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Original Article

Phytoremediation of toxic heavy metals in polluted soils and water of Dargai District Malakand Khyber Pakhtunkhwa, Pakistan

Fitorremediação de metais pesados tóxicos em solos e água poluídos do distrito de Dargai Malakand Khyber Pakhtunkhwa, Paquistão

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Abstract

The contamination of natural resources with heavy metals released from steel mills is the primary cause of soil and water pollution in the Dargai Malakand, located on the northern side of Pakistan. Therefore, the present study was aimed to determine the level of heavy metals in soil and water samples of this area. The wild plant growing (nine native plants: *Pteris vittata, Populus nigra, Eucalyptus camaldulensis, Persicaria maculosa, Arundo donax, Xanthium strumarium, Verbascum thapsus, Ricinus communis* and *Parthenium hysterophorus*) there were then tested for their phytoremediation capabilities which is an environmentally friendly, generally utilized, and low-cost approach to eliminate heavy metals from polluted soils and water. Soil, water, and effluent samples were taken from the contaminated sites of seven steel mills in Dargai District Malakand and subjected to heavy metals analysis. Based on bioconcentration factor (BCF) and translocation factor (TF) calculated, The highest BCF for zinc was recorded for *Pteris vittata* roots (3.93), while the lowest value was observed for *Verbascum thapsus* leaves (0.306). *Pteris vittata* root showed the highest BCF for iron (1.618), while *Ricinus communis* leaves showed the lowest (0.023). The highest BCF value for chromium was highest for *Populus nigra* roots (0.717), while the lowest value was recorded for *Persicaria maculosa* leaves (0.031). For the selected metals; Fe, Zn and Cr the highest TF were recorded for *Pteris vittata* (0.988), *Verbascum thapsus* (0.944) and *Xanthium strumairum* (0.968) respectively. Therefore, it is recommended that these plants should be grown near to steel mills to reclaim heavy metals from industrial effluent, polluted soil as well as from polluted water.

Keywords: chromium, heavy metals, iron, zinc.

Resumo

A contaminação dos recursos naturais com metais pesados liberados pelas siderúrgicas é a principal causa da poluição do solo e da água no Dargai Malakand, localizado no lado norte do Paquistão. Portanto, o presente estudo teve como objetivo determinar o teor de metais pesados em amostras de solo e água desta área. O cultivo de plantas silvestres (nove plantas nativas: *Pteris vittata*, *Populus nigra*, *Eucalyptus camaldulensis*, *Persicaria maculosa*, *Arundo donax*, *Xanthium strumarium*, *Verbascum thapsus*, *Ricinus communis* e *Parthenium hysterophorus*) foi testado quanto às suas capacidades de fitorremediação, que é um meio ambiente, geralmente utilizado, e abordagem de baixo custo para eliminar metais pesados de solos e águas poluídas. Amostras de solo, água e efluentes foram retiradas dos locais contaminados de sete siderúrgicas no distrito de Dargai, Malakand, e submetidas à análise de metais pesados. Com base no fator de bioconcentração (BCF) e fator de translocação (TF) calculados, o maior BCF para zinco foi registrado para as raízes de Pteris vittata (3,93), enquanto o menor valor foi observado para as folhas de *Verbascum thapsus* (0,306). A raiz de *Pteris vittata* apresentou o maior BCF para ferro (1,618), enquanto as folhas de *Ricinus communis* apresentaram o menor (0,023). O maior valor de BCF para cromo foi maior para raízes de *Populus nigra* (0,717), enquanto o menor valor foi registrado para folhas de Persicaria maculosa (0,031). Para os metais selecionados, Fe, Zn e Cr, os maiores TF foram registrados para *Pteris vittata* (0,988), *Verbascum thapsus* (0,944) e *Xanthium strumairum* (0,968), respectivamente. Portanto, recomenda-se que essas plantas sejam cultivadas próximas a siderúrgicas para recuperar metais pesados de efluentes industriais, solo poluído e água poluída.

Palavras-chave: cromo, metais pesados, ferro, zinco.

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1. Introduction

In Pakistan one of the main causes of soil and water pollution is mining and steel processing mills that contribute to environmental pollution that adds constantly heavy metals to water bodies. In developing countries like Pakistan, there are strict regulations to bound the factories owners to adapt proper mechanism for treating industrial effluents before they are discharged into the environment. These industries effluents contain toxic heavy metals into the soil and water bodies. Metals being non-biodegradable and their presence in environmental compartments are a serious threat to living organisms (Rahman et al., 2019; Yadav et al., 2017). In some case they are toxic to plants as well but plant being more tolerant to environmental changes can adopt new means of survival in the altered environment. The contaminant from soil and water can also be transported to human through a natural phenomenon called phytoremediation where heavy metals are concentrated into different portion of the edible plants (Liu et al., 2018). At the same time this phenomenon is considered as a gifted natural process capable of soil and reclamation if it occurs in wild less beneficial plants. Certain plant have high capabilities of concentrating heavy metals in their various parts and are recommended to be grown near industrial drains.

Steel is made by chemically reducing iron ore, either through an integrated steel manufacturing process or by a direct reduction process. In the conventional integrated steel manufacturing process, the iron from the blast furnace is converted to steel in an oxygen furnace (Ajao et al., 2011). From steel mills contaminants like iron, zinc, lead, chromium, cadmium, fluoride, oil, and grease are released into environment. Thus, there is a direct need to properly treat steel mills effluents as it not only causes water and soil pollution but can also lead to other secondary issues like dissolved oxygen depletion, discoloration, turbidity, algal and fungal growth, sludge formation etc. The main objective of treatment procedures is to remove pollutants from effluent and improve water quality to acceptable levels (Lenore et al., 1999). Chemical and thermal treatments are limited by labor constraints, high costs, irreversible soil alterations, and disruption of local tiny plants. Secondary pollutants can also be produced by chemical processes. To remediate heavy metal from polluted soils, cost-effective, well-organized, and environmentally friendly purification processes are required. Phytoremediation is a biological control and is a natural phenomenon in which plants are used to eliminate contaminants from the surroundings. The process has been shown to be a successful in many studies (Elbehiry et al., 2020; Favas et al., 2014; Festin et al., 2019; Gerhardt et al., 2009; Sarwar et al., 2017; Sinkala, 2018; Wiszniewska et al., 2016). For the rehabilitation of contaminated soil, phytoremediation is regarded to be the most suitable and environment friendly option (Yan et al., 2015). Being a natural phenomenon, it is the most effective and affordable technique used to extract, remove or isolate inactive metals and remediate the polluted soil as the plants have a unique and selective uptake system and have bioaccumulation and translocation capabilities (Tangahu et al., 2011; Ali et al., 2013). A variety of phytoremediation processes are employed to treat polluted soil, including phytoextraction, phytodesalination, phytodegradation, phytofiltration, phytovolatilization, and phytostabilization (Rafati et al., 2011). Phytoextraction and phytodesalination are thought to be superior to the others (Manousaki and Kalogerakis, 2011).

From the discussion above, phytoremediation is a technique of choice for soil cleaning; therefore, in the current study nine wild plants growing around the drainage lines of the steel mills installed in Dargai, Pakistan was evaluated for their phytoremediation capabilities. Initially, effluents of steel mills were subjected to heavy metal analysis then soil samples were also evaluated for heavy metal contamination where finally, nine wild plants were evaluated for the uptake capabilities of the selected heavy metals from soil. The bioaccumulation and translocation factor of each plant were also calculated.

2. Materials and Methods

2.1. Area selection

This study focus was the industrial area of Dargai District Malakand, Pakistan being a free-trade zone with numerous industries especially steel mills. The purpose of the study was to prevent the natural environment of the area through informing the government agencies for strict regulations to be implemented and to recommend efficient plants to be grown to reclaim the contaminated soil.

2.2. Sample collection

Pteris vittata, Populus nigra, Eucalyptus camaldulensis, Persicaria maculosa, Arundo donax, Xanthium strumarium, Verbascum thapsus, Ricinus communis and *Parthenium hysterophorus* were the few native plant species that were collected along soil samples, industrial effluents, and surrounding water samples. The roots, stems, and leaves of the plants were separated. Polythene bags were used to collected the soil samples.

The steel mills effluents, soil samples from polluted area, and water samples were taken from the canals where industrial effluents are released constantly. Water samples (100 mL) were taken in cleaned plastic bottles from seven different canal sites. To prevent bubble formation, the bottles were filled below the water's surface followed by filtration.

The industrial effluents were collected from seven different steel mills in Dargai Malakand, Pakistan, and analyzed for heavy metals as previously stated above. To avoid legal issues, the steels mills are presented with numbers from 1 to 7 rather than their real names.

The soil samples were taken from a depth of 15 cm below the surface at particular sites in which steel mills waste water was disposed. The samples were brought in polyethylene bags to the laboratory and examined for heavy metals as explained below.

2.3. Heavy metal analysis of the samples

The filtered samples were stored in flasks that had been washed with HNO_3 (55%) previously to prevent metal adsorption. The acidified water samples (100 mL) were then evaporated to almost 20 mL volume on a hot plate. After cooling 5 ml of HNO_3 (55%) and 10 ml of perchloric acid (70%) were added to each sample. The mixtures were evaporated on a hot plate till the brown fumes turned into dense white fumes of perchloric acid ($HClO_4$). Following that, the solutions were checked through atomic absorption spectrophotometer (AAS) for heavy metals analysis (Khan et al., 2019).

2.4. Preparation of plant samples for heavy metal analysis

To eliminate soil and dust particles, the roots, stems, and leaves of the collected plants were washed with distilled water. The samples were dried in the shade until dry, and then grinded into a fine powder. The powder and soil samples were dried in an oven before being digested using the method of Awofolu (2005). About 0.5g sample of each part was digested in 5 mL of conc. HNO_3 and 2 mL of $HClO_4$ solution. The filtrates were preserved in a 50 mL flask, and the volume was increased to 50 mL by adding distilled water. The filtrates were then analyzed using atomic absorption spectrophotometer. From the concentrations calculated, bioconcentration and translocation factors were estimated (Ladislas et al., 2012; Wu et al., 2011).

3. Result and Discussion

The concentration of heavy metals in water and soil is crucial because the plant gets its food from it. Though plants have a very specific uptake capability, but sometime they also take unwanted substances such as metals from the soil and assimilates in their body parts like root, stem and leaves. Heavy metal concentrations in industrial effluents, nearby waterbodies samples, and soil samples have been determined as described below.

Table 1 shows the concentrations of the selected heavy metals in industrial effluent samples. The heavy metal concentrations in steel mill effluent samples was in the order of Fe > Zn > Cr. In terms of iron concentration, steel mill 4 had discharged the highest (0.908 mg/L) amount, while steel mill 2 had released the lowest (0.377 mg/L) amount. Iron concentrations in steel mill effluent samples were measured in the following order; steel mill 4 (0.908 mg/L) > steel mill 7 (0.695 mg/L) > steel mill 6 (0.564 mg/L) > steel mill 1(0.562 mg/L) > steel mill 5(0.519 mg/L) > steel mill 3 (0.423 mg/L) > steel mill 2 (0.377 mg/L). In terms of zinc concentration in industrial effluents, the order was; steel mill 4 (0.717 mg/L) > steel mill 7 (0.597 mg/L) > steel mill 5 (0.498 mg/L) > steel mill 6 (0.431 mg/L) > steel mill 2 (0.364 mg/L) > steel mill 1 (0.361 mg/L) > steel mill 3 (0.266 mg/L). The chromium concentrations in steel mill effluent samples were as follows; steel mill 7 (0.550 mg/L) > steel mill 4 (0.364 mg/L) > steel mill 6 (0.337 mg/L) > steel mill 2 (0.0.248 mg/L) > steel mill 1 (0.175 mg/L) > steel mill 3 (0.130 mg/L)> steel mill 5 (0.109 mg/L).

The heavy metal concentrations in the polluted soil samples were in the order of Fe > Zn > Cr. In the seven soil samples collected from the polluted area of steel mill sites Fe concentration was comparatively high (64.75 mg/Kg, 63.27 mg/mg/Kg, 100.9 mg/Kg, 57.99 mg/Kg,72.99 mg/Kg, 46.8 mg/Kg, 53.85 mg/Kg) followed by Zinc (1.043 mg/Kg, 3.479 mg/Kg, 3.779 mg/Kg, 2.253 mg/Kg, 2.054 mg/Kg, 3.243 mg/Kg, 3.736 mg/Kg) and Chromium (1.602 mg/Kg, 0.781 mg/Kg, 0.288 mg/Kg, 1.399 mg/Kg, 0.404 mg/Kg, 1.389 mg/Kg, 0.882 mg/Kg).

Table 2 displays the concentrations of heavy metals in the collected seven soil samples taken from the contaminated sites. The table shows that soil sample 3 from a polluted area of steel mill has the highest concentration of iron, while soil sample no 6 from a polluted area where steel mill is operational has the lowest concentration of iron. The overall order of iron concentrations in soil taken from polluted areas of each of seven different steel sites was in the order of soil 3 (100.9 mg/Kg)> soil 5 (72.99 mg/Kg) > soil 1 (64.75 mg/Kg) > soil 2 (63.27 mg/Kg) > soil 4 (57.99 mg/Kg) > soil 7 (53.85 mg/Kg) > soil 6 (46.8 mg/Kg). When it comes to Zn, soil 3 (3.779 mg/Kg) > soil 7 (3.736 mg/Kg) > soil 2 (3.479 mg/Kg) > soil 6 (3.243 mg/Kg) > soil 4 (2.253 mg/Kg) > soil 5 (2.054 mg/Kg) > soil 1 (1.043 mg/Kg). In the instance of Cr; soil 4 (1.399 mg/Kg) > soil 6 (1.389 mg/Kg) > soil 1 (1.602 mg/Kg) > soil 7 (0.882 mg/Kg) > soil 5 (0.404 mg/Kg) > soil 3 (0.288 mg/Kg).

The amounts of heavy metals in water samples taken from canals where industrial effluent is discharged are shown in Table 3. Seven canal sites were chosen for sample collection as they were polluted by these steel mills. Iron concentrations in canal samples were; site 1 (0.460 mg/L) > site 6 (0.225 mg/L) > site 2 (0.219 mg/L) >

Table 1. Concentration of Heavy metals (mg/L) in the seven steel mill effluents.

Sample	Heavy Metals		
	Fe	**Zn**	**Cr**
Steel mill 1	0.562	0.361	0.175
Steel mill 2	0.377	0.364	0.248
Steel mill 3	0.423	0.266	0.130
Steel mill 4	0.908	0.717	0.364
Steel mill 5	0.519	0.498	0.109
Steel mill 6	0.564	0.431	0.337
Steel mill 7	0.695	0.597	0.550

Table 2. Concentration of Heavy metals (mg/Kg) in soil.

Sample	Heavy Metals		
	Fe	**Zn**	**Cr**
Soil 1	64.75	1.043	1.602
Soil 2	63.27	3.479	0.781
Soil 3	100.9	3.779	0.288
Soil 4	57.99	2.253	1.399
Soil 5	72.99	2.054	0.404
Soil 6	46.8	3.243	1.389
Soil 7	53.85	3.736	0.882

site 5 (0.183 mg/L) > site 3 (0.182 mg/L) > site 4 (0.145 mg/L). In case of Zn: site 1 (0.217 mg/L) > site 3 (0.175 mg/L) > site 2 (0.147 mg/L) > site 6 (0.105 mg/L) > site 4 (0.048 mg/L) > site 7 (0.036 mg/L) > site 5 (0.034 mg/L) were discovered. In terms of chromium concentration in the water samples; site 7 (0.514 mg/L) was higher than site 5 (0.409 mg/L), site 2 (0.244 mg/L), site 6 (0.221 mg/L), site 1 (0.209 mg/L), site 4 (0.185 mg/L) and site 3 (0.165 mg/L) respectively.

3.1. Phytoextraction of heavy metals by plant species collected from polluted area

As mentioned earlier, 9 native plant species were collected from the contaminated area of Tehsil Dargai District Malakand in order to recommend best plant for heavy metal cleaning from soil. The concentrations of heavy metals in the leaves and roots of *Pteris vittata* are given in the Table 4. In the leaves of *Pteris vittata,* iron was found in the highest concentration (102.8 mg/Kg), followed by Zn (3.103 mg/Kg) and Cr (0.250 mg/Kg). *Pteris vittata* roots were found to contain the highest amount of iron (104.8 mg/Kg), followed by zinc (4.105 mg/Kg) and chromium (0.355 mg/Kg). The data shows that uptake is concentration dependent. Table 4 shows that *Populus nigra* has also taken heavy metals; Fe, Zn and Cr from soil. The iron concentration in leaves was highest (9.47 mg/Kg), followed by zinc (1.294 mg/Kg) and chromium (0.088 mg/Kg). The concentration of iron (11.25 mg/Kg) was found in the stem of *Populus nigra*, followed by zinc (2.05 mg/Kg) and chromium (0.095 mg/Kg). In the roots of *Populus nigra,* iron was reported in the highest amount (15.65 mg/Kg), followed by zinc (3.55 mg/Kg) and chromium (1.15 mg/Kg). The high uptake of Fe, Zn, and Cr was also concentration dependent in relation to corresponding soil where the found naturally found. Table 4 indicates that the highest concentration of iron (3.323 mg/Kg) is there in the leaves of *Eucalyptus camaldulensis*, followed by zinc (1.239 mg/Kg) and chromium (0.065 mg/Kg). Furthermore, iron (4.21 mg/Kg) was identified in the stem of *Eucalyptus camaldulensis,* followed by zinc (1.82 mg/Kg) and chromium (0.071 mg/Kg). The heavy metal content in the roots of this plant was in the order of Fe (4.85 mg/Kg) > Zn (2.05 mg/Kg) and Chromium (0.076 mg/Kg).

Table 3. Concentration of heavy metals (mg/L) in water samples collected from water canals.

Sample	Heavy Metals		
	Fe	Zn	Cr
Site 1	0.460	0.217	0.209
Site 2	0.219	0.147	0.244
Site 3	0.182	0.175	0.165
Site 4	0.145	0.048	0.185
Site 5	0.183	0.034	0.409
Site 6	0.225	0.105	0.221
Site 7	0.107	0.036	0.514

As shown in Table 4, the metal composition reported in the leaves of *Persicaria maculosa* were in the order of iron (2.283 mg/Kg) > zinc (1.269 mg/Kg) and chromium (0.051 mg/Kg). The iron concentration (2.56 mg/Kg) in the stem of *Persicaria maculosa* was high followed by zinc (1.325 mg/Kg) and chromium (0.052 mg/Kg).

Table 4 also presents that the metal concentrations in the leaves of *Arundo donax* are; iron = 3.213 mg/Kg, zinc = 0.901 mg/Kg, and chromium = 0.057 mg/Kg. The heavy metal concentrations in the stem of *Arundo donax* were; iron = 3.485 mg/kg, zinc = 1.2 mg/Kg, and chromium = 0.061 mg/Kg.

The iron concentration (21.35 mg/Kg) in the leaves of *Xanthium Strumarium* was high followed by zinc (1.316 mg/Kg) and chromium (0.061 mg/Kg). Iron was found in the highest concentration (23.35 mg/Kg) in the stem of this plant, followed by zinc (1.89 mg/Kg) and chromium (0.0625 mg/Kg). The Iron (24.1 mg/Kg) was the most abundant element in the roots of *Xanthium strumarium*, followed by zinc (1.95 mg/Kg) and chromium

Table 4. Concentration (mg/Kg) of Heavy Metals in Plants.

Sample	Plant part	Heavy Metals		
		Fe	Zn	Cr
Pteris vittata	Leaves	102.8	3.103	0.250
	Root	104.2	4.105	0.355
Populus nigra	Leaves	9.47	1.294	0.088
	Stem	11.25	2.05	0.095
	Root	15.65	3.55	1.15
Eucalyptus camaldulensis	Leaves	3.323	1.239	0.065
	Stem	4.21	1.82	0.071
	Root	4.85	2.05	0.076
Persicaria maculosa	Leaves	2.283	1.269	0.051
	Stem	2.56	1.325	0.052
	Root	2.91	1.45	0.057
Arundo donax	Leaves	3.213	0.901	0.057
	Stem	3.485	1.2	0.061
	Root	3.785	1.45	0.066
Xanthium strumarium	Leaves	21.35	1.316	0.061
	Stem	23.35	1.89	0.0625
	Root	24.1	1.95	0.0639
Verbascum Thapsus	Leaves	11.09	1.067	0.063
	Stem	11.62	1.075	0.065
	Root	11.85	1.13	0.067
Ricinus communis	Leaves	1.497	1.557	00
	Stem	1.86	1.87	00
	Root	1.96	1.97	00
Parthenium hysterophorus	Leaves	9.24	0.892	00
	Stem	9.54	0.95	00
	Root	9.88	0.98	00

(0.0639 mg/Kg) respectively. By correlating the composition of soil and different parts of *Xanthium strumarium* it was revealed that a strong uptake of iron has been occured, followed by zinc and chromium, indicating that the uptake is concentration dependent.

Table 4 illustrated that the iron concentration (11.09 mg/Kg) in the leaves of *Verbascum thapsus* is higher than the zinc (1.067 mg/Kg) and chromium (0.063 mg/Kg) concentrations. Iron (11.62 mg/Kg) was reported in this plant's stem, followed by zinc (1.075 mg/Kg) and chromium (0.065 mg/Kg). Iron (11.85 mg/Kg) was found in the roots of *Verbascum thapsus*, along with zinc (1.13 mg/Kg) and chromium (0.067 mg/Kg). By analyzing the composition of soil samples collected from this plant's native habitat, the high uptake of iron, as determined have been found to be concentration dependent.

The iron concentration (1.497 mg/Kg) was recorded high in the leaves of *Ricinus communis*, followed by zinc (1.557 mg/Kg) and chromium (0 mg/Kg). This plant stem contained iron (1.86 mg/Kg), zinc (1.87 mg/Kg), and chromium (0 mg/Kg). The iron concentration (1.96 mg/Kg), zinc concentration (1.97 mg/Kg), and chromium concentration (0 mg/Kg) in roots *Ricinus communis* were recorded.

Table 4 also shows that the concentrations of heavy metals in the leaves, stems, and roots of *Parthenium hysterophorus*. Iron was found in a high concentration (9.24 mg/Kg) in the leaves sample, followed by zinc (0.892 mg/Kg) and chromium (0 mg/Kg).In this plant stem samples, iron was observed at the highest concentration (9.54 mg/Kg), followed by zinc (0.95 mg/Kg) and chromium (0 mg/Kg). The heavy metal concentrations in this plant roots were in the following order; iron (9.88 mg/Kg) > zinc (0.98 mg/Kg) > chromium (0 mg/Kg).

3.2. Bioconcentration factor

The bioconcentration factor (BCF) measures a plant ability to accumulate a metal into its tissue. In the Table 5, *Pteris vittata* had the highest BCF in terms of iron (1.618 root sample) and *Ricinus communis* had the lowest (0.023 leaf sample). The *Pteris vittata* roots (3.93) had the highest BCF for zinc, while *Verbascum thapsus* leaves (0.306) had the lowest. The roots of *Populus nigra* had the greatest BCF value in terms of chromium (0.717), whereas the leaves of *Persicaria maculosa* had the lowest (0.031).

3.3. Translocation factor

A translocation factor (TF) describes a plant ability to translocate metal from its roots to aerial sections, and its value can be used to determine plant suitability for phytoextraction of a certain metal. The numerical values of TF calculated are given in Table 6. In regard of iron, the TF values shown by plants were as follows; *Pteris vittata* (0.988) > *Verbascum thapsus* (0.936) > *Parthenium hysterophorus* (0.935) > *Xanthium strumairum* (0.885) > *Arundo donax* (0.848) > *Persicaria maculosa* (0.784) > *Ricinus communis* (0.763) > *Eucalyptus camaldulensis* (0.685) > *Populus nigra* (0.605).The significant values of Translocation factor (TF) in terms of Zn were in the order of *Verbascum thapsus* (0.944) > *Parthenium hysterophorus* (0.910) > *Persicaria maculosa* (0.875) > *Ricinus communis* (0.786) > *Pteris vittata* (0.755) > *Xanthium strumairum* (0.674) > *Arundo donax* (0.621) > *Eucalyptus camaldulensis* (0.604) > *Populus nigra* (0.364). In respect of Cr, the maximum TF results were as follows; *Xanthium strumairum* (0.968) > *Verbascum thapsus* (0.940) > *Persicaria maculosa* (0.895 > *Arundo donax* (0.863) > *Eucalyptus camaldulensis* (0.855) > *Pteris vittata* (0.704) > *Populus nigra* (0.0549).

Table 5. Bioconcentration factor of different heavy metals uptake by selected Plants.

Plant	BCF	Heavy Metals		
		Fe	Zn	Cr
Pteris vittata	Leaves	1.58	2.97	0.156
	Root	1.618	3.93	0.221
Populus nigra	Leaves	0.146	1.240	0.054
	Stem	0.173	1.96	0.095
	Root	0.241	3.40	0.717
Eucalyptus camaldulensis	Leaves	0.0525	0.356	0.0832
	Stem	0.0665	0.523	0.0909
	Root	0.0766	0.589	0.0973
Persicaria maculosa	Leaves	0.0352	1.21	0.031
	Stem	0.0395	1.27	0.032
	Root	0.0449	1.39	0.0355
Arundo donax	Leaves	0.0507	0.258	0.0729
	Stem	0.0550	0.344	0.0781
	Root	0.0598	0.416	0.084
Xanthium strumarium	Leaves	0.329	1.26	0.0380
	Stem	0.360	1.81	0.0390
	Root	0.372	1.869	0.0398
Verbascum Thapsus	Leaves	0.175	0.306	0.0806
	Stem	0.183	0.308	0.083
	Root	0.187	0.324	0.019
Ricinus communis	Leaves	0.023	1.99	00
	Stem	0.0293	2.394	00
	Root	0.0309	2.522	00
Parthenium hysterophorus	Leaves	0.146	1.142	00
	Stem	0.150	1.21	00
	Root	0.156	1.254	00

Table 6. Translocation factor of different heavy metals uptake by selected Plants.

Plants	Heavy Metals		
	Fe	Zn	Cr
Pteris vittata	0.988	0.755	0.704
Populus nigra	0.605	0.364	0.0549
Eucalyptus camaldulensis	0.685	0.604	0.855
Persicaria maculosa	0.784	0.875	0.895
Arundo donax	0.848	0.621	0.863
Xanthium strumarium	0.885	0.674	0.968
Verbascum Thapsus	0.935	0.944	0.940
Ricinus communis	0.763	0.786	00
Parthenium hysterophorus	0.935	0.910	00

4. Conclusion

In this study as attempt was made to corelates the heavy metals release from steel mills effluent with their uptake by wild native plant with a purpose to recommend best plant among the selected 9 plants to be grown for the reclamation of soil of the metal contaminated areas. Steel mills effluents, nearby water bodies water, soil, and 9 wild plants have been analyzed for heavy metal concentrations. It was found that the uptake of Fe, Zn, and Cr was concentration dependent. The highest BCF in term of iron and Zn have been shown by the root of *Pteris vittata* (1.618 and 3.93 respectively). The highest BCF in term of Cr was observed for the roots of *Populus nigra* (0.717). The order of TF values in term of Fe were; *Pteris vittata* (0.988) > *Verbascum thapsus* (0.936) > *Parthenium hysterophorus* (0.935) > *Xanthium strumairum* (0.885) > *Arundo donax* (0.848) > *Persicaria maculosa* (0.784) > *Ricinus communis* (0.763) > *Eucalyptus camaldulensis* (0.685) > *Populus nigra* (0.605). The highest TF values in term of Zn was noted for *Verbascum thapsus* (0.944) while lowest for *Populus nigra* (0.364). In case of Cr the highest TF value was shown by *Xanthium strumairum* (0.968) and lowest by *Populus nigra* (0.0549). All of the native plant species listed above have the potential for heavy metal bioaccumulation and are hence recommended for planting in affected region.

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