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Change in the available and toxic concentrations of metals in the soil when compost and commercial soil conditioners were used

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ABSTRACT

In order to determine the possible effects of metals in soil on plants and other living beings, it is being beneficial to determine the available and toxic concentrations of metals in the soil. For the improvement of soils with rich metal content, addition of organic remediators such as compost, or lime in the soil is among the applicable methods. In this study, it was aimed to examine the changes in the immediately available, potentially available and toxic concentrations of metals found in the soil having acidic character when municipal solid waste compost, lime ($CaCO_3$) and commercial soil conditioners (A2 and T50) were used. When the toxicity characteristic leaching procedure results were examined, it was observed that the concentrations which can be regarded as the amount of compost added to the soil were increasing as toxic concentrations for heavy metals decrease. When the values are defined as immediately available which are expressing the weakly bound metal concentrations was determined that the mobility of metals in soil is pretty decreasing by the use of T50 from among the soil remediators. And by the use of lime, it was observed that the potentially available concentrations of metals are being reduced to minimum.

Keywords: Soil remediation; Metal; Soil remediators

1. Introduction

The major risk of soil contamination with metals is their potential to leach into groundwater and threaten all forms of life. Metals persist in soils for a long time after their introduction into the environment, and most metals stand in soil without microbial or chemical degradation [1].

It had been proven that heavy metals have biological accumulation's toxic effects on plants and animals. For this reason, it is very important to implement remediation techniques on areas contaminated by heavy metals [2]. It is possible to treat soils contaminated with metals by various methods such as phytoremediation, soil washing, stabilization, solidification, electroremediation and excavation [3,4].

Organic materials of diverse origins -such as municipal solid waste, wastes of food industry and composts from animal fertilizers can be used to remediate soils contaminated by heavy metals [5,6]. The addition of organic substances to contaminated soils has positive or negative effects on the mobility of metals depending on the properties of the material and receiving soil (i.e. soil pH, organic matter and clay content) [7].

It is known that the use of compost improves the physical, chemical and biological properties of the soil [8].

If compost contains high amounts of organic matter, there are studies indicating that the metals in the soil form complexes by linking them with the humic substances and thus reducing the biodegradability of metals [9]. Both organic

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and inorganic pollutants can be treated using compost. Even though the concentration of heavy metals in the compost is high, it is possible to improve the soil by the addition of this compost [10].

Addition of soil lime is one of the most common remediation methods, and can lead to the settling of heavy metals as metal-carbonates considerably reduce the exchangeable parts of heavy metals in the soil [11].

In this study, it was intended to examine the changes in the available and toxic concentrations of metals by the addition of compost, lime and commercial soil remediators in soil which include high amounts of metal, and which have acidic character.

2. Materials and methods

2.1. Characterization of samples

Soil sample used within the scope of the study was obtained from a field where agriculture was unable to be performed (due to the structure of soil) at the Kume Houses Locality of Bastimar Village being within the borders of Trabzon Province. In this study, municipal solid waste compost (MSW) was obtained from İSTAÇ Kemerburgaz Recovery and Compost Facility. $CaCO_3$ was used as lime. A2 and T50 commercial soil conditioners were obtained from the international company Virotec (Australia). T50 is a commercial chemical used in the treatment of acidic and heavy metal contaminated soils. A2 is a commercial chemical used to improve the acidic character.

For determining the pH values of the compost samples, distilled water was added to the samples by a ratio of 5:2 (v/w). The measurement of pH values was carried out using a pH meter (Jenway 3040 Ion Analyzer, United Kingdom) after being mixed by a magnetic mixer for 10 min [12]. For determining the soil's pH, a Jenway 3051 pH meter (United Kingdom) and soluble ion sensitive electrode were used. The pH values of the soil samples were determined in a water suspension having a solution ratio of 1:2.5, and in KCl 0.1 N [13].

The elemental analysis of the compost and soil samples used in the study was carried out with Thermo-Flash 2000 CHN-S elemental analyzer at the laboratory of Istanbul University Cerrahpaşa Environmental Engineering Department. ASTM-D5373 [14] method was used for analysis.

The determination of the organic matter (%) of the soil and compost samples used in the study was carried out at the Halic Environmental Laboratory.

Soil and compost samples were air-dried, and then were sieved to pass a 2 mm mesh for determination of total Ni, Fe, Cu, Cd, Zn, Pb and Mn concentrations. The "Microwave Solubilization Method" was used to determine the total metal concentrations of the soil and compost samples (EPA Method 3051A) [15].

2.2. Toxicity characteristic leaching procedure

The EPA Method 1311 [16] was used for the toxicity characteristic leaching procedure (TCLP). Soil samples and distilled water (the pH value was adjusted to 4.93 with acetic acid) were mixed by a ratio of 1:10, and were shaken at 25°C for 18 h at 30 rpm. After the extraction, the mixture was centrifuged at 2,000 rpm for 15 min. Then, the extracts were filtered through a 0.45 μm membrane filter. Determination of metal concentrations was made on these filtrates [10].

2.3. Determination of immediately available and potentially available elements concentrations

In order to determine the immediately available elements, and the concentrations for Ni, Fe, Cu, Cd, Zn, Pb and Mn, 2 g were taken from each of the air-dried samples. For these samples, 20 mL was added from 0.01 N $CaCl_2$ solution, and then shaken for 3 h. Extracts were filtered through a 0.45 μm membrane. Metal concentrations in filtrates were determined [10].

In the determination of potentially available elements, 50 mL of the solution with a pH of 4.95 and comprising 0.5 M ammonium acetate and 0.02 M ethylenediaminetetraacetic acid was added to 5 g of air-dried samples. After shaking for 1 h, they were centrifuged at 700 rpm for 15 min. Extracts were filtered through a 0.45 μm membrane filter. Then, metal concentrations in filtrates were determined [16].

Metal concentrations of extracts obtained at each stage were measured by AAS (Perkin Elmer AAS 400, USA).

2.4. Preparation of pots

In order to prepare the experimental setup, soil samples obtained from the working site were made homogenous as being pounded in porcelain mortar. And then the compost, lime and commercial soil remediators called A2 and T50 were mixed with soil having compost rates of 10% (v/v) compost, 25% (v/v) compost, 50% (v/v) compost, 1.5% (v/v) lime, 2.5% (v/v) lime, 1.5% lime and 10% compost, 1.5% (v/v) A2, 2.5% (v/v) A2, 5% (v/v) A2, 2.5% (v/v) A2 and 10% (v/v) compost, 0.5% (v/v) T50, 1.5 % (v/v) T50, 2.5% (v/v) T50, 1.5% (v/v) T50 and 10% (v/v), and they were placed flowerpots (with a volume of 150 mL) as having two iterations for each mixture. Only irrigation was applied to the pot for one week in order to allow time for the substances added to the soil to react with the soil. After 40 d, analyses of immediately available elements, potentially available elements and TCLP were performed for the mixtures in the flowerpots.

All the analyses were performed for three times, and average values and standard deviation values were provided as a result.

3. Results

3.1. Characterization of samples

The characterizations of soil and compost used in the study are provided in Table 1. When the soil's characterization was considered, it was observed that it has acidic character (pH 3). In the European Union Standards, the maximum permissible heavy metal limit values (in mg/kg-dry weight) were determined as 140 for Cu, 300 for Cd, 100 for Ni, 300 for Pb and 300 for Zn [17]. It was observed that the soil's C and N contents were very low, and that values of its heavy metals (Pb, Cd, Ni, Cu, Zn), metals (Fe, Mn) and other elements (Ca, Na, Mg, K) were quite high (Table 1).

3.2. Result of TCLP Test

When the results of TCLP (Table 2) were examined, it was observed that the toxic concentrations of metals were decreasing as the amount of compost added in soil increases. It was determined that the concentrations of heavy metals except Cu which were measured with TCLP were decreasing (a decrease of 50% or more) as the amount of lime added in soil increases.

In case of use of lime and compost as soil remediators, it was observed that concentrations of all the heavy metals measured as the result of TCLP were quite decreasing compared to the original soil, but a bit higher values were obtained compared to the results obtained by the addition of 1.5% (v/v) lime (excluding Cd and Ni). It was determined that the addition of A2 was causing the decrease of concentrations of Cu, Cd and Zn measured by TCLP. And no decrease was in subject for Pb (Table 2).

And in case of co-use of A2 and compost, it was observed that the concentrations of heavy metals measured by TCLP were higher compared to the condition in which only A2 was used. In the addition of T50 in soil, it was determined that the concentrations of heavy metals determined by TCLP were significantly decreasing as the amount of added T50 increases. As the result of co-use of T50 and compost, it was determined that the concentrations of heavy metals measured by TCLP were decreasing excluding Pb. When the concentrations of Fe and Mn determined by TCLP were examined, it was observed that the addition of soil remediators was decreasing the Fe concentrations which were determined by TCLP. But when the results of TCLP relevant to Mn were considered, it was observed that the Mn value was reaching to higher values in some soil mixtures compared to the original soil. It was observed that the lowest TCLP value for Fe was measured when 2.5% (v/v) lime was added (Table 2).

In literature, in the study performed by Tsang et al. [16], it had been specified that the stabilization of arsenic couldn't be ensured while the stabilization of Cu in soil could be

Table 1
Characterization of soil and compost used in the study

Parameters	Compost	Soil
pH	7.9 ± 0.01	3 ± 0.01
Organic Matter (OM) (%)	1.36 ± 0.001	28.4 ± 0.02
C (%)	11.07 ± 0.001	0.1 ± 0.0002
H (%)	ND	0.76
N (%)	0.28 ± 0.001	ND
S (%)	0.17 ± 0.0015	0.09 ± 0.001
Ca (mg/kg-dry weight)	22,727 ± 22.22	4,045 ± 4.016
Na (mg/kg-dry weight)	17,525 ± 10.34	1,002 ± 2.03
Mg (mg/kg-dry weight)	5,100 ± 3.25	6,705 ± 2.023
K (mg/kg-dry weight)	7,995 ± 4.17	19,022 ± 11.55
Pb (mg/kg-dry weight)	98 ± 0.01	5,984 ± 1.52
Cd (mg/kg-dry weight)	0.01 ± 0.0001	367 ± 0.2
Ni (mg/kg-dry weight)	39 ± 0.002	12 ± 0.001
Cu (mg/kg-dry weight)	244 ± 0.3	11,206 ± 21.2
Zn (mg/kg-dry weight)	455 ± 0.45	70,024 ± 32.55
Fe (mg/kg-dry weight)	16,498 ± 25.21	27,043 ± 20.56
Mn (mg/kg-dry weight)	356 ± 0.15	389 ± 0.22

ND: Not Detected
± Standard deviation

Table 2
Results of TCLP test (mg/kg-dry matter)

Sample	Zn	Pb	Cd	Ni	Cu	Fe	Mn
Soil	1,043.25 ± 1.11	5.61 ± 0.02	2.98 ± 0.001	ND	275.88 ± 0.1	227.43 ± 0.2	3.26 ± 0.001
Soil + 10% (v/v) compost	599.75 ± 0.22	9.76 ± 0.02	2.02 ± 0.001	ND	106.95 ± 0.2	14.06 ± 0.01	4.53 ± 0.002
Soil + 25% (v/v) compost	583.55 ± 0.1	2.02 ± 0.001	0.9 ± 0.0002	ND	19.58 ± 0.01	2.77 ± 0.001	11.37 ± 0.01
Soil + 50% (v/v) compost	32.17 ± 0.02	3.73 ± 0.01	ND	ND	9.79 ± 0.0002	39.6 ± 0.02	5.17 ± 0.001
Soil + 1.5% (v/v) Lime	14.52 ± 0.01	2.28 ± 0.001	ND	ND	1.53 ± 0.0001	5.48 ± 0.002	ND
Soil + 2.5% (v/v) Lime	7.36 ± 0.01	ND	ND	ND	1.58 ± 0.0001	ND	ND
Soil + 1.5% (v/v) Lime + 10%(v/v) compost	16.26 ± 0.02	7.5 ± 0.01	0.11 ± 0.0001	ND	7.46 ± 0.001	31.91 ± 0.01	ND
Soil + 1.5% (v/v) A2	611.23 ± 0.22	8.46 ± 0.02	1.9 ± 0.002	ND	138.95 ± 0. 1	5.19 ± 0.001	2.37 ± 0.001
Soil + 2.5% (v/v) A2	425.8 ± 0.21	9.2 ± 0.12	1.2 ± 0.001	ND	77.48 ± 0.01	7.41 ± 0.001	1.76 ± 0.001
Soil + 5% (v/v) A2	519.75 ± 0.2	5.71 ± 0.02	1.12 ± 0.001	ND	4.27 ± 0.001	15.57 ± 0.002	1.9 ± 0.001
Soil + 2.5% (v/v) A2 + 10% (v/v) compost	1,269.75 ± 1.01	13.02 ± 0.01	2.46 ± 0.002	ND	48.77 ± 0.01	26.28 ± 0.01	8.19 ± 0.002
Soil + 0.5% (v/v) T50	1,314.75 ± 1.21	16.72 ± 0.02	3.8 ± 0.001	1.05 ± 0.001	162.23 ± 0.2	24.45 ± 0.01	4.02 ± 0.001
Soil + 1.5% (v/v) T50	118.43 ± 0.1	1.06 ± 0.001	0.21 ± 0.001	ND	4.2 ± 0.001	0.47 ± 0.0001	1.75 ± 0.0001
Soil + 2.5 % (v/v) T50	21.38 ± 0.02	ND	0.23 ± 0.001	ND	4.04 ± 0.001	1.99 ± 0.001	ND
Soil + 1.5% (v/v)T50 + 10% (v/v) compost	8.29 ± 0.01	1.4 ± 0.001	ND	129.18 ± 0.1	2.3 ± 0.001	24.45 ± 0.01	69.26 ± 0.2

ND: Not Detected
± Standard Deviation

ensured by the addition of compost in soil. In the same study, it had been specified that it was estimated that the stabilization of Cu was arising from the formation of complex in between the organic parts in the structure of compost and Cu [16]. In another study performed by Paradelo et al. [13], it had been specified that the toxic concentrations of Cu, Pb and Zn were decreasing by the addition of MSW compost in the soil. In the study performed by Özbaş [18], it had been observed that the addition of compost was not affecting the leachability of Cd while it was decreasing the TCLP concentration of Ni [18]. When these findings in literature are considered, the results of this study are also in parallel with literature.

3.3. Immediately and potentially available element amounts

When Table 3, in which immediately available element concentrations are shown, is considered, it is being observed that there is a decrease in the concentrations of this form regarding the heavy metals as the added compost amount increases. When lime was added, it was observed that immediately available amounts of all the heavy metals were significantly decreasing as the amount of lime increases, and that better results were obtained compared to the addition of compost. And in case of co-use of lime and compost, it was determined that better results were obtained for Zn and Cu compared to the single use of 1.5% (v/v) lime, and that a slight increase was obtained in the immediately available amounts of other heavy metals (Table 3).

When A2 was added, it was observed that a decrease was obtained in the immediately available amounts of heavy metals even if not as much as a decrease obtained by the addition of compost or lime. In case of co-use of A2 and compost, while worse results were obtained for Zn compared to the single use of 2.5% (v/v) A2, it was observed that similar results were obtained for other heavy metals (Table 3).

By the addition of T50, it was determined that the immediately available amounts of heavy metal were decreasing as per the amount of T50, and it was determined that the best results regarding the decrease of immediately available amounts of heavy metals in soil were obtained by the addition of 2.5% (v/v) T50. When immediately available concentrations for Fe and Mn were considered, it was observed that the immediately available concentrations of Fe and Mn in original soil were decreasing by the addition of soil remediators (Table 3).

Similarly to the results obtained in this study, in the study performed by Paradelo et al. [10], it had been specified that the immediately available concentrations for Cu, Pb and Zn were decreasing by the addition of compost in soil. In the study performed by Özbaş [18], it had been found that the addition of compost in soil was decreasing the concentrations of immediately available forms of Ni and Cd [18]. Moreover, again in literature, it had been stated that there was a decrease in the mobile forms of metals in the soil by the addition of lime in soil [19–21].

When Table 4 is considered, it is being observed that the potentially available amounts for Zn, Cd and Cu are significantly decreasing as the amount of added compost increases. It was determined that there was a slight increase in the potentially available amounts of Ni, and that the potentially available amount of Pb was first increasing, and then decreasing by the increase of the amount of compost added

Table 3
Immediately available element amounts (mg/kg-dry matter)

Sample	Zn	Pb	Cd	Ni	Cu	Fe	Mn
Soil	913.75 ± 1.01	17.78 ± 0.02	3.09 ± 0.002	ND	280.15 ± 0.10	282.38 ± 0.12	4.78 ± 0.001
Soil + 10% (v/v) compost	596.5 ± 0.21	14.64 ± 0.01	1.82 ± 0.001	ND	92.83 ± 0.02	16.17 ± 0.02	6.72 ± 0.002
Soil + 25% (v/v) compost	410.15 ± 0.22	ND	0.96 ± 0.0001	ND	9.02 ± 0.01	ND	7.92 ± 0.001
Soil + 50% (v/v) compost	39.33 ± 0.02	7.25 ± 0.02	ND	ND	8.99 ± 0.01	12.91 ± 0.01	2.87 ± 0.0001
Soil + 1.5% (v/v) Lime	16.19 ± 0.01	0.65 ± 0.0001	ND	ND	2.86 ± 0.0002	ND	ND
Soil + 2.5% (v/v) Lime	2.24 ± 0.001	ND	ND	ND	ND	ND	2.09 ± 0.0001
Soil + 1.5% (v/v) Lime + 10%(v/v) compost	7.43 ± 0.02	1.77 ± 0.0001	ND	ND	1.01 ± 0.0001	22.97 ± 0.02	ND
Soil + 1.5% (v/v) A2	587.5 ± 0.20	4.78 ± 0.02	2.47 ± 0.002	ND	113.38 ± 0.10	8.9 ± 0.002	1.96 ± 0.0002
Soil + 2.5% (v/v) A2	557 ± 0.20	3.65 ± 0.015	1.91 ± 0.002	ND	81.23 ± 0.01	3.99 ± 0.001	2.25 ± 0.001
Soil + 5% (v/v) A2	428.28 ± 0.15	2.16 ± 0.01	1.01 ± 0.001	ND	5.13 ± 0.002	26.08 ± 0.01	1.18 ± 0.0001
Soil + 2.5% (v/v) A2 + 10% (v/v) compost	869.25 ± 0.20	9.95 ± 0.01	1.88 ± 0.002	ND	52.95 ± 0.01	29.9 ± 0.01	6.62 ± 0.002
Soil + 0.5% (v/v) T50	1,521.5 ± 1.11	13.34 ± 0.02	3.86 ± 0.01	ND	323.95 ± 0.20	35.66 ± 0.02	6.04 ± 0.001
Soil + 1.5% (v/v) T50	24.13 ± 0.01	6.77 ± 0.01	ND	ND	3.97 ± 0.0001	3.72 ± 0.0001	ND
Soil + 2.5 % (v/v) T50	1.38 ± 0.0001	ND	ND	ND	ND	ND	ND
Soil + 1.5% (v/v)T50 + 10% (v/v) compost	0.99 ± 0.0001	ND	ND	ND	ND	7.95 ± 0.001	ND

ND: Not Detected
± Standard Deviation

afterwards. When lime was added, it was observed that potentially available amounts of all the heavy metals were significantly decreasing as the amount of lime increases, and that better results were obtained compared to the addition of compost except the Pb examined in the study. And in case of co-use of lime and compost, it was determined that worse results were obtained compared to the single use of 1.5% (v/v) lime, and that a slight increase was obtained in the potentially available amounts of heavy metals (Table 4).

When A2 was added, it was observed that a decrease was obtained in the potentially available amounts of heavy metals even if not as much as a decrease obtained by the addition of compost or lime. In case of combined use of A2 and compost, it was observed that worse results were obtained for the potentially available metal concentrations compared to the case of single use of 2.5% (v/v) A2 (Table 4).

By the addition of T50, it was determined that the potentially available amounts of heavy metals were decreasing as per the amount of added T50. Regarding Fe and Mn, it was observed that the potentially available concentrations were at the lowest level by the addition of 2.5% (v/v) lime (Table 4). In literature, it had been specified that no decrease had been observed in the potentially available concentrations by the addition of MSW compost in soil [13]. In the experiments on potentially available elements performed by Özbaş [18], it had been observed that the addition of compost in soil had increased this form of Ni. It had been observed by the end of 3 months that the Cd concentrations in this form were 50% less compared to soil samples without compost [18]. And in the results obtained in this study, it was observed that the co-use of compost with other soil remediators was not as effective as its single use even if it was observed that the potentially available concentrations of metals were decreasing by the single use of compost. Potentially beneficial effect of organic remediators added in soil is able to vary. Organic substances my decrease the presence of heavy metals by increasing the specific interaction of pH of soil and metals, because the reactive groups in the organic substance may convert the heavy metals in soil to immobile forms, and may absorb them [11,22]. However, results of some studies are showing that the organic substances are able to increase the metal mobility in soil depending on potential decrease of pH value of soil, increase in organic substance dissolved in the resulting mixtures, and increase in the metal – organic substance dissolvable complexes [5,23]. The behavior and transport of a heavy metal in the soil depends on the chemical form and the properties of the metal [24]. For this reason, when the same soil remediator is used, different heavy metals are affected in different ways.

4. Conclusions

As the result of the study, it was observed that immediately and potentially available metal concentrations determined by TCLP were decreasing in cases of single use of compost. By the addition of lime, it was observed that the immediately available concentrations which can be leached by TCLP were quite decreasing. But it was observed that the addition of lime was not as effective as compost in decreasing the potentially available metal concentrations. It was observed that the use of T50 was providing better results in decreasing the immediately and potentially available metal concentrations determined by TCLP compared to A2. When a general assessment was made for all the metals

Table 4
Potentially available element amounts (mg/kg-dry matter)

Sample	Zn	Pb	Cd	Ni	Cu	Fe	Mn
Soil	1,595.25 ± 2.22	222.68 ± 0.21	5.86 ± 0.012	ND	517.03 ± 2.10	1,096.25 ± 2.72	7.39 ± 0.01
Soil + 10% (v/v) compost	858.25 ± 1.21	292.28 ± 0.23	2.84 ± 0.01	ND	255.48 ± 1.12	250.2 ± 1.10	9.48 ± 0.03
Soil + 25% (v/v) compost	638 ± 1.14	247.58 ± 0.31	2.16 ± 0.01	ND	184.55 ± 1.10	190.03 ± 0.90	14.77 ± 0.03
Soil + 50% (v/v) compost	528.75 ± 1.10	212.48 ± 0.21	2.41 ± 0.012	1.08 ± 0.001	156.03 ± 1.16	201.8 ± 1.10	28.12 ± 0.05
Soil + 1.5% (v/v) Lime	696.5 ± 1.12	280.45 ± 0.41	2.61 ± 0.014	ND	167.25 ± 1.14	106.9 ± 1.11	ND
Soil + 2.5% (v/v) Lime	549.75 ± 1.11	419.13 ± 0.51	2.21 ± 0.012	ND	161.35 ± 1.12	93.98 ± 0.04	ND
Soil + 1.5% (v/v) Lime + 10%(v/v) compost	1,539.5 ± 2.41	757.25 ± 0.55	5.25 ± 0.022	ND	311.98 ± 2.11	195.83 ± 1.22	10.95 ± 0.02
Soil + 1.5% (v/v) A2	710.75 ± 1.15	240.35 ± 0.21	2.1 ± 0.01	ND	198.93 ± 1.10	150.88 ± 1.10	2.61 ± 0.001
Soil + 2.5% (v/v) A2	831.25 ± 1.13	222.55 ± 0.24	3.12 ± 0.012	ND	191.7 ± 1.07	120.38 ± 0.91	3.49 ± 0.004
Soil + 5% (v/v) A2	2,027.25 ± 3.11	661.75 ± 0.63	4.62 ± 0.015	ND	240.83 ± 2.21	162.23 ± 1.42	7.72 ± 0.01
Soil + 2.5% (v/v) A2 + 10% (v/v) compost	2,336.5 ± 3.23	693.5 ± 0.61	5.82 ± 0.022	ND	371.63 ± 3.10	265.18 ± 2.10	17.36 ± 0.04
Soil + 0.5% (v/v) T50	2,263.75 ± 3.21	562.75 ± 0.47	6.05 ± 0.024	ND	445.3 ± 2.90	487.63 ± 3.32	7.3 ± 0.02
Soil + 1.5% (v/v) T50	715.25 ± 1.11	240.23 ± 0.21	2.39 ± 0.012	1.48 ± 0.001	192.75 ± 1.11	172.6 ± 1.02	5.21 ± 0.001
Soil + 2.5 % (v/v) T50	772 ± 1.13	343.78 ± 0.26	2.63 ± 0.01	ND	209.9 ± 2.10	273.65 ± 1.15	6.67 ± 0.002
Soil + 1.5% (v/v)T50 + 10% (v/v) compost	1,890.5 ± 3.01	853 ± 0.67	6.45 ± 0.021	1.52 ± 0.001	352.48 ± 3.20	459.25 ± 2.98	17.01 ± 0.04

ND: Not Detected
± Standard Deviation

examined within the scope of the study, it was observed that the best results for minimizing the leachable metal amounts determined by TCLP was being obtained by the use of lime. It was again observed that the best result for decreasing the metal concentrations in immediately available form was obtained by the addition of lime.

As the result of this study regarding the remediation of soil having acidic character, it was determined that the leachable metal concentrations in immediately available form determined by TCLP may be decreased by 50% and more by the addition of soil remediators. But regarding the decrease of metal concentrations in potentially available form, it couldn't be successful relevant to the decrease of concentrations of other forms especially for Pb. It is also being intended to examine the change of these obtained results as the result of long-term applications by performing more long-term studies.

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