original article

Effect of industrial wastewater effluent containing heavy metals and phosphate on the bed soil of the zayandehrood river

Marzieh Vahid Dastjerdi, Mohammad Reza Shahmansouri, Saeed Shanbehzadeh[1], Asadolah Zahab Sanee[2]

Environment Research Center, Isfahan University of Medical Sciences (IUMS), and Department of Environmental Health Engineering, School of Health, IUMS, Isfahan, Iran, [1]Health Center of Massjed Soleyman, Massjed Soleyman, Iran, [2]Isfahan Water Organization, Isfahan, Iran

Address for correspondence:
Eng. Marzieh Vahid Dastjerdi,
Environment Research Center, Isfahan University of Medical Sciences, Hezar-Jerib Avenue, Isfahan, Iran.
E-mail: vahid@hlth.mui.ac.ir

ABSTRACT

Aims: This research was conducted to determine the concentration of Zn, Cu, Pb, Ni, Cr and orthophosphates in the soil of the river bed from Zayandehrood dam to Gavkhoni wetland.

Materials and Methods: This cross-sectional study was conducted in the Zayandehrood river of Isfahan, central area of Iran**.** Seventeen points were sampled through the upstream, Zayandehrood Dam, and downstream, Gavkhooni Wetland, of the river. The samples were selected from soil of the river bed at certain locations during 6 months. Heavy metals and orthophosphates analysis was done by Atomic Absorption and Spectrophotometry methods, respectively.

Results: The results indicated that concentration of heavy metals and orthophosphates increased from upstream to Choom bridge in downstream of the river and then decreased from this point to Govkhooni wetland. In the first sampling point, the concentration of Zn, Cu, Pb, Ni, Cr and orthophosphates were 29, 9, 51, 83, 49, and 570 mg/kg (dried weight). For Choom bridge it were 1413, 406, 289, 123, 86, and 104 mg/kg and in the wetland were 820, 24, 49, 68, 87, and 88 mg/kg (dried weight), respectively.

Conclusion: The metal concentration from the first point to Choom bridge has been increased and then has been decreased in the wetland. The maximum amount of Zn, Ni, Cu, and Pb in the river bed was higher than and closer to maximum allowed concentration of heavy metals in soil (mg/kg dried weight) and for Cr was within normal limits. Industrial plants located on the banks of the river, widening of the river in downstream and entering the drainages to the river are among effective factors in these changes.

Key words: Atomic absorption, digestion, heavy metals, orthophosphate

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INTRODUCTION

Great interest in the issue of possible structures of heavy metals, accumulation (caused by discharge of industrial effluent), and their effects on soil has caused many studies to be conducted on the fate of these materials in soil. In this regard, the highest attention is given to zinc, copper,

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nickel, cadmium, and lead, which are usually found in different wastewaters. Discharge of domestic and industrial wastewater, entrance of natural runoff to surface water resources and passage of rivers through fields, and pastures increase pollutants like heavy metals and phosphate compounds in these resources; these compounds enter river bed sediments via the sequestration of materials inside water and are accumulated in the bed soil over time.[1]

Studies have shown that these elements are combined with different components of soil and are not easily washed away. Only in highly acidic soils, their considerable movement can be observed since they become soluble and are weakly absorbed by soil in acidic conditions. Researchers have categorized the reaction of heavy metals to soil to the following groups.[2] A low ratio of these elements is absorbable for plants. A group of these elements are combined with organic matters and are not absorbable for plants; however, they are released and available for plants over time. They are in combination with carbonates and, as a result of the comparison between the two previous states. A low ratio of them is available for plants and they exist in soil as sulfide and insoluble compounds.

The increase in the concentration of heavy metals in soil of riverbed and their entrance to soil, plant, animal, and human cycle leads to their negative effects on humans, animals, and environment.[3] Moreover, increased concentration of phosphorous in soil and water of rivers accelerates the growth of algae and their excessive growth has considerable effects on the quality of water like odor and taste and reduced dissolved oxygen and critical conditions.[4]

Since the river is a vital artery for Isfahan and its neighboring provinces and due to the presence of large and small industrial units and wastewater treatment plants around it and passage of rivers from the vicinity of agricultural lands, the possibility of pollution in this river has increased. Therefore, investigating the presence and determining the amount of considered elements and their comparison with the standard amounts can be effective in managing the quality control of river water.

MATERIALS AND METHODS

This cross-sectional study was conducted in Isfahan, Iran. The characteristics of sampling station are shown in Table 1.

These points were mainly in the vicinity of special places such as point of effluent discharge, intake of treatment plants, or recreation sites and upstream and downstream points of the river. In the sampling time, the river bed was dry. Each sample was dried at 103°C, then 1 g of the sample was weighed and digested by sulfuric acid and hydrogen peroxide.[5] The obtained digestion was diluted to a certain volume after being passed through a filter. The concentration of the metals was measured using Atomic Absorption Instruments (PerkinElmer). Orthphosphate analysis was done using Spectrphotometers based on Standard Methods.[6,7]

RESULTS

The results obtained from analyzing the samples of bed soil of the river are given in the Table 1. These results show the influence of industrial wastewater discharge and drainages of agricultural farms in the margins of the river. In Choom Bridge, the maximum concentrations of Zn, Cu, Pb, Ni were higher and closer to the maximum allowed concentration of heavy metals in soil and for chromium was within normal limits (mg/kg) [Table 2].

DISCUSSION

Copper and zinc

The investigation showed that the concentration of zinc and copper had an ascending trend from upstream points to Choom Bridge and their amount decreased thereafter. The

Table 1: Concentration of heavy metals and orthophosphate in the bed soil samples of Zayandehrood (mg/kg)

Sampling location	P	PO_4^{-3}	Cu	Zn	Pb	Cr	Ni
Behind Zayandehrood dam	190	570	9	29	51	49	83
Regulation dam	193	580	22	59	52	56	104
Chamaseman before Yazd Basin	180	540	32	69	101	76	108
Location of Zarrin Shahr wastewater flow	250	750	32	57	51	58	106
Bodagh abad bridge	233	700	20	50	97	52	77
The area of Felman Wells	240	720	44	106	99	90	114
Washing location of dyers	250	750	178	186	70	94	115
Vahid bridge	286	860	44	93	71	92	132
Ferdowsi bridge	283	850	35	80	200	74	118
Bozorgmehr bridge	270	810	38	90	72	90	138
Abshar dam	290	870	54	98	120	114	145
Qadir bridge	293	880	86	139	129	79.4	107
Choom bridge	471	1413	406	289	123	86	104
Zeyar	363	1089	53	193	182	91	117
Ejieh	320	960	17	43	146	89	111
Varzaneh	266	800	21	48	58	98	86
Gavkhooni wetland	273	820	24	49	68	87	88

presence of different industrial factories around the river and discharge of their effluent to the river along with the discharge of effluent from the wastewater treatment plant to the river are effective in this regard. Decreasing in the amount of these metals after Choom bridge was because of the presence of agricultural drainage and widening of the river [Figures 1 and 2]. In the effluent discharge location of dyers, a considerable increase in the amounts of Zn and Cu can be observed, which were 186 and 178 mg/kg, respectively; this increase included the discharge effect of the related effluent. Lee *et al.* in study of heavy metals in the bed and suspended sediments of Anyang river, Korea, found that difference in the enrichment seems to reflect the human activities influence in the basin.[9] The concentrations of copper and zinc were higher and lower than their allowed concentrations in soil, respectively.[9] Their concentration increased around dying workshops and decreased again near Vahid bridge. The concentration change of these elements might be due to their settling and formation of insoluble metal salts in bed soil that are rapidly settled and a small amount of them is transferred to lower parts by water flow[9] [Figures 1 and 2]. In the Choom bridge, the maximum amount of zinc and copper was 289 and 406 mg/kg in the bed soil of the river, respectively; while compared with standard levels, the concentrations of copper and zinc were higher and closer to the upper standard limits, respectively [Table 2].[9,10] Norville showed that high concentrations of Pb, Zn, Cu, and Cr in sediments from Paria, river Trinidad were (3.53–73.30 μg/g), (45.8–313.9 μg/g), (8.43–39.71 μg/g), (0.03–0.10 μg/g), (17.22–28.41 μg/g) respectively. Singh *et al.* in 2003 showed that concentrations of Cr, Cu, Pb, Ni, and Zn in bed sediments of river Gomti were (6.105–20.595 μg/g), (21.25–92.15 μg/g), (13.905–37.370 μg/g) and (1 5.72–99.35 μg/g) of dry weight, respectively.[11] The existence of these amounts can be justified by the effluent discharge from wastewater treatment plants in south of Isfahan [Figures 1 and 2]. In Gavkhooni wetland, the average concentration of zinc and copper was lower than the average amount available along the way and the permitted level [Table 2]. Average concentration of Zn and Cu in other points are more than the average concentration of Zn and Cu in the wetland.

Nickel, chromium, and lead

In general, concentration of nickel, chromium, and lead had an ascending trend from upstream to downstream of the river that can be justified by the effluent discharge of the industries located around the river. The maximum obtained concentration for nickel and chromium in Abshar dam was 144.9 and 114.1 mg/ kg, respectively, and lead concentration was 20 mg/kg in Ferdowsi bridge; in all three points, the concentration of the mentioned elements was higher than their permitted level in soil. Also, the concentration of lead and nickel and that of chromium decreased relatively from Zeyar bridge and Varzaneh that can be justified by the widened river and entrance of drainage to its downstream[Figures 3-5].

Table 2: Compare the heavy metals concentrations in the Choom bridge with the maximum allowed concentration of heavy metals in soil (mg/kg)[8]

Element	Allowed level	Concentration in choom bridge
Cadmium	3	–
Chromium	100	86
Copper	100	406
Nickel	50	104
Lead	100	123
Zinc	300	289

Ortho phosphate

Studies showed that the concentration of orthophosphate in

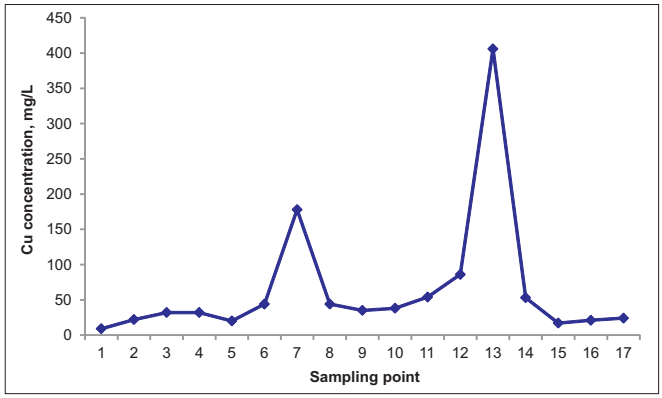

Figure 1: Cu concentration in bed soil

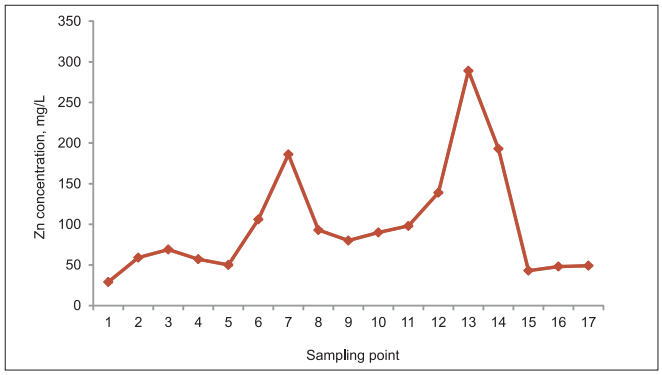

Figure 2: Zn concentration in bed soil

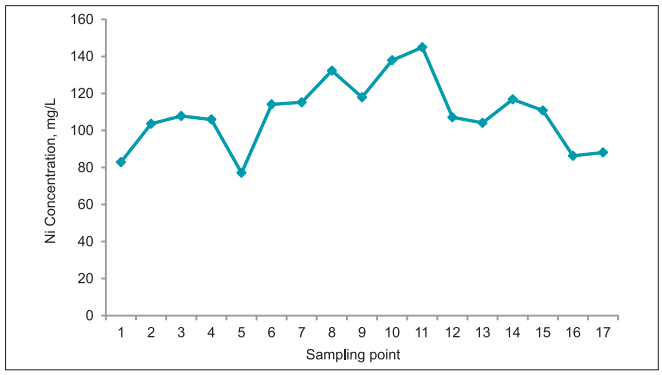

Figure 3: Ni concentration in bed soil

the river bed gradually increased from upstream the river to the Zeyar area and decreased from this point to Gavkhooni wetland[Figure 6]. In this regard, using phosphate fertilizers for agriculture and also the flow of wastewater effluent along the way to the river can affect the increase in the amount of orthophosphate. Moreover, widened river and its dilution with the water of drainages in the downstream area can decrease the concentration of orthophosphate in this area [Figure 3]. From the point behind Zayandehrood dam to Chamaseman dam and before Yazd Basin (river upstream), the average amount of orthophosphate in river bed was almost constant and equal to 540 mg/kg. No kind of flow to the river happened in this area and the amount of measured orthophosphate showed its natural level [Figures 1 and 3]. In the Zarrinshahr

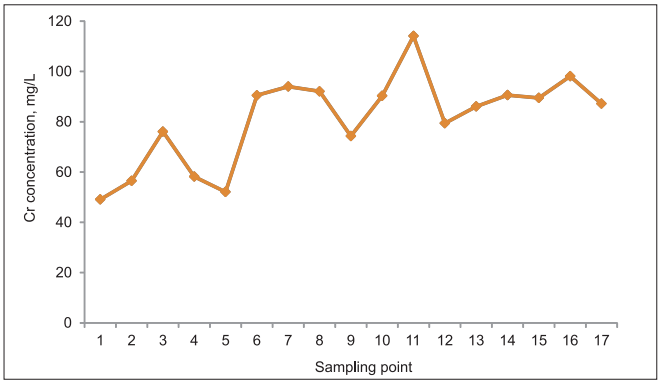

Figure 4: Cr concentration in bed soil

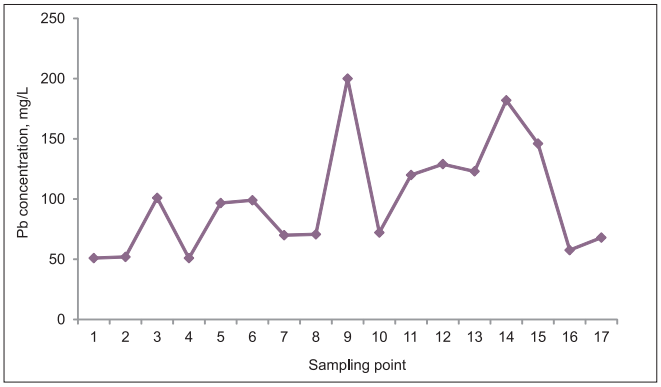

Figure 5: Pb concentration in bed soil

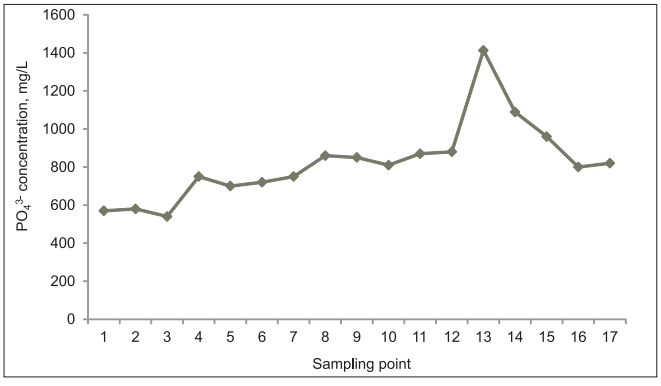

Figure 6: PO_4^{-3} concentration in Zayandehrood bed soil

wastewater discharge place, the amount of orthophosphate began to increase, reached 860 mg/kg at the entrance of city of Isfahan (Vahid bridge) and reached its maximum level of 1413 mg/kg in Choom bridge (city exit). This issue was due to the discharge of Zarrinshahr wastewater effluent, effluent containing phosphate, workshops around the river, effluent discharge of dyers washing before Vahid bridge, and that of Isfahan wastewater treatment plant to the river which generally included detergents with an amount of phosphorous compounds [Figures 1 and 3]. From the Choom bridge to Gavkhooni wetland, the amount of orthophosphate gradually decreased and reached 800 mg/kg, which can be attributed to the widened river and entrance of drainages to it. This amount was higher than that in upstream and lower than its maximum level [Figures 1 and 3]. The minimum inorganic phosphorous required for the growth of algae is 5 μg/L.[12] Considering the concentration of phosphorous in bed soil, it can be concluded that the presence of a considerable amount of phosphorous in this river bed can affect the concentration of this element in its water, the growth of algae and the creation of critical and nutritious conditions [Table 1].

Considering the obtained results and the importance of the river as a resource for supplying the required water for drinking, agriculture, industry, and recreation and also due to similar results that were obtained from the investigation on the concentration of heavy metals in water and solid sedimentation in this river, it is recommended to the provincial management of water resources to plan and take appropriate measures in order to control pollutants of the river.

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