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Full Length Research Paper

Analysis to determine Heavy metal concentration in water bodies in Malaysia

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This study was conducted to determine heavy metal lead (Pb), cadmium (Cd), Zinc (Zn) and copper (Cu) concentrations in water body of the Juru River, Penang, Malaysia. A total of 20 sampling stations were chosen and water at 1 m below the surface was sampled using Van Dorn water sampler in December 2009 and April 2010. Collected water samples were kept in ice and acidified to pH 2 using nitrite acid (analytical grade HNO_3). Heavy metal concentrations were determined using inductively couple plasma (ICP model Perkin elmer/elan 9000) following standard method procedures. For comparison purposes, the river was divided into three different zones in the first and second samplings that is, upstream zone, middle reach zone and estuary zone and each zone consists of 7, 7, 6 sampling sites, respectively. Generally, results indicate that Pb and Cd and Cu in the first sampling were higher than the second sampling while the concentrations of Zn in the second sampling were higher than the first sampling. Also the results indicate that the Cd and Pb and Zn in the estuary zone were the lowest as compared to other zones. Meanwhile the highest concentration of Cu was in the middle zone. In conclusion, the lowest concentrations of some heavy metals were in estuary zone, it seems to be naturally due to dilution to heavy metals from sea water. Average metal concentrations from 20 water samples indicate that studied metal concentrations were still lower than Malaysian's National Water Quality Standards (INWQS) guideline.

Key words: Heavy metals, pollution, river, inductively couple plasma.

INTRODUCTION

Aquatic ecosystem is the ultimate recipient of almost all the substances including heavy metals which are molecules of specific gravity >5.0 and non-biodegradable in nature.

Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important problem worldwide (Fernandez and Olalla, 2000). Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Storelli et al., 2005).

Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances (Kabata-Pendias and Pendias, 2001). In aquatic ecosystems, water contamination by heavy metals is one of the main types of pollution that may stress the biotic community (Baldantoni et al., 2004). The rapid economical growth has resulted in increasing production and usage of toxic chemicals such as trace elements in Malaysia (Tetsuro et al., 2005). Following the introduction of heavy metal contaminants into a river, whether via natural or anthropogenic sources, they partition between aqueous (pore water and overlying water) and solid phases (sediment, suspended particulate matter and biota) (Prudencioa et al., 2007; Zhang et al., 2007).

There is an increasing concern about heavy metal contamination in river systems. Rivers play major roles to the community especially in the fishing industry and a source of water supply for people residing within the vicinity of the area. River contamination either directly or indirectly will affect humans as a final consumer. Although some of heavy metals are required as micronutrients, it can be toxic when present higher than the

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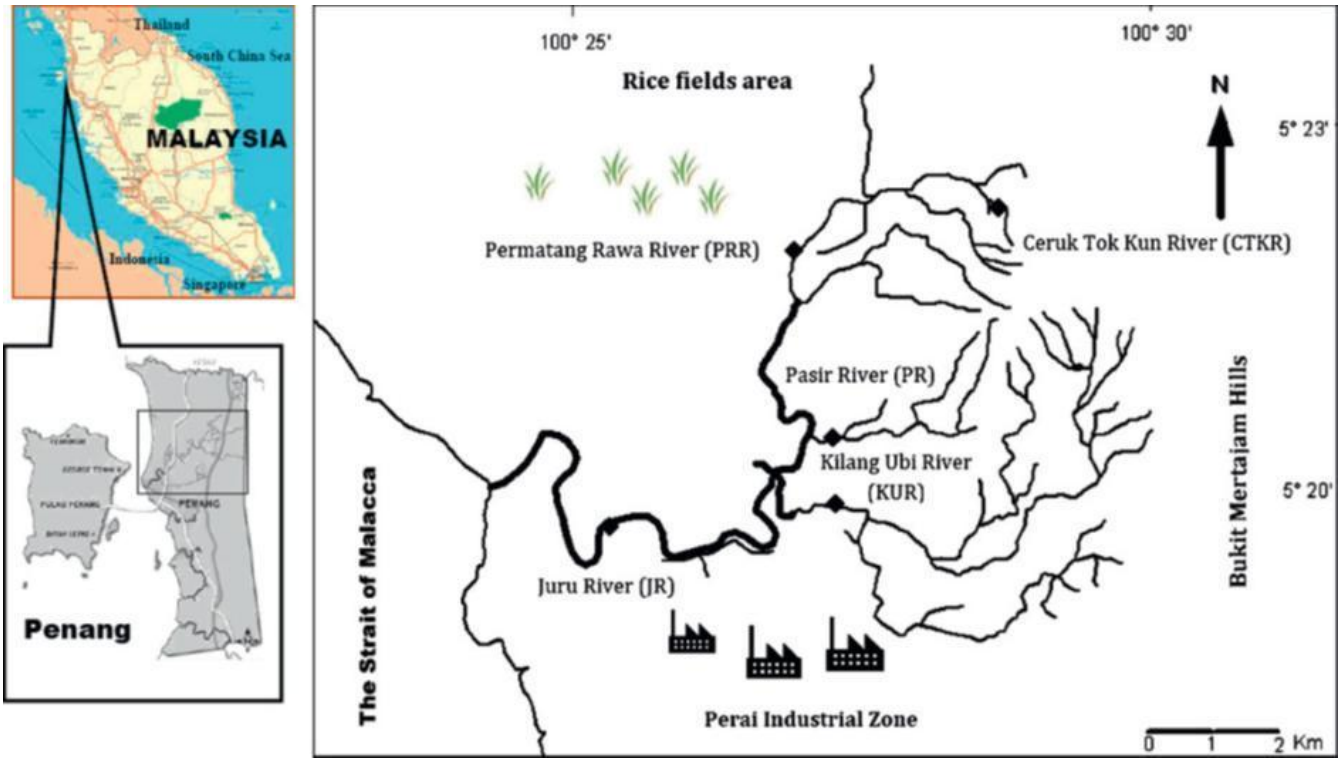

Figure 1. Map of the Juru River system.

minimum requirements. Rivers in Malaysia have sometimes been as dumping sites for heavy metal waste legally or illegally. Heavy metals have been introduced into rivers through land surface runoff, rainfall precipitation and factory waste outlet point discharge. Anthropogenic metals may consistently retain within the water bodies or may be taken up by organisms such as plankton, benthos or fish and finally transferred to humans (Ahmad et al., 2009). As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000), thus causing heavy metal pollution in water bodies. In an aquatic environment, metal toxicity can be influenced by various abiotic environmental factors such as oxygen, hardness (Ghillebaert et al., 1995), pH, alkalinity and temperature (Adhikari et al., 2006).

The results of number of previous studies (Seng et al., 1987; DOE-USM, 1992; Mat et al., 1994; Lim and Kiu, 1995; DOE, 2005) conducted at various periods indicate that the Juru River Basin is grossly polluted by domestic wastes and discharges from pig farms. Other than carrying highly polluting organic materials, these wastes are also contaminated with heavy metals. Recently, Abbas et al. (2007) reported elevated concentrations of heavy metal concentrations in Kuala Juru based on the water samples collected in 2005. Juru River is one of the most productive mudflats for cockle farming in Peninsular Malaysia but the pollution inputs due to urban and industrial activities in the Juru area are of much ecotoxicological concern (Yap and Tan, 2008). It is therefore important that a baseline study is conducted to determine the background of heavy metal concentrations in the area before any records of pollution might be accounted for. This is necessary to understand the source of heavy metal pollution for future environmental planning strategies. Therefore, the objectives of this study were to determine the total concentrations of (Pb, Cd, Zn and Cu) in the surface water collected from 20 sites in the Juru River.

MATERIALS AND METHODS

Study area

Juru River originates from Bukit Mertajan hills located at 05° 22 N latitude and 100° 28 E longitudes, Penang, Northeastern of Malaysia (Figure 1) and drains approximately 7.95 km long. The sampling sites and locations in the Juru River are shown in Table 2. In this study latitude and longitude for all sites were marked using global positioning system (GPS) reading at the site. At sampling station 10 there are numerous plastic industries. Near sampling station 19, there is a fishing port and shipyards.

Sampling

Sampling was undertaken two times along the Juru River which involves 20 sampling stations. The date for each sampling is illustrated in Table 1. Longitudinally, sampling stations in the two

Table 1. The date for each sampling site.

Sampling	Date
First	26, 27/12/2009
Second	24, 25/4/2010

Table 2. List of sampling sites and geographical locations along in the Juru River.

Sampling station	Latitude (N)	Longitude (E)
1	N 05˚19'54.2	E 100˚26´41.8
2	N 05˚19´59.7	E 100˚26´30.6
3	N 05˚19.932´	E 100˚26.371´
4	N 05˚19.862´	E 100˚26.250´
5	N 05˚19´49.7	E 100˚26´05.9
6	N 05˚19´48.2"	E 100˚26´01.2"
7	N 05˚19´47.1	E 100˚25´55.3
8	N 05˚19´52.4"	E 100˚25´52.1"
9	N 05˚20´00.9"	E 100˚25´51.4"
10	N 05˚20´08.2"	E 100˚25´46.1"
11	N 05˚20´08.3"	E 100˚25´36.5"
12	N 05˚20´06.6"	E 100˚25´27.7"
13	N 05˚20´02.1"	E 100˚25´18.9"
14	N 05˚19´49.2"	E 100˚25´19.2"
15	N 05˚19´42.4"	E 100˚25´14.3"
16	N 05˚19´57.0"	E 100˚25´02.1"
17	N 05˚20´35.0"	E 100˚25´07.7"
18	N 05˚20´27.0"	E 100˚24´30.6"
19	N 05˚20´09.1"	E 100˚24´04.9"
20	N 05˚19´49.6"	E 100˚23´45.1"

samplings were divided into three different zones, which cover upstream zone, middle reach zone and estuary zone and each zone consists of 7, 7 and 6 sampling sites, respectively. Prior to the sampling activities, *in situ* water quality measurements were done using multisensory probe YSI meter model 440D. Temperature, conductivity, total dissolved solids, salinity, dissolved oxygen and pH were measured *in situ*. The meter was calibrated in the laboratory prior to the measurements and all *in situ* measurements were done during the high tide period.

River water was sampled at one meter below the surface using Van Dorn water sampler. Collected water samples were transferred into acid soaked teflon bottle (100 ml capacity) and acidified to pH 2 using analytical grade nitrite acid. A triplicates water samples were collected at each sampling point.

All water samples were kept cooled in ice box and transported to the laboratory for analysis. In the laboratory, water samples were thawed to room temperature and were filtered through 0.45 µm pore size filter paper using vacuum pump. Heavy metals (Pb, Cd, Zn and Cu) concentrations in filtrates were determined using ICP model Perkin Elmer/Elan 9000. Reagents and quality assurance high purity chemicals and reagents (purchased from Merck and Aldrich Chemical Company), together with distilled – deionized water were used. Stock solutions (Merck) of 1,000 mg/L of the different metals were used to prepare the calibration standards.

RESULTS AND DISCUSSION

Concentrations of Pb, Cd, Zn and Cu in water from the first sampling sites are given in Table 1. In general, the heavy metal concentrations of water were found to decrease in the sequence: Zn>Cu>Pb>Cd. The highest mean concentration of Pb in the first sampling was measured at site 10 at 2.25 ppb, while the lowest mean concentration of it was measured at site 20 at 0.33 ppb. The highest mean concentration of Cd was measured at sites 2 and 17 ppb, while the lowest mean concentration of Cd was measured at sites 1 and 3 at 0.06 ppb. The highest mean concentration of Zn was measured at site 7 at 71.30 ppb, while the lowest mean concentration of Zn in water was measured at site 1 at 15.38 ppb. The highest mean concentration of Cu was measured at site 12 at 10.81 ppb, while the lowest mean concentration of Cu was measured at site 5 at 1.58 ppb.

Results for heavy metals concentrations in water from the second sampling are presented in Table 2. In general, the heavy metals concentrations in the second sampling were arranged in decreasing order of Zn>Cu>Pb>Cd. The highest mean concentration of Pb was measured at site 10 at 1.98 ppb, while the lowest mean concentration of it was measured at site 19 at 0.37 ppb. The highest mean concentration of Cd was measured at site 14 at 0.27 ppb, while the lowest mean concen-tration of Cd was measured at site 3 at 0.04 ppb. The highest mean concentration of Zn was measured at site 11 at 81.34 ppb, while the lowest mean concentration of Zn was measured at site 19 at 24.49 ppb. The highest mean concentration of Cu was measured at site 13 at 7.17 ppb, while the lowest mean concentration of Cu was measured at site 5 at 1.5 ppb. For comparison purpose, the river is divided into three zones named: upstream zone, middle reach zone and estuary zone in the first and second sampling. The concentration of Pb (0.001 mg/L) was in upstream and middle zones in the first and second samplings. Whereas, the concentration of Pb in the estuary zone was higher in the second sampling compared to the first sampling (0.0006 and 0.0005 mg/L, respectively) (Tables 3 and 4).

However, the results illustrate that no appreciable amount of Cd was found in the upstream zones in the both samplings compared to Malaysian's National Water Quality Standards (INWQS) requirements; it was (0.0002 mg/L) in the first sampling and (0.0001 mg/L) in the second sampling. In the middle zone, was the same Cd concentration was (0.0002 mg/L) in the first sampling while it was 0.0001 mg/L in the second sampling. Generally, in the second sampling the concentration of Zn in the three zone was higher than the concentration in the first sampling, in upstream it was 0.038 and 0.035 mg/L, in the middle zone was the same 0.052 mg/L, in estuary zone was 0.036 and 0.034 mg/L in the second and first samplings, respectively. The result clearly indicates that concen-tration of Cu (0.0004 mg/L) in the estuary zone in the first sampling was higher than the

Table 3. Means and SD for the first sampling of heavy metal concentrations ppb in water from 20 sites in Juru river.

Sites	**Pb**		**Cd**		**Zn**		**Cu**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
`1	0.95	0.26	0.06	0.03	15.38	2.62	3.25	0.44
2	1.19	0.08	0.49	0.10	23.11	0.10	2.71	0.40
3	1.85	0.41	0.06	0.01	54.85	8.08	1.97	0.32
4	1.24	0.14	0.43	0.18	22.93	5.00	3.56	0.68
5	1.09	0.04	0.10	0.01	27.39	3.00	1.58	0.39
6	1.45	0.39	0.16	0.07	31.57	0.42	4.21	1.06
7	1.74	0.39	0.34	0.08	71.30	0.35	2.46	0.07
8	1.43	0.10	0.11	0.04	46.33	8.76	5.77	1.36
9	1.63	0.14	0.19	0.05	58.01	9.27	2.65	0.65
10	2.25	0.66	0.08	0.03	68.12	9.57	3.62	0.75
11	1.59	0.13	0.09	0.04	55.77	2.78	4.76	0.56
12	1.65	0.14	0.37	0.06	59.51	8.72	10.81	0.79
13	1.32	0.03	0.35	0.04	60.02	5.20	8.54	1.32
14	0.83	0.04	0.21	0.08	21.34	3.71	5.60	1.25
15	1.09	0.00	0.16	0.05	53.88	1.92	3.72	0.43
16	0.66	0.15	0.16	0.08	27.94	0.40	3.07	0.59
17	0.54	0.05	0.49	0.20	17.69	9.71	1.97	1.20
18	0.42	0.00	0.12	0.01	33.48	3.00	6.11	0.49
19	0.43	0.01	0.41	0.11	30.61	3.04	8.26	0.26
20	0.33	0.08	0.26	0.06	43.92	11.47	3.41	1.51

Table 4. Means and SD for the second sampling of heavy metal concentrations ppb in water from 20 sites in Juru River.

Sites	Pb		Cd		Zn		Cu	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.19	0.25	0.10	0.03	38.73	5.67	2.62	0.65
2	1.07	0.13	0.23	0.01	42.51	6.48	1.61	0.32
3	1.50	0.39	0.04	0.02	39.82	5.42	1.90	0.89
4	0.82	0.33	0.07	0.01	41.48	5.36	1.89	0.68
5	1.37	0.21	0.25	0.10	40.04	2.02	1.50	0.05
6	1.26	0.18	0.08	0.02	34.20	2.52	2.76	0.37
7	1.79	0.49	0.06	0.02	35.44	1.62	2.81	0.66
8	1.31	0.21	0.21	1.00	46.50	7.64	2.89	0.51
9	1.83	0.61	0.12	0.05	43.81	1.35	2.56	0.62
10	1.98	0.40	0.10	0.05	39.26	4.28	2.42	0.70
11	1.40	0.23	0.11	0.01	81.34	6.49	3.50	0.60
12	1.56	0.23	0.15	0.06	61.16	9.42	6.07	0.69

Table Contd

13	1.21	0.10	0.22	0.08	60.004	10.05	7.17	0.77
14	0.90	0.15	0.27	0.10	32.56	6.94	4.83	1.41
15	1.14	0.20	0.16	0.06	51.64	5.00	2.06	0.42
16	0.73	0.09	0.12	0.04	35.38	7.92	3.28	0.38
17	0.62	0.11	0.17	0.02	27.74	1.76	1.92	0.60
18	0.43	0.10	0.17	0.05	43.37	7.426	5.18	0.64
19	0.37	0.05	0.08	0.03	24.49	1.66	6.32	1.10
20	0.44	0.14	0.21	0.08	38.49	7.07	3.34	0.66

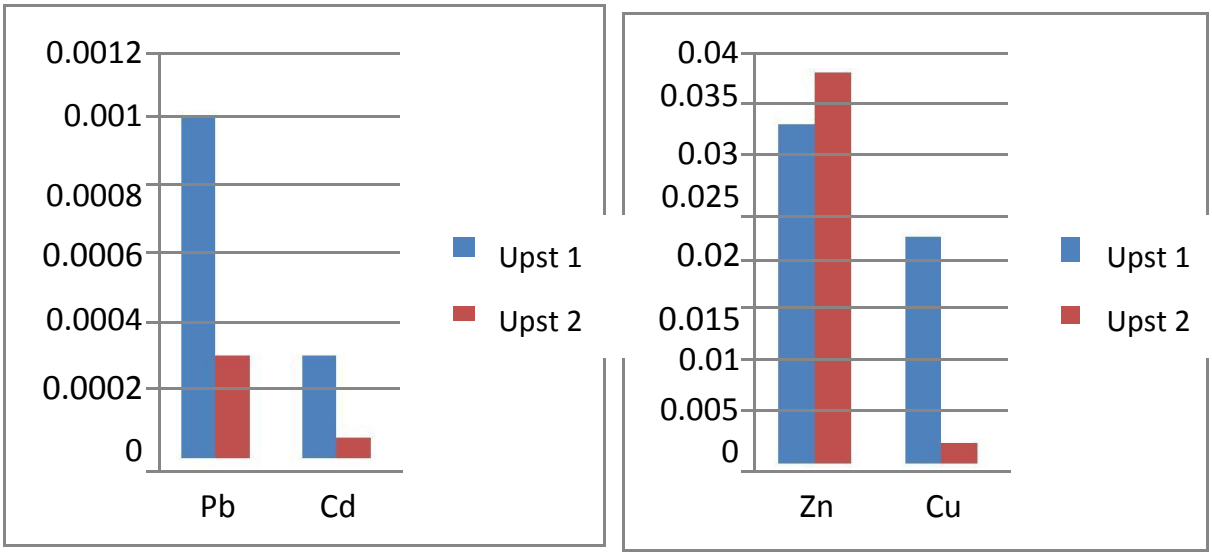

Figure 2. Comparison between the concentration of the metals in the upstream middle zone for first and second sampling (mg/L). Upst 1, Upstream zone in the first sampling. Upst 2, Upstream zone in the second sampling.

the concentration in the second sampling (0.0003 mg/L). the same concentration of Cu (0.002mg/L) was noted in was recorded in the middle zone in the first sampling, while the concentration (0.002 mg/L) resulted in the second sampling. Figures 2, 3 and 4 show the concentration of the studied metals in the three zones for the both samplings. A previous study (Yap and Tan, 2008) was conducted on water and sediments at the three sites (upstream, middle reach and estuary zones of the Juru River). Results show that the concentrations of heavy metals (Cd, Cu, Ni, Fe, Pb and Zn) in the estuary zone were 0.024, 0.005, 0.001, 2.520, 0.0287 and 0.240 mg/L, respectively. In the middle reach zone the concentrations were 0.019, 0.070, 0.001, 35.7, 0.677 and 0.609 mg/L, respectively. Concentrations of the metals in the upstream zone were 0.015, 0.017, 0.001, 0.761, 0.255 and 0.073 mg/L, respectively. In general the concentrations of the heavy metals in the present study were less than the concentrations men-tioned in the study above. Another study (Shuhaimi et al., 2008) with the upstream zone in the both samplings. The concentration of Cu (0.005 mg/L) samples collected in October 2004 mentioned that the concentrations of heavy metals (Fe, Cu, Pb, Cd and Zn) were 1028, 0.871, 2.105, 0.473 and 5.589 µg/L, respectively. A study (Sanayei et al., 2009) conducted in the autumn at the Morgan site showed that the concen-tration of the heavy metals (Cd, Cu, Ni, Pb and Zn) were ND, 0.061, 0.72, 0.41 and 0.05 mg/L, respectively.

A previous study (DOE-USM, 1992) had estimated that Juru River and industrial effluent from a nearby man made canal may be two of the main reasons for the decline in fisheries in the area since the early 1970s (Yahya and Leong, 1987). Sathiamurthy (2008) resulted that the sources of pollutants in Juru River are mainly from domestic sewage and agricultural runoff. According to the INWQS for Malaysia (DOE, 2002), levels of all the studied metals (Pb, Cd, Zn and Cu) in the three zones(upstream, middle reach zone and estuary zones) in the first and second samplings were all categorized in

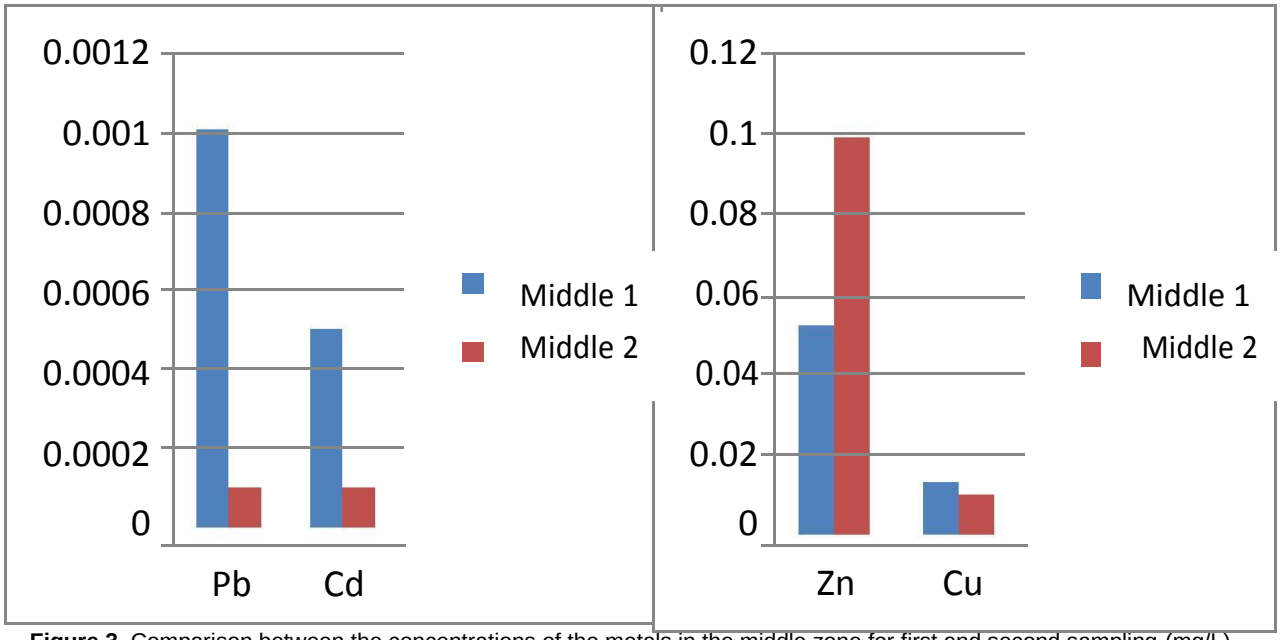

Figure 3. Comparison between the concentrations of the metals in the middle zone for first and second sampling (mg/L). Middle 1, Middle zone in the first sampling; Middle 2, middle zone in the second sampling.

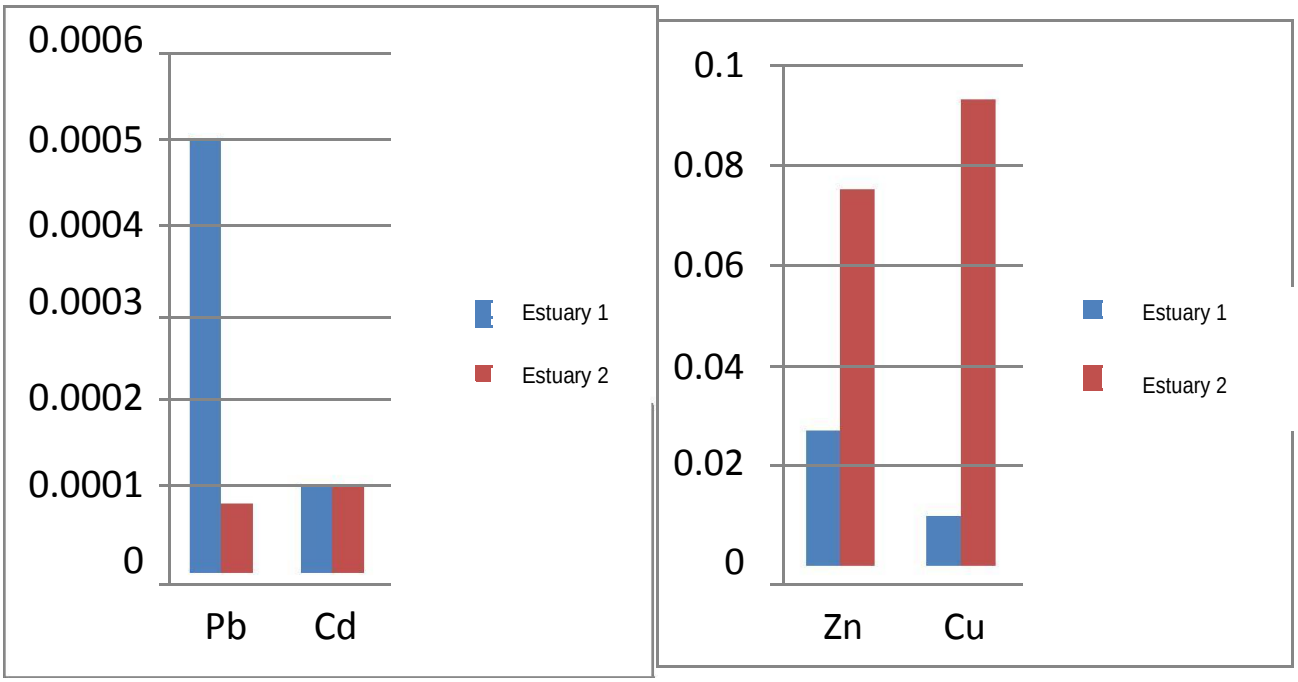

Figure 4. Comparison between the concentration of the metals in the estuary zone for first and second sampling (mg/L). Estuary 1, Estuary zone in the first sampling. Estuary 2, Estuary zone in the second sampling.

Table 5. The mean concentrations of the heavy metals in the first sampling in the three zones comparing with INWQS.

Mg/L	INWQS	Upstream	Middle	Estuary
Pb	0.02	0.001	0.001	0.0005
Zn	0.4	0.035	0.052	0.034
Cd	0.01	0.0002	0.0002	0.0002
Cu		0.002	0.005	0.004

Table 6. The mean concentrations of the heavy metals in the second sampling in the three zones comparing with INWQS.

Mg/L	INWQS	Upstream	Middle	Estuary
Pb	0.02	0.001	0.001	0.0005
Zn	0.4	0.038	0.052	0.036
Cd	0.01	0.00006	0.0001	0.0001
Cu		0.002	0.002	0.003

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As far as industrial waste is concerned, apparently the presence of heavy metals in Juru River is not alarming. Tables 5 and 6 explain the mean concentrations of the heavy metals in the three zones in the first sampling and the second sampling compared with the INWQS.

Conclusion

The river generally has low concentrations of the studied metals compared with the INWQS. Sources of pollutants in Juru River are mainly from domestic sewage and agricultural runoff. As far as industrial waste is concerned, apparently the presence of heavy metals levels in Juru River is not alarming.

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