals / elements (As, Cd, Pb, Sb, Ag, Sn and Se) was not evaluated due to below the limit value. The concentrations of other all elements (Al, B, Cr, Cu, Fe, Mn, Ni, Zn) included five replicates (n = 5) and analyzed by SPSS Statistics (version 24.0, IBM Corp., Chicago, IL) and all the statistical tests were performed at a significance level of 0.05.

RESULTS AND DISCUSSION

In this study, it was investigated the accumulation level of the heavy metal and trace element in the root, stem and leaf parts of *Chenopodium album* L. that were naturally established on the sewage sludge lagoons in the Bursa East WWTP (Bursa-EWWTP), Turkey. The heavy metal (Al, Cr) and trace element (B, Cu, Fe, Mn, Ni, Zn) concentrations in different plant parts of *C. album* are shown in Table 2. The data had shown the metal content among the plant parts of *Chenopodium album* is variable and the plant parts have their different capacities for metal uptake. The total metal deposition order in *C. album* for each lagoon is given in Table 2. Overall, Cu accumulation in *Chenopodium album* was lower than other examined elements and metals, while Fe, Zn, Cr and Mn deposition were quite high ($p<0.05$). Cu may have shown a negative correlation with other heavy metals, as sewage sludge lagoons contain too many contaminants. It is known that Cu is also one of necessary elements for plants. Copper (Cu) content in leaves of *C. album* among the lagoons ranged from 37.50 to 161.25 with an average of 84.11 ± 25.37 mg/kg DW ($p<0.05$). This is ranged from 48.75 to 300.00 with an average of 118.39 ± 11.46 mg/kg DW in roots and from 37.50 to 146.05 with an average of 73.02 ± 21.36 mg/kg DW in stems ($p<0.05$). As can be seen, *C. album* generally accumulates more copper in the roots. According to Borkert et al. [36], when Cu accumulation in roots and shoots is exceed 20 mg/kg, it has toxic effects in all other plants, except to hyperaccumulative plants. A similar view is reported by Kabata-Pendias and Pendias [37]. Our results dedicated that *Chenopodium album* located natively in the sewage sludge landfills contained high concentration of Cu than this threshold. This supports that *Chenopodium album* is the a hyperaccumulator species. The similar observations have been reported by Yoon et al. [38] and Chandra et al. [39].

In our study, Iron (Fe) content in *Chenopodium album* was the highest accumulating elements in all lagoons (Table 2). Fe accumulation was high, especially in the root parts of *C. album* with sometimes in the stem parts ($p<0.05$). It is also seen high Fe accumulation at the roots of *C. album* in the results of Mazumdar and Das [40] and Chandra et al. [39]. Excess Fe deposited by plants often precipitates on the roots and then this accumulation might interfere with other plant processes [41]. This may be related to the fact that Fe, is an essential element for plants and present in sewage sludge in high amount, affects the plant's ability to withstand metal stress. Thus, it is emphasized by various researchers that the plant's phytoremediation potential will be positively affected [39,42].

Manganese (Mn) accumulation was remarkable in *Chenopodium album* ($p<0.05$). Mn accumulation was highest especially in the leaf of the plant with an average of 1889.95 ± 237.87 mg/kg DW and this situation are observed similarly in all lagoons ($p<0.05$). Toxic Mn value for plants is 400–1000 mg/kg according to Kabata-Pendias and Pendias [37] and our findings for Mn is inside in this value (Table 2). Chandra et al. [39] shown similarly data, that the leaves of *Chenopodium album* in sewage sludge lagoons have higher Mn contents than other its parts. At the same time, Tőzsér et al. [43] also found that the Mn accumulation of *C. album* located in the contaminated areas is higher in the leaf parts. Mn is included in photosynthesis and many redox enzymatic processes due to it is an essential micronutrient for plants [44, 45]. It is known that Mn have improve heavy metal toxicity by reducing root growth inhibition, and also cause alteration in mitotic activity in many cases [46, 47]. Therefore, Mn accumulation can be an important factor in the survival of *C. album* in an environment where pollutants such as sewage sludge are coexisting.

Similarly, the concentration of boron (B) was also high in leaves of *Chenopodium album* in present study ($p<0.05$). Xiao et al. [48] mentioned that *Chenopodium album* have a greater amount of B accumulation in the leaves than other parts. However, this situation could have changed in *C. album* natively located in the sewage sludge lagoons, but it was shown in this study that it was not so happen. Boron (B) is ranged from 163.13 to 918.75 with an average of 367.77 ± 51.92 mg/kg DW in leaves (Table 1). B have toxic effects at high concentrations even if it is a useful element at low concentrations. 200 mg/kg and up for boron cause negative alterations in normal plants and B accumulation at these concentrations is only seen in boron tolerant plants [37].

One of the other essential micronutrient is zinc (Zn). Porębska and Ostrowska [29] indicated that high Zn accumulation in *Chenopodium album* grown on the sludge and waste substrates. It is also seen in the results of Yañez et al. [49], Simantiraki et al. [50] and Suchkova et al. [51]. We have also been observed similar situation in present study (Table 2). One of the most accumulating elements in present study is Zn and it is more clear in the stem parts of *C. album*, ranged from 787.50 to 2096.05 with an average of 1329.70 ± 103.77 mg/kg DW ($p<0.05$). On the other side, Mazumdar and Das [40] reported that Zn accumulation in root of *C. album* is higher than the other plant parts. According to the findings of Tőzsér et al. [43], the leaves of *C. album* was major in zinc accumulation. It appears that there is variability regarding the location of the zinc in plant parts. As a matter of fact, it is seen that there is also higher Zn accumulation at the roots in some lagoons studied in here (Table 2).

A similar situation has been observed in nickel (Ni). In our study, it is observed to Ni accumulation in the above-ground parts of *C. album* (Table 2). This is ranged from 80.92 to 842.76 with an average of 351.88 ± 71.80 mg/kg DW in stems and from 60.00 to 1151.25 with an average of 383.57 ± 53.37 mg/kg DW in leaves ($p<0.05$). Chandra et al. [39] also determined that Ni accumulation is in leaves of *C. album*. Like Zn, Ni is also the essential micronutrient. But Ni might not be readily mobile in the sewage sludge lagoons [52]. This situation might be due to the high affinity of Ni to other minerals and oxides [53, 54, 55]. Bogusz and Oleszczuk [56] stated similarly less of bioavailability for Ni in sewage sludge.

Chromium (Cr) are considered as environmental pollutants and cause toxic effects even when it is very low concentrations for the plants. The levels of Cr accumulation in *Chenopodium album* were relatively high in all lagoons, but it was not seen any phytotoxicity symptoms ($p<0.05$). Our results shown that it is ranged from 172.50 to 3585.00 mg/kg DW for leaves, ranged from 168.75 to 2212.50 mg/kg DW for roots, ranged from 234.87 to 2696.05 mg/kg DW for stems of *C. album* (Table 2). The Cr accumulation is enough to qualifies as a hyperaccumulator species. In the findings of Porębska and Ostrowska [29], Cr accumulation was also high in *C. album* grown in sewage sludge landfills, which is similar to our experimental area. Similarly, Suchkova et al. [7] showed that Cr accumulation was high in *C. album* which is located in sewage sludge.

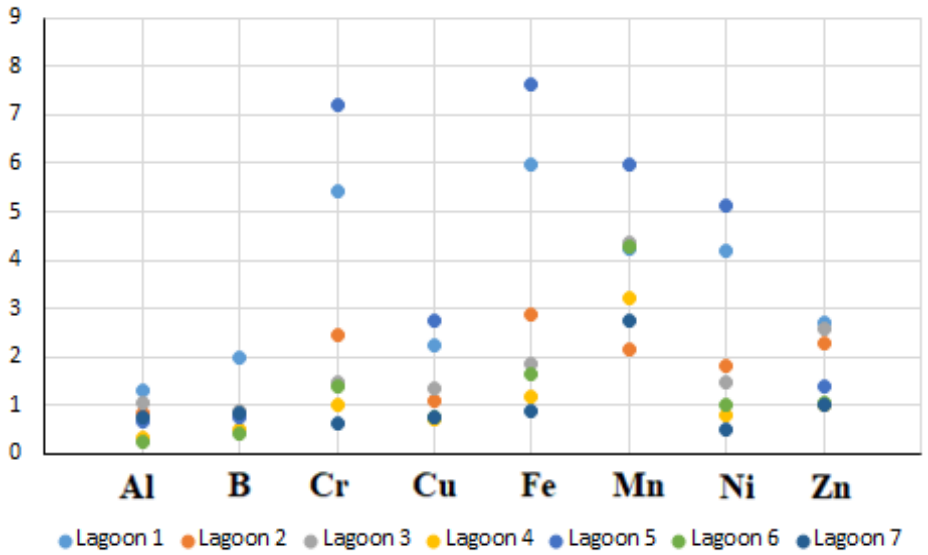


FIGURE 3
Bioaccumulation factor (BAF) values of *Chenopodium album* for each one of sewage sludge lagoons in the Bursa-EWWTP, Turkey.

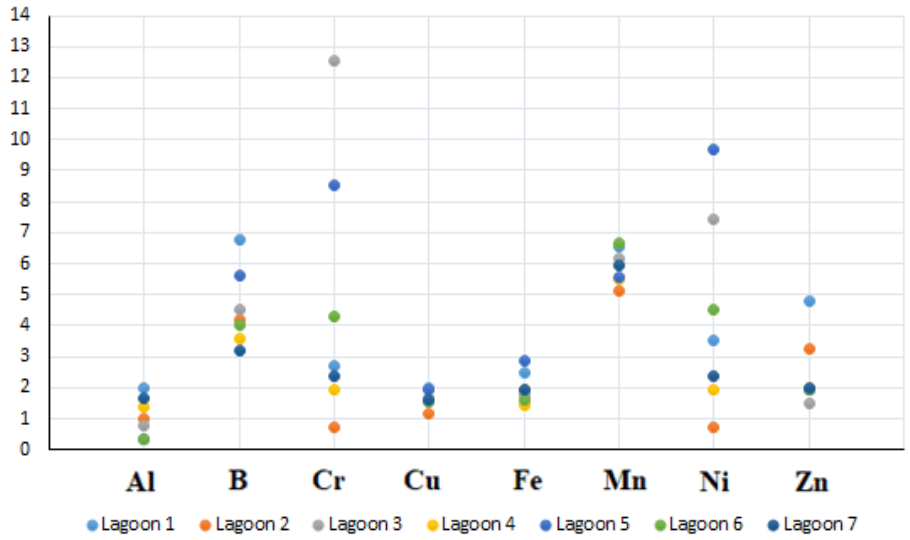


FIGURE 4
Translocation factor (TF) values of *Chenopodium album* for each one of sewage sludge lagoons in the Bursa-EWWTP, Turkey.

Aluminum accumulation in *Chenopodium album* was ranged from 852.43 to 2088.95 mg/kg DW in present study (Table 1). At the same time, it was higher in the roots of *C. album* then the other parts ($p<0.05$). It was also indicated by Tőzsér et al. [43] that the roots of *Chenopodium album* was remarkable in Al accumulation.

Bioaccumulation factor (BAF) values of *C. album* were given in Figure 3. BAF values in all lagoons were higher than 1 for Fe, Mn and Zn. This values for Fe, Mn and Zn coherent with accumulation found in *C. album.* BAF values for B were lower than 1 in all lagoons except to Lagoon 1. While the highest BAF values in *C. album* were seen in Lagoon 1 and 5 for all metals and elements (Figure 3). In lagoon 7, BAF values for all elements and metals except to Mn and Zn were less than 1 in *Chenopodium album*. This shows that *C. album* is a bioaccumulator species for Mn and Zn.

TF ratio indicates internal metal transportation from root to shoot in *Chenopodium album* and it was calculated for each one element or metal (Figure 4). The TF of B, Cr, Ni and Zn were variable as shown in Figure 4. But, the TF of Al, Cu, Fe and Mn were more stable when it was evaluated results of all lagoons. The high TF values might be due to *Chenopodium album* have higher biomass production and fast growth. As a matter of fact, we know that these species are important in the improvement of sewage sludge storage areas due to this property [22, 24].

CONCLUSION

The results of this study indicated that the metals deposition in the *Chenopodium album*' tissue (roots, stems and leaves) natively growing in sewage sludge lagoons of the Bursa-EWWTP was significant high level. Numerous weeds like that *C. album* exhibit high levels of an inherent metal tolerance. They can diffuse to contaminated areas due to they have high colonization ability [57]. The high TF value show that the metals/elements in *C. album* is more mobile/available and *C. album* is a fast growing plant species characterized by high biomass production. In reclamation of sewage sludge landfills, this kind of plant species should be choosen [21, 22, 23, 24]. Because they are often better than other plants in terms of survival, growth, and also maintenance and contribute to soil conservation [58]. TF values of *C. album* were high in Lagoon 5 among sewage sludge lagoons in the Bursa-EWWTP, Turkey. BAF values have also been top level in Lagoon 1 and 5. These results gave us insight into the mobility of metals and elements in lagoons. Thus, it provided a data for future studies to improve this work area. This study also given detail information on metals/elements deposition behavior in *Chenopodium album*'s sewage sludge landfills.

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