Studies on Heavy Metal Contamination in Mithi River, Mumbai

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Abstract

The Mithi River has come into focus, as one of the main reasons which caused substantial flooding around the airport area, in the aftermath of the heavy down pour of 26th July 2005. The Government of Maharashtra has appointed several Committees to look into the problems of Mithi River and several suggestions have been made to reduce the pollution levels. However, not all suggestions could be implemented due to the practical difficulties or constraints of costs involved. In the meantime the water quality of Mithi River continues to suffer. To determine the current status, the present study has been undertaken to find out the existence and the toxicity levels of heavy metals in the water of Mithi River.

The study covered a period of one year from October 2011 to September 2012. Four sampling stations (S_1, S_2, S_3 & S_4) were selected considering heavy population in the surrounding areas and possibility of pollution from point and non point sources. The heavy metals viz., As, Hg, Pb, Cd, Cr, Al, Ni, Mn and Zn were analysed. The present study reveals that some of the metals have crossed the permissible levels as prescribed by environmental authorities. The heavy metals in excess of the limits have an adverse effect on the surrounding environment and the aquatic life in the river as well as in the Arabian Sea. There is thus an increasing need for continuous monitoring of the pollution levels of Mithi River waters and a check on the disposal of sewage, waste water and effluents from residential and industrial units on areas adjoining the river banks.

KEYWORDS: Heavy Metals, Water Pollution, Sewage, Toxicity levels, Mithi River, Mumbai,

INTRODUCTION:

Water is a very precious natural resource essential for existence of all living organisms. Rivers have become highly polluted and deteriorated due to discharge of untreated domestic and industrial waste; which enhance the levels of heavy metals contamination in river waters (***Venugopal et al., 2009***). Management of quality of this precious natural resource is a great concern. This makes it very much essential to have a regular check on the quality of water bodies. The maintenance of healthy ecosystem depends upon quality of water in the various water bodies in the region and the biological diversity of the aquatic life (fish, other organisms etc.) in the river waters. Heavy metal concentration and other impurities in the river waters also affect plant life which consumes such untreated waters. Small fish which eats these plants are also affected due to bio-accumulation. When humans eat the fish, small animals or plants which are affected, the adverse effect moves up the food chain (biomagnifications). Regular checks and balances will not only prevent the outbreak of diseases and other hazards; but will also have a check on the future deterioration of these water bodies.

Several metals are available in the environment, some of which are toxic and some are non-toxic. Toxic metals are released by industries to air, soil & water. Natural sources such as, weathering of rocks, volcanoes, may also release toxic metals. Heavy metal is a term used to describe those metals which have an atomic number higher than iron (Fe) and have a density more than 5 gm/ cm^3. They usually belong to the atomic number 22 – 34 and 40- 52. Such metals are members of actinides & lanthanide series.

Rivers get polluted as a result of discharge of untreated industrial effluents from the Industrial belt ***(Singh et al., 2008)***. Substantial pollution of ecosystems and ground water resources had been caused by heavy metals, worldwide ***(Nriagu et al., 1998*****).** Fish is one of the most sensitive indicators of trace metal pollution and also risks potential human consumption ***(Ashraf 2005).*** Metals enter into the human body through the food chain causing different diseases and damages to humans (***Tuzen & Salyal, 2007****)*. Most anthropogenic sources of heavy metal contamination are industrial discharges, petroleum contamination and sewage disposal. Toxic and harmful effects of heavy metals include their ability to accumulate in the body of organisms, via the food chain and this affects humans as well when they consume such food/organisms contaminated by heavy metals ***(Martin et al., 2004****)*. High concentration of heavy metals accumulates in different organs of the organism, damage tissues, and interferes with the normal growth and proliferation ***(Alkarkhi et al., 2009).***

A review of the various literatures relating to the “Water Quality” of various water bodies indicates that “pollution of Water” is a global phenomenon and care needs to be taken to ensure that water of adequate quality is provided to the people for domestic and industrial purposes. Due to rapid industrialization and rise in human population there is a pressure on water bodies; they are getting polluted ***(Sahu et al., 1991****)*. The physico-chemical properties of river waters have been greatly affected due to the discharge of domestic and municipal wastes, industrial effluents, recreational and anthropogenic activities on lands adjoining the river banks *(****Panda et al., 1991****)*. The growing demand for water for irrigational purposes has increased the use of untreated waste water for irrigational purposes. The unequal distribution of water on the surface of the earth and the fast declining availability of fresh usable water are major concerns in terms of water quality and quantity ***(Leonard, 1971****)*.

MATERIALS & METHODS:

a) Study Area:

Mumbai City is a Metro and the financial capital of India. The Mithi River which flows through the heart of Mumbai City. It originates at an altitude of 246 Meters above sea level, in the hills located in the east of “Sanjay Gandhi National Park”. Further, it is a convergence of water discharges of Tulsi, Powai and Vihar lakes and it flows to Mahim Bay where it meets Arabian Sea. The river flows through residential and industrial complexes of Powai, Saki Naka, Kurla, Bandra- Kurla complex and Mahim over a distance of around 18 km (Refer Chart). The river is narrow in its initial stretches, but widens gradually and is the widest at Bandra-Kurla Complex (BKC). Also, in its initial stretches its course follows a rather steep gradient and hence the water flows quite fast, while in the later part (after Andheri) it flows through a flat region, so water and waste get accumulated. The Fig. 1 shows the flow of Mithi River & Table 1 shows the different sampling points & its topographical details.

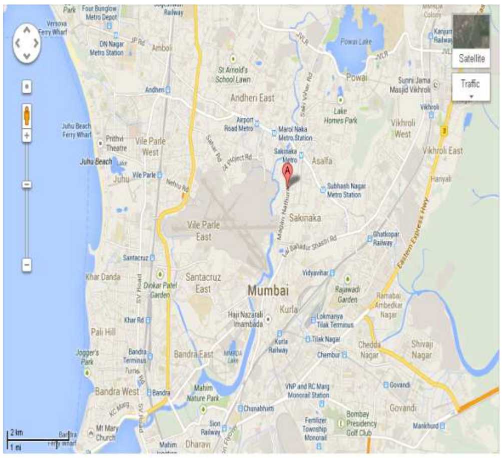

Figure 1: Mithi river from origin to destination
(Source: National Environment Engineering research Institute Report – 2011.)

Table1: Mithi River sampling points the topographical details of these points

S. T.	Description of sampling point	Latitude	Longitude	Remarks
S1	Airport- Bridge on road from LBS to IA colony (road from behind airport.)	19.08	72.87	Heavy residential area, slums- Airport Waste discharged.
S2	Safed pool	19.09	72.88	Slums, unauthorized industrial units
S3	CST Bridge	19.07	72.88	Thickly populated area. Unauthorized industrial units
S4	Kalanagar Bridge	19.05	72.85	Area surrounded by mangroves, acting as city’s oxygen lungs. Near “Saleem Ali” bird Sanctuary.

b) Climatic Conditions: The Mithi River flows along the Western Coast of India. It is not more than 10 Kms from the Arabian Sea at it origin. The water shed of Mithi River is covered within latitude 19^{o} 00' to 19^{o} 15'and longitude 72^{o} 45' to 73^{o}.00' E. (*National Energy Engineering & research Institute. 2011*). The region through which Mithi River flows experiences a tropical climate. It receives south west monsoon during the June – September period. The average annual rainfall received is around 2200 mm per annum. The temperature ranges from 18^{o} C in winter to around 44^{o} C in summer. The relative humidity varies from 55% to 86%.

c) Requirement of Chemicals & Regents:

Regents and chemicals used for evaluating the presence of various heavy metals were of analytical grade (AR). Accuracy of the regent would be checked by taking a blank reading. In order to calculate the different parameters of the study, standard operating procedures were followed in laboratory. In case any equipment was to be used, the operating guidelines issued by the equipment manufacturer were followed. All laboratory glasswares were thoroughly cleaned by acid (HCl) before analysis. Then it was thoroughly rinsed by tap water to remove any traces of acid. Further, the apparatus were cleaned by using deionised distilled water to remove any traces from earlier usage.

d) **Preparation of Water Samples:**

Collection of water samples were done randomly, twice every week from the different sampling stations along the flow of Mithi River. The samples drawn in different seasons, over a period of one year and were analyzed. Polythene bottles of 2 litres capacity were used to collect the water samples (grab sampling method). The bottles were thoroughly cleaned with HCl and then washed with tap water to remove acid completely and rinsed with distilled water. Then the bottles were filled with sample water without leaving much air gap. Water samples were acidified immediately after collection to minimize absorption of heavy metals on the wall of the bottle (APHA 1998). Water sample from the surface is collected in polythene bottles after rinsing the bottles 3 to 4 times in the water where the sample is being collected.

The samples were digested as per the guidelines suggested in APHA. The samples were then concentrated to half. These samples were filtered into 50.0 cm^{3} standard volume flask using Whatman No.41 filter paper. The volume was made up to the mark using de-ionized water. After this, the respective element is determined by directly aspirating the sample in the specified flame and setting appropriate wavelengths.

e) Heavy metal analysis by atomic absorption spectrophotometer (AAS):

The concentration of metals, like Cadmium (Cd), Chromium (Cr), Arsenic (As), Aluminum (Al), Lead (Pb), Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu) were analysed by AAS (AAS 7000) aspirating the sample in the specified flame and by setting the appropriate wavelengths, using Holious cathode lamp. Instructions of the manufacturer were followed. A calibration curve is prepared by using standard solutions of elements to be analysed. Mercury (Hg) was analysed with cold vapour atomic absorption spectroscopy. Arsenic (As) is determined with hydride generation, coupled with atomic absorption spectrophotometer.

RESULTS & DISCUSSIONS:

The details of observations at each of the sampling points for different metals are as follows:

i) ARSENIC:

At each of the sampling points S1, S2, S3 & S4 the concentration of this metal ranged from 0.02-0.09, 0.03-0.24, 0.07-0.31 & 0.10-0.31 respectively. The average concentration was observed to be 0.05 and 0.14 at sampling points S1 & S2 and 0.21 at points S3 & S4. Analysis of seasonal variations revealed that the concentration of this metal was highest during the pre-monsoon and lowest during the monsoon season.

Arsenic (As) is a highly toxic element. Arsenic compound occurs in insecticides, fungicides and herbicides. As in its form As (III) is highly toxic. It exerts toxic action by attaching – SH group of enzymes and thereby inhibiting enzymatic action. As (III) compound in higher concentration coagulates proteins. Other source of As entering into water, is burning of coal which releases significant amount of As. This enters into water bodies through rainfall and dry fall outs. Treatment of woods using chromate copper arsenate, chemical wastes from industries, mining operations (gold mining) have increased levels of this heavy metal in the environment and fresh water bodies. This has affected aquatic organisms, like fishes, as they have a capacity to accumulate As in their bodies. Marine organisms accumulate greater quantity of As than freshwater organisms in their bodies. They are found to be toxic to many fish and other organisms in aquatic environment (**Anonymous, 1971).**

Long term exposure to Arsenic affects head, kidneys and impairs numerous immune response functions of clarias batrachus (***Gosh et al., 2007).*** A recent study of water resources in a major metropolis in India revealed that the arsenic levels in water were more than the maximum permissible limits. Further, a positive correlation was observed between the arsenic levels and other heavy metals, which indicated that the toxic elements were of anthropogenic origin ***(Ramesh et al., 1995*****).**

ii) MERCURY:

It was observed that at each of the sampling points S1, S2, S3 & S4 the concentration levels of this metal ranged from 0.03-0.10, 0.03-0.10, 0.02-0.08 & 0.04-0.31 respectively. The averages at each sampling points S1, S2, S3 & S4 were observed to be 0.07, 0.06, 0.05 & 0.13 respectively. At the Sampling points S1, S2 & S3, the concentration of this metal was observed to be lowest in the monsoon and highest in the pre-monsoon season.

Mercury is discharged into aquatic systems as a result of both manmade and natural causes. Natural sources are – weathering of rocks, (Hg rocks), lava produced by volcanic eruptions. Mercurious ions affect protein, hemoglobin, serum albumin. Organomercurials (eg. Methyl mercury chloride) incorporates in food chain. As it is fat soluble, it penetrates into the body of the simple organism. In complex species, which feed on simple organism, the organomercurial (eg Methyl mercury chloride) gets accumulated (bio accumulations). This is the most well known toxic metal. The cases of Minamata disease in Japan from 1953 to 1960 as a result of consumption of mercury. More than 100 people died and thousands were permanently paralysed by consumption of food (fish) contaminated with mercury. Even genetic defects were observed in children whose mothers had consumed such fish contaminated by mercury. In 1963 it was found that this disease was due to methyl mercury. A similar incident took place in Iraq in 1972, where over 500 people died after consuming wheat which had been sprayed by pesticides containing mercury. Mercury also inhibits enzyme action; it affects the nervous system - leading to neurological disorders like dysphasia, ataxia, deafness and death. Due to global concerns for environmental pollution, mercury poisoning has become an issue of current importance. Bioaccumulation & biomagnifications affect plants, aquatic organisms and hence pose a hazard to aquatic environment (***Favretto et al., 1997).***

iii) CHROMIUM:

The concentration of this metal ranged from 0.13-0.19 at S1, 0.89- 2.97 at S2, 0.15 to 0.58 at S3 and 0.9-0.49 at S4. The average monthly concentration levels were observed to be 0.16, 1.71, 0.30 & 0.24 at sampling points S1, S2, S3 & S4. It was observed that concentration of this metal was highest at S2. It was observed that the concentration was lowest during the monsoons, though the season wise variations were observed to be less at point S1. Highest concentration was observed in the post monsoon season.

Hazardous effect of chromium is due to occupational exposure rather than intake through diet and water. Source of chromium are wastes from its industrial application, since it is used for the manufacture of alloys steel, manufacture of bricks, electro plating, catalyst, pigment, tanneries, for wood preservation, corrosion, inhibitor etc. Concentration of chromium in excess of 0.032 mg/l in water can inhibit growth of algae. Chromate toxicity affects organs such as lungs, intestinal tract, liver and kidneys (***Rom et al., 2007***). Chromium (Cr) in higher concentration has a toxic effect on algae (Mangi et al., 1978).

iv) CADMIUM:

At each of the sampling points S1, S2, and S3 & S4 the concentration of this metal ranged from 0.03-0.09, 0.03-0.08, 0.04-0.15 & 0.10-0.42 respectively. The average concentration was observed to be 0.06, 0.05, 0.08 & 0.21 at sampling points S1, S2, S3 & S4 respectively. Analysis of seasonal variations revealed that the concentration of this metal was highest during the pre monsoon and lowest during the monsoons. The concentration levels were observed to be higher at S4.

Due to its high toxicity, it is considered as a hazardous element having greater capabilities of accumulation and retention in the body of an organism, including human. Cadmium is highly toxic as Cd^{2+}. In nature it exists as sulphides. It is used in electroplating industries, pigments & paints, primary inks, plastics, manufacture of alloys with Pb, Al, Ag, insecticides, fluorescent tubes, television tubes, rechargeable batteries etc. Metallurgical operations of Pb, Zn & Cu also throw this material in the air. In the human body its biological halftime is 10-30 years. A large number of freshwater and marine organisms accumulate the element. Larvae and eggs of fishes are more prone to such accumulation than adults. In human body it accumulates in liver, kidneys, pancreas & thyroid. In Japan in 1912, thousands of people suffered from disease known as "itai

itai". The river water concentration of Cd reaches a high level of 1 – 9 ppm. Itai Itai disease impairs kidney functions and progressively causes bone bitterness, resulting into fractures even when people try to walk. Low level of exposure to cadmium also affects fertility in men ***(Dickman et al., 1998***). Metallothionein (MT) cysteine rich protein in marine organisms and it regulates Cu and Zn homeostasis, and it detoxifies the cell of Cd & Hg (***Klassen et al., 1999).***

v) MANGANESE:

The concentration levels of this metal ranged from 0.19-1.99, 0.96-2.84, 0.50-1.35, and 0.98-1.28 at the sapling points, S1, S2, and S3 & S4 respectively. The average concentration (Oct 11 to Sept 12) levels at each of the sampling points S1, S2, S3 & S4 was 0.96, 1.53, 0.92 & 1.07 respectively. The highest concentration values were observed during the pre monsoon period; while the lowest concentration was observed during the monsoon or the post monsoon periods.

It is a naturally derived metallic pollutant. Soil and rocks commonly contain Mn bearing minerals. Fertilizers and fuel oils are also significant sources of Mn. Most natural water contains 0.02 mg lit^{-1} or less. In acidic waters its concentration may exceed 10 mg lit^{-1}. If the water surface gets contaminated the concentration may also exceed 10 mg. lit^{-1}. Water with excessive quantity of decaying organic matter; also have significant quantity of Mn. Chronic Mn poisoning leads to progressive deterioration of Central Nervous System, lethargy and symptoms similar to Parkinson's disease. Concentration above 0.5 mg lit^{-1} in water imparts a metallic taste to water. The growth of certain nuisance organisms in water is supported by Manganese (***Griffin et al., 1960).***

vi) NICKEL:

The concentration of this heavy metal, ranged from 0.22-0.57, 0.51-0.93, 0.30-0.98 & 0.49 -0.95 at each of the sampling points S1,S2, S3 & S4.The average concentration levels were 0.41, 0.77, 0.67, 0.66 at the sampling points S1, S2, S3 & S4. The highest concentration levels were observed during the pre monsoon while the lowest levels were observed during monsoons.

Organic matter like coal & oil have a tendency to absorb this metal hence they contain considerable amounts of this metal. Uptake of small quantity of Ni is essential, but when uptake becomes too high it becomes dangerous to human health. Intake of large quantities of Ni causes cancer of lung, nose, larynx and prostate cancer. Birth defects also result. Allergic reactions like skin rashes are also observed. Nickel is released into air by power plants and thrashes incerators. It comes to the surface by combining with rain drops. It also comes from waste water from industries. High content of Ni in surface water can diminish growth of algae. Niclel concentration in water increases by point sources/non point sources. Pure Ni is often used as protective coating on steel and copper objects. Ni objects are used for making kitchen ware, jewelry etc. Nickel is a minor essential element for animal species when present in excess quantities; it affects behavior, survival, growth and reproduction of aquatic animals ***(Wong et al., 1993).*** Higher concentration of this metal also causes a number of disorders in human beings and fish ***(Shreedevi et. al., 1992 & Brix et al., 2004).***

vii) ALUMINIUM:

The concentration level of the metal at each of the sampling stations, S1, S2, and S3 & S4 ranged from 1.97-4.16, 12.39-38.58, 1.86-4.18, and 1.96-4.06 respectively. The average concentration levels were 3.01, 23.64, 2.83 & 2.88 at the four sampling stations, S1, S2, S3 & S4 respectively. The concentration levels were highest in the pre-monsoon season; while they were lowest during the monsoon except for sampling point S2.

Aluminum is the most abundant metal comprising 8% of the earth's crust. It occurs in the form of minerals, rocks and clay. Aluminum is released to the environment by natural processes. Acid environment caused by acid mine drainage or acid rain may cause an increase in dissolved aluminum content of surrounding water (***WHO 1997).*** Concentration of dissolved Al increases at lower and higher pH. The concentration of Al in natural waters can vary significantly depending upon various physicochemical and mineralogical factors. Aluminum can occur in a number of different forms in H_2O. It can form monomeric or polymeric hydroxyl species, colloidal polymeric solution and gel. It can form complexes with various organic compounds e.g. humic acid and fulvic acid& inorganic ligands, fluorides, chlorides and sulphates. Dissolved aluminum concentration in water with near neutral pH value, usually ranges from 0.001 to 0.05 ml/L but rises to 0.5 – 1 mg/L in more acidic waters or waters rich in organic matter. Aluminium accumulates in plants and when animals consume the plants, health problems are observed in these animals (***Mc Cohen et al., 1989***). The effects may be passed to humans through the food chain. Aluminium reacts with proteins in gills of fish and embryo of frogs; this causes a decline in fish and amphibians in aquatic environment ***(Verbost et al., 1992).***

viii) LEAD:

The concentration level of the metal at each of the sampling stations, S1, S2, S3 & S4 ranged from 0.098-0.230, 0.519-1.203, 0.619 -1.398 & 0.62-1.12 respectively. The average (Oct 11- Sept 12) concentration levels were 0.157 0.878, 0.950 & 0.89 at the four sampling stations, S1, S2, S3 & S4 respectively. The concentration levels were highest in the pre-monsoon season except at point S3; while they were lowest concentration was generally observed during the monsoon except for sampling point S2.

The most common form of lead in the environment is Pb^{2+}. The most common mineral where lead exists in nature is

Pbs (galena). Most of the lead containing minerals is sparingly soluble in H_2O. The mean global content of lead in lakes and rivers is presently estimated to be in the range of 1- 10 ug L^{-1}. Concentration of lead in natural waters is increased mainly through anthropogenic activities. Lead is extensively used in pesticides as lead arsenate. Industrial burning of coal also releases significant amounts of Pb in the atmosphere (Fly ash). Dumping of solid wastes and industrial rubbish is also an important source of lead in water. A large number of industries like battery manufacturers, petroleum, paints, ceramics, electric cable insulation, pesticides and plastics use lead in the various operations. Waste water from these industries contains varying quantities of lead and that contaminates water resources. The runoff water from lead mining contains lead. Higher level of Pb occurs in water bodies near highways and large cities due to gasoline combustion (Banat et al.,

2005) The insoluble galena (Pbs) is slowly oxidized to soluble $PbSO_4$ by atmospheric oxygen ($PbS + 2O_2 \rightarrow PbSO_4$). The toxicity of lead is acute in children and infants than adults. In mild cases of Pb poisoning lead to insomnia, restlessness, loss of appetite and some gastro- intestinal problems are common symptoms.

ix) IRON:

The concentration level of the metal at each of the sampling stations, S1, S2, S3 & S4 ranged from 3.82-11.43, 6.21-14.72, 1.72-4.10 & 1.12-1.99 respectively. The average (Oct 11- Sept 12) concentration levels were 7.68, 11.45, 2.77 & 1.59 at the four sampling stations, S1, S2, S3 & S4 respectively. The concentration levels were highest in the pre-monsoon season except at point S4; while they were lowest concentration was generally observed during the monsoon except for sampling point S1.

Fe is a naturally derived metallic pollutant which owes its origin in H_2O mostly from sources derived from soil and rocks. Anthropogenic sources are effluents from certain sources like steel mills, metal plants. Iron in natural H_2O remains present in ferric or ferrous form. Large quantities of iron can leak out from soil runoff, especially in acidic conditions such as associated with acid mine drainage and degradation of excessive organic matter accumulated in the soil. Iron has hardly got any health significance, though its appreciable quantities can pose problems in domestic use of water. The limit of Fe in water is 0.1 mg Lit^{-1} not because of health consideration but due to aesthetic value and task significance. Iron is a component of hemoglobin, and myoglobin. Iron toxicity occurs when there is free iron in a cell. Free iron reacts with peroxides to produce free radicals which are highly reactive and they damage DNA, proteins, lipids and other cellular components.

x) ZINC:

The concentration level of the metal at each of the sampling stations, S1, S2, S3 & S4 ranged from 0.18-0.43 0.18-0.40, 0.17-0.31, & 0.10-0.42 respectively. The average (Oct 11- Sept 12) concentration levels were 0.27, 0.24, 0.23, & 0.21 at the four sampling stations, S1, S2, S3 & S4 respectively. The concentration levels were highest in the pre-monsoon season; while the lowest concentration was generally observed during the post-monsoon.

CONCLUSION:

From above data it has seen that the concentration of heavy metals has exceeded the maximum permissible limits for many of the heavy metals and the water of the Mithi River is polluted to a great extent. The water cannot be used for any domestic or industrial purposes. Besides the various adverse effects of the heavily polluted waters on the people staying in areas adjoining the river banks, it is also ecologically damaging to the flora and fauna in the sensitive ecosystems near the river (e.g. Samil Ali bird sanctuary at Mahim). Therefore a system continuous monitoring of the quality of the water of river Mithi is required. Also concentrated efforts are required from all concerned to reduce dumping of industrial and residential wastes in the river waters. The State Government, Municipal Authorities need to work together to achieve this.

Table 2: HEAVY METAL CONTENT AT DIFFERENT SAMPLING STATIONS

MON /YR	Arsenic (As)				Mercury (Hg)				Chromium (Cr)				Cadmium (Cd)			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Oct-11	0.02	0.19	0.31	0.29	0.06	0.07	0.07	0.31	0.16	0.89	0.19	0.24	0.06	0.07	0.07	0.26
Nov-11	0.02	0.10	0.30	0.19	0.07	0.09	0.03	0.06	0.14	1.01	0.22	0.20	0.05	0.04	0.06	0.20
Dec-11	0.03	0.11	0.22	0.19	0.08	0.06	0.04	0.07	0.14	1.02	0.15	0.11	0.03	0.05	0.04	0.10
Jan-12	0.04	0.20	0.27	0.20	0.10	0.03	0.03	0.06	0.17	1.91	0.16	0.09	0.07	0.04	0.07	0.11
Feb-12	0.05	0.21	0.24	0.29	0.09	0.04	0.03	0.04	0.19	2.18	0.24	0.19	0.09	0.06	0.10	0.20
Mar-12	0.08	0.24	0.26	0.31	0.09	0.09	0.08	0.07	0.16	2.14	0.30	0.30	0.07	0.08	0.11	0.29
Apr-12	0.07	0.18	0.28	0.30	0.09	0.10	0.08	0.07	0.18	2.97	0.38	0.21	0.07	0.08	0.15	0.21
May-12	0.09	0.22	0.25	0.30	0.08	0.08	0.08	0.06	0.18	2.51	0.46	0.49	0.09	0.06	0.10	0.42
Jun-12	0.09	0.10	0.12	0.12	0.03	0.05	0.05	0.10	0.16	2.03	0.58	0.38	0.06	0.04	0.09	0.31
Jul-12	0.04	0.03	0.07	0.11	0.05	0.05	0.03	0.23	0.15	1.96	0.32	0.20	0.05	0.03	0.05	0.21
Aug-12	0.03	0.03	0.09	0.12	0.04	0.04	0.02	0.18	0.13	0.92	0.28	0.18	0.04	0.04	0.04	0.11
Sep-12	0.03	0.04	0.08	0.10	0.04	0.04	0.02	0.26	0.14	1.00	0.28	0.26	0.07	0.05	0.05	0.10
Minimum	**0.02**	**0.03**	**0.07**	**0.10**	**0.03**	**0.03**	**0.02**	**0.04**	**0.13**	**0.89**	**0.15**	**0.09**	**0.03**	**0.03**	**0.04**	**0.10**
Maximum	**0.09**	**0.24**	**0.31**	**0.31**	**0.10**	**0.10**	**0.08**	**0.31**	**0.19**	**2.97**	**0.58**	**0.49**	**0.09**	**0.08**	**0.15**	**0.42**
Average	**0.05**	**0.14**	**0.21**	**0.21**	**0.07**	**0.06**	**0.05**	**0.13**	**0.16**	**1.71**	**0.30**	**0.24**	**0.06**	**0.05**	**0.08**	**0.21**

MONTH / YEAR	Manganese (Mn)				Niclel (Ni)				Aluminium (Al)				Lead (Pb)			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Oct-11	0.19	1.08	0.65	1.13	0.36	0.71	0.62	0.61	2.31	12.39	2.01	1.96	0.137	0.593	0.953	0.82
Nov-11	0.60	0.97	0.99	1.02	0.49	0.86	0.71	0.72	2.87	15.45	2.98	2.41	0.119	0.519	0.619	0.62
Dec-11	0.90	0.96	1.01	0.99	0.49	0.68	0.61	0.51	3.19	17.31	2.41	2.36	0.126	0.689	0.689	0.79
Jan-12	1.00	1.26	1.04	1.12	0.39	0.85	0.53	0.53	2.81	21.53	2.31	2.53	0.152	0.614	0.810	0.91
Feb-12	1.16	2.84	1.35	1.24	0.48	0.76	0.62	0.63	3.17	38.58	2.17	2.81	0.185	0.980	1.028	0.89
Mar-12	1.99	2.19	1.22	0.99	0.57	0.89	0.76	0.81	4.16	31.47	3.83	3.82	0.213	1.203	1.241	1.01
Apr-12	1.08	1.96	0.97	1.28	0.46	0.86	0.98	0.95	3.92	33.29	4.18	4.06	0.230	1.157	1.398	1.12
May-12	0.96	2.17	0.90	1.02	0.49	0.93	0.81	0.84	3.65	29.17	3.84	3.91	0.173	1.123	1.281	1.09
Jun-12	0.98	1.95	0.91	1.02	0.40	0.82	0.80	0.80	3.01	21.83	3.92	3.68	0.159	1.098	1.007	0.99
Jul-12	0.85	0.99	0.57	1.01	0.28	0.75	0.68	0.49	2.18	18.03	2.16	2.89	0.161	0.987	0.813	0.81
Aug-12	0.80	0.96	0.50	0.98	0.22	0.51	0.39	0.49	1.97	21.61	1.86	2.05	0.098	0.893	0.763	0.71
Sep-12	1.00	1.05	0.94	1.02	0.26	0.60	0.50	0.53	2.83	23.02	2.27	2.13	0.129	0.680	0.789	0.89
Minimum	**0.19**	**0.96**	**0.50**	**0.98**	**0.22**	**0.51**	**0.39**	**0.49**	**1.97**	**12.39**	**1.86**	**1.96**	**0.098**	**0.519**	**0.619**	**0.62**
Maximum	**1.99**	**2.84**	**1.35**	**1.28**	**0.57**	**0.93**	**0.98**	**0.95**	**4.16**	**38.58**	**4.18**	**4.06**	**0.230**	**1.203**	**1.398**	**1.12**
Average	**0.96**	**1.53**	**0.92**	**1.07**	**0.41**	**0.77**	**0.67**	**0.66**	**3.01**	**23.64**	**2.83**	**2.88**	**0.157**	**0.878**	**0.950**	**0.89**

Table 2: CHART SHOWING HEAVY METAL CONTENT AT EACH SAMPLING POINT

MONTH/ YR	Iron (Fe)				Zinc(Zn)			
	S1	S2	S3	S4	S1	S2	S3	S4
Oct-11	4.98	12.90	2.86	1.40	0.20	0.19	0.22	0.26
Nov-11	3.82	12.82	2.91	1.48	0.21	0.18	0.19	0.20
Dec-11	4.21	13.48	2.11	1.32	0.18	0.19	0.17	0.10
Jan-12	6.38	13.92	2.39	1.12	0.18	0.21	0.18	0.11
Feb-12	10.67	14.72	3.16	1.41	0.19	0.22	0.20	0.20
Mar-12	9.60	12.83	3.99	1.67	0.30	0.21	0.27	0.29
Apr-12	9.89	13.21	4.10	1.98	0.35	0.33	0.30	0.21
May-12	11.43	12.86	3.13	1.99	0.43	0.40	0.31	0.42
Jun-12	8.98	10.01	2.92	1.84	0.38	0.31	0.30	0.31
Jul-12	9.9	6.21	2.10	1.78	0.31	0.29	0.16	0.21
Aug-12	7.81	6.51	1.98	1.51	0.22	0.20	0.19	0.11
Sep-12	4.52	7.98	1.72	1.61	0.21	0.20	0.23	0.10
Minimum	**3.82**	**6.21**	**1.72**	**1.12**	**0.18**	**0.18**	**0.17**	**0.10**
Maximum	**11.43**	**14.72**	**4.10**	**1.99**	**0.43**	**0.40**	**0.31**	**0.42**
Average	**7.68**	**11.45**	**2.77**	**1.59**	**0.27**	**0.24**	**0.23**	**0.21**

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Fig.2: SEASONAL VARIATIONS IN HEAVY METAL CONCENTRATIONS IN MITHI RIVER WATER

NOTE - Sampling Stations: S1=Airport, S2=Safed Pool, S3=CST Bridge, S4=Kalanagar

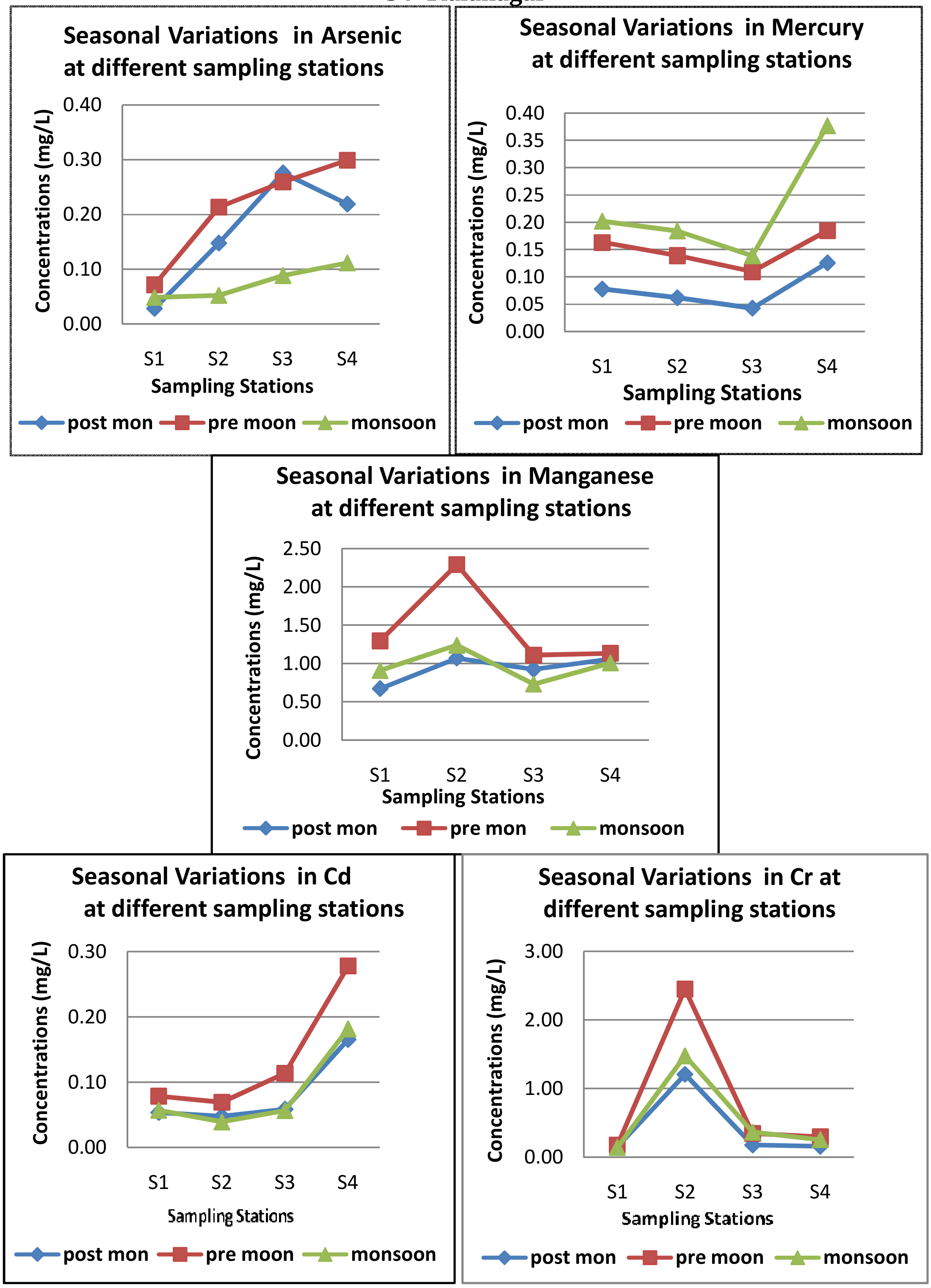

Fig.2: SEASONAL VARIATIONS IN HEAVY METAL CONCENTRATIONS IN MITHI RIVER WATER

NOTE - Sampling Stations: S1=Airport, S2=Safed Pool, S3=CST Bridge, S4=Kalanagar