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Research and evaluate contents of heavy metal in river sediment in the To Lich River, Hanoi City

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Abstract:

Deposited sediments contain toxic heavy metals that can pollute surface water as well as aquatic ecosystems. In this study, the accumulation of heavy metals in surface sediment collected from To Lich River, Hanoi city was assessed based on the geoaccumulation index (Igeo), and the potential ecological risk was also assessed based on the ecological risk index (RI). Heavy metals concentrations were determined by Atomic Absorption Spectrophotometer. Results of the research, All heavy metals were detected in sediment samples with mean concentrations of Cr, Mn, Fe, Cu, Zn, As, Cd and Pb were range of 18.73-188.00; 99.00 - 437.00; 3,352.00-27,378.00; 16.56-292.60; 87.00-1693.00; 3.96-72.76; 0.18-5.90; and 9.87-176.80 mg/kg dry weight, respectively. Calculation of different ecological contamination factors showed that As is the primary contribution to ecological risk index (RI) origins from anthropogenic, and urbanization sources. Special attention should be paid to this problem in order to continue further research and to consider possible ways of remediation of the sites where contamination has been observed.

Key Words: *Heavy metal, sediment, potential ecological risk, To Lich River*

1. Introduction

Heavy metal is a relatively dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. The elevation of metal levels often results in a high concentration in the bottom sediment (Cundy A. 2003). These metals may accumulate to very high toxic levels and cause an acute impact on the aquatic organisms without any visible sign (Giguère et al. 2004). The presence of heavy metals is the indication of pollution in any aquatic environment, and the toxicity of these metals stems are biologically non-degradable and have the tendency to accumulate in water and sediment (Gale et al. 2004). The investigation of heavy metals in water and sediment might be used to assess the anthropogenic and industrial impacts and risks posed by waste discharges on the riverine ecosystems (Zheng et al. 2008).

Rivers, especially those flowing through urban areas, play a key role in preserving freshwater, adjusting the local climate, and improving the environmental conditions. However, with accelerated population growth, urbanization, and industrialization, heavy metal pollution of rivers has become a serious issue. To Lich River is a river in urban Hanoi. It’s estimated length is 13.5 km. To Lich River begins in West Lake, Cau Giay district (south of the Hoang Quoc Viet road), running the same direction as the Buoi, Lang, and Kim Giang road to the south, southwest, and then turns to the southeast and flows to Nhue River. Currently, the water quality of the To Lich River is seriously de-

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grading. Owing to lack of or improper wastewater treatment facilities, domestic and services wastewater are often discharged into the To Lich River, resulting in pollution. The poor quality of wastewater effluents is responsible for the degradation of the receiving sources and the aquatic ecosystem. Besides, releases of untreated toxic effluents are the major sources of heavy metals in any aquatic ecosystem (Tran Duc Ha. 2018). Unfortunately, no research is still conducted to assess the metal pollution of the To Lich River, including its biotic resources, sediment, and water quality. Therefore, the study was conducted with an objective to assess the abundance of some heavy metals, i.e. Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), and Arsenic (As) in water and sediment of the To Lich River to estimate the status metal pollution.

2. Materials and methods

2.1. Study area

The study areas represent a part of the To Lich River of Hanoi (Figure 1). The samples were collected from six stations of To Lich River namely TL1 (21.039722, 105.806389), TL2 (21.030556, 105.801389), TL3 (21.015278, 105.804722), TL4 (21.001944, 105.817778), TL5 (20.980000, 105.819167), and TL6 (20.970278, 105.824722). The distance among the sampling points was approximately 1 km.

2.2. Sediment digestion for metal analysis

Around 2 grams of the sample was taken in a 100 ml beaker and placed on a hot plate. 15 ml concentrated HNO_3 was added, and the samples were heated at 120ºC for 1 hour. 5 ml of HCl was added and heated at 120ºC for 1 hour. Then 5 ml of $HClO_4$ was added and heated until 1-2 ml remains. For mercury and arsenic analysis, 1 ml of H_2O_2 added and heated for 30 minutes and made volume with DI (Deionized water) in a 100 ml volumetric flask. Further dilution was made as required. Finally, the samples were examined with AAS for metal estimation.

2.3. Pollution Assessment Methods

Geo-Accumulation Index (Igeo) and ecological risk index (RI) were utilized in the present research to evaluate the levels of contamination of heavy metals found in the analyzed sediment samples.

Igeo of each heavy metal was measured through the following equation (Lu, X.W. et al. 2009):

$$I_{geo} = log_2 \frac{C_i}{1.5B_i} \qquad (1)$$

Where Ci is the calculated heavy metal's I concentration in the sample; Bi is the heavy metals' i geochemical background value. For this present study, Bi is the background value of local soil (Wang, X. et al. 2007). The constant 1.5 is brought in to bring down the consequence of likely deviation in the background values. The Igeo for every heavy metal was computed and categorized as: "uncontaminated" (Igeo $\leq$ 0); "uncontaminated to moderately contaminated" (0 < Igeo $\leq$ 1); "moderately contaminated" (1 < Igeo $\leq$ 2); "moderately to heavily contaminated" (2 < Igeo $\leq$ 3); "heavily contaminated" (3 < Igeo $\leq$ 4); "heavily to extremely contaminated" (4 < Igeo $\leq$ 5); "extremely contaminated" (Igeo $\geq$ 5) (Lu, X.W. et al. 2009).

- The degree of contamination (C_d)

The C_d represents the degree of contamination with respect to heavy metals.

$$C_d = \sum_{i=1}^{n} C_f^i \qquad (2)$$

Where $C_f^i = \frac{C_D^i}{C_R^i}$ is the contamination factor, C_D^i is the measured concentration of the sample, and C_R^i is the reference value according to Class I of the environmental quality standard for surface water;

The classes of C_d are uncontaminated, low, medium, and high for C_d values < 8, $8 \leq C_d < 16$, $16 \leq C_d < 32$, and ≥ 32, respectively.

Figure 1: Locations of sampling sites along the To Lich River, Hanoi, Vietnam

- Potential ecological risk index (RI) (L. Hakanson, 1980)

The potential ecological risk index (RI) was proposed by Hakanson and had been used to evaluate the harm of heavy metals in the sediments. RI is calculated using the following formulas

$$RI = \sum E_r^i \qquad (3)$$

Where E_r^i is the potential ecological risk factor of each heavy metal. The formula E_r^i for the single heavy metal pollution is deduced as follows:

$$E_r^i = C_f^i \cdot T_f^i \qquad (4)$$

Where C_f^i is the value of the concentration of heavy metal divided by the background value. T_f^i is the toxic factor of heavy metal, the values for Zn, Cr, Cu, Pb, and Cd were 1, 2, 5, 5, and 30, respectively (L. Hakanson, 1980). RI is categorized into four classes (L. Hakanson, 1980; Zhu et al., 2013). To describe the RI, the following terminology was used: RI < 110, low risk; 110 ≤ RI < 220, moderate; 220 ≤ RI < 440, considerable; RI ≥ 440, very high.

3. Results and discussion

3.1. Heavy metal concentration in water

Heavy metals concentrations of water in six different stations of To Lich River were measured. Arsenic (As), Zinc (Zn), Iron (Fe), Copper (Cu), Cadmium (Cd), Lead (Pb), Manganese (Mn), and Chromium (Cr) concentration were assessed in this study (Figure 2).

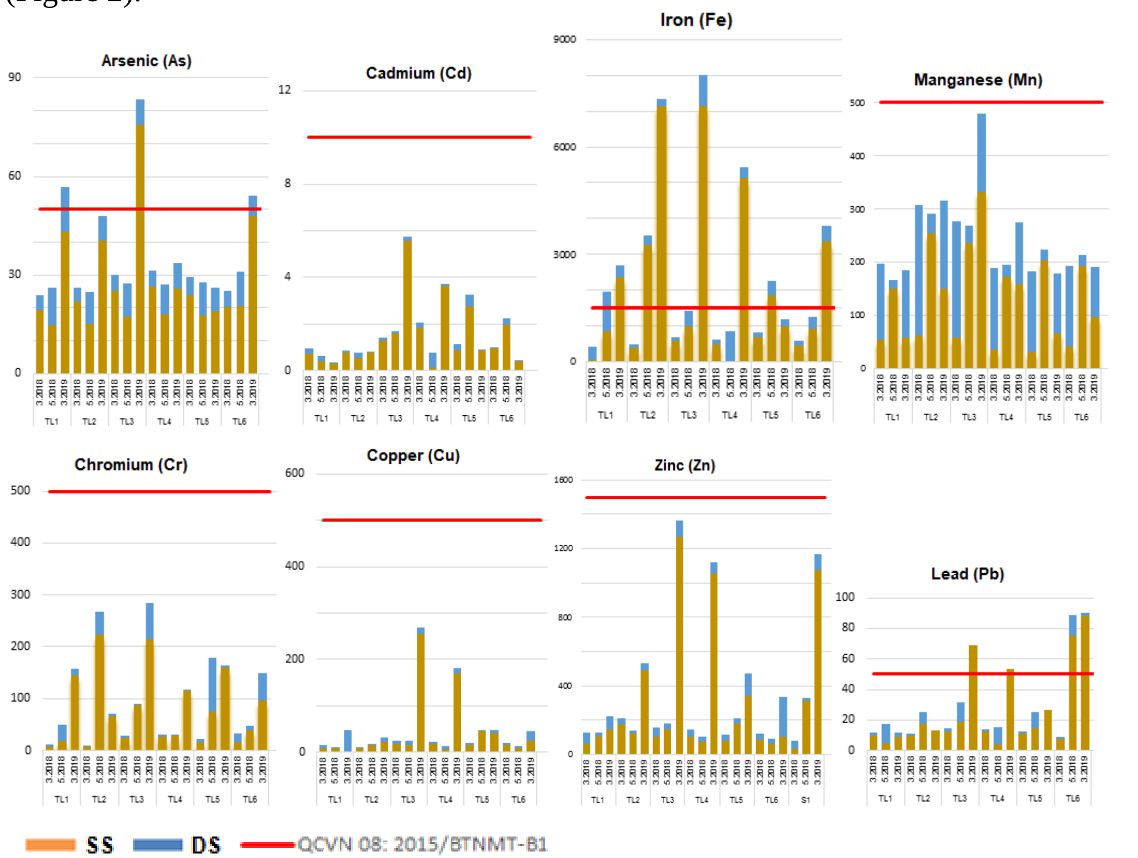

Figure 2. Station wise heavy metal concentration (micrograms per litre) in samples of To Lich river water according to location and sampling time

As shown in Figure 2, the concentrations of heavy metals (Cd, Pb, Cu, Cr, Zn, and Mn) in three sampling periods (March 2018, May 2018, and March 2019) met the standard of Class B1 (QCVN:08-MT/BTNMT) for surface water in Vietnam, while the Fe and As are not included in the environmental quality standard. The mean metal concentration in the water samples increased in the following order: Cd < Pb < Cu < As < Cr < Zn < Mn << Fe. Significant variations in the concentrations of metals were found among sites. However, overall, no clear trend could be observed in the six areas.

3.2. Heavy metal concentration in sediment

The heavy metal concentration in sediment was significantly different among the periods (Figure 3). Among the analyzed results of Iron (Fe) show that there is a pollution phenomenon, the Iron content at some points has been 1.2 to 1.4 times higher than the permitted level. The increase or decrease of Copper (Cu) content in the monitoring sessions did not follow any rules, greater than the limit from 1.2 to 1.5 times. The Cadmium content at one has been 1.7 times higher than the permitted level. Analytical results of Arsenic (As) showed that there was a pollution phenomenon, the content of Arsenic at most monitoring points was higher than the limit for allowed 1.7 to 4.3 times; the content of Zinc (Zn) at most monitoring points was higher than the limit for allowed 1.5 to 5.4 times.

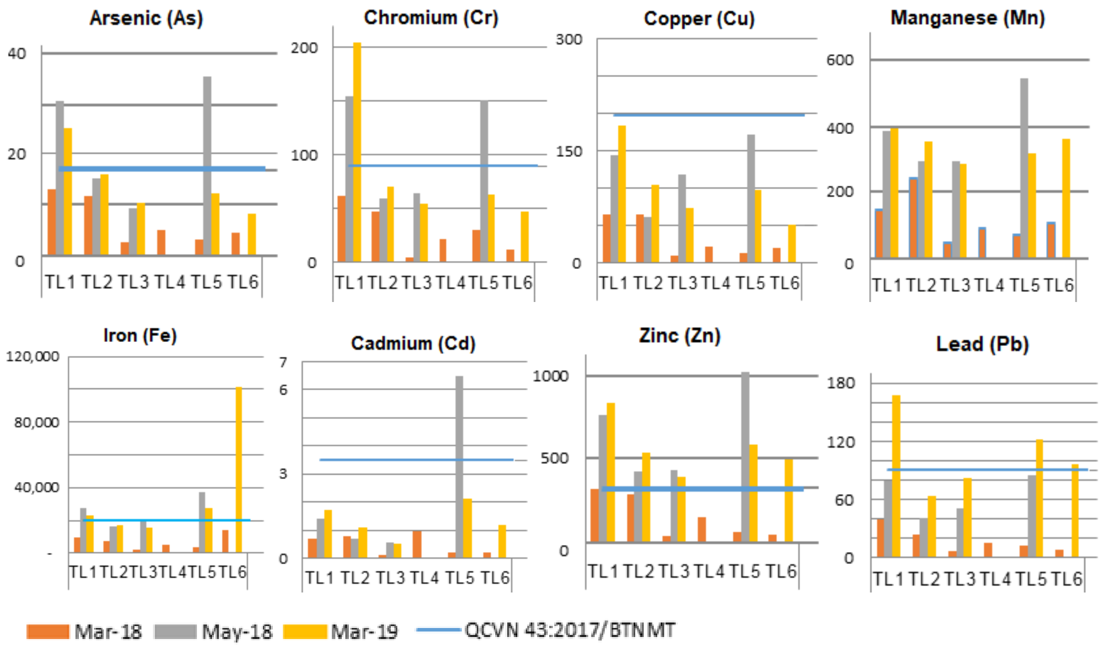

Figure 3. Station wise heavy metal concentration (milligrams per kilogram) in samples of sediment according to location and sampling time

The results of Chromium (Cr) show that there is a pollution phenomenon, the Chromium content at many points through monitoring is greater than the allowed limit 1.7 to 2.1 times; the Lead content (Pb) at many points through monitoring is greater than the allowed limit 1.6 to 1.9 times. Most periods have a cadmium (Cd) density that is lower than the allowed limit (QCVN 43:2017/BTNMT).

The values of the Igeo and the RI are summarized in three tables (Table 1, 2, and 3); Igeo was used to evaluate the pollution level in terms of single metals. Based on our results, the river sediments were largely uncontaminated (Class 0) as the Igeo values of the metals were all below zero. The RI values were below 110, ranging from 14.4 to 53.0, which suggests low ecological risk.

Table 1. Description of Geo-Accumulation Index (Igeo) of selected heavy metals at different sites.

Sampling times	Sampling sites	Geo-Accumulation Index (Igeo)							
		Cr	Mn	Fe	Cu	Zn	As	Cd	Pb
3/2018	TL1	-0.4	-1.0	-0.9	-0.1	0.5	0.7	0.5	-
	TL2	-0.5	-0.8	-1.0	-0.1	0.4	0.6	0.5	-
	TL3	-1.5	-1.6	-1.5	-0.9	-0.4	0.0	-0.3	-
	TL4	-0.8	-1.2	-1.2	-0.5	0.2	0.3	0.6	-
	TL5	-0.7	-1.3	-1.3	-0.8	-0.2	0.1	0.0	-
	TL6	-1.1	-1.2	-0.8	-0.6	-0.4	0.2	-0.1	-
5/2018	TL1	0.0	-0.6	-0.5	0.3	0.9	1.1	0.8	0.6
	TL2	-0.4	-0.7	-0.7	-0.1	0.6	0.7	0.5	0.3
	TL3	-0.4	-0.7	-0.6	0.2	0.6	0.5	0.4	0.4
	TL5	0.0	-0.4	-0.3	0.4	1.0	1.1	1.5	0.7
3/2019	TL1	0.1	-0.6	-0.5	0.4	0.9	1.0	0.9	1.0
	TL2	-0.3	-0.6	-0.7	0.1	0.7	0.8	0.7	0.5
	TL3	-0.4	-0.7	-0.7	0.0	0.6	0.6	0.3	0.6
	TL5	-0.4	-0.7	-0.5	0.1	0.7	0.7	1.0	0.8
	TL6	-0.5	-0.6	0.1	-0.2	0.7	0.5	0.7	0.7

Table 2. Results of contamination factor (C_d) of selected heavy metals at different sites

	Cr	**Cu**	**Zn**	**As**	**Cd**	**Pb**	**C_d**	**Level**
C_f^i	0.36-1.3	0.20-0.8	0.63-3.1	0.64-1.9	0.15-0.6	0.21-1.3	2.19-9.0	Low - Moderate

Table 3. Results of ecological risk factor (RI) of selected heavy metals at different sites

	Cr	**Cu**	**Zn**	**As**	**Cd**	**Pb**	**RI**	**Level**
E_r^i	0.7-2.5	1.0-3.8	0.6-3.1	6.4-18.9	4.6-18.4	1.1-6.3	14.4-53.0	Low Ecological risk

4. Conclusion

The concentrations of the heavy metals Cr, Cu, Zn, As, Cd, and Pb in water samples were below the first-grade levels outlined in the Vietnam Environmental Quality Standards for Surface Water, suggesting low pollution. The sediment in the junction of the river was uncontaminated (Class - Low risk) on the basis of Igeo and RI values. Spatial distribution showed that heavy metal concentration of water and sediment in different areas remained almost constant, strongly suggesting that the inflow of the tributaries increased the risk of heavy metal concentration.

In the present study (March 2018, May 2018, and March 2019) concentrations of Cr, Cu, Zn, As, Cd, and Pb were found lower than the safe values in water and sediment of the To Lich River. But the direct discharges of domestic and services wastewater without treatment as well as rainwater and urban runoff polluted the To Lich River with heavy metals and might create an adverse effect on this riverine and aquatic ecosystem in the coming decades. The values for heavy metals indicate an increasing trend of bioaccumulation may cause many health problems and diseases to humans if the current trend of bioaccumulation continues without taking stern measures against heavy pollution.

However, further research is necessary to make a pathway to reduce the metal pollution level of the To Lich River.

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