Available online at www.worldscientificnews.com

World Scientific News

WSN 10 (2015) 1-16 EISSN 2392-2192

Quantification of Heavy Metals in the Sediment ecosystem of Ulhas River flowing along Dombivli City of Mumbai

Amol M. Jadhav[1], **Pravin U. Singare**[2,*]

[1]Research Scholar, Department of Chemistry, Shri. Jagdishprasad Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan 333001, India

[2]Department of Chemistry, Bhavan's College, Munshi Nagar, Andheri (West), Mumbai 400058, India

*E-mail address: pravinsingare@gmail.com

ABSTRACT

The Dombivli city near Mumbai has rapid industrialized. However the improper environmental planning has resulted in discharge of industrial waste effluents from the industrial belt into the Ulhas River. These wastes from these industries include various toxic heavy metals which subsequently accumulate in the sediments of Ulhas River. This day by day increasing tremendous pollution load has provoked us to carry the systematic and detailed study of heavy metal content in the sediment samples collected along the Ulhas River along the Dombivli City, near Mumbai. The study was conducted in year 2012 and 2013. The study was carried out in along the banks of Ulhas River near the discharge of effluents from Dombivli Industrial belt Phase I and Phase II. Accordingly the sampling points were identified. The analysis for the majority of the toxic heavy metals like Cadmium *(Cd)*, Copper *(Cu)*, Nickel *(Ni)*, Chromium *(Cr)*, Cobalt *(Co)*, Iron *(Fe)*, Lead *(Pb)*, Mercury *(Hg)*, Arsenic *(As)* and Zinc *(Zn)*, in sediment samples was done. From the results of our study, it can be concluded that there is a need of systematic and regular monitoring of pollution level along the Ulhas River so as to generate the data on accumulation of heavy metals in the river sediments which will further help in improving the industrial waste treatment technology adopted along the Dombivali industrial belt. It is expected that such scientific studies will help to gauge the extent of pollution in order to avoid long term irreparable damage to the ecosystem.

***Keywords*:** Ulhas River; heavy metals; sediments; industrial pollution; Dombivli; Mumbai

1. INTRODUCTION

India has witnessed a tremendous growth in the industrial sector. This has resulted to increase in pollution of air, water and soil. Due to the discharge of waste including various toxic chemicals, heavy metals, carcinogens, pesticides and many other chemicals, from a variety of industries in a large amount, there is a significant impact on the quality of water in comparison to the international standards. It is found that almost all rivers are polluted in most of the stretches by some industry or the other [1]. Although all industries in India function under the strict guidelines of the Central Pollution Control Board (CPCB) but still the environmental situation is far from satisfactory. Most major industries have treatment facilities for industrial effluents. In case of small scale industries, they do not afford huge investment for pollution control facility since they have fewer profit margins. In India, thus there are sufficient evidences available related with the mismanagement of industrial wastes [2-7].

The problem of water pollution has become still worse due to toxic heavy metals. Untreated or allegedly treated industrial effluents and sewage water contains variable amounts of heavy metals such as mercury, arsenic, nickel, copper cadmium, lead, zinc and chromium [6-8] and their excess lead to number of disorders [9]. These heavy metals have a marked effect on the aquatic flora and fauna. They enter the food chain through bio-magnification and ultimately affect the human beings as well. India is one of the identified hotspots of Hg pollution in the world [10]. Studies show that the aquatic ecosystem in India has significant amount of Hg [11-13]. The toxic heavy metals enter in aquatic environment are adsorbed onto particulate matter, although they can form free metal ions and soluble complexes that are available for uptake by biological organisms [14].

The metals associated with particulate material are also available for biological uptake [15] and are deposited in estuarine sediments [16]. Once deposited, binding by sulfides and/or iron hydroxides immobilizes trace metals until a change in redox or pH occurs [17,18]. Thus, in surfical sediments, in particular the fine fraction, trace metals are accumulated and provides a means for evaluating the long term accumulation of contaminants [6,19]. Hence there is a need for extensive pollution monitoring along the different water bodies over a long period of time in order to describe average metal precipitation [20] and the precipitation trend, which forms an important component of pollution control management. The Ulhas River is one of the important water bodies in Thane District of Maharashtra State. The effluent water from the nearby industrial belt of Dombivli city contributes the largest source of heavy metal concentration in the river, so it is expected that this reservoir can serve as a model for studying heavy metal concentration.

The increase in residue levels of heavy metal content in sediments will result in decreased productivity and increase in exposure of humans to harmful substances [21]. The main sources of river water pollution, as observed by the Maharashtra Pollution Control Board (MPCB), are the occasional discharge of untreated sewage and industrial effluent in rivers across the state. The data on pollution of water bodies due to discharge of industrial waste [6,7,22-27] and the pollution data of Ulhas river [28,29] points out the need of systematic and regular monitoring of pollution level for further improvement in the industrial waste water treatment methods. Therefore, we initiated such a study to understand the accumulation of heavy metal content in sediment of Ulhas River along the Dombivli city situated near Mumbai, India. The experimental data will help in understanding the effectiveness of pollution control measures already is existence; extent of pollution control needed; rational planning of pollution control strategies and their prioritization.

2. MATERIALS AND METHODS

2. 1. Area of study

The study was carried out along the banks of Ulhas River where the industrial effluents released from the Dombivli MIDC (Maharashtra Industrial Development Corporation) Industrial belt Phase I and Phase II are discharged. The Dombivali industrial area was established by Maharashtra Industrial Development Corporation (*M.I.D.C*) in 1964. The industrial belt occupies an area of about 347.88 hector, is located in south of Ulhas River.

There are many small/ medium/ large scale agrochemicals, fine chemicals, dyes manufacturing, textile, pharmaceutical, engineering, metallurgical and paint manufacturing industries located in this industrial belt which are contributing heavy pollution in the surrounding area [30-38]. About 14 MLD of industrial effluent generated from the industrial area is regularly discharged through open drainages into the nearby flowing Ulhas River [39]. Following suitable location/s for sampling of sediments were identified:

Sampling Point S1: Before the discharge of effluent from Dombivli MIDC Phase I.
Sampling Point S2: After the discharge of effluent from Dombivli MIDC Phase 1.
Sampling Point S3: Before the discharge of effluent from Dombivli MIDC Phase II.
Sampling Point S4: After the discharge of effluent from Dombivli MIDC Phase II.

The sampling locations are as shown in (Figure 1).

2. 2. Climatic conditions

Dombivali enjoys a tropical climate with mean annual temperature of 24.3 ºC (min) to 32.9 ºC (max). The hottest and driest part of the year is April-May, when temperature rises to 38.0 ºC. The humidity is usually in the range of 58 to 84% and sea breeze in the evening hours is a blessing to combat the high temperature and humidity during summer months. The average southwest monsoon rainfall is in the range of 1850 mm to 2000 mm. The average annual rainfall in the region is the range from 1286 to 1233 mm [39].

2. 3. Sample planning, collection and preservation

The study on pollution status along the Ulhas River was carried out for two years 2012 and 2013. The sampling of sediment was done every week along identified locations of the Ulhas River along Dombivli. The samples collected for four months were mixed separately to give gross sample of one season. This was done for all the three seasons – summer, rainy and winter for a period of twenty four months.

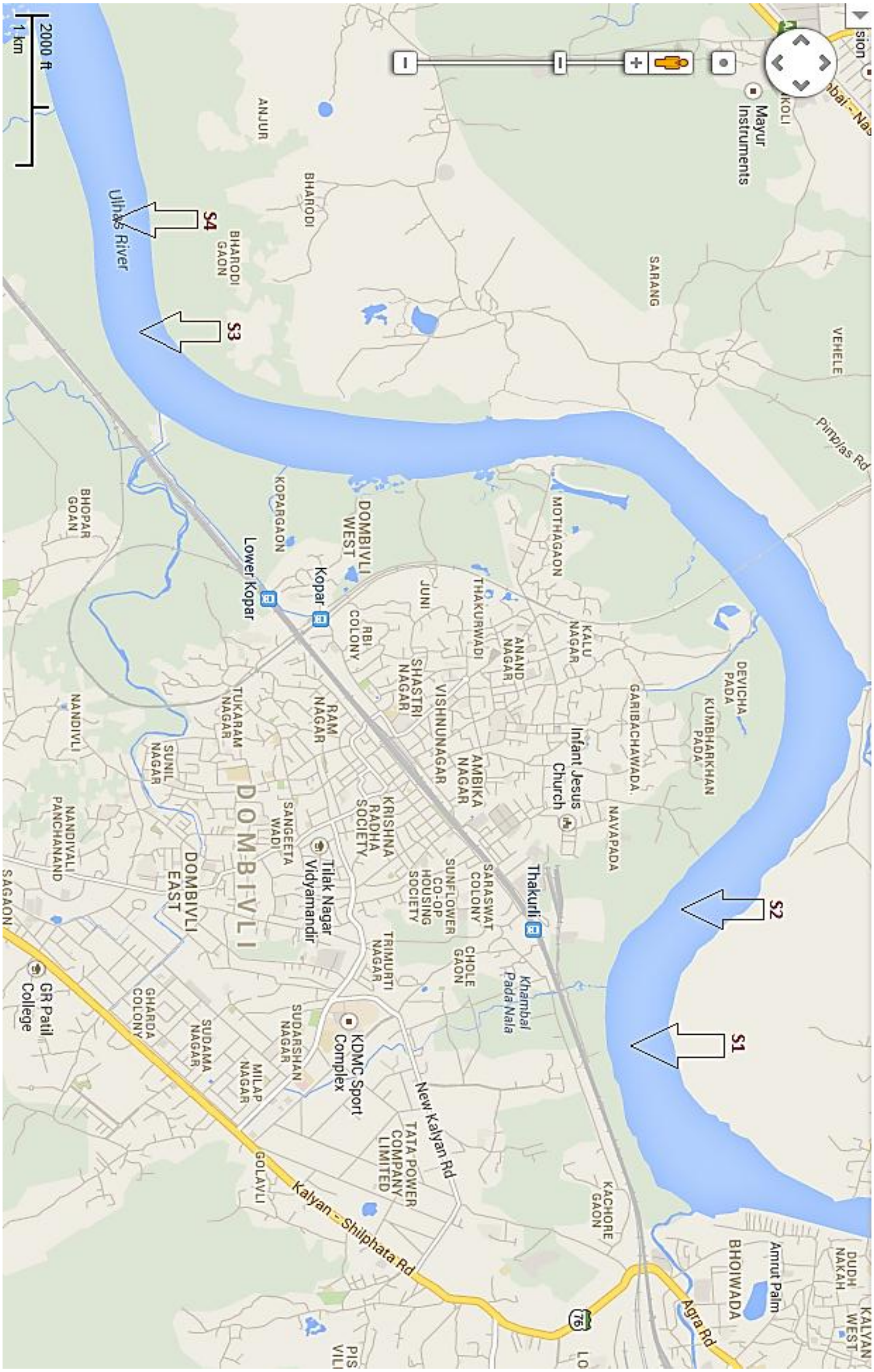

Figure 1. Sampling locations of Ulhas River along Dombivli City.

The samples were collected by hand-pushing plastic core tubes (7 cm diameter) as far as possible into the sediment. Sediment samples were thoroughly mixed, placed in polythene bags and kept in a dry place until analyses. The sediment samples where air dried for eight days and ground using agate mortar. To remove stones, plant roots and to obtain sediment of uniform particle size it was sieved with 0.5 mm mesh size sieve. Sediment samples were thoroughly mixed and packed in polythene bags. Until analysis, these bags were kept in a dry place. 2 g of each sample were taken in 250 ml glass beakers, digested on a sand bath for 2 hours with 8 ml of aqua regia and evaporated to near dryness.

The samples where then dissolved with 10 ml of 2% nitric acid and filtered through Whatman No. 1 filter paper followed by dilution with deionised water to give final volumes depending on the suspected level of the metals [40]. The sediment samples were subjected to nitric acid digestion using the microwave-assisted technique after setting pressure at 30 bar and power at 700 watts [41,42]. The treated samples were analyzed for the majority of the toxic metals - cadmium *(Cd),* copper *(Cu),* Nickel *(Ni),* chromium *(Cr),* cobalt *(Co),* iron *(Fe),* lead *(Pb),* mercury *(Hg),* arsenic *(As)* and zinc *(Zn)* by Flame Atomic Absorption Spectrophotometer. For estimation of arsenic *(As)* and mercury *(Hg),* hydride generation coupled with an atomic fluorescence detector and cold-vapor techniques were used respectively [43]. The techniques and methods followed for analysis and interpretation were according to the standard procedures [25-27,40,43-47].

2. 4. Quality Assurance

The chemicals and reagents which were used for analysis were of analytical reagent grade. All reagents were standardized against primary standards to determine their actual concentrations. Reagent blanks were used in analyses to correct the interference of reagent impurities and other environmental contaminations, if any, during analyses. It was ensured that all instruments before use were calibrated. Samples were analyzed in triplicate to check precision of the analytical methods and instruments. The relevant laboratory apparatus were soaked in nitric acid before analysis followed by rinsing thoroughly with tap water and de-ionised distilled water to ensure that all traces of cleaning reagents are removed. The glassware used in the analysis was washed with distilled de-ionised water. The pipettes and burette were rinsed with the experimental solution before final use. Sediment samples were collected with plastic-made implements to avoid any contamination. Samples were stored in polythene bags and were carefully well covered during their transporting from sampling locations to the laboratory to avoid contamination from the environment. To avoid any cross contamination for each sample during grinding, the tools and work surfaces were carefully cleaned.

2. 5. Heavy metal analysis by AAS technique

The analysis for the majority of the toxic heavy metals like Cadmium *(Cd),* Copper *(Cu),* Nickel *(Ni),* Chromium *(Cr),* Cobalt *(Co),* Iron *(Fe),* Lead *(Pb),* Mercury *(Hg),* Arsenic *(As)* and Zinc *(Zn),* in sediment samples was done by Perkin Elmer Analyst 200 Flame Atomic Absorption Spectrophotometer (2003 model). For estimation of Arsenic and Mercury, hydride generation coupled with an atomic fluorescence detector and cold-vapor techniques was used [43]. The standard solutions were prepared by using analytical Reagent Analytical grade chemicals in acidified metal free deionised water.

The calibration curves were prepared separately for all the metals, after running different concentrations of standard solutions. A reagent blank was used during the analysis and subtracted from the samples to correct for reagent impurities and other sources of errors from the environment. For each determination, average value of three replicates was taken.

3. RESULTS AND DISCUSSION

The sediment samples collected at various sampling points from the Ulhas River flowing along the Dombivli city near Mumbai in year 2012 and 2013 where analyzed for their heavy metal content. The average analytical results are presented in Table 1.

Table 1. Concentration of heavy metals in sediment at various locations during the year 2012 and 2013.

Sampling Point	Year	Season	Hg (ppm)	As (ppm)	Cr (ppm)	Cd (ppm)	Pb (ppm)	Cu (ppm)	Ni (ppm)	Zn (ppm)	Fe (ppm)	Co (ppm)
S1	2012	Rainy	0.04	0.04	80.36	0.29	16.47	89.36	35.62	150.26	10068	6.89
S1	2012	Winter	0.06	0.04	106.69	0.36	18.89	100.04	80.36	145.63	15686	24.05
S1	2012	Summer	0.06	0.06	67.98	0.07	15.63	79.89	38.23	87.96	12601	8.98
AVERAGE	**2012**		**0.05**	**0.05**	**85.01**	**0.24**	**17.00**	**89.76**	**51.40**	**127.95**	**12785**	**13.31**
S1	2013	Rainy	0.04	0.06	75.35	0.38	10.25	80.36	25.62	223.18	11598	9.87
S1	2013	Winter	0.05	0.05	129.53	0.45	20.66	128.78	99.89	123.63	18656	40.89
S1	2013	Summer	0.06	0.06	66.79	0.07	15.63	85.65	20.83	59.69	10686	8.98
AVERAGE	**2013**		**0.05**	**0.06**	**90.56**	**0.30**	**15.51**	**98.26**	**48.78**	**135.50**	**13647**	**19.91**
S2	2012	Rainy	0.06	0.06	100.66	0.36	20.36	100.07	68.95	300.26	18457	12.36
S2	2012	Winter	0.06	0.06	189.66	0.69	33.36	113.86	150.62	336.96	24876	55.36
S2	2012	Summer	0.07	0.06	85.98	0.1	25.68	98.38	54.36	200.68	18886	11.36
AVERAGE	**2012**		**0.06**	**0.06**	**125.43**	**0.38**	**26.47**	**104.10**	**91.31**	**279.30**	**20740**	**26.36**
S2	2013	Rainy	0.04	0.05	123.75	0.46	19.84	110.77	55.95	424.95	21446	16.25
S2	2013	Winter	0.06	0.06	383.14	0.89	26.5	491	205.08	445.08	28400	107.36
S2	2013	Summer	0.07	0.06	80.66	0.08	27.2	102.11	39.01	114.29	17600	16.88
AVERAGE	**2013**		**0.06**	**0.06**	**195.85**	**0.48**	**24.51**	**234.63**	**100.01**	**328.11**	**22482**	**46.83**
S-3	2012	Rainy	0.07	0.07	130.63	0.58	29.89	176.65	100.58	390.11	23236	16.65
S-3	2012	Winter	0.06	0.08	297.41	0.98	37.46	441.73	263.23	390.64	30024	102.36
S-3	2012	Summer	0.08	0.07	115.95	0.15	33.33	138.87	85.63	250.63	23687	19.63

AVERAGE	**2012**		**0.07**	**0.07**	**181.33**	**0.57**	**33.56**	**252.42**	**149.81**	**343.79**	**25649**	**46.21**
S3	2013	Rainy	0.04	0.06	140.36	0.56	38.01	182.83	118.84	578.11	24003	18.82
S3	2013	Winter	0.05	0.08	405.2	13.2	37.44	501.2	304.11	453.11	35300	137.32
S3	2013	Summer	0.07	0.07	105.2	0.1	27.62	125.81	47.73	247.34	21400	21.83
AVERAGE	**2013**		**0.05**	**0.07**	**216.92**	**4.62**	**34.36**	**269.95**	**156.89**	**426.19**	**26901**	**59.32**
S4	2012	Rainy	0.08	0.06	136.98	0.69	35.67	180.66	125.43	401.1	22698	17.77
S4	2012	Winter	0.06	0.08	350.69	1.12	34.98	491.01	300.35	375.07	32598	100.36
S4	2012	Summer	0.08	0.09	189.68	0.19	39.89	208.98	89.16	233.65	22963	25.63
AVERAGE	**2012**		**0.07**	**0.08**	**225.78**	**0.67**	**36.85**	**293.55**	**171.65**	**336.61**	**26086**	**47.92**
S4	2013	Rainy	0.08	0.08	130.35	0.61	40.23	191.15	110.36	509.12	25089	19.89
S4	2013	Winter	0.07	0.06	439.01	0.96	45.32	520.83	335.15	486.65	34892	140.36
S4	2013	Summer	0.09	0.07	145.69	0.15	30.36	130.68	55.33	220.23	22303	24.36
AVERAGE	**2013**		**0.08**	**0.07**	**238.35**	**0.57**	**38.64**	**280.89**	**166.95**	**405.33**	**27428**	**61.54**

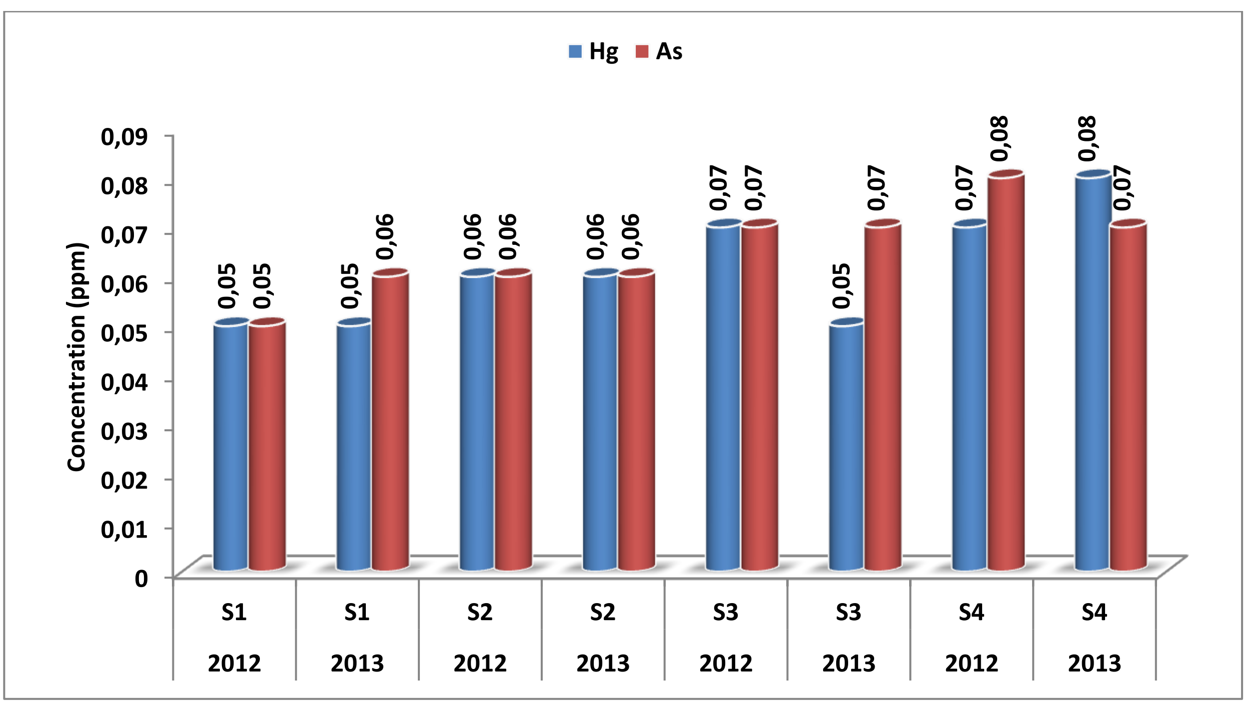

Figure 2. Variation in the average concentration of Mercury and Arsenic in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average values of concentration of Mercury and Arsenic in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 2.

The average concentration of Mercury in 2012 at sampling points S1, S2, S3, S4 was 0.05 ppm, 0.06 ppm, 0.07 ppm and 0.08 ppm respectively. The average concentration of Mercury in 2013 at sampling points S1, S2, S3, S4 was 0.05 ppm, 0.06 ppm, 0.05 ppm and 0.08 ppm respectively. The trend indicates that there was an increase in the concentration of Mercury each year. Also, there was an increase in concentration of mercury after the addition of effluent. For most inorganic mercury compounds, the acute lethal dose, for an adult is 1-4 g (or 14 to 57 mg/kg) for a 70 kg person [48].

Therefore exposure to mercury and its compounds can result to acute adverse health problems. It may permanently damage kidneys, brain and developing foetus. Mercury affects the functioning of brain which may result in memory problems, changes in vision or hearing, tremors and irritability. Mercury compounds inhibit cell growth and impair permeability in aquatic plants.

The average concentration of Arsenic in 2012 at sampling points S1, S2, S3, S4 was 0.05 ppm, 0.06 ppm, 0.07 ppm and 0.07 ppm respectively. The average concentration of Arsenic in 2013 at sampling points S1, S2, S3, S4 was 0.06 ppm, 0.06 ppm, 0.07 ppm and 0.07 ppm respectively. The trend indicates that there was an increase in the concentration of Arsenic, sampling point wise and year wise. Arsenic occurs naturally or is possibly aggravated by over powering aquifers and by phosphorus from fertilizers. Arsenic is usually accumulated in soil, water and airborne particles, from which it is taken up by various organisms. High concentrations of inorganic arsenic in surface waters increases the possibility of genetic alteration in fishes. This is mainly due to accumulation of arsenic in the bodies of plant-eating freshwater organisms. Plants absorb arsenic very easily as a result of which, so that higher arsenic concentrations may be present in food. High concentrations of arsenic in water can have an adverse effect on health [49,50]. In the past, high concentrations of arsenic were found in drinking water in six districts in West Bengal. A majority of people in the area were found suffering from arsenic skin lesions. Other causes of arsenic poisoning through water are skin cancer, liver and nervous system damage and vascular diseases. Arsenic poisoning has become a worldwide public health concern.

The skin is sensitive to arsenic and skin lesions are the most common and earliest non-malignant effects associated to chronic arsenic exposure [51]. Long-term inorganic arsenic exposure is associated with certain forms of cancer of skin, lung, colon, bladder, liver and breast [52]. The average values of concentration of Cadmium in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 3.

The average concentration of Cadmium in 2012 at sampling points S, S2, S3, S4 was 0.24 ppm, 0.38 ppm, 0.57 ppm and 0.67 ppm respectively. The average concentration of Cadmium in 2013 at sampling points S1, S2, S3, S4 was 0.30 ppm, 0.48 ppm, 4.62 ppm and 0.57 ppm respectively. The trend indicates that there was a increase in the concentration of Cadmium after the addition of effluent discharge from Dombivli MIDC Phase I and Phase II. Also if we compare the concentration values at each sampling point, there is an increase in concentration per year. The concentration of Cadmium in year 2013 at sampling point 3 was considerably higher (4.62 ppm).

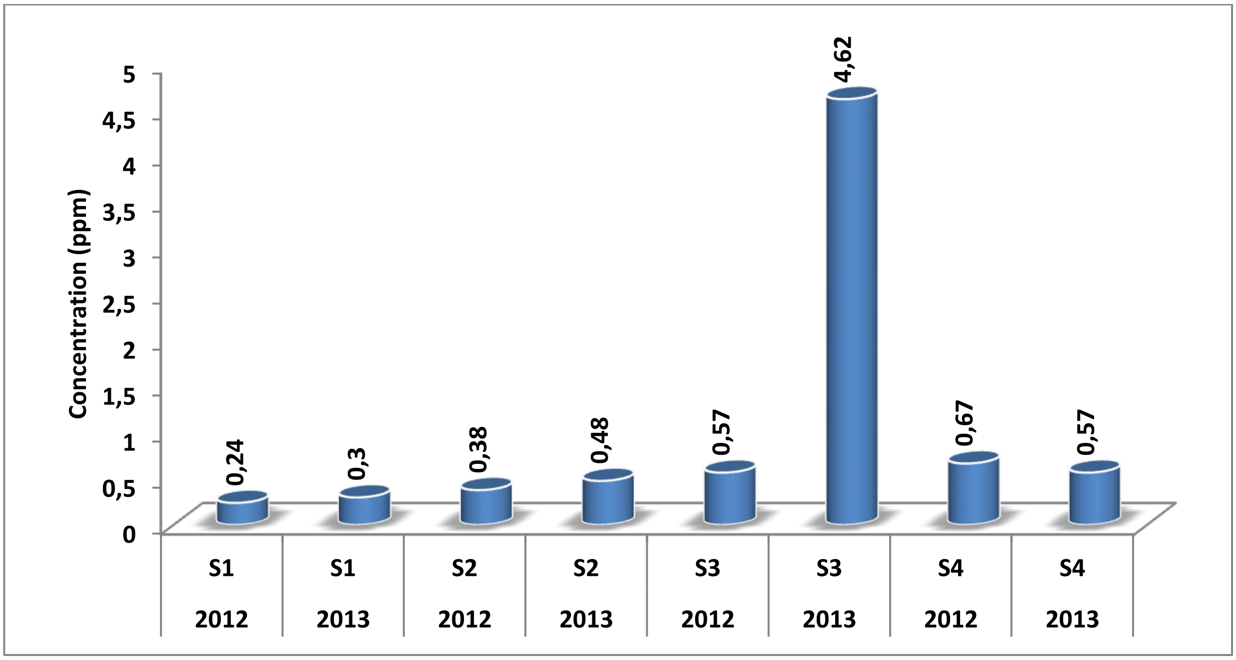

Figure 3. Variation in the average **c**oncentration of Cadmium in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

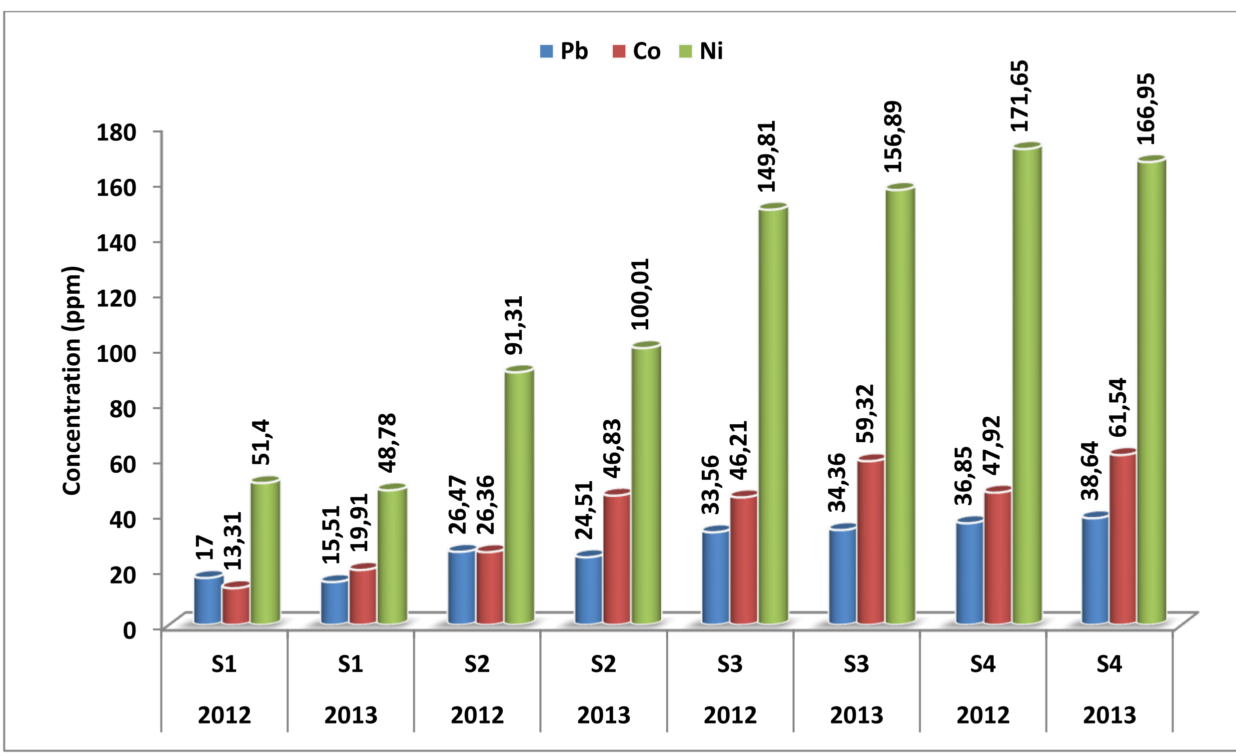

Figure 4. Variation in the average **c**oncentration of Lead, Cobalt and Nickel in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

This may be the result of the sporadic release of untreated effluent from textile industry, where cadmium is used as a mordant in the dyeing and printing of textiles. In the past there are incidences of Cadium poisoning in human beings after the consumption of contaminated fishes. It is less toxic to plants when compared with Copper, similar in toxicity to lead and chromium. It is equally toxic to invertebrates and fishes [21].

The average values of concentration of Lead, Cobalt and Nickel in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 4.

The average concentration of Lead in 2012 at sampling points S1, S2, S3, S4 was 17 ppm, 26.47 ppm, 33.56 ppm and 36.85 ppm respectively. The average concentration of Lead in 2013 at sampling points S1, S2, S3, S4 was 15.51 ppm, 24.51 ppm, 34.36 ppm and 38.64 ppm respectively. The trend indicates that the concentration of Lead in 2012 and 2013 were almost the same. However, the increase in concentration after the addition of effluent discharge is evident from the increasing concentration values of Lead sampling point wise. Lead is toxic in most of its chemical forms. It is an accumulative metabolic poison which affects the behavior, as well as the hematopoietic, vascular, nervous, renal, and reproductive systems. It can be incorporated into the body by dermal absorption, placental transfer to the fetus ingestion and inhalation. Lead is neither essential nor beneficial to living organisms.

The existing data indicate that the metabolic effects of Lead are adverse. Ecological and toxicological aspects of lead and its compounds in the environment have been extensively reviewed [53-58].

The average concentration of Cobalt in 2012 at sampling points S1, S2, S3, S4 was 13.31 ppm, 26.36 ppm, 46.21ppm and 47.92 ppm respectively. The average concentration of Cobalt in 2013 at sampling points S1, S2, S3, S4 was 19.91 ppm, 46.83 ppm, 59.32 ppm and 61.54 ppm respectively. Here we can distinctively observe that the concentration of Cobalt increases each year i.e. 2012 and 2013.

The data values also indicate that there is an increase in concentration of Cobalt at sampling point after the addition of effluent discharge from Dombivli industrial belt. The average concentration of Nickel in 2012 at sampling points S1, S2, S3, S4 was 51.40 ppm, 91.31 ppm, 149.81ppm and 171.65 ppm respectively. The average concentration of Nickel in 2013 at sampling points S1, S2, S3, S4 was 48.78 ppm, 100.01 ppm, 156.89 ppm and a slight increase in concentration to 166.95 ppm respectively. The trend is almost similar to that of lead. In aquatic life, Nickel has the potential to accumulate, however its magnification along in food chain is not confirmed [59]. Decreased body weight, heart and liver damage, and skin irritation are caused due to long term exposure to nickel [59]. For rats, the LDLO (lethal dose low) of Nickel is 12 mg/kg.

The average values of concentration of Chromium, Copper and Zinc in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 5.

The average concentration of Chromium in 2012 at sampling points S1, S2, S3, S4 was 85.01 ppm, 125.43 ppm, 181.33 ppm and 225.78 ppm respectively and that in 2013 at sampling points S1, S2, S3, S4 was 90.56 ppm, 195.85 ppm, 216.92 ppm and 238.35 ppm respectively which shows an increasing trend per year and per sampling point. The values highlight increase in chromium pollution each year and after the discharge of industrial effluents in the Ulhas River. Chromium is a skin sensitizer and causes skin sensitizing effect in the general public.

Chromium penetrates the skin and cause painless erosive ulceration ("chrome holes") with delayed healing. This commonly occurs on fingers, knuckles, and forearms. The characteristic chrome sore initially forms a papule followed by forming an ulcer with raised hard edges. These ulcers can penetrate deep into soft tissue or become the sites of secondary infection. These secondary sites of infection are not known to lead to malignancy [60,61]. Besides the intestinal tract and lungs, many times chromate toxicity also targets other organs such as liver and kidney [62].

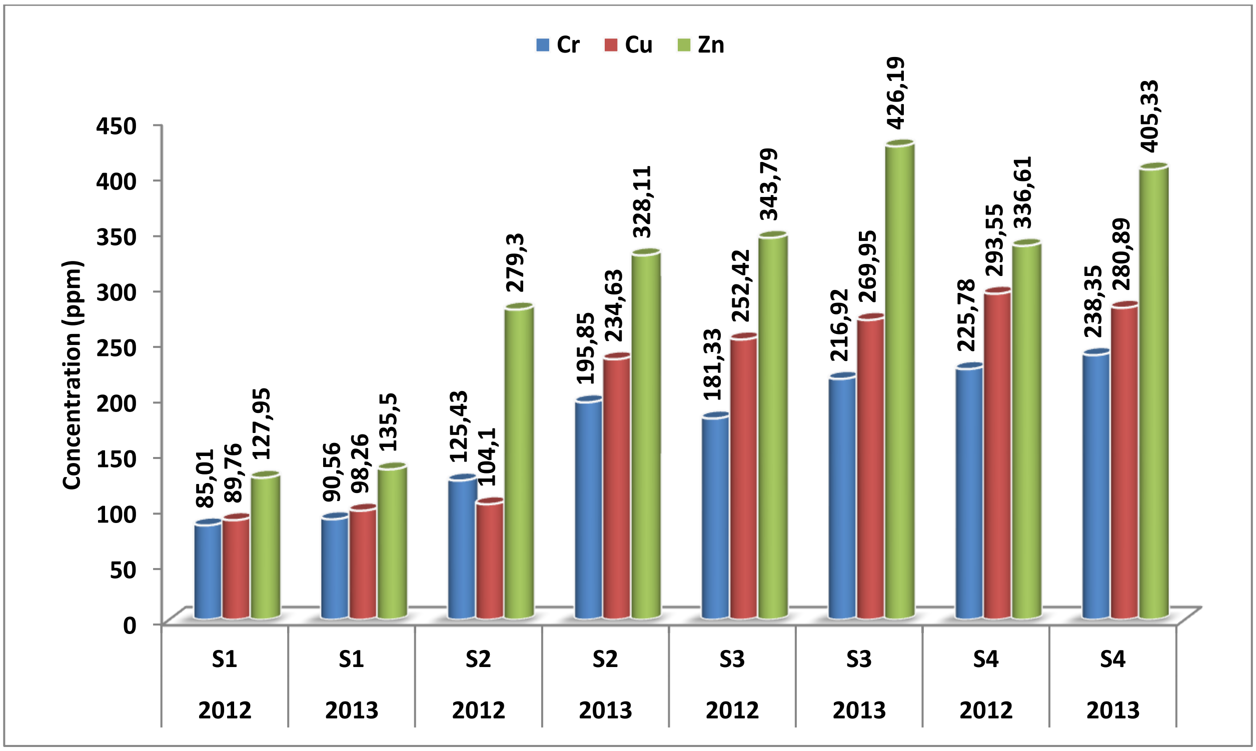

Figure 5. Variation in the average **c**oncentration of Chromium, Copper and Zinc in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average concentration of Copper in 2012 at sampling points S1, S2, S3, S4 was 89.76 ppm, 104.1 ppm, 252.42 ppm and 293.55 ppm respectively. The average concentration of Copper in 2013 at sampling points S1, S2, S3, S4 was 98.26 ppm, 234.63 ppm, 269.95 ppm and 280.89 ppm respectively. We can observe that at the sampling point after the discharge of industrial effluent, the concentration of Copper increases. The average concentration of copper at each sampling point has also increased in year 2013 as compared to year 2012. Aquatic plants absorb three times more copper than plants on dry lands. Copper is readily accumulated by plants and animals [63]. Excess copper content can damage roots, by attacking the cell membrane and destroying the normal membrane structure thus inhibiting root growth and formation of numerous short, brownish secondary roots. Copper is highly toxic to most fishes, aquatic plants and invertebrates. It reduces growth and rate of reproduction in plants and animals. 0.02-0.2 mg/L is the chronic level of copper [21].

The average concentration of Zinc in 2012 at sampling points S1, S2, S3, S4 was 127.95 ppm, 279.3 ppm 343.79 ppm and 336.61 ppm respectively.

The average concentration of Zinc in 2013 at sampling points S1, S2, S3, S4 was 135.5 ppm, 328.11 ppm, 426.19 ppm and 405.33 ppm respectively. The concentration of Zinc at sampling point S4 was observed to be less than that at sampling point S3 in both the years. Excessive concentration of Zinc may result in necrosis, chlorosis and inhibited growth in plants [59]. Exposure to Zinc causes metal-fume fever with symptoms like fever, fatigue, pain, sweating, shivering.

The average values of concentration of Iron in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 6.

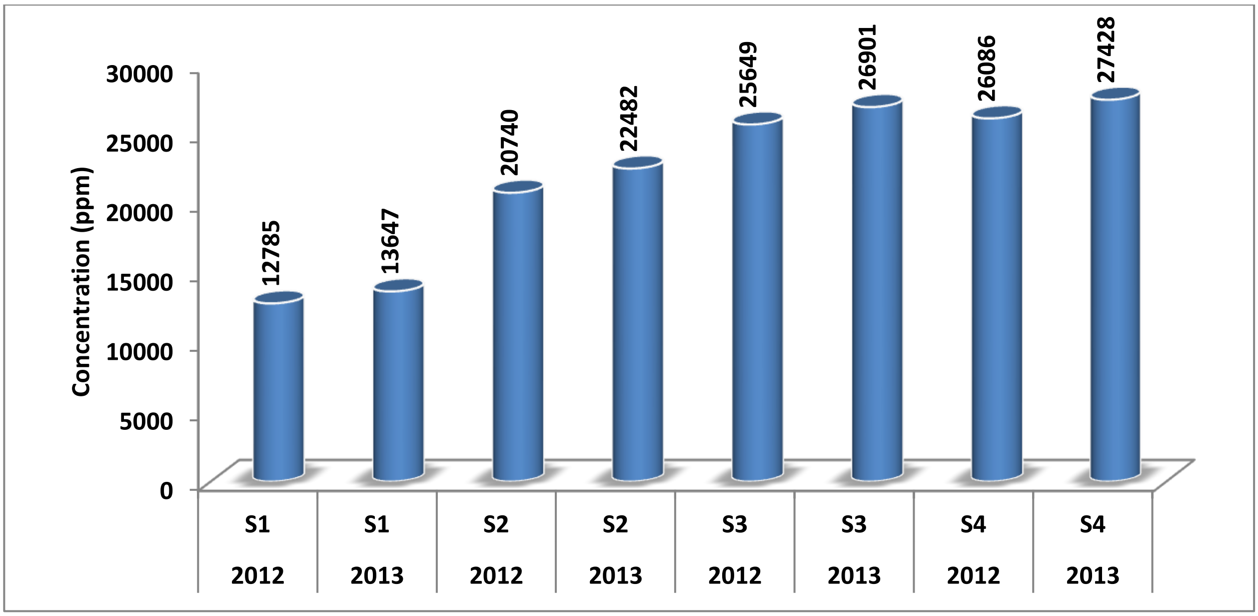

Figure 6. Variation in the average **c**oncentration of Iron in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average concentration of Iron in 2012 at sampling points S1, S2, S3, S4 was 12785 ppm, 20740 ppm 25649 ppm and 26086 ppm respectively. The average concentration of Iron in 2013 at sampling points S1, S2, S3, S4 was 13647 ppm, 22482 ppm, 26901 ppm and 27428 ppm respectively. The values clearly indicate the increasing pollution of Iron. High concentration of iron may increase the hazard of pathogenic organisms, since most of these organisms need iron for their growth [59].

4. CONCLUSIONS

The extensive industrialization along the Dombivali industrial belt has resulted to an increase in discharge of effluents into the Ulhas River. Though most of major industries have treatment facilities for industrial effluents. In case of small scale industries, they do not afford huge investment for pollution control facility since they have fewer profit margins. As a result there are sufficient evidences available related to the mismanagement of industrial wastes. Therefore, at the end of each time period the pollution problem takes menacing concern. In the present study, it is evident that the concentration of toxic heavy metals in the river sediment is increasing due to release of industrial effluent from Dombivli industrial belt Phase I and Phase II.

The high concentration of heavy metals in sediment may result into an increase in concentration of heavy metals in the above surface water. Also, the data highlights that there is an increase in pollution, which is evident from the increasing sediment heavy metal concentration values in year 2013 as compared to those in year 2012.

The present experimental data on quantification of toxic heavy metals in the sediment of Ulhas River along the Dombivli city will be useful in rational planning of pollution control strategies and their prioritization; to assess the nature and extent of pollution control needed; to evaluate effectiveness of pollution control measures already in existence. The present study of heavy metals in sediments will also help to provide a means for evaluating the long term accumulation of heavy metal contaminants in the sediment ecosystem of the Ulhas River.

References

1. Zingde M.D., Govindan K., Health status of coastal waters of Mumbai and regions around. In: Environmental Problems of Coastal Areas in India (ed. Sharma, V. K.), Bookwell Publ., New Delhi, (2001) pp.119–132.
2. Rajaram T., Das A., *Futures*, 40 (2008), 56.
3. Khurshid S., Abdul B., Zaheeruddin, Usman S.M., *Indian J. Environ. Health*, 40 (1998) 45.
4. Pachpande B.G., Ingle S.T., *Orient J. Chem.*, 20 (2004) 117.
5. Prabha S., Selvapathy P., *Indian J. Environ. Prot.*, 17 (1997) 641.
6. Singare P.U., Lokhande R.S., Pathak P.P., *J. Environmental Protection*, 1 (2010) 121.
7. Singare P.U., Lokhande R.S., Pathak P.P., *Interdisciplinary Environmental Review*, 11, (2010) 38.
8. Sharma R. K., Agrawal M., Marshall F.M., ‘Effects of waste water irrigation on heavy metal accumulation in soil and plants’, Paper presented at a National Seminar, Bangalore University, Bangalore, Abst. no. 7, (2004) 8.
9. Ward, N. I. ‘Environmental analytical chemistry’ *In*: Fifield, F. W. and Haines, P. J. (eds.), *Trace Elements*, UK: Blackie Academic and Professional, (1995) pp.320–328.
10. Kureshi T.W., Mesquita A.M., Sengupta R., *Contrib. Mar. Sci*., 60 (1987) 29.
11. Anon., Sixth Annual Progress Report (July 1991–June 1992), Industrial Toxicology Research Centre, Lucknow, (1992) pp. 123.
12. Anon., *Down to Earth*, 12, (2003) 63.
13. Govindsamy C., Roy Viji A.G., Jayapaul A., *Int. J. Ecol. Environ. Sci*., 24, (1998)141.
14. Salomons W., Forstner U., ‘Metals in the Hydrocycle’, Springer-Verlag, New York, (1984) pp.5-62.

15. Lee B.G., Griscom S.B., Lee J.S., Choi H.J., Koh C.H., Luoma S.N., Fisher N.S., *Science*, 287 (2000) 282.
16. Weston D.P., Maraya K. A., *Environ Toxicol Chem.*, 21 (2002) 962.
17. Adams W.J., Kimerle R.A., Barnett J.W. Jr, *Environ. Sci. Technol.*, 26 (1992) 1864.
18. Maher W., Batley G.E., Lawrence I., *Freshw Biol*., 41(1999) 361.
19. Kennicutt M.C., Wade T.L., Presley B.J., Requejo A.G., Brooks J.M., Denoux G.J., *Environ. Sci. Technol.*, 28 (1993) 1.
20. Johansson J. and Rasmussen L., *Bryologist*, 80 (1977) 625.
21. Moore, J.W. and Ramamoorthy, S., *Heavy Metals in Natural Waters: Applied Monitoring and Impact Assessment*, Springer-Verlag, New York (1984) pp.28-246.
22. Singare P.U., Lokhande R.S., Naik K.U., *Interdisciplinary Environmental Review*, 11(2010) 90.
23. Maharashtra Pollution Control Board (2010–2011) 'Annual Report', 14, 24.
24. Lokhande R.S., Singare P.U., Pimple D.S., *New York Science Journal*, 4 (2011) 66.
25. Rainwater F.H., Thatchar L.L., 'Methods for Collection and Analysis of Water Samples' *U.S. Geol. Surv. Water Supply Papers*, 1454 (1960) 1-301.
26. Brown E., Skougstad M.W., Fishman M.J., 'Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases', *Techniques of Water Resources Investigations of the U.S. Geological Survey*, 160, Book 5, Chapter A1(1970).
27. ICMR, Indian Council of Medical Research, Manual of Standards of Quality for Drinking Water Supplies (1975).
28. Menon J.S., and Mahajan S.V., *Our Nature*, 8 (2010) 170.
29. Rathod S.D., Patil N.N., Quadros G., Athalye R.P., 'Qualitative study of finfish and shellfish fauna of Thane creek and Ulhas River estuary', in Proc. of the National Seminar on Creeks, Estuaries and Mangroves – Pollution and Conservation, Vidya Prasarak Mandal's B.N. Bandodkar College of Science, Thane, India, 28–30 November 2002, pp.135 –141.
30. P.U. Singare, S.S. Dhabarde**,** *European Journal of Environmental and Safety Sciences*, 2 (2014) 5.
31. P.U. Singare, S.S. Dhabarde**,** *Interdisciplinary Environmental Review*, 15 (2014) 20.
32. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 56.
33. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 48.
34. P.U. Singare, S.S. Dhabarde**,** *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 40.

35. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 32.
36. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 24.
37. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astronomy*, 3 (2014)16.
38. P.U. Singare, S.S. Dhabarde, *International Letters of Chemistry, Physics and Astro*nomy, 3 (2014) 8.
39. Action Plan for Industrial Cluster "Dombivali", Maharashtra Pollution Control Board, November 2010. http://www.mpcb.gov.in
40. Chen, M., Ma, L.Q., *Soil Science Society of American J*ournal, 65 (2001) 491.
41. Clesceri, L.S., 'Standard methods for the examination of water and waste water', in Arnold, E., Greenbergy and Eaton, A. D. (Eds.): *Collection and Preservation of Samples and Metals*, APHA, AWWA, WEF, Washington DC, (1998) pp.1-27–1-35, 3-1–3-21.
42. Paar, A., *Microwave Sample Preparation System – Instruction Handbook*, Anton Paar GmbH, Austria (1998) pp.128.
43. Jeffery G.H., Bassett J., Mendham J., Denny R.C., *Vogel's Textbook of Quantitative Chemical Analysis*, Longman Scientific & Technical, England, 5th Edition, (1989) pp. 788-789.
44. Hem J.D., '*Study and Interpretation of Chemical Characteristics of Natural Water*', 3rd edition U.S. Geological Survey, Washington (1985).
45. American Public Health Association (APHA), 'Standard Methods for Estimation of Water and Wastewater', 19th edition, *American Water Works Association*, Water environment Federation, Washington, (1995).
46. Jackson M.L., 'Soil Chemical Analysis', New Delhi: Prentice-Hall of India Private Limited (1973).
47. Lark B.S., Mahajan R.K., Walia T.P.S., *Indian J. Environ. Health*, 44 (2002) 164.
48. Agency for Toxic Substances and Disease Registry (ATSDR) 'Case studies in environmental medicine', *Mercury Toxicity*, US Public Health Service, US Department of Health and Human Services, Atlanta, GA (1992).
49. Cai, L., Liu, G., Rensing, C., Wang, G., *BMC Microbiology*, 9 (2009) 4.
50. Pokhrel, D., Bhandari, B.S., Viraraghavan, T., *Environment International*, 35 (2009) 157.
51. Gbaruko, B.C., Ana, G.R.E.E., Nwachukwu, J.K., *African Journal of Biotechnology*, 7 (2008) 4737.
52. Kazi, T.G., Arain, M.B., Baig, J.A. *The Science of the total environment*, 407 (2009) 1019.

53. EPA. 1985. Ambient water quality criteria for lead - 1984. U.S. Environ. Protection Agency Rep. 440/5-84-027. pp. 81 Available from Natl. Tech. Infor. Serv., 5285 Port Royal Road, Springfield, Virginia 22161.
54. Feierabend, J.S.,Russell, A.B., (eds.), Lead poisoning in wild waterfowl - a workshop. National Wildlife Federation, 1412 Sixteenth St. NW, Washington, D.C. (1986) pp.139.
55. FWS. Use of lead shot for hunting migratory birds in the United States. Final supplemental environmental impact statement. pp. 535 Available from U.S. Fish Wildlife Service, Office of Migratory Bird Management, Washington, D.C. 20240 (1986).
56. Lansdown, R., W. Yule (eds.). Lead toxicity. History and environmental impact, Johns Hopkins Univ. Press, Baltimore, Maryland. (1986) pp.286.
57. McDonald, L.J., *Can. Vet. J.*, 27 (1986) 131.
58. Sanderson, G.C., Bellrose, F.C., *Illinois Natural History Survey*, Spec. Publ. (SP-04) (1986) 1.
59. Tiwana, N.S., Jerath, N., Singh, G., Ravleen, M. (Eds.) ‘Heavy metal pollution in Punjab Rivers’, in *Newsletter Environmental Information System (ENVIS)*, Punjab State Council for Science and Technology, India, Vol. 3, No. 1, (2005) pp. 3–7.
60. Geller, R., "Chromium." In: Clinical Environmental Health and Toxic Exposures. Sullivan, J.B., Jr. and Krieger, G.R., editors. 2nd Ed. Lippincott Williams & Wilkins, Philadelphia, PA (2001).
61. Meditext - Medical Management, "Chromium Hexavalent Salts." TOMES Information System. Denver, CO: Micromedex, Inc (2005).
62. Rom, W. N., Environmental and Occupational Medicine. 4th Ed. by Lippincott Williams & Wilkins (2007).
63. Centre for Ecological Sciences, IIS (2001) ‘Environmental hand book – documentation on monitoring and evaluating environmental impacts’, *Compendium of Environmental Standards*, Vol. III, Indian Institute of Science, Bangalore, available at http://wgbis.ces.iisc.ernet.in/energy/HC270799/HDL/ENV/enven/vol329.htm#copper (accessed on 03/05/2015).

(Received 22 April 2015; accepted 04 May 2015)