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Evaluation of heavy metals pollution in water and sediments of Changdang Lake, China

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Abstract

An investigation of the water and sediments of Changdang Lake China was carried out to know how seriously they are polluted from heavy metals. Water samples and sediments were collected from six sites in March, June and September 2015. The total average concentrations of heavy metals in water were measured as Mn 0.08 mg/L, Fe 72.48mg/L, Cu 0.10 mg/L, Cr 0.001 mg/L, Cd 0.0002 mg/L, Ni 0.014 mg/L, Zn 0.022 mg/L, and Hg 0.058 mg/L, while in sediments Cu 70.50 mg/Kg, Zn 255.55 mg/Kg, As 12.83 mg/Kg, Ni 42.50 mg/Kg, Cr 96.39 mg/Kg, Cd 0.02 mg/Kg, Pb 41.50 mg/Kg, Hg 0.25 mg/Kg, respectively. By applying the USEPA health risk assessment models, results indicated that the total heavy metal health risk levels in water were in the range of 2.7×10^{-5} -$4.3\times10^{-5}a^{-1}$, with an average risk of $3.7\times10^{-5}a^{-1}$.The highest risk was found at site 6# ($4.3\times10^{-5}a^{-1}$) which is inlet from the Xuebu River, while the lowest risk was found at site 2# ($2.7\times10^{-5}a^{-1}$), which is located near the center of the Lake. All the risks values were below the ICRP recommended maximum acceptable level ($5\times10^{-5}\cdot a^{-1}$). The ecological risk assessment in sediments was carried out by the potential ecological risk index (PERI) proposed by Hakanson (1980). Results showed that the risk posed by heavy metals is low both in sediments and water. PCA factor loadings suggested that the sources of heavy metals in Changdang Lake sediments are from anthropogenic and lithogenic activities.

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Introduction

In recent years, heavy-metal pollution due to the increasing number of industries and the effects of human activity has attracted the public attention worldwide (Hopenhayn, 2006; Bundschuh, 2012; Ma, 2013).Heavy metals are persistent in ecosystem such as water, sediments and biota because of their resistant to decomposition in natural condition. Water contamination with heavy metalcaused by natural (i.e. weathering, erosion of bed rocks, and ore deposits) (Smedley, 2002)and anthropogenic (i.e. mining, industries, and agriculture) processes (Muhammad, 2011).Certain elements like calcium(Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), cobalt (Co), and zinc (Zn) are essentially required by living organisms in required dose, but may produce harmful effects in high concentrations,(S. Muhammad, 2011). For these essential metals there is a specific dose of intake over which their consumption is adequate to the body (Fe 8-18 mg/day, Ni 0.5 mg/day, Cu 0.9 mg/day, Mn 1.8-2.3 mg/day, Zn 8-11 mg/day)(USEPA, 2001; Singh, 2006). Toxicity appears after exceeding limit of indispensability. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues.

The main threats to human health from heavy metals are related with exposure to lead (Pb), mercury (Hg), cadmium (Cd) and arsenic (As), which are extremely harmful due to their toxicity, long persistence, and bioaccumulative nature (Arup, 2003).A high consumption of Fe and Mn causes pathological events such as the iron oxides deposition in Parkinson's disease(USEPA, 2001; Powers, 2003), Cu surplus cause liver damage and Zn may produce adverse nutrient interactions with Cu. Also, Zn reduces immune function and the levels of high density lipoproteins (Food and Drug Administration, 2001). Other metals like Pb and Cd are toxic even at low concentration (Llobet, 2003). Pb is known to cause renal tumors, reduce cognitive development, and enhance blood pressure and cardiovascular diseases risk for adults and Cd may cause kidney dysfunctions, osteomalacia and reproductive deficiencies (USEPA, 2001; Ikem, 2005).

Metals have low solubility in water, get adsorbed and accumulated on bottom sediments (Jain, 2008; Suresh, 2012).

Thus, the sediment could be a potential source of heavy metals that will be released into the overlying water through natural and anthropogenic processes, where they could have a harmful effect on the drinking water quality and significant ecological effects throughout the food chain(Alkorta, 2004; Atkinson, 2007).Heavy metals found in different chemical fractions within sediments, and these different fractions have different levels of mobility, bioavailability, and potential toxicity. As a result, ecological risk and bioavailability are more dependent on the chemical forms of heavy metals within an aquatic environment than on their total concentrations (Tack, 1995; Jain 2004).

This study is an attempt to investigate about the occurrence, risks and sources of heavy metals in water and sediments from Changdang Lake, China. Which will help the local administration to know the present level of heavy metals in Changdang Lake.

Materials and methods

Studyarea

Changdang Lake, situated in Jintan City is one of the tenth largest drinking water sources in Jiangsu Province. The Lake covers 13 million acres area, which is more than 90 % in the territory of Jintan and play a key role in drinking water supply in the City.Jintan City comes under the northern subtropical monsoon climate zone and its climate is mild and humid with four distinct seasons. The annual average temperature of the lake water is 15.3 °C (59.5 °F), while average annual precipitation in the area is 1063.5 mm (41.87″). The frost-free period covers 228 days and the average humidity is 78%.

For the investigation of the heavy metals pollution in water and sediments, samples were collected from 6 sites in the lake. Among the six sampling sites, site 1#, 2# and 3# were selected from the north shore to the center of the lake, site 4# was selected near the outlet from the lake to the Huangli River, site 5# was selected near the inlet from Sudou River, while site 6# was chosen near the inlet from Xuebu River. The sampling locations were recorded (Latitudinal and Longitudinal position) using hand-held Global Positioning System (GPS) (Model: GARMIN GPS-12) unit. Sampling site is shown in **Error! Reference source not found.**.

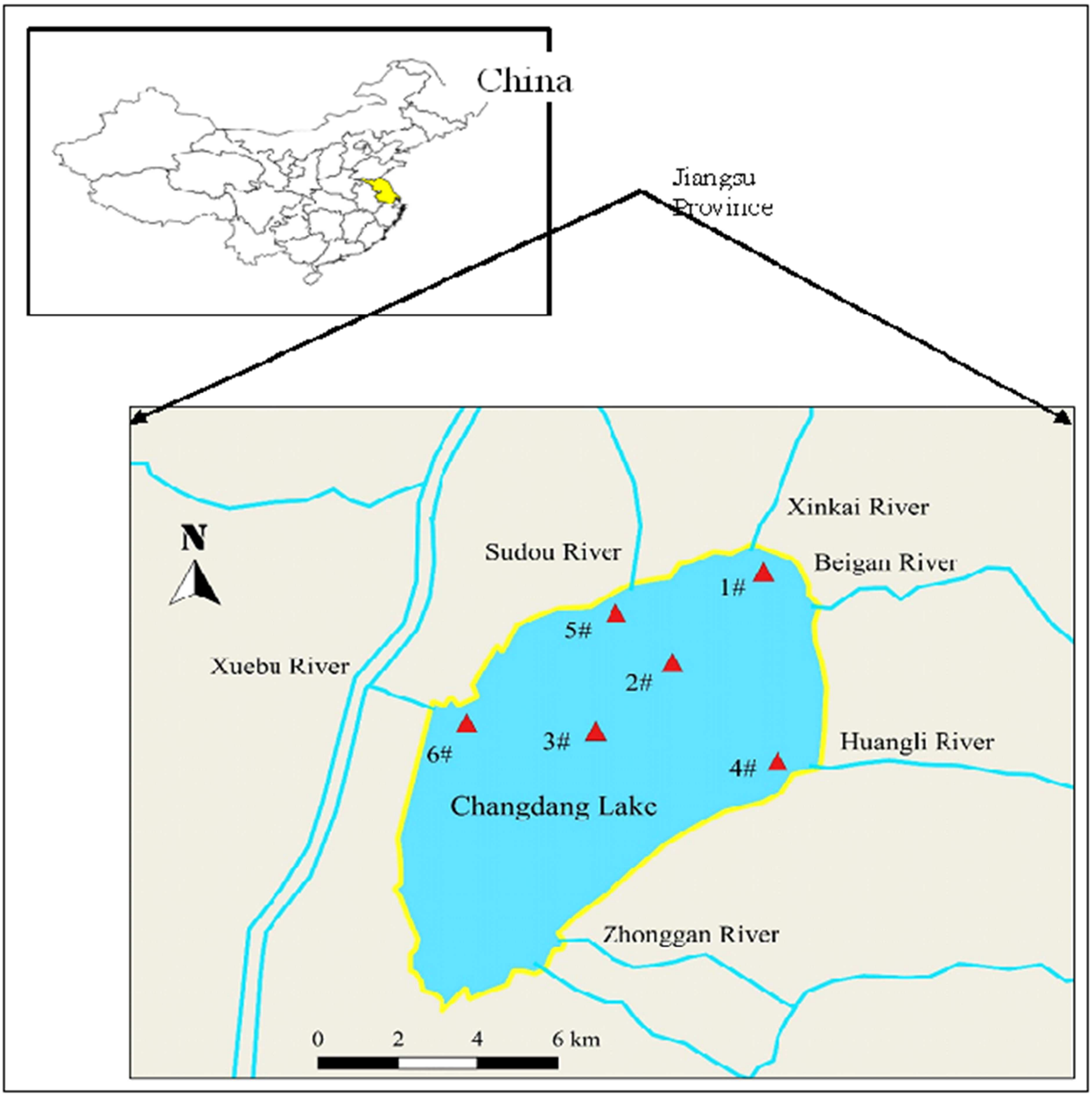

Fig. 1. Locations of the sampling sites in Changdang Lake.

Sediments samples

Approximately the top 1cm of sediments was collected with the help of a plastic spoon. They were then kept into polyethylene bags, and transferred to the laboratory (Wu, 2002). All samples were air dried at room temperature and sieved through a 2mm nylon sieve to remove coarse debris.

In order to analyze the level of heavy metals, 0.5 g of sediments were digested by microwave in Teflon vessels using 6 mL of supra-pure concentrated HNO_3, 2 mL of H_2O_2 30% and 2 mL of concentrated HF; HF was then removed by the addition of an excess of H_3BO_3 (US EPA Method 3052, 1996).

The solution was transferred into a polyethylene volumetric flask and diluted with milliQ water to 100 mL. 1mL of the solution was then diluted to 10mL by adding HNO_3 (Suresh 2011, 3050B December 1996). All glass wares and plastic containers were washed with 10% nitric acid solution and rinsed thoroughly with milliQ water. Heavy metal contents (Cd, Cr, Cu, Ni, Pb, As, Mg, Ni and Zn) were measured by Inductively Coupled Plasma Optical Emission Spectrometry (Perkin Elmer 2100DV) (USEPA Method 6020, 1996) (Agency, 1996).

The accuracy of the analytical determination was established using the reference material of GSD-9 and GSD-11, supplied by the Chinese Academy of Geological Sciences. The analytical results for all elements were found to be in agreement with the certified values, with measurement errors <5% (Zeng, 2009).

Water samples

Water sampling sites were collected from the same sites as the sediments sites. Samples were collected in pre-washed high-density polyethylene bottles in triplicate and subsequently well-mixed in-situ following standard methodology (WEF) 1995). The samples were filtered through pre-washed 0.45 µm Millipore nitrocellulose filters to remove any remaining suspension, acidified with ultra-purified MNO_3 (2 mL/L) to keep pH <2, and stored at -4°C for elemental analysis (USEPA 2003).

The level of zinc (Zn), copper (Cu), manganese (Mn), iron (Fe), chromium (Cr), cadmium (Cd), and lead (Pb) were analyzed using a graphite furnace atomic absorption spectrometer (Perkin Elmer, AAS-PEA-700) under optimum analytical conditions (Muhammad, 2011; Shah, 2012).

Data treatment and multivariate statistical analysis

Analytical data were processed using SPSS software. Basic statistics such as min., max., mean, and standard deviation (SD) were computed, along with the multivariate statistics. Principal component analyses (PCA) was used to identify the possible heavy metal sources.

Risk assessment of heavy metals in water

As China has not yet set a standard for heavy metals health risk assessment, Therefore in this study USEPA recommended two models, including carcinogenic risk and non-carcinogenic risk models were used to evaluate the human health risk posed by heavy metals in water ofChangdang Lake.

Carcinogen risk model:

$$R_i^c = \frac{1 - \exp(-D_i q_i)}{70}$$

In equation, R^c_i is the average cancer risk caused by individual carcinogen through ingestion, Di refers to the referenced dose ingested through ingestion (mg/kg/day),q_i refers to daily intake through ingestion, (mg/kg/day), and 70 refers to the average human life, a^{-1}.

Non-carcinogenic risk model:

$$R_j^n = \frac{D'_j \times 10^{-6}}{RfD'_j \times 70}$$

Where R^n_j is the average cancer risk caused by individual non carcinogen through ingestion, D'_j indicate the daily exposure to the non-carcinogens through ingestion, Rf D'jrefers to the non-carcinogens daily dose through ingestion, (mg/kg/day); 70 is the average human life.

The daily exposure dose through drinking water (D_i, D'_j) can be calculated as follows:

$$D_i = \frac{2.2 \times C_i}{70}$$

In equation, 2.2 is the average daily water intake by adult; C_i is the concentration of carcinogens (or non-carcinogens, mg/kg/day), 70 is the average human life. Total health risks (R):

$$R^c = \sum_{i=1}^{m} R_i^c$$

$$R^n = \sum_{f=1}^{k} R_f^n$$

IARC (IARC) and the World Health Organization (WHO) have categorized the Cr, As and Cd as carcinogens and Pb, Cu, Zn and Hg non-carcinogens. In this study selected reference values for the carcinogenic and non-carcinogenic heavy metals are presented in (**Error! Reference source not found.**, 2).

Risk assessment of heavy metals in sediments

Potential ecological risk index (PERI) proposed by Hakanson, (Hakanson, 1980) was used to evaluate the ecological risk posed by of heavy metals in sediments. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals (Nabholz, 1991; Singh, 2010; Douay, 2013). PERI is formed by three basic modules: degree of contamination (CD), toxic-response factor (TR) and potential ecological risk factor (ER). According to this method, the potential ecological risk index of a single element (E^i_r) and comprehensive potential ecological risk index (C^i_f) can be calculated via the following equations:

$$C^i_f = C^i_s / C^i_n$$

In formula, C^i_s is the measured value of individual element at sampling sites; C^i_n is the reference value for the metal. The evaluation reference value (C^i_n) and toxic response (T^i_r) of heavy metals coefficients are shown in (Table 3).

Heavy metal pollution comprehensive coefficient Cf is calculated as,

$$C_f = \sum_{i=1}^{n} C_{i,f}$$

Potential ecological risk coefficient of individual element E^i_r is calculated as,

$$E_{i,r} = T_{i,r} \times C_{i,f}$$

In equation, T^i_r is the biological toxic factor of a single element, which is determined for Zn = 1, Cr = 2, Cu = Pb = 5 and Cd = 30 (**Error! Reference source not found.**) (Hakanson, 1980).

Comprehensive potential ecological risk index (I_R) can be calculated via the following equations:

$$I_R = \sum_{i=1}^{n} E_{i,r} = \sum_{i=1}^{n} \frac{T_{i,r} \times C_{i,s}}{C_{i,n}}$$

Heavy metals pollution coefficient grading criteria are presented in (**Error! Reference source not found.**).Grading potential ecological risk index is shown in (**Error! Reference source not found.**).

Principle component analysis

Multivariate techniques have been used for evaluation and characterization of analytical data (Fadigas, 2010). Various multivariate techniques such as CA, HACA and PCA have been shown to be useful for identification of sources of heavy metals (Fu, 2014). In this study principal component analyses (PCA) was used to identify the possible heavy metal sources.

The PCA finds out the diagonalization of the covariance or correlation matrix transforming the original chemical measurements into linear combinations of these measurements, which are the principal components (PCs). It rotates the coordinate space axes so that the explained variance of each PC is maximized. This technique allows for data reduction from higher to lower dimensional spaces to simplify their representation. PCA was performed using Varimax Normalized Rotation on the dataset (Singh, 2005; Iqbal, 2011; Gielar, 2012).

Results and discussion

Heavy metals content in water

Concentrations of heavy metals in water in March (dry season), June (wet season) and September (Temperate season) in terms of statistical distribution parameters are shown in

Fig..

Concentrations of heavy metal ranges in March can be ordered as Fe>Mn>Cu>Zn>Hg>Ni>Cr>Cd>As>Pb. In June the order was as Fe>Mn>Cu>Ni>Zn>Hg>Cr>Cd>Pb>As>.

In September the heavy metals contents can be ordered as Fe>Hg>Mn>Cu>Zn>Ni>Cr>Cd>As>Pb. The total average concentration in different months was measured as Mn 0.08 mg/L, Fe 72.48 mg/L, Cu 0.10 mg/L, Cr 0.001 mg/L, Cd 0.0002 mg/L, Ni 0.014 mg/L, Zn 0.022 mg/L, and Hg 0.058 mg/L Overall, the lowest total heavy metals content in water was found at sites 2# and 3# and the highest content was observed in site 6# as shown in

Fig.. Heavy metal concentrations in the water observed from Changdang Lake is lower by comparing with the results obtained from Poyang Lake, China (Cr 3.38 mg/kg, Cu 4.18 mg/kg, Zn 11.19 mg/kg, Cd Pb 4.06 mg/kg) (Hu, 2012).

Table 1. Carcinogens coefficient factor.

Carcinogens	Cr	Cd	As
q_{ig}/ mg/kg^{-1}/d^{-1}	41	6.1	15

Table 2. Non- carcinogens coefficient factor.

Non-carcinogens	Pb	Cu	Zn	Hg
RfD_{ig}/mg/ kg^{-1}/d^{-1}	1.4×10^{-3}	5.0×10^{-3}	0.3	3.0×10^{-4}

Heavy metals content in sediments

Sediment contamination poses one of the worst environmental problems in ecosystems, acting as sinks and sources of contaminants in aquatic systems and sediment analysis plays an important role in assessing the pollution status of the environment (Mucha, 2003). The heavy metal concentrations in different sediment samples collected from Changdang Lake from different months are presented in Fig. Concentrations of heavy metal in March can be shown in increasing order as Zn>Cr>Cu>Pb>Ni>As>Hg>Cd. In June the heavy metals concentrations can be ordered as Zn>Cr>Cu>Ni>Pb>As>Hg>Cd, while the concentrations of heavy metals in September can be ordered as Zn>Cr>Cu>Ni >Pb>As<Hg>Cd.

Table 3. The evaluation reference value (C^i_n) and toxic response (T^i_r) of heavy metals coefficient.

Element	C^i_n mg/kg	$T^i_{,r}$
Cu	34	5
Zn	90	1
Cr	60	2
Cd	0.5	30
Pb	25	5
As	7.5	10
Hg	0.15	30
Ni	40	5

In this study Zn and Cu showed the highest contend in all the seasons, while Hg and Cd were at the lowest concentration in sediments from Changdang Lake. The total average concentration of heavy metals in different months was calculated as Cu 70.50 mg/kg, Zn 255.55 mg/kg, As 12.83 mg/kg, Ni 42.50 mg/kg, Cr 96.39 mg/kg, Cd 0.02 mg/kg, Pb 41.50 mg/kg, Hg 0.25 mg/kg. These results suggest that, Cu, Zn and As content exceeds the "soil environmental quality standards" of China (GB15618-1995) in sediments in some locations. The highest content was found at sites 5# and 6#, while the lowest content was found at sites 2# and 3# as shown in Fig.

Heavy metal concentrations in the sediments observed from Changdang Lake is lower by comparing with the results obtained from Poyang Lake (Cr 28.05, Cu 61.53, Zn 194.11, Cd 1.54, Pb 48.17) (Hu, 2012) and Jinji Lake (Pb107 mg/kg, Zn 431 mg/kg and Cu 370 mg/k)

Table 1. The adjusted grading standard of potential.

C^i_f	Cf	Contamination level
≤1	≤8	Low
＞1-3	＞8-16	Moderate
＞3-6	＞16-32	Considerable
＞6	＞32	Very high

NOTE: C^i_f is the single element pollution factor; Cf comprehensive pollution factor.

Risk assessment of heavy metals in water

According to the International Commission on Radiological Protection (ICRP, the maximum acceptable value of individual element is $5.0\times10^{-5}a^{-1}$, per million population per year due to various pollutants in drinking water, the number of harm or death cannot exceed 50 people. The average annual risk and the overall risk of heavy metal pollutants in each sampling sites are shown in Table 2. Which shows, that the average health risks value of carcinogens ranged as, Cr 24.52×10^{-6}-$36.77\times10^{-6}a^{-1}$, with an average of $31.67\times10^{-6}a^{-1}$, maximum risks value was measured at sites 1#, 4# and 6#; the range of health risks values caused by the carcinogens Cd was 0.55×10^{-6}-$2.01\times10^{-6}a^{-1}$, with an average of $1.23\times10^{-6}a^{-1}$, at site 3# emerged maximum; the range of health risks values caused by the carcinogen as of 1.57×10^{6}- $5.39\times10^{-6}a^{-1}$, with an average of $3.52\times10^{-6}a^{-1}$, at site 6# emerged maximum. Among Pb, Cu, Zn and Hg, the maximum individual non-carcinogenic annual health hazards risk value was calculated for Pb with the range of 1.2×10^{-9}-$4.3\times10^{-9}a^{-1}$, with an average of 2.7×10-9a^{-1} highest at site 6#; the range of Cu was 4.2×10^{-9}-$6.6\times10^{-9}a^{-1}$, with an average of $5.4\times10^{-9}a^{-1}$, at 1# was maximum; Zn range of 5.0 × 10-10-1.3×10^{-9}, an average of $8.0\times10^{-10}a^{-1}$, at site 5# observed maximum; Hg was in the range of 6.0×10^{-10}- $1.2\times10^{-9}a^{-1}$, with an average of $9.0\times10^{-10}a^{-1}$, with the maximum value at 6#.

Table 5. Heavy metals potential ecological risk index classification standard.

Potential ecological risk index of individual element, E^i_r	Potential ecological index (I_R)	Potential ecological risk
≤40	≤150	Low
＞40-80	＞150-300	Moderate
＞80-160	＞300-600	Considerable
＞160-320	＞600	Sever
＞320		Very serious

The total health risk level of heavy metal in Changdang Lake was in the range of 2.7×10-5-$4.3\times10^{-5}a^{-1}$, with an average of $3.7\times10^{-5}a^{-1}$, the highest at site 6#, 4.3×10- 5a^{-1}, the lowest at site 2#, was 2.7×10-5a^{-1}, All the risks values were below the ICRP recommended maximum acceptable level. Overall the total highest heavy metals risk was found at site 6# and the lowest at site 2#.

Risk assessment of heavy metals in sediments

Potential ecological risk index (PERI) proposed by Hakanson (Hakanson, 1980) was used to evaluate the ecological risk posed by of heavy metals in sediments.

Based on the risk assessment formula results of Single element pollution factor coefficient C^i_f and comprehensive pollution coefficient Cf are shown in

Table . From the evaluation results Cu, Zn, Cr, Pb, As, Ni in sediments are at moderate risk level, Cd, Hg in low risk levels, The results can be ordered as follows, Zn>Cu> As >Pb>Cr>Ni>Hg>Cd.

From the heavy metals comprehensive risk coefficient (Cf), the contamination level in sediment of each site can be ranked as 6#>5#>1#>4#>2#>3#.

Table 2. Results of the total heavy metal risks in water from Changdang Lake Unit: ×10-6a-1.

Sampling Sites		1#	2#	3#	4#	5#	6#
Carcinogenic	Cr	36.77	24.52	24.52	36.77	30.65	36.77
	Cd	1.37	0.55	1.55	2.01	1.19	0.73
	As	3.82	1.57	1.80	4.04	4.26	5.39
Non-Carcinogenic	Pb	0.0022	0.0012	0.0021	0.0036	0.0030	0.0043
	Cu	0.0066	0.0057	0.0048	0.0063	0.0048	0.0042
	Zn	0.0008	0.0005	0.0005	0.0009	0.0013	0.0006
	Hg	0.0009	0.0006	0.0006	0.0009	0.0012	0.0012
Total		41.96	26.65	27.88	42.83	36.11	42.90

Overall heavy metal risk level in sediments was found at moderate level in Changdang Lake with the lowest risk at site 2# and 3#.

Based on results of potential ecological risk coefficient (E^i_r), the potential ecological risk can be arranged in the order of ER Cu>As>Pb>Ni>Hg>Zn>Cr>Cd, These results shows that the risk posed by heavy metals in is low in sediments from Changdang lake.

Results from heavy metal potential ecological risk index, shows that, total potential ecological risk of all sites are at low level, the degree of risk at each site can be ranked as 6#>5#>1#>4#>2# >3#.

From the evaluation it can be seen that the lowest potential ecological risk coefficient (E^i_r) and potential ecological risk index is at site 2# and 3#.

Table 7. Single element pollution factor coefficient Cif and comprehensive pollution coefficient. Cf.

C^i_f	1#	2#	3#	4#	5#	6#	Average Value
Cu	2.24	1.57	1.85	2.10	2.52	2.64	2.15
Zn	3.03	2.44	2.80	3.04	2.97	3.46	2.96
Cr	1.26	0.79	1.01	1.12	1.34	1.44	1.16
Cd	0.046	0.027	0.017	0.022	0.023	0.021	0.03
Pb	1.72	0.93	1.12	1.44	1.82	2.09	1.52
Ni	1.15	0.80	0.92	1.04	1.25	1.37	1.09
As	2.08	0.78	1.20	1.60	2.30	2.73	1.78
Hg	0.22	0.09	0.22	0.09	0.13	0.24	0.17
Cf	11.74	7.42	9.14	10.43	12.36	14.00	10.85

Table 8. Heavy metal potential ecological risk coefficient (E^i_r) and potential ecological risk index (IR).

E^i_r	1#	2#	3#	4#	5#	6#	Average
Cu	11.18	7.84	9.26	10.49	12.60	13.19	10.76
Zn	3.03	2.44	2.80	3.04	2.97	3.46	2.96
Cr	2.51	1.57	2.02	2.23	2.68	2.89	2.32
Cd	0.046	0.027	0.017	0.022	0.023	0.021	0.03
Pb	8.58	4.64	5.62	7.19	9.10	10.47	7.60
Ni	5.74	3.99	4.58	5.18	6.25	6.83	5.43
As	20.84	7.82	12.00	16.00	23.02	27.33	17.84
Hg	6.67	2.67	6.67	2.67	4.00	7.33	5.00
I_R	58.60	31.01	42.96	46.81	60.64	71.52	51.92

Source analysis

One of the important aspect of the present study is the source analysis of the metals in sediments using PCA.

The principal component loadings of the heavy metals in sediments in March and June and September are given in (Table 9). Two PCs are extracted with eigenvalues more than 1 for each season.

In March two PCs explaining about 83.96% of the cumulative variance.

The first PC (60.75% variance) reveals elevated loadings of As, Zn, Cu, Ni, Cr, Fe, supported. The second PC (23.21% variance) shows significant loadings of Hg and Pb.

Table 9. Principal component loadings of heavy metals in March, June and September.

	March		June		September	
Heavy Metals	PC1	PC2	PC1	PC2	PC1	PC2
As	0.984	0.146	.991	.096	.946	-.017
Zn	0.976	0.179	.975	.075	.882	.391
Cu	0.963	0.122	.971	.180	.856	.091
Ni	0.933	0.318	.955	.081	.850	.397
Hg	0.324	0.913	.084	.955	.702	.592
Pb	0.317	0.872	.097	.911	.024	.906
Cr	0.086	0.75	-.040	.866	.195	.798
Cd	-0.027	-0.676	.344	.831	-.578	-.631
Variance %	60.75	23.21	56.11	33.39	63.94	17.59
Cumulative %	60.75	83.96	56.11	89.50	63.94	81.53

The counterpart data in June also yield two PCs with eigenvalues greater than 1, explaining more than 89.50% of the total variance. PC1 (56.11% variance) exhibits higher loadings for As, Zn Cu, Ni,

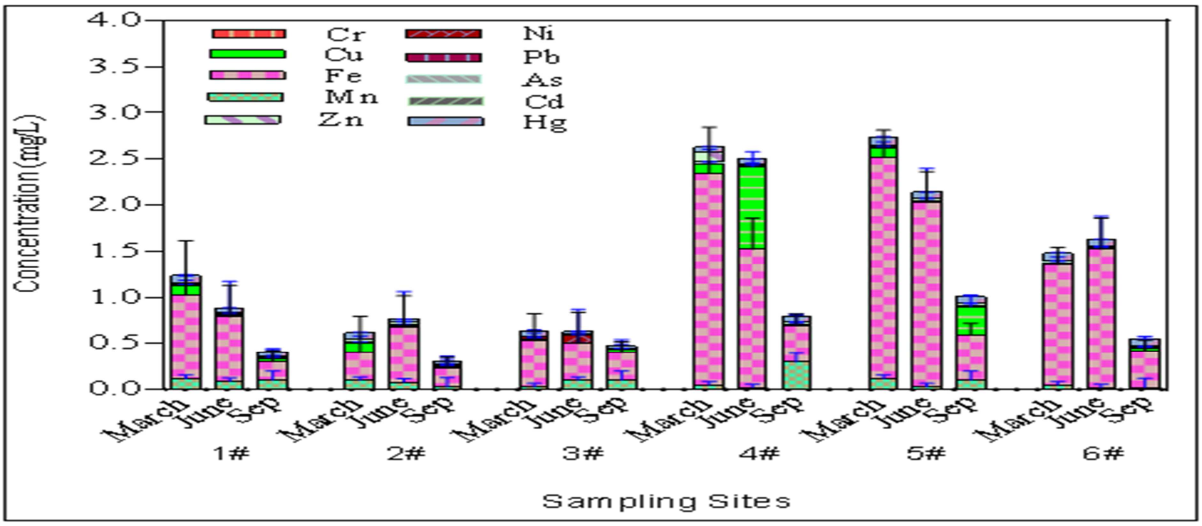

Fig. 2. Heavy metals content in water from Changdang Lake.

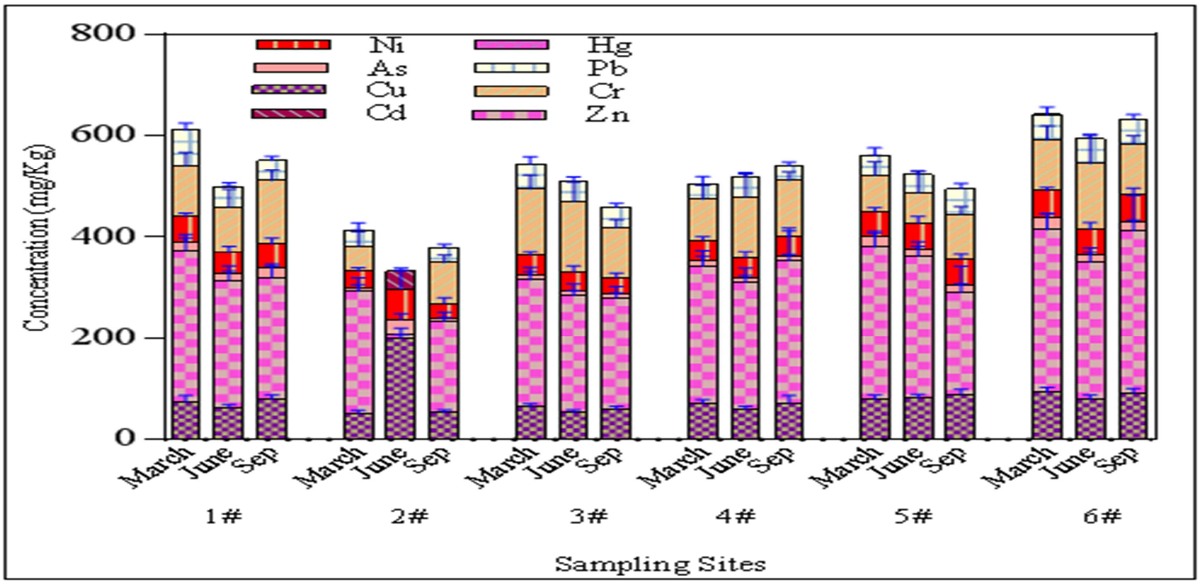

Fig. 3. Heavy metals content in sediments from Changdang Lake.

The second PC (33.39 % variance), shows significant loadings of Hg, Pb, Cr, and Cd. In September explaining about (81.53 % of the cumulative variance) first PC (63.94% variance) reveals elevated loadings of As, Zn, Cu, Ni and Hg, while the second PC with 17.59% variance exhibit higher loading of Pb and Cr. If we look at the (Table 9), almost same results was observed in different seasons, which show that the sources of heavy metals in Changdang Lake are the same in different seasons which are predominantly contributed by anthropogenic activities (Zhu, 2013). Today much of the anthropogenic Cu, Zn and Pb originates from smelters, fossil fuel uses, industrial discharges, mining and wastewaters (Bertin, 1995; Maldonado, 2008). Heavy metals have been used by humans for a variety of purposes throughout the 20th century.

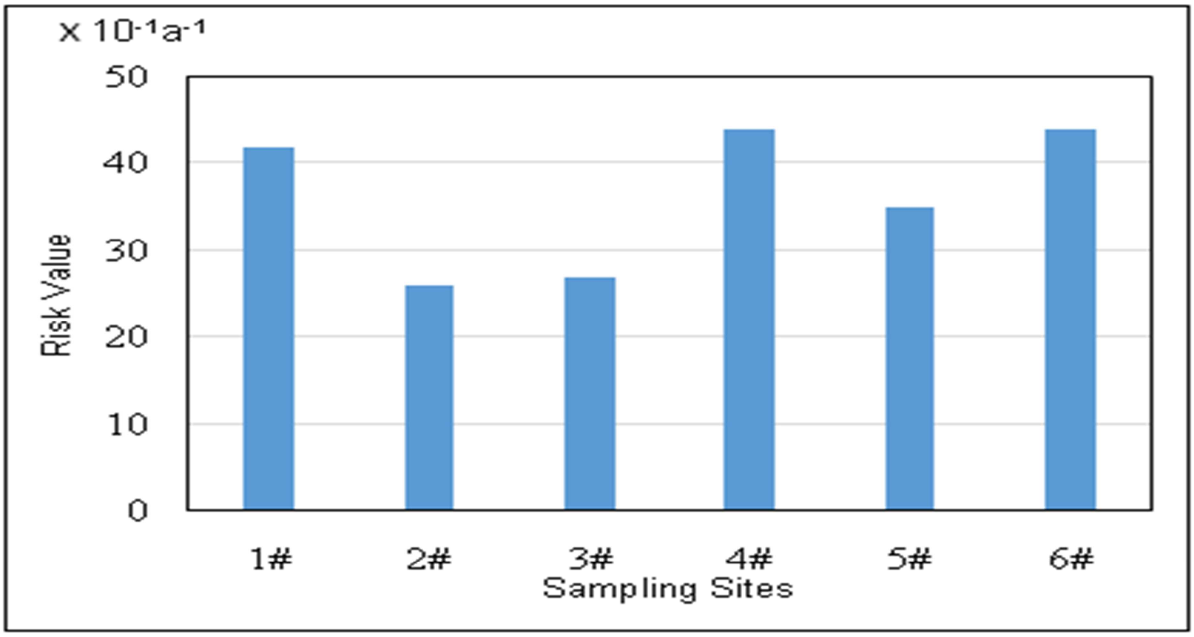

Fig. 4. Human health risks values of heavy metals in water from Changdang Lake.

The results suggested that the urban and industrial activities have made great contributions to heavy metal inputs.

Conclusion

The total average concentration of heavy metals in water was measured as Mn 0.08 mg/L, Fe 72.48mg/L, Cu 0.10 mg/L, Cr 0.001 mg/L, Cd 0.0002 mg/L, Ni 0.014 mg/L, Zn 0.022 mg/L, and Hg 0.058 mg/L,the major contributors were Mn 9% and Fe 72.48%. while the total average concentration of heavy metals in sediments was measured as Cu 70.50 mg/Kg, Zn 255.55 mg/Kg, As 12.83 mg/Kg, Ni 42.50 mg/Kg, Cr 96.39 mg/Kg, Cd 0.02 mg/Kg, Pb 41.50 mg/Kg, Hg 0.25 mg/Kg, respectively, where Zn 38.74 % and Cr 14.32 % were dominant.

The highest average content of heavy metal was found at site 6# both in water and sediment in different months, while the lowest concentrations were found at site 3#. Results obtained from the ecological risk models showed that the risk posed heavy metals was low in water and sediments. The PCA results indicated that the sources of heavy metals in Changdang Lake are mainly comes from lithogenic and anthropogenic activities, such as fossil fuel uses, industrial discharges, mining and wastewaters. Overall the water and sediments are safe, however further investigation and protective measures are necessary to protect the ecology and public health from heavy metals pollution in Jintan City.

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