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Research Article

Study of kabul river canal sediments for heavy metals status and its accumulation in wheat plant (*triticum aestivum*)

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Abstract

Canal cleaning is a routine activity on the canals diverted from the Kabul River. As a result, thousands of tons of sediment are removed as sludge and flushed back into the Kabul River. In Peshawar city, most people use this sediment as a soil conditioner in lawns. But the farmers are hesitant to apply it in agricultural fields. It is perceived that the sediment may be rich in heavy metal contents and, if used as a soil conditioner, may contaminate the food chain. To unveil the facts, this study was conducted with the aim of analyzing sediment samples for selected heavy metals and their uptake and accumulation in different parts of the wheat plant. For this purpose, the sediment collected from Warsak Gravity Canal (WGC) was analyzed for total essential heavy metals including iron (Fe), copper (Cu), cobalt (Co), manganese (Mn), and Zinc (Zn). Wheat crop was grown in four different pots consisting of pure soil, pure sediment, and two amendments i.e. soil mixed with 25% and 50% sediments. In comparison to sediment, the soil samples were high in copper, cobalt, and Zinc concentration. The concentration of iron and manganese was comparatively high in pure sediment but within permissible limits. The heavy metals uptake by the wheat crop was also within the permissible limits. The highest accumulation of copper, iron, and Zinc was observed in the roots of wheat plants. The highest value of cobalt was observed in the seed (0.407 mg Kg^{-1}), which was within the safe range. Therefore, it is concluded that the sediment of the Kabul River canal cannot be considered a source of pollution in terms of heavy metals and can be used as a soil conditioner.

More Information

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Introduction

The Kabul River canal is the largest irrigation canal in Khyber Pakhtunkhwa province, irrigating two large districts, Peshawar and Charsasda [1]. In 1960, Warsak Dam was constructed with the objectives of producing electricity and providing water for irrigation to the Peshawar Valley. For this purpose, two canals, the left bank canal, and the right bank canal were diverted in 1962. The average monthly discharge of the Kabul River is 20500 cusecs [2]. The total length of the Warsak Gravity Canal is 72.8 Km [3]. This canal passes through Peshawar city. The canal receives a heavy amount of municipal wastewater from thousands of houses that deteriorate water quality [4]. Previous studies revealed that the suspended load of the Kabul River is also increasing. Since 1972, a five-time increase has been observed in suspended loads. Studies conducted in 2004 revealed that the suspended solid range between 255 mg L^{-1} in winter to 655 mg L^{-1} during summer [2,5]. This suspended load settled in the canal and was removed as sludge in the winter season. As the canal receives huge amounts of municipal wastewater, people are hesitant to use this sediment (sludge) as soil manure, creating solid water problems in Peshawar city [6].

The sediments are the end result of soil erosion which not only affects the irrigation system but also causes pollution in rivers. This not only creates economic problems for farmers but also causes great resource loss to the nation [7]. To overcome this, irrigation canals require cleaning after regular intervals of time to remove windblown or water-deposited sediments. The sediment after being removed is usually piled next to the canals for drying or temporary storage [8,9]. In developing countries in general and Pakistan in particular, it is stored for a long time and huge piles are formed. This contributes to dust formation and can cause health problems [10]. Sediment piles remain in place for around 10 years or more and are a continuous source of air pollution [7].

The sediments contain a higher proportion of silt, sand,

and clay and also contain higher concentrations of essential nutrients [11,12]. These essential plant nutrients, i.e. macro and micro nutrients play a very vital role in a plant's growth [13]. Therefore, after proper evaluation, sediments can be used as soil conditioners for agricultural purposes [14,15]. It contains high levels of heavy metals which can contaminate the soil. Crop plants use these toxic heavy metals which can lead to toxicity in the food chain [16].

Heavy metals, on the one side, have importance as micronutrients and, on the other side, have got negative impacts on human health in terms of toxic effects [17]. The majority of heavy metals come to us through plants/crops. Among these important metals are Iron, Zinc, Copper, Molybdenum, and Manganese [18]. If a particular soil appears deficient in these metals, it not only affects plant growth but also makes our diet deficient. For example, for efficient plant growth, the required level of copper is 5 mg Kg^{-1} to 20 mg Kg^{-1} [19,20]. If the level is dropped below 0.2 mg Kg^{-1} is considered as low [21].

Heavy metals, like copper, zinc, and cobalt if found in excess soil, can lead to toxicity in the food chain [22]. For example, a copper concentration of above 20 mg Kg^{-1} can encourage uptake by plants and can create health problems in animal and human health [23]. Usually, copper-based fungicides are blamed as a major source of copper in soil (Arias, et al. 2004). Researchers blame sewage as a major source of copper if used for irrigation [24]. Recent studies revealed that substantial increases in cadmium, copper, and zinc accumulation have been observed in crops irrigated with sewage [25]. Uptake and accumulation of heavy metals are dependent on a variety of parameters including pH, weather conditions, and soil texture. Therefore, the uptake will vary from place to place [26].

Studies conducted in Pakistan revealed that industrial effluents are used for irrigation, which is usually high in various heavy metal contents such as copper, cadmium; zinc and iron, etc [27]. The wastewater is discarded without any treatment and the agricultural belt increases the level of various heavy metals such as copper, zinc, and molybdenum in the soil. For example, Rive Ravi receives a pollution load from industries as well as municipalities that increased the level of copper, manganese, zinc, chromium, nickel & lead in river water. It was observed that the level of these metals was high in sediments in comparison with water [28]. The elevated level may encourage the uptake of various crops like wheat and maize and get introduced into the food chain (Nauman and Khalid 2010).

This study was an attempt to evaluate the sediments collected from the Kabul River canal for various plant heavy metals of health concern. As the sediments receive municipal waste, therefore, it was dried and was analyzed for heavy metals, and applied to the wheat crop. Different parts of the plant were also analyzed with the objective of evaluating its concentration.

Methods and materials

Sampling and sample preparation

In order to analyze the soil/sediment, samples were taken from the banks of the canals at 10-30 cm depth for laboratory analysis. Soil samples were collected from the garden of the botany department at, the University of Peshawar, which was also used for the preparation of different amendments. Soil/sediment samples were air-dried, and then sieved through a 2 mm mesh. The sieved samples were stored in polythene bags for chemical and physical analysis. The Mehlich-3 extracting solution was used for metal extraction [29].

Preparation of pots for wheat crop (Triticum aestivum)

Three replicates of soil, sediments, and two different amendments were used for this experiment. The two soil-sediment amendments were prepared in a ratio of 50:50 and 75:25. 10 wheat seeds of wheat were grown in each pot and were observed till maturity.

The experiment was conducted at the Botany Department of Peshawar University. The study period was from December to June with the average minimum and maximum temperatures of 2.3 °C – 20 °C and 25 °C – 35 °C respectively [30]. The average rainfall during March is 78 mm and 7 mm during June [31].

Plant heavy metals analysis

The wheat crop after harvest was placed on paper and dried at 60 °C - 65 °C. The plant was divided into different parts i.e. seed, leaves, stem, and roots. After drying, each part was grounded and passed through a sieve of 20 meshes of 20 mesh size [32]. The tri-acid mixture of nitric acid, sulfuric acid, and hydro perchloric acid (HNO_3: H_2SO_4: $HClO_4$) was added together in the ratio of 5:1:1 for preparing the extracting solution (Aqua-regia). Then the plant samples of 1 g were digested with 15 ml of aqua-regia on a digestion block. After cooling down, the suspension was filtered. The filtrate was diluted to 50 ml with distilled water. Concentrations of selected heavy metals in the digested samples were determined by using the Atomic Absorption Spectrophotometer.

Results and discussion

Copper: Was found in both sediment and soil samples with an average concentration of 0.011 mg Kg^{-1} (in pure sediment) to 0.206 mg Kg^{-1} (in pure soil). The average value of copper was comparatively high in pure soil (Table 1). A literature survey revealed that soil with a concentration of 0.01 mg Kg^{-1} is considered as low, 0.11 to 2 as medium, while above 2 mg Kg^{-1} is high [21]. The concentration of copper in both sediment and soil can be termed a medium. Therefore, the copper deficiency was not expected. The permissible limit (upper level) of copper in the soil is 20 mg Kg^{-1} [33], therefore no toxicity in the food was expected.

Table 1: Descriptive statistic of different heavy metals in soil, sediments samples, and different amendments (mg Kg^{-1})

Samples Name	Range	Copper	Cobalt	Iron	Zinc	Manganese
100% soil	Min	0.091	0.418	61.639	0.968	0.968
	Max	0.316	0.853	65.847	1.926	1.926
	Average	0.206	0.598	63.734	1.518	1.418
25:75	Min	0.074	0.416	56.262	0.762	0.728
	Max	0.294	0.812	62.637	1.866	1.866
	Average	0.184	0.532	59.450	1.314	1.501
50:50	Min	0.056	0.314	58.063	0.663	0.685
	Max	0.185	0.624	63.612	1.745	1.872
	Average	0.118	0.428	60.681	1.204	1.506
100% sediments	Min	0.036	0.216	61.726	0.896	0.896
	Max	0.176	0.523	65.945	1.846	1.876
	Average	0.116	0.309	63.368	1.496	1.513

The pot experiment shows that copper was found in different parts of potatoes with different concentrations. The average copper concentration in stems, leaves, seeds, and roots were 0.058, 0.054, 0.32, and 0.286 mg Kg^{-1} respectively (Table 2). The maximum accumulation of copper was found in roots (0.302 mg Kg^{-1}), followed by seeds (0.245 mg Kg^{-1}). The lowest accumulation was observed in leaves. The value of copper was found within the recommended range of 5.24 mg Kg^{-1} - 10.52 mg Kg^{-1} in all the samples [34].

Table 2: Average Concentration of Copper in Different Parts of Plants (mg Kg^{-1}).

Samples Name	Stem	Leaves	Seed	Root
100% soil	0.147	0.153	0.245	0.302
25:75	0.110	0.090	0.215	0.238
50:50:00	0.122	0.116	0.260	0.241
100% sediments	0.133	0.084	0.322	0.336
Min	0.040	0.044	0.294	0.238
Max	0.105	0.067	0.337	0.363
A co-relation with Soil Contents (R^2)	0.0559	0.2814	0.4734	0.6256

The correlation (R2) of copper in relation to accumulation in different parts of the wheat plant was comparatively high for root (0.6256) followed by seed (0.4734). Therefore, comparatively, a strong correlation was found between soil concentrations and roots. As the wheat seed is used as food, the correlations in seed, leaves, and stem are not significant (Table 2).

Table 3: Concentration of Cobalt in different parts of plants.

Samples Name	Stem	Leaves	Seed	Root
100% soil	0.375	0.381	0.426	0.388
25:75	0.345	0.360	0.395	0.372
50:50:00	0.286	0.388	0.398	0.347
100% sediments	0.363	0.372	0.410	0.388
Min	0.286	0.360	0.395	0.347
Max	0.375	0.388	0.426	0.388
R^2	0.0512	0.0183	0.0884	0.005

Cobalt: Cobalt is an essential plant micronutrient and plays an integral role in the life process of microorganisms and is also important for plants [35,36]. Cobalt concentration was comparatively high in sediment. The average cobalt concentration ranged from 0.309 mg Kg^{-1} in pure sediment to 0.598 mg Kg^{-1} in pure soil (Table 1). The concentration of cobalt in soil was quite low when compared with the permissible limit of 50 mg Kg^{-1} [37].

The results of different parts of the wheat plant show that the average value of cobalt was comparatively high in seed for all amendments. For 100% soil, 25:75 and 100% sediment amendments, the concentration of cobalt was in the sequence, seed >root> leaf >stem, while for 50:50 amendments the sequence was seed>leaf>root>stem (Table 3). Different studies revealed that the lower desirable range of Cobalt in the wheat seed is 0.1–10 mg Kg^{-1} [36]. In this regard, the co-concentration is below the upper limit of 10 mg Kg^{-1}.

In the case of cobalt, the R-square values were low for all amendments, with a range from 0.005 (root) to 0.0884 (seed). On the basis of such a low correlation, the food chain cannot be interpreted as cobalt-related toxicity.

Iron: Iron is a very vital component of human and animal hemoglobin. As compared to other trace elements, iron was found comparatively high, in both soil and sediment samples (Table 1). The average concentration of iron in soil/sediment samples was in the range of 59.45 (25:75 amendment) to 63.737 mg Kg^{-1} (pure soil). A literature survey revealed that soil with a concentration below 2.5 mg Kg^{-1} is considered as low, 2.6 to 4.5 is medium and above 4.6 is high [38]. The highest value of iron was found in 100% soil while the lowest was observed in the 25:75 sediment sample (Table 1).

In the wheat crop, the concentration of iron in seed was in a range of 2.051(50:50 amendment) to 2.863 mg Kg^{-1} (pure sediment). The upper dietary limit of iron is 200 mg Kg^{-1} (Trumbo, et al. 2001). Wheat in this range can contribute to dietary requirements. A high concentration was observed in the root of 32.59 mg Kg^{-1} for 100% sediment. For pure soil, the value was comparatively low with 12.602 mg Kg^{-1}, while stem was the lowest with a range of 1.33 mg Kg^{-1} (55:50 amendments) to 4.059 mg Kg^{-1} for 100% sediment. The overall results of iron accumulation revealed that sediments have a positive impact on iron uptake (Table 4).

The R-square relationship of iron was found in the range of 0.0450 in leaves to 0.8031 in stems (Table 4). In this way, the stem had a comparatively high correlation with soil iron

Table 4: Concentration of Iron in different parts of plants mg Kg^{-1}.

Samples Name	Stem	Leaves	Seed	Root
100% soil	4.000	6.000	2.172	12.602
25:75	2.029	4.602	2.164	27.400
50:50:00	1.333	5.291	2.051	22.600
100% sediments	4.059	1.815	2.863	32.590
Min	1.333	1.815	2.051	12.602
Max	4.059	6.000	2.863	32.590
R^2	0.8031	0.0450	0.2832	0.0801

concentration and was within safe limits. Therefore, the application of canal sediment will not create problems in the case of the wheat crop.

Zinc: Zinc is one of the essential micronutrients. A level of 20 or above is required for proper crop production [39]. Another study revealed that a zinc level of 25 mg Kg^{-1} - 200 mg Kg^{-1} is adequate for normal plant growth [40]. In comparison with these two studies, the concentration of zinc in soil/ sediment samples was found very low. The average zinc contents ranged from 1.204 mg Kg^{-1} in 100% sediment to 1.5 mg Kg^{-1} in pure soil (Table 1).

The overall Zinc accumulation was found in the roots of the wheat plant. The dietary limit of zinc is allowable within 100 mg Kg^{-1} (Jones 1987), while the Zn concentration in seed was at a range of 0.262 mg Kg^{-1} (25:75 amendment) to 0.360 mg Kg^{-1} (100% sediment). This shows that zinc concentration was found below the permissible limit and was very low (Table 5). The R-square value was higher for the stem (0.744) followed by the root and seed with R-square of 0.586 and 0.480 respectively (Table 5).

Manganese: Table 1 summarizes the average concentration of manganese in the soil/ sediment samples under investigation. The concentration of zinc ranged from 1.418 mg Kg^{-1} (pure soil) to 1.513 mg Kg^{-1} (pure sediment). The average concentration of manganese was comparatively low in pure soil (Table 1).

Manganese is an essential plant nutrient. For better plant growth, the normal manganese range is 50 – 200 mg Kg^{-1} on a dry weight basis. However, in the majority of cases, it is found in a range of 200 mg Kg^{-1} – 300 mg Kg^{-1}. The minimum level is 1 mg Kg^{-1}, below which plants are affected negatively [41]. Results revealed that the manganese level was just above the minimum required level of 1 mg Kg^{-1} (Table 1).

Plant analysis revealed that uptake and accumulation of manganese were low in different parts of the wheat plant. The minimum and maximum concentrations of Manganese in stem leaves seed and roots are 1.533-1.617, 1.523-1.601, 1.480-1.592 and 0.695-1.519 mg Kg^{-1} respectively (Table 6).

As the result shows that the manganese level was found low in all the samples. Therefore, we cannot blame the canal sediment for deficiency or excess of manganese.

Table 5: Concentration of Zinc in different parts of plants mg Kg^{-1}.

Samples Name	Stem	Leaves	Seed	Root
100% soil	0.18	0.2	0.291	0.357
25:75	0.134	0.22	0.262	0.307
50:50:00	0.221	0.246	0.28	0.286
100% sediments	0.223	0.16	0.36	0.442
Min	0.134	0.16	0.262	0.286
Max	0.223	0.246	0.360	0.442
R^2	0.744	0.014	0.48	0.586

Table 6: Concentration of Manganese in different parts of plants.

Samples Name	Stem	Leaves	Seed	Root
100% soil	1.617	1.601	1.592	0.695
25:75	1.56	1.578	1.48	1.28
50:50:00	1.533	1.531	1.551	1.375
100% sediments	1.534	1.523	1.51	1.519
Min	1.533	1.523	1.48	0.695
Max	1.617	1.601	1.592	1.519
R^2	0.1561	0.0756	0.0291	0.1065

Conclusion

Kabul River canal sediment is a good source of plant micronutrients. The concentrations of different heavy metals in sediments were found in the safe range. Besides, the concentrations of selected heavy metals in different parts of the wheat plant were also within safe limits. Therefore, instead of throwing away the sediment, it is better to use it as a soil conditioner. Canal cleaning and sediment production is a common practices throughout the world. There is a need to evaluate such sediment for potential alternate uses.

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