

Heavy Metals in Vasai Creek, Mumbai: Applied Monitoring and Impact Assessment

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Abstract The present study deals with the assessment of toxic heavy metals in water of Vasai Creek of Mumbai. The study was carried for the assessment years 2009-10 and 2010-11 at four different sampling stations. The heavy metals studied were Al, As, Cd, Cr, Hg, Ni, Pb, Sr and Mn. It was observed that the concentration level of the various toxic heavy metals for the year 2010-11 was higher than that obtained during the year 2009-10 by a factor of 1.1 to 1.5 µg/L. The environmental impact of these toxic heavy metals is discussed. The results of the present investigation point out the need to implement adequate environmental control and management programmes so as to minimise the toxicity effects of the heavy metals on marine life.

Keywords Heavy Metals, Toxicity, Marine Life, Environmental Impact, Quantification, Atomic Absorption Spectroscopy, Cold Vapour Technique, Vasai Creek, Mumbai, India

1. Introduction

Land and water are precious natural resources on which rely the sustainability of agriculture and the civilization of mankind. Unfortunately, they have been subjected to maximum exploitation and severely degraded or polluted due to anthropogenic activities. The pollution includes point sources such as emission, effluents and solid discharge from industries, vehicle exhaust and metals from smelting and mining, and nonpoint sources such as soluble salts (natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers[1,2]. Each source of heavy metals contamination has its own damaging effects to plants, animals and ultimately to human health, but those sources that contaminate soils and waters are of serious concern due to the persistence of these heavy metals in the environment and carcinogenicity to human beings. These heavy metals cannot be destroyed biologically but are only transformed from one oxidation state or organic complex to another[3, 4]. The environmental parameters of waters effect toxicity of the metal either by influencing physiology of organisms or by altering chemical form of the metal in water. In general, metals are less toxic at lower temperatures and high salinity than at high temperatures and lower salinity. Toxicity of a metal is also dependent upon residence time of metals concerned. Generally, most metals

have a long residence time and hence exert their toxic effect over a long time.

The toxicity of heavy metals has long been concerned since it is very important to the health of people and ecology. With the growing interest in pollution of marine environment, many countries are conducting monitoring studies on metals in aquatic marine environment. Therefore, this heavy metal pollution possessing a potential threat to the environment and human health has become a national and international problem. Extensive work has been carried out recently all over the world on heavy metals in different rivers[5-7]. In Western Europe, 1,400,000 sites were affected by heavy metals[1], of which, over 300,000 were contaminated, and the estimated total number in Europe could be much larger, as pollution problems increasingly occurred in Central and Eastern European countries[8]. In India, use of heavy metal fungicides in agriculture is increasing as seed-dressing agents. Antifouling properties of mercury compounds are yet used in pulp mills, industrial and domestic sewage wastes from various sources are now a threat to the survival of fishes and other organisms. The common feature of these metals is that they are all relatively toxic even at fairly low concentrations and are readily concentrated by aquatic organisms, and plants. The seriousness of heavy metal contamination is further compounded by the fact that they are generally water soluble, non-degradable, vigorously oxidizing and are strongly bonded to many biochemicals inhibiting their functions. Today, additional quantities of heavy metals are being added to estuarine and coastal regions from agricultural and industrial waters, hospitals, domestic sewage and from the polluted atmosphere. At sufficiently

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Published online at <http://journal.sapub.org/scit>

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high concentrations, heavy metals are toxic to marine and estuarine organisms and to their consumers at higher trophic levels including man.

The preservation of aquatic resources for ecosystem and human health and well-being is a paramount concern worldwide and it has become evident that approaches to managing aquatic resources must be undertaken within the context of ecosystem dynamics in order that their exploitation for human uses remains sustainable[9]. If aquatic resources are not properly managed and aquatic ecosystems deteriorate, then human health and well-being may be compromised. Water quality monitoring for the detection of trends, impacts, and improvements is further complicated because the issues of concern and available resources are constantly changing[10]. Although it is not always possible to predict new and emerging threats to aquatic ecosystems, baseline water quality monitoring must be maintained to facilitate the early detection of such threats. The success of local, regional, and global efforts to curb rates of water quality degradation is only possible if sufficient monitoring data are available that enable the tracking of trends over time and space.

The problem of environmental pollution due to heavy metals has begun to cause concern now in most of the major metropolitan cities in Maharashtra state and Mumbai is not an exception to it. The day by day increasing tremendous industrial pollution[11-20] has prompted us to carry the systematic and detail study of water pollution due to toxic heavy metals in Vasai Creek of Mumbai which is becoming highly polluted due to rapid urbanisation and industrialisation.

2. Materials and Methods

2.1. Area of Study

Vasai Creek is an estuarine creek, one of the two main distributaries of the Ulhas Creek in Maharashtra state of western India. The Ulhas Creek splits at the northeast corner of Salsette Island into its two main distributaries, Vasai Creek and Thane Creek. Vasai Creek which lies between latitude 19.315°N longitude 72.875°E, forms the northern boundary of Salsette Island, and empties west into the Arabian Sea. The Creek receives domestic raw sewage as well as industrial waste water effluent from surrounding habitation and nearby industrial belt. The activities like cattle washing, cloth washing, and religious activities like immersion of idols of Lord Ganesha and Deity Durga during Ganesh festival and Navratri festival is also a major source of pollution of creek water.

2.2. Climatic Conditions

Climate is subtropical, with mild winters and warm summers. The weather is typical coastal sultry and humid. The average rainfall of records from 1500 mm to 2000 mm. The place experiences the onset of the monsoon in the month

of June and experiences monsoon till the end of September. The average temperature recorded in varies from 25 to 37 degrees.

2.3. Requirements

The chemicals and reagent used for analysis were of analytical reagent grade. The procedure for calculating the different parameters were conducted in the laboratory. The laboratory apparatus were soaked in nitric acid before analysis and then rinsed thoroughly with tap water and de-ionised distilled water to ensure any traces of cleaning reagents were removed. Finally, it is dried and stored in a clean place. The pipettes and burette were rinsed with the same solution before final use.

2.4. Water Sampling and Sample Preparation

The water samples were collected randomly four times in a month in morning, afternoon and evening session at four different sampling stations namely near Vasai Bunder (*S-1*), Bhayandar west side of Railway Bridge (*S-2*), Bhayandar east side near RetiBundar (*S-3*), and Ghodbundar site (*S-4*) along the Vasai Creek (Figure 1). The samples were collected and subsequently analysed for a span of two years starting from October 2009 to September 2011. The sampling was done in three shifts i.e. morning shift between 07:00 a.m. to 09:00 a.m., afternoon shift between 02:00 p.m. to 04:00 p.m. and evening shift between 07:00 p.m. to 09:00 p.m. Polythene bottles of 2.5 L and 2.0 L were used to collect the grab water samples (number of samples collected, $n = 19$). The bottles were thoroughly cleaned with hydrochloric acid, washed with tap water to render free of acid, washed with distilled water twice, again rinsed with the water sample to be collected and then filled up the bottle with the sample leaving only a small air gap at the top. The sample bottles were stoppered and sealed with paraffin wax. Water samples (500 mL) were filtered using Whatman No. 41 (0.45 μ m pore size) filter paper for estimation of dissolved metal content. Filtrate (500 mL) was preserved with 2 mL nitric acid to prevent the precipitation of metals. The samples were concentrated to tenfold on a water bath and subjected to nitric acid digestion using the microwave-assisted technique, setting pressure at 30 bars and power at 700 Watts[21,22]. About 400 mL of the sample was transformed into clean glass separating funnel in which 10 mL of 2% ammonium pyrrolidine dithiocarbamate, 4 mL of 0.5 M HCl and 10 mL of methyl isobutyl ketone (MIBK) are added[23]. The solution in separating funnel was shaken vigorously for 2 min and was left undisturbed for the phases to separate. The MIBK extract containing the desired metals was then diluted to give final volumes depending on the suspected level of the metals[24]. The sample solution was then aspirated into air acetylene flame in an atomic absorption spectrophotometer.

2.5. Heavy Metal Analysis by AAS Technique

The analysis for the majority of the trace metals like aluminum (Al), cadmium (Cd), chromium (Cr), nickel (Ni),

precision of the analytical method and instrument. To validate the analytical procedures used, the spike recovery test was conducted on some samples for Al, As, Cd, Cr, Ni, Pb, Sr, Mn and Hg.

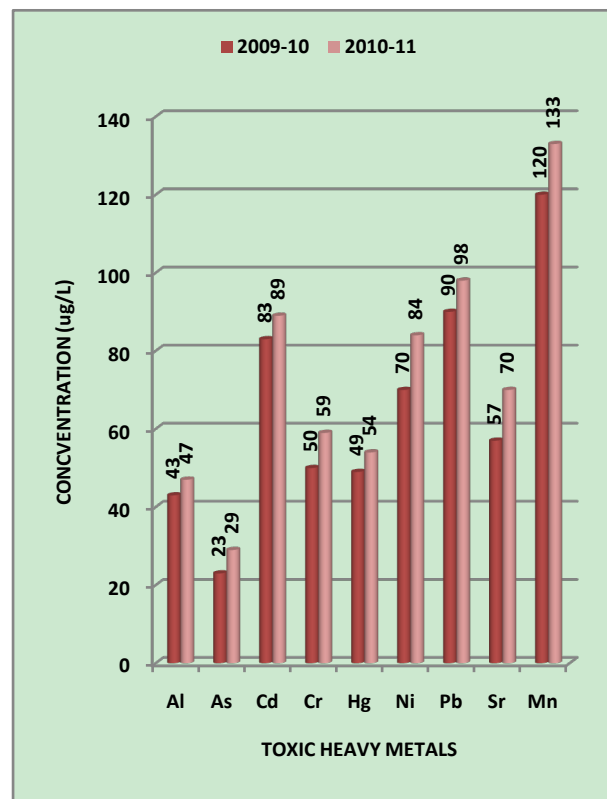
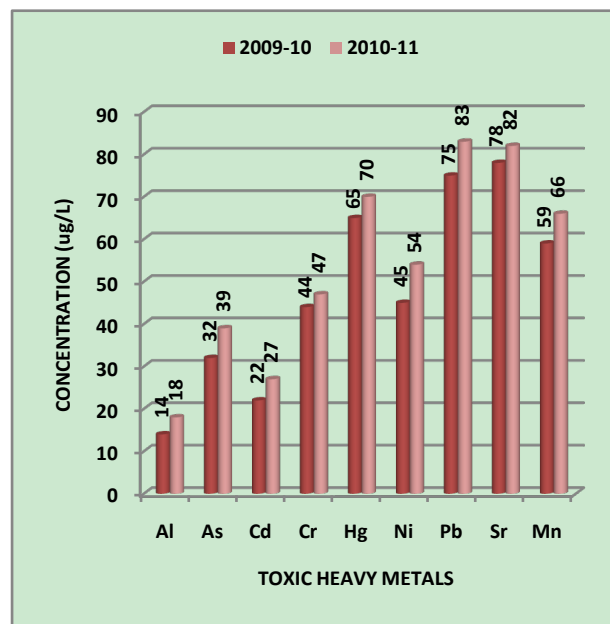
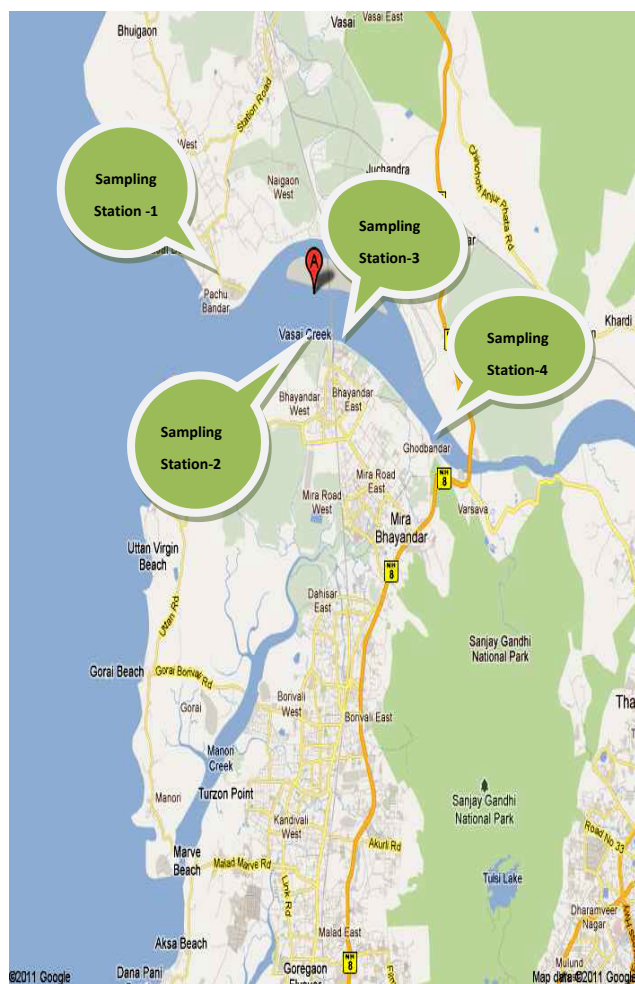


Figure 3. Variation in average concentration values of different toxic heavy metals in water samples collected at S-2 sampling station of Vasai Creek during the assessment year 2009-10 and 2010-11

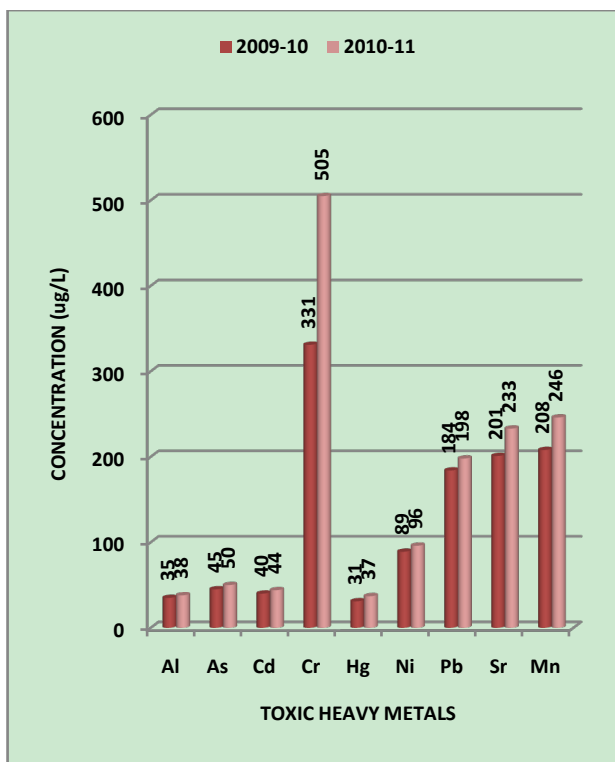


Figure 4. Variation in average concentration values of different toxic heavy metals in water samples collected at S-3 sampling station of Vasai Creek during the assessment year 2009-10 and 2010-11

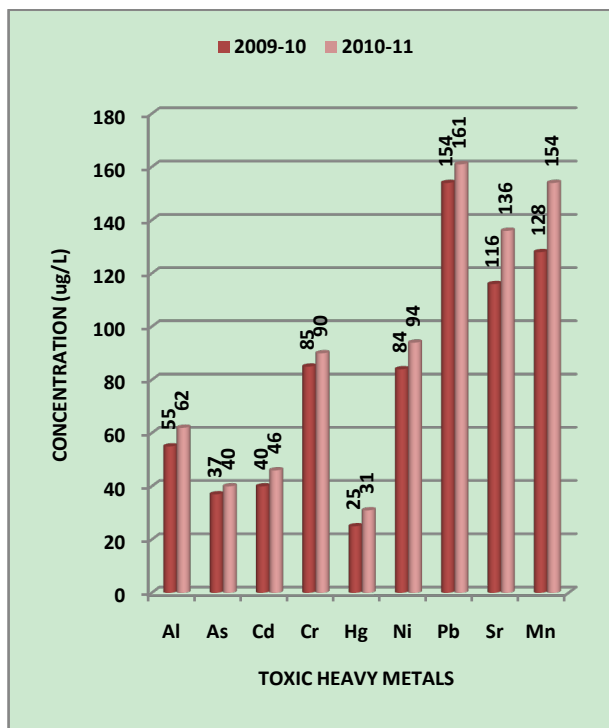


Figure 5. Variation in average concentration values of different toxic heavy metals in water samples collected at S-4 sampling station of Vasai Creek during the assessment year 2009-10 and 2010-11

3. Results and Discussion

Although there is no clear definition of what a heavy metal

is, density is in most cases taken to be the defining factor. Heavy metals are thus generally defined as those having a specific density of more than 5 g/cm³. Heavy metals are among the most common environmental pollutants, and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources. Although adverse health effects of heavy metals have been known for a long time, discharge of heavy metals continues and is even increasing in some areas, in particular in less developed countries. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic (arsenic is a metalloid, but is usually classified as a heavy metal). Their accumulation and distribution in soil and aquatic environment are increasing at an alarming rate thereby affecting marine life[25-27]. The experimental data on concentration (µg/L) of toxic heavy metals like Al, As, Cd, Cr, Hg, Ni, Pb, Sr and Mn in the water samples collected along sampling stations S1, S2, S3 and S4 of Vasai Creek is presented in Table 1. The trend in average concentration of these metals at different sampling stations for the assessment years 2009-10 and 2010-11 is graphically represented in Figures 2-5.

The effects of aluminum (*Al*) have drawn our attention, mainly due to the acidifying problems. Aluminum may accumulate in plants and cause health problems for animals that consume these plants. The concentrations of aluminum appear to be highest in acidified aquatic environment[28]. In such aquatic environment the number of fish and amphibians is declining due to reactions of aluminum ions with proteins in the gills of fish and the embryo's of frogs[29, 30]. From the results of present investigation it was observed that *Al* concentration at different sampling stations lies in the range of 10-25, 28-80, 17-65 and 43-70 µg/L at S1, S2, S3 and S4 sampling stations respectively. The biyearly average *Al* concentration was found to be 16, 45, 36 and 58 µg/L respectively at different sampling stations (Table 1). It was also observed that the average *Al* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.09 at S2 and S3 sampling stations to 1.29 at S1 sampling station (Figures 2-5).

Levels of arsenic (*As*) are higher in the aquatic environment than in most areas as it is fairly water-soluble and may be washed out of arsenic bearing rocks[31]. Recently, the anthropogenic activities such as treatment of agricultural land with arsenical pesticides, treating of wood using chromated copper arsenate, burning of coal in thermal plants power stations and the operations of gold-mining have increased the environmental pervasiveness of *As* and its rate of discharge into freshwater habitat [32]. *As* can also interfere with the fish immune system by suppressing antibody production[33] as well as by lowering macrophage activity and maturation[34]. Several studies are reporting *As* induced liver fibrosis, hepatocellular damage, inflammation, focal necrosis in addition to hepatocellular carcinoma[35, 36]. In the present investigation it was observed that *As* concentration at S1, S2, S3 and S4 sampling stations lies in

the range of 15-59, 11-51, 15-68 and 10-62 $\mu\text{g/L}$ respectively. The biyearly average *As* concentration was found to be 35, 26, 47 and 38 $\mu\text{g/L}$ respectively at different sampling stations (Table 1). It was also observed that the average *As* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.08 at S4 to 1.26 at S2 (Figures 2-5).

Cadmium (*Cd*) is typically a metal of the 20th century, and is mainly used in rechargeable batteries and for the production of special alloys. It was the outbreak of the Itai-Itai bone disease in Japan in the 1960s that really drew the attention of the public and regulatory bodies to this heavy metal that had been discharged in the environment at an uncontrolled rate for more than one century. Although emissions in the environment have markedly declined in most industrialized countries, *Cd* remains a source of concern for populations living in polluted areas, especially in less developed countries[37]. *Cd* dispersed in the environment can persist in soils and sediments for decades. When taken up by plants, *Cd* concentrates along the food chain and ultimately accumulates in the body of people eating contaminated foods. By far, the most salient toxicological property of *Cd* is its exceptionally long half-life in the human body. Once absorbed, *Cd* irreversibly accumulates in the human body, in particularly in kidneys, the bone, the respiratory tract and other vital organs such the lungs or the liver[38]. In addition to its extraordinary cumulative properties, *Cd* is also a highly toxic metal that can disrupt a number of biological systems, usually at doses that are much lower than most toxic metals[39-41]. In the present investigation it was observed that *Cd* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 12-38, 19-114, 14-55 and 15-75 $\mu\text{g/L}$ respectively. The biyearly average *Cd* concentration was found to be 24, 86, 42 and 43 $\mu\text{g/L}$ respectively at different sampling stations (Table 1). It was also observed that the average *Cd* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.07 at S2 to 1.23 at S1 (Figures 2-5).

Chromium (*Cr*) is one of the most common skin sensitizers and often causes skin sensitizing effect in the general public. A possible source of chromium exposure is waste dumps for chromate-producing plants causing local air or water pollution. Penetration of the skin will cause painless erosive ulceration ("chrome holes") with delayed healing. These commonly occur on the fingers, knuckles, and forearms. The characteristic chrome sore begins as a papule, forming an ulcer with raised hard edges. Ulcers can penetrate deep into soft tissue or become the sites of secondary infection, but are not known to lead to malignancy[42, 43]. Besides the lungs and intestinal tract, the liver and kidney are often target organs for chromate toxicity[44]. In the present investigation it was observed that *Cr* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 22-64, 34-103, 80-782 and 54-111 $\mu\text{g/L}$ respectively. The biyearly average *Cr* concentration was found to be 45, 54, 418 and 88

$\mu\text{g/L}$ respectively at different sampling stations (Table 1). It was also observed that the average *Cr* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.06 at S4 to 1.53 at S3 (Figures 2-5).

Mercury (*Hg*) poisoning has become a problem of current interest as a result of environmental pollution on a global scale. High concentration of mercury, which could pose an ecological hazard, leading to contamination of plants, aquatic resources and bioaccumulation in the food chain[45]. Although elemental mercury is relatively innocuous and non-toxic, it can be converted to organomercurials, which are particularly toxic and are retained in the cells of plants and living organisms. Bodaly et al.[46] have reported that treated sewage water discharged into rivers and similar water bodies could result in an appreciable increase in the build up of alkyl mercury. Further reports by Tanaka[47] and Goldstone et al.[48] have dwelt on the natural alkylation of total mercury in waste water and water bodies. In the present investigation it was observed that *Hg* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 10-131, 10-101, 10-67 and 12-48 $\mu\text{g/L}$ respectively. The biyearly average *Hg* concentration was found to be 67, 52, 34 and 28 $\mu\text{g/L}$ respectively at different sampling stations (Table 1). It was also observed that the average *Hg* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.08 at S1 to 1.24 at S4 (Figures 2-5).

Nickel (*Ni*) and nickel compounds have many industrial and commercial uses, and the progress of industrialization has led to increased emission of pollutants into ecosystems. Nickel is a nutritionally essential trace metal for at least several animal species, micro-organisms and plants, and therefore either deficiency or toxicity symptoms can occur when, respectively, too little or too much *Ni* is taken up. Although a number of cellular effects of nickel have been documented, a deficiency state in humans has not been described[49-52]. Although *Ni* is omnipresent and is vital for the function of many organisms, concentrations in some areas from both anthropogenic release and naturally varying levels may be toxic to living organisms[53, 54]. Nickel compounds have been well established as carcinogenic in many animal species and by many modes of human exposure but their underlying mechanisms are still not fully understood[55]. Nickel can cause cancer of the lungs and nasal passages. The most common effect of nickel exposure is an allergic reaction. Approximately 10-15% of the population is sensitive to nickel. The most common reaction is a rash at the site of contact. Less frequently, some people that are sensitive to nickel suffer asthma attacks after exposure. Some workers exposed to high levels of nickel have developed chronic bronchitis and changes to their lungs. In the present investigation it was observed that *Ni* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 15-105, 18-125, 15-146 and 10-145 $\mu\text{g/L}$ respectively. The biyearly average *Ni* concentration was

found to be 49, 77, 93 and 89 µg/L respectively at different sampling stations (Table 1). It was also observed that the average *Ni* concentration for assessment year 2010-11 was

higher than that obtained for the assessment year 2009-10 by a factor of 1.08 at S3 to 1.20 at S1 and S2 (Figures 2-5).

Table 1. Heavy Metal Content in Water Samples Collected at different Sampling Stations along Vasai Creek of Mumbai (values in $\mu\text{g/L}$)

[illegible]

Table 1. Heavy Metal Content in Water Samples Collected at different Sampling Stations along Vasai Creek of Mumbai (values in µg/L)(continue)

Heavy Metals	Cr				Hg				Ni			
Sampling Stations	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Month-Year												
October-09	60	35	378	101	120	85	53	34	65	107	109	121
November	52	39	243	95	97	73	44	36	52	84	119	108
December	43	34	147	86	74	50	35	32	36	43	123	113
January-10	42	35	80	78	61	43	44	29	18	18	136	145
February	41	74	146	80	42	33	24	22	15	22	120	99
March	29	82	255	71	25	23	14	17	20	40	81	65
April	34	59	344	63	12	14	13	12	23	55	41	48
May	22	62	478	54	16	20	19	16	27	72	39	41
June	47	39	398	81	19	30	23	14	35	86	33	36
July	51	49	357	96	70	61	23	25	54	98	76	64
August	46	43	513	105	116	72	30	24	91	103	91	75
September	55	53	631	111	126	86	51	35	99	106	104	94
October	64	51	525	110	128	101	67	40	95	125	146	138
November	56	56	221	106	107	76	59	42	56	107	135	125
December	58	41	334	96	86	55	50	48	33	89	139	130
January-11	50	37	267	90	77	43	44	33	25	45	134	134
February	34	84	156	82	45	35	29	39	22	56	129	115
March	40	73	299	75	31	28	20	24	26	49	94	90
April	38	65	457	68	15	31	15	18	39	61	71	88
May	27	103	738	71	10	10	10	12	42	75	15	10
June	44	50	750	82	26	33	24	18	45	86	25	39
July	47	58	765	95	68	57	30	31	68	94	68	71
August	51	43	771	102	110	81	40	29	90	100	87	88
September	58	41	782	107	131	99	58	38	105	119	105	103
AVERAGE	45	54	418	88	67	52	34	28	49	77	93	89
Range	22-64	34-103	80-782	54-111	10-131	10-101	10-67	12-48	15-105	18-125	15-146	10-145
Median	43	68.5	431	82.5	70.5	55.5	38.5	30	60	71.5	80.5	77.5

Ecological and toxicological aspects of lead (*Pb*) and its compounds in the environment have been extensively reviewed[56-61]. There is agreement by all authorities on five points. First, *Pb* is ubiquitous and is a characteristic trace constituent in rocks, soils, water, plants, animals, and air. Second, more than 4 million metric tons of *Pb* is produced worldwide each year, mostly for the manufacture of storage batteries, gasoline additives, pigments, alloys, and ammunition. The widespread broadcasting of *Pb* through anthropogenic activities, especially during the past 40 years, has resulted in an increase in *Pb* residues throughout the environment-an increase that has dislocated the equilibrium of the biogeochemical cycle of *Pb*. Third, *Pb* is neither essential nor beneficial to living organisms; all existing data show that its metabolic effects are adverse. Fourth, *Pb* is

toxic in most of its chemical forms and can be incorporated into the body by inhalation, ingestion, dermal absorption, and placental transfer to the foetus. Fifth, *Pb* is an accumulative metabolic poison that affects behaviour, as well as the hematopoietic, vascular, nervous, renal, and reproductive systems. In the present investigation it was observed that *Pb* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 25-163, 17-146, 152-276 and 119-195 µg/L respectively. The biyearly average *Pb* concentration was found to be 79, 94, 191 and 158 µg/L respectively at different sampling stations (Table 1). It was also observed that the average *Pb* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.04 at S4 to 1.11 at S1 (Figures 2-5).

Table 1. Heavy Metal Content in Water Samples Collected at different Sampling Stations along Vasai Creek of Mumbai (values in $\mu\text{g/L}$)(continue)

Heavy Metals	Pb				Sr				Mn			
Sampling Stations	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Month-Year												
October-09	106	102	177	153	84	95	253	122	63	108	57	72
November	78	86	162	131	63	85	121	85	42	87	43	59
December	42	51	152	123	48	54	76	50	36	56	29	54
January-10	25	17	157	119	34	32	15	38	20	39	14	50
February	36	37	170	141	45	25	74	71	27	79	164	139
March	48	45	181	135	62	30	114	102	52	117	292	183
April	43	85	189	167	77	43	160	123	79	167	421	150
May	63	132	190	159	87	38	255	146	103	202	522	233
June	59	123	205	168	103	47	299	158	96	142	426	167
July	88	125	214	185	114	62	311	147	76	175	331	182
August	149	146	213	174	103	81	328	174	63	161	105	135
September	163	134	201	195	118	92	400	179	54	105	91	113
October	124	121	228	168	95	105	321	129	66	136	52	85
November	118	106	276	175	87	87	210	177	47	99	39	74
December	78	86	178	183	73	79	169	145	43	81	26	89
January-11	57	35	159	150	46	56	87	126	54	48	43	72
February	45	49	166	169	52	40	58	149	66	76	156	137
March	44	57	175	125	66	54	167	100	78	120	278	189
April	41	99	188	147	84	45	203	108	87	183	495	250
May	56	121	197	155	102	51	277	119	94	219	688	301
June	53	129	205	159	105	56	312	148	75	198	501	243
July	107	118	210	168	98	77	321	135	61	167	315	186
August	137	123	194	174	90	92	334	146	66	153	199	115
September	140	131	198	162	89	101	341	150	52	118	157	107
AVERAGE	79	94	191	158	80	64	217	126	63	127	227	141
Range	25-163	17-146	152-276	119-195	34-118	25-105	15-400	38-179	20-103	39-219	14-688	50-301
Median	94	81.5	214	157	76	65	207.5	108.5	61.5	129	351	175.5

Strontium (*Sr*) compounds that are water-insoluble can become water-soluble, as a result of chemical reactions. The water-soluble compounds are a greater threat to human health than the water-insoluble ones. Therefore, water-soluble forms of strontium have the opportunity to pollute aquatic environment. For children exceeded strontium uptake may be a health risk, because it can cause problems with bone growth. In the present investigation it was observed that *Sr* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 34-118, 25-105, 15-400 and 38-179 $\mu\text{g/L}$ respectively. The biyearly average *Sr* concentration was found to be 80, 64, 217 and 126 $\mu\text{g/L}$ respectively at different sampling stations (Table 1). It was also observed that the average *Sr* concentration for

assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.05 at S1 to 1.23 at S2 (Figures 2-5).

Manganese (*Mn*) is one out of three toxic essential trace elements, which means that it is not only necessary for humans to survive, but it is also toxic when too high concentrations are present in a human body. Excess manganese interferes with the absorption of dietary iron. Long-term exposure to excess levels may result in iron-deficiency anaemia. Increased manganese intake impairs the activity of copper metallo-enzymes. The presence of manganese in drinking water supplies may be objectionable for a number of reasons unrelated to health. At concentrations exceeding 0.15 mg/L, manganese stains

plumbing fixtures and laundry and causes undesirable tastes in beverages[62]. Oxidation of manganese ions in solution results in precipitation of manganese oxides and incrustation problems. Even at concentrations of approximately 0.02 mg/L, manganese may form coatings on water distribution pipes that may slough off as black precipitates[63]. The growth of certain nuisance organisms is also supported by manganese[62, 64]. The presence of "manganese" bacteria, which concentrate manganese, may give rise to taste, odour and turbidity problems in the distributed water. Highly toxic concentrations of manganese in soils can cause swelling of cell walls, withering of leaves and brown spots on leaves. In the present investigation it was observed that *Mn* concentration at S1, S2, S3 and S4 sampling stations lies in the range of 20-103, 39-219, 14-688 and 50-301 µg/L respectively. The biyearly average *Mn* concentration was found to be 63, 127, 227 and 141 µg/L respectively at different sampling stations (Table 1). It was also observed that the average *Mn* concentration for assessment year 2010-11 was higher than that obtained for the assessment year 2009-10 by a factor of 1.11 at S2 to 1.20 at S4 (Figures 2-5).

4. Conclusions

The real problem today is not whether heavy metals are toxic or not, since we know that they are: but what concentrations are permissible/safe levels in our waters which do not produce harmful effects on users of water and biological life from the waters. Although much work has been done on heavy metal pollutants, there is still a great need for information on influences of metals and their toxicities fully. It is impossible to prevent pollution of environment totally, but metal pollution and toxicity could be minimized by certain precautionary measures like development of adequate environmental control and management programmes and continuous scientific monitoring of our aquatic environment must be built up. It is expected that the experimental data obtained on pollution level from such continuous monitoring will help to reduce pollution threat to aquatic environment.

ACKNOWLEDGEMENTS

The authors are thankful to SAP Productions for developing and maintaining the paper template.

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