OCCURRENCE OF TRACE AND TOXIC METALS IN RIVER NARMADA

Jakir Hussain [(1)]*, Ikbal Husain [(2)], Mohammed Arif [(3)]

[(1)] North Western Region, Central Ground Water Board, Chandigarh, India
[(2)] Public Health Engineering Department, Laboratory, Bhilwara, Rajasthan, India
[(3)] Department of Chemistry, Banasthali University, Tonk, Rajasthan, India

* Corresponding author E-mail: drjakirhussain@gmail.com

Abstract

Deteriorating water quality has become a serious problem in developing countries. Almost 70% of Indian's surface water resources have become contaminated due to the discharge of untreated sewage and industrial effluents. The results reveals that out of nine water quality stations monitored, water samples collected at 5 water quality stations (Amarkantak, Dindori, Manot, Barmanghat and Handia) are found to be within the permissible limit for all purposes in respect to trace & toxic metals. While Sandia, Hoshangabad, Mandleshwar and Garudeshwar stations were beyond the permissible limit due to presence of chromium, copper and iron metals. The major source of pollution to the Narmada river is the anthropogenic municipal solid waste and sewage from nearby towns/habitations, agricultural runoff and native soil erosion. The quality of the Narmada River is degraded due to the municipal and industrial discharges from the catchment.

Key words: *Water Quality, Narmada River, Domestic and Industrial waste, AAS, Toxic metals, India*

Introduction

Fresh water is of vital importance for human existence. Man uses water for domestic, industrial and agricultural purposes. The past decade has seen remarkable impact of man on the environment due to unprecedented increase in population and rapid rate of urbanization as well as the intensification of the use of fragile and marginal ecosystems. This has led to progressive and continual resources degradation especially surface water. Polluted water is an important vehicle for the spread of diseases. In developing countries about 1.8 million people, mostly children, die every year as a result of water related diseases (WHO, 2006). In most urban-rural communities in the developing countries surface waters (rivers, streams, and lakes among others) have been the most available sources of water used for domestic purposes. The water from these sources are contaminated with domestic, agricultural, and industrial wastes and likely to cause water related diseases.

Every human use of water, whether for drinking, irrigation and industrial processes or for recreation has some quality requirements in order to make it acceptable. This quality criterion can be described in terms of physical, chemical and biological properties of such water (Gore, 1985). According to the World Commission on

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water for the 21st century, more than half of the world's major rivers are so depleted and polluted that they endanger human health and poison surrounding ecosystems (Inter-press, 1999). The infiltration of rainfall into landfill, together with the biochemical; and chemical breakdown of the waste, produces leachate, high in suspended solids and of varying organic and inorganic content. If the leachate enters surface or ground water before sufficient dilution has occurred, serious pollution incidents can occur. In surface water leachate high in organic material and reduced metals will cause severe oxygen depletion and result in death of fish. Leachate high in non-biodegradable synthetic organic compounds is a particular threat, through bioaccumulation. Concentration of these substances may increase to toxic levels and thus endanger animal and human life. Trace metals are those having density greater than 5 gcm^{-3}. Most often this term denotes metals that are toxic. These include Al, As, Cd, Cr, Co, Pb, Hg, Ni, Se, and Zn (Rodier, 1975). These metals or their compounds may be discharged from industries, farmlands, municipal urban water runoffs, and agricultural activities into surface water and can cause pollution. They vary in type and include large quantities of raw materials, by-products, co-products and final products of human activities. Many of these wastes are toxic and they find their ways into land water/sediments and air. In view of the hazardous nature of metal ions, an attempt has been made to study the pollution potential of toxic metals in the Narmada River. It warrants immediate attention for the enhancement of the water quality of the river.

Materials and methods

River system

The Narmada River is the largest west flowing river and ranks seventh in terms of water discharge and drainage area in India. It originates from Amarkantak in the Maikala Hills in Anuppur District of Madhya Pradesh. Thereafter, the river flows mostly through the Deccan Traps, separating the Vindhyan and the Satpura range of hills on both sides and joins the Arabian Sea at about 10 km north of Bharuch via the Gulf of Cambay. The Narmada river basin is situated between 72°32′ E and 81°45′ E longitudes and between 21°20′ N and 23°45′ N latitudes. The Narmada River flows along the ENE-WSW trending Narmada-Son Fault (NSF), a well-known seismotectonic feature. The NSF is laterally traceable for more than 1,000 km. and parallels the Satpura orogenic belt (Biswas 1987). It demarcates the peninsular India, into two geographically distinct provinces, the Vindhyan-Bundelkhand province to the north and the Deccan province to the south. The Narmada and the Tapti Rivers throughout their course follow these tectonic trends. The river basin drains an area of 98,796 km^2. The total length of this river is 1,312 km. The catchment area of the river extends to Madhya Pradesh (86.18%), Gujarat (11.6%) Maharashtra (1.5%) and Chattisgarh States (0.72%). Just opposite to the pronounced feature of other peninsular rivers, which discharge their water in Bay of Bengal, Narmada River along with the Tapti River drain westward into the Arabian Sea. The Narmada and Tapti River does not form any deltaic features, but only form estuaries. The Narmada River has 41 tributaries of which 22 are on the left bank and 19 on right bank. Out of 41 important tributaries, the Burhner, Banjar, Hiran Tawa, Chota-Tawa, Orsang and the Kundi river are the major tributaries. The basin is characterized by humid tropical climate with an average annual rainfall of 1,178 mm. A major portion of the precipitation in the basin takes place during the southwest monsoon season, which accounts for about 85–95% of the total precipitation. The major lithologies in the basin are the Deccan basalts followed by sedimentary rocks of Vindhyan and Gondwana Super Groups and Quaternary formations. Quaternary alluvium is confined essentially to the Narmada valley. Basalts are characterized by high concentrations of Al and Fe. Approximately, 35, 60 and 5% of areas in the basin are under forest cover, arable land and scrub and grassland respectively. Average population density in the Narmada basin is between 100–200 persons km^{-2}. In comparison to the other densely populated basins of India, average population density in the Narmada basin is significantly lower than the Indian national population average of 324 person km^{-2} (CPCB 1994). The hydrological characteristics of study locations (Narmada mainstream) in the basin have been summarized in Table 1 (Gupta and Chakrapani 2005).

Table 1. *Hydrological characteristics of the Narmada River*

Station No.	Location (District)	Latitude Longitude	Elevation MSL(m)	Basin area km^2	River length km	Water flux km^3/yr	Sediment load 10^6ton/yr
WQ-1	Amarkantak (Amarkantak)	22°42'01"N 81°42'10"E	1057	NA	8	NA	NA
WQ-2	Dindori (Dindor)i	22°56'51"N 81°04'40'E	666	2292	95	1.24	NA
WQ-3	Manot (Mndia)	22°36'15"N 80°21'43"E	452	13000	218	3.31	5.9
WQ-4	Barmanghat (Narsinghpur)	23°01'49"N 79°00'35"E	319	26453	504	12.6	12.0
WQ-5	Sandia (Hoshangabad)	22°54'57"N 78°20'51"E	309	33953	594	15.2	12.8
WQ-6	Hoshangabad (Hoshangabad)	22°45'22"N 77°43'58"E	292	44548	676	22.2	23.6
WQ-7	Handia (Harda)	22°29'26"N 76°58'33"E	270	54027	747	26.2	32.5
WQ-8	Mandleshwar (Khargone)	22°10'06"N 75°39'36"E	154	72809	940	33.2	38.1
WQ-9	Garudeshwar (Garudeshwar)	21°53'06"N 73°39'16"E	31	87892	1169	35.4	28.3

NA = data not available; Sources: CWC, 2012; Jain et al., 2008

Geology

The Narmada Valley is a rift valley situated between the Narmada North fault and the Narmada South fault. These in turn are part of the longer Narmada-Son lineament, which is an active fault zone, and a distinguishing tectonic feature of central India. Extensive basaltic flows known as Deccan Traps have come out of these faults and underlie most of the basin. Apart from this there are some granite,

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and the Gondwana shale and sedimentary rocks in parts of the hills and plains and alluvial deposits near the river courses. A layered block called a graben has dropped down in the middle relative to the blocks on either side of the faults due to ancient spreading of the earth's crust. The Two faults parallel the river's course, and mark the boundary between the Narmada block and the Vindhya and Satpura blocks that have risen relative to the Narmada Graben. In between the two blocks there is an alluvial plains area of about 500 kms length and 35 - 45 kms width stretching from Jabalpur district to Barwani district which overlies the Deccan traps and and Gondwanas on both banks of the river.

Sampling points

The following 9 sampling points were selected for the study (Fig. 1).

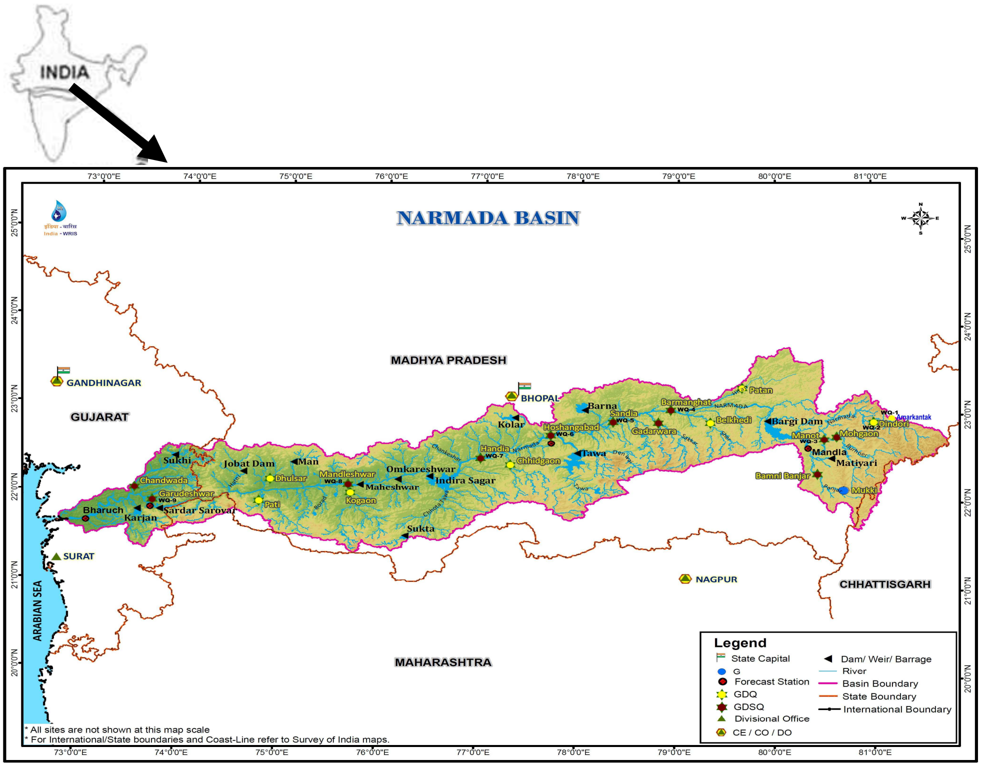

Figure 1. *Study Area*

Amarkantak (WQ-1) This station located 8 km downstream to the place of origin of the Narmada River. This station gives opportunity to examine the natural abundance of heavy metals in soils derived from weathering of Deccan basalts, since anthropogenic inputs are negligible. The station is dominated by basalt rock type and soil cover is dominated by red soils.

Dindori (WQ-2) This station is located on the left bank of Dindori town, first large urban habitat along the course of the Narmada River. Municipal solid waste is dumped in the river at this location. The station is dominated by basalt rock type with red soil cover.

Manot (WQ-3) The sampling station location is located on the right bank of the Narmada River. There is no major anthropogenic input. The first major tributary Burhner meets the Narmada River just upstream of this station. The station is dominated by basalt rock type with red soil cover.

Barmanghat (WQ-4) This station is located 100 km downstream of Jabalpur City, the largest habitat in the basin, a tributary draining sewerage from Jabalpur City, joins the river upstream of station. Tributary the Hiren and the Sher river meet to the Narmada River upstream of the station.

Sandia (WQ-5) Sandia is a small village, the sampling station is located downstream of confluence of tributary the Shakkar river.

Hosangabad (WQ-6) Second largest city in the basin and major source of pollution (municipal solid waste and sewage) to the Narmada River. Station is located on downstream of confluence of dammed tributary Tawa.

Handia (WQ-7) The station is located downstream to the confluence of tributary Ganjal. At this location Harda city water supply is drawn from the Narmada River.

Mandleshwar(WQ-8) Mandleshwar is a small township. The sampling station is located downstream of confluence of tributary Kundi.

Garudeshwar (WQ-9) This station is located 12 km downstream to the largest dam (Sardar Sarovar) on the Narmada River.

Experimental methodology

Grab samples were collected from midstream of the Narmada river at a depth of about 0.3 meters from all the sampling locations. The sample bottles were soaked in 10 percent HNO_3 for 24h and rinsed several times with double distilled water prior to use. 500ml of water samples were collected and immediately acidified with 2ml ultra pure nitric acid (1:1 or 50ml Con HNO_3 + 50 ml DW) and 2ml HCl for arsenic to bring down the pH to <2.0. The samples thus preserved were stored at 4^0C in sampling kits and brought to the laboratory for metal analysis. In the laboratory water samples were filtered through 0.45 µm membrane filter. Samples were collected in the months of November, 2011; February, 2012 and June 2012.

All the chemicals and reagents used were of analytical grade and were procured from Merck, India. The standard solutions of metals were obtained from Merck, Germany. Deionized water was used throughout the study. All glass wares and other containers were thoroughly cleaned and finally rinsed with deionized water several times prior to use. Trace metal analysis was carried out using Agilent 240 FS Atomic Absorption Spectrometer (AAS) following the standard methods given in APHA, 2012.

Quality criteria. As it is a well-known fact that the sources of usable water on the earth are limited, any kind of pollution in them will further reduce its availability. Polluted water cannot be utilized for drinking because of its inherent health risk.

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Water with high salt contents is not suitable for agriculture and most industries. The quality of water also interferes with the aesthetic and economic pursuits of water bodies by affecting marine and fresh water life. However, the water, which is not suitable for irrigation, may be quite suitable for industrial cooling. Every use of water requires a certain minimum quality standards with regards to the presence of dissolved and suspended materials of both chemical and biological nature. The desirable quality of water ensures no harm to the user.

To maintain the minimum quality standard for diverse user has led to the formulation of water quality criteria, and water quality standards. Water quality criteria can be considered as specific requirements on which a decision or judgment to support a particular use will be based. The criteria for the various uses are developed based on the experimental data, and our current knowledge of the health, ecology and other issues and assessing its overall economical effect these are not a set of fixed values, but subject to modification as the scientific data get updated and more and more knowledge is gathered. The term standard applies to any definite principle or measure established by an authority by limiting concentration of different constituents in water to ensure the safe use of water and safeguard the environment.

Drinking water standards. In view of the direct consumption of water by human beings, the domestic water supply is considered to be most important use of water and drinking use has been given first priority on utilization of water resource in the National Water Policy. In India, agencies like the Bureau of Indian Standards (BIS) and Indian Council of Medical Research (ICMR) have formulated drinking water standards. The World Health Organization (WHO) has also laid down drinking water standards, which are considered international standards. Values of the trace and toxic metals covered in this research paper and given in table 1 are according to BIS 10500, 2012 as given below.

Table 2. *Drinking water standards for trace and toxic metals (mg/l) (BIS:10500;2012)*

S. No	Toxic metal	Requirement (Acceptable Limit)	Permissible limit in the absence of alternative source
1	Total arsenic as As	0.01	No relaxation
2	Cadmium as Cd	0.003	No relaxation
3	Total chromium as Cr	0.05	No relaxation
4	Copper as Cu	0.05	1.5
5	Iron as Fe	0.3	No relaxation
6	Lead as Pb	0.01	No relaxation
7	Mercury as Hg	0.001	No relaxation
8	Nickel as Ni	0.02	No relaxation
9	Zinc as Zn	5	15

Results and discussion

Heavy metals or trace elements is the term referred to those elements that occur at very low levels of few parts per million in a given system. They are among the most harmful of the elemental pollutants. Some of them like Pb, Sn, Hg, Zn and Cu can be very toxic to the system (Bhatia, 2006). Trace metals include essential elements like Iron as well as toxic metals like Cd and Hg. Most of them have strong affinity for Sulphur and disrupt enzyme function by forming bonds with sulphur groups in enzyme. Heavy metals are highly persistent and can easily enter a food chain and accumulate until they reach toxic levels. These may eventually kill fish, birds and mammals. Many countries in the world have experienced menace of metal pollution in water and large number of people has been affected. Causes of this pollution have been well documented. However, the main sources of metal toxicity in surface water have been thought to be natural occurrence and subsequent degradation of the environment.

Table 3. *Trace and toxic metal concentration in water quality sites of River Narmada*

S. No.	Water Quality Sites	Month of Sampling	As	Cd	Cr	Cu	Ni	Pb	Zn	Fe
			µg/L							mg/l
1	Amarkantak	Nov, 2011	-	-	-	-	-	-	-	-
		Feb, 2012	-	-	-	-	-	-	-	-
		June, 2012	0.02	0.03	0.90	0.01	0.15	0.04	0.01	0.01
2	Dindori	Nov, 2011	1.48	0.117	6.26	5.85	2.20	2.26	5.85	0.148
		Feb, 2012	0.10	0.68	39.90	34.24	10.24	2.49	52.70	0.05
		June, 2012	3.45	0.01	7.10	0.02	8.90	4.90	0.05	0.09
3	Manot	Nov, 2011	1.5	0.093	8.44	9.14	5.40	2.64	9.14	0.215
		Feb, 2012	0.05	0.12	11.47	13.61	16.46	1.19	19.70	0.21
		June, 2012	0.63	0.46	4.88	0.98	3.80	4.50	0.02	0.02
4	Barmanghat	Nov, 2011	0.99	0.061	2.93	3.67	2.30	1.9	3.67	0.155
		Feb, 2012	0.58	0.03	14.18	22.46	6.00	0.61	14.50	0.11
		June, 2012	0.94	0.02	14.45	7.90	9.20	5.29	0.06	0.13
5	Sandia	Nov, 2011	1.16	0.059	2.61	4.79	3.20	1.34	4.79	0.145
		Feb, 2012	0.41	0.01	5.33	69.54	5.50	1.73	9.60	0.08
		June, 2012	1.09	0.15	203.97	8.90	11.28	5.32	0.06	0.20
6	Hoshangabad	Nov, 2011	1.27	0.068	2.51	3.21	0.50	0.66	3.21	0.165
		Feb, 2012	0.46	0.01	10.08	32.78	1.42	0.86	8.70	0.07
		June, 2012	1.07	0.15	111.06	6.70	1.54	4.34	0.06	0.21
7	Handia	Nov, 2011	1.16	0.067	2.70	2.49	3.10	1.1	2.49	0.155
		Feb, 2012	0.83	0.05	5.70	25.49	0.72	1.00	18.50	0.08
		June, 2012	-	-	-	-	-	-	-	-
8	Mandleshwar	Nov, 2011	0.98	0.071	1.87	1.97	2.30	0.07	1.97	0.02
		Feb, 2012	0.31	0.10	8.16	52.02	4.16	0.55	9.30	0.07
		June, 2012	0.80	1.40	54.41	1.76	4.21	9.06	0.02	0.11
9	Garudeshwar	Nov, 2011	1.19	0.061	3.06	9.95	3.40	2.18	10.451	1.95
		Feb, 2012	2.76	0.14	12.19	34.21	6.63	4.13	18.60	0.65
		June, 2012	0.95	0.06	26.93	6.45	7.40	5.51	0.07	0.22

Arsenic. Arsenic is a natural element that is widely distributed throughout the Earth's crust. Arsenic is classified as a human carcinogen. The maximum acceptable concentration for arsenic in drinking water was established based on the incidence of internal (lung, bladder, and liver) cancers in humans, through the calculation of a lifetime unit risk. This guideline for arsenic has been set at a level that is higher than the level that would be considered to be associated with an "essentially negligible" risk, based on limitations of available treatment

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technology. Bureau of Indian Standard (10500, 2012) have recommended acceptable limit of arsenic is 0.01 mg/l or 10µg/l in drinking water. 24 samples from nine water quality stations were analyzed for a period of November, 2011; February, 2012 and June 2012. Arsenic concentration has been observed ranged 0.02 – 3.45 µg/L. All the samples having arsenic concentration in Narmada river within the acceptable limit prescribed by Bureau of Indian Standard IS:10500, 2012. Dindori water quality station on river reported to have the highest arsenic values 3.45 µg/L during June, 2012.

Copper. Copper is an essential element in human metabolism, and it is well-known that deficiency results in a variety of clinical disorders, including nutritional anaemia in infants. BIS, 10500, 2012 has recommended a acceptable limit of 0.05 mg/l (50µg/l) of copper in drinking water; this concentration limit can be extended to 1.5 mg/l (1500 µg/l) of copper in case no alternative source of water with desirable concentration is available. The intake of large doses of copper has resulted in adverse health effects. Copper and its compounds are widely distributed in nature, and copper is found frequently in surface water and in some groundwater. 24 samples from 09 water quality stations were analyzed for a period of November, 2011; February, 2012 and June 2012. Copper concentration of the Narmada river was found between 0.01- 69.54 µg/L. The maximum concentration (69.54 µg/L) was found in Sandia and minimum (0.01 µg/L) at Amarkantak water quality station. In the study area all the river water quality stations having copper concentration is well within the acceptable limits of Bureau of Indian Standard (BIS) and there is no toxicity of Cu in the river water.

Cadmium. Cadmium is a relatively rare element. It is uniformly distributed in the Earth's crust, where it is generally estimated to be present at an average concentration of between 0.15 and 0.2 mg/kg. A maximum acceptable concentration for cadmium in drinking water has been established on the basis of health considerations. BIS proposed the maximum desirable limit of cadmium is 0.003 mg/l or 3µg/l and no relaxation maximum permissible limit in absence of another source. The concentration of cadmium in unpolluted fresh waters is generally less than 0.001 mg/L. Surface waters containing in excess of a few micrograms of cadmium per litre have probably been contaminated by industrial wastes from metallurgical plants, plating works, plants manufacturing cadmium pigments, textile operations, cadmium-stabilized plastics, or nickel–cadmium batteries, or by effluents from sewage treatment plants. 24 samples from 09 water quality stations were analyzed. Cadmium concentration in the river Narmada varies from 0.01-1.40 µg/L. In the study area the concentration of cadmium is within the acceptable limits of Bureau of Indian Standard (BIS) and there is no toxicity of cadmium in the river water.

Chromium. Chromium can exist in di to hexa valent forms but is present in the environment mainly in the trivalent or hexavalent state. Trivalent chromium (Cr^{+3}) is the most common naturally occurring state; hexavalent chromium (Cr^{+6}) present in the environment are generally the result of industrial and domestic emissions. A maximum acceptable concentration of 0.05 mg/L (50µg/L) for chromium in drinking water has been established on the basis of health considerations. Trivalent chromium, the most common naturally occurring state of chromium, is not considered to be toxic. Toxic effects of chromium in man are attributed primarily to this hexavalent form. BIS (Bureau of Indian Standard), 10500; 2012 have recommended acceptable limit of 0.05 mg /l or 50 µg/l of chromium in drinking water. 24 samples from 09 water quality stations were analyzed. Data reveal that chromium concentration varies from 0.9 – 203.97. Narmada river have maximum 203.97µg/L concentration observed at Sandia during June, 2012. Table 3 shows that Sandia, Hoshangabad and Mandleshwar water quality stations affected by high chromium water (>50 µg/L) and these WQ stations are hot spots from point of view of chromium.

Iron. Iron is the fourth most abundant element in the earth's crust and the most abundant heavy metal; it is present in the environment mainly as Fe^{+2} or Fe^{+3}. Iron an essential element in human nutrition, is an integral component of cytochromes, porphyrins and metalloenzymes. The ingestion of large quantities of iron results in haemochromatosis. It is a condition in which normal regulatory mechanisms do not operate effectively which leads to tissue damage as a result of the accumulation of iron. Tissue damage has occurred, however, in association with excessive intake of iron from alcoholic beverages in some cases of alcoholism. Iron is generally present in surface waters as salts containing Fe (III) when the pH is above 7. According to BIS the acceptable limit of Iron is 0.3 mg/L. The occurrences of iron in river water above maximum acceptable limit (>0.3mg/L) have been shown on the table 3. Twenty four water quality samples from 09 water quality stations were analyzed. High concentration of iron > 0.3 mg/l at only two river water samples during Nov, 2011 and Feb, 2012 was observed. The highest concentration 1.95 mg/l is observed at Garudeshwar on river Narmada .

Lead. Lead is the one of the most common of the heavy elements. It has therefore been used extensively since Roman times and, as a result, has become widely distributed throughout the environment. The acceptable limit (AL) for lead in drinking water is 0.010 mg/L (10µg/L). Above the acceptable limit lead is a cumulative general poison, with foetuses, infants, children up to six years of age and pregnant women (because of their foetuses) being most susceptible to adverse health effects. Lead can severely affect the central nervous system. Overt signs of acute intoxication include dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, hallucinations and loss of memory. Signs of chronic lead toxicity, including tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal symptoms, may appear in adults. After one or two years of exposure, muscle weakness, gastrointestinal symptoms, lower scores on psychometric tests, disturbances in mood and symptoms of peripheral neuropathy were observed in occupationally exposed populations. Bureau of Indian Standard (10500, 2012) have recommended a acceptable limit of lead is 0.01 mg/l or 10µg/l in drinking water. In India some rivers have lead concentration above the acceptable limit prescribed by Bureau of Indian Standards, 10500; 2012. Twenty four samples from 9 water quality stations were analyzed. Mandleshwar water

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quality station was reported to have the highest lead concentration 9.06 µg/L during June, 2012. All the samples have lead concentration within the acceptable limit.

Nickel. The average abundance of nickel in the earth's crust is 1.2 mg/L; in soils it is 2.5 mg/L; in streams it is 1 µg/L, and in groundwater it is <0.1 mg/L. Nickel is obtained chiefly from pyrrhotite and garnierite. It is suspected to be an essential trace element for some plants and animals. The standards of BIS, 10500;2012 for drinking water is 20 µg/L. Manot water quality station was reported to have the highest nickel concentration 16.46 µg/L during February, 2012. Toxic behavior of river water with respect to nickel was not observed at all water quality stations of Narmada river. 24 samples from 9 water quality sites have nickel concentration within the acceptable limit (0.02 mg/l or 20 µg/L).

Zinc. Zinc is an essential element for all living things, including man. Zinc-containing proteins and enzymes are involved in every aspect of metabolism, including the replication and translation of genetic material. BIS has recommended 5mg/l acceptable concentration of zinc in drinking water, which can be extended to 15 mg/l in case no alternative source of water is available. If water have zinc concentration of more than 5 mg/l are not suitable for drinking purposes. 24 samples from 9 water quality stations were analyzed for a period of November, 2011; February, 2012 and June 2012. The Zinc concentration varies from 0.01-52.70 µg/L. High zinc level is found at Dindori water quality site during February, 2012. In the study area all the water quality stations having zinc concentration is well within the acceptable and permissible limits of Bureau of Indian Standard (BIS) and there is no toxicity of Zn in the river water. Zinc is an essential element for human nutrition. The daily requirement is between 4 and 10 mg depending on age and sex, but pregnant women and new mothers may require up to 16 mg/day. Food constitutes the most important source of zinc.

Table 4 *Water quality hot spot in River Narmada*

S. No.	Water quality sites	Month of sampling	Cr µg/l	Cu µg/l	Fe mg/l
1	Sandia	Feb, 2012		69.54	
	Sandia	June, 2012	203.97		
2	Hoshangabad	June, 2012	111.06		
3	Mandleshwar	Feb, 2012		52.02	
	Mandleshwar	June, 2012	54.41		
4	Garudeshwar	Nov, 2011			1.95
	Garudeshwar	Feb, 2012			0.65

Conclusion

Metals occur naturally and become integrated into aquatic organisms through food and water. Trace metals such as iron, copper selenium, and zinc are essential metabolic components in low concentrations. However metals tend to bio-accumulate in tissues and prolonged exposure or exposure at higher concentrations can lead to illness. Elevated concentrations of trace metals can have negative consequences for both wildlife and humans. Human activities such as mining and heavy industry can result in higher concentrations than those that would be found naturally. Comprehensive study of the results reveals that out of nine water quality stations monitored, water samples collected at 5 water quality stations (Amarkantak, Dindori, Manot, Barmanghat and Handia) are found to be within the permissible limit for all purposes. While Sandia, Hoshangabad, Mandleshwar and Garudeshwar stations were beyond the permissible limit due to presence of chromium, copper and iron metals. The contents of metal ions were higher during February and June month. The trace and toxic metal studies presented in the entire course of Narmada River add a new dimension in the assessment of river water quality studies for determination of eco-toxicity of different metals. The major source of pollution to the Narmada river is the anthropogenic municipal solid waste and sewage from nearby towns/habitations, agricultural runoff and native soil erosion. The quality of the Narmada River is degraded due to the municipal and industrial discharges from the catchment.

References

APHA (2012) Standard Methods for the Examination of Water and Wastewater 22nd (Edition). American Public Health Association Washington, DC.
BHATIA S.C. (2006) Environmental Chemistry. CBS Publishers, New Delhi. Pp. 88-89.
BISWAS S. K. (1987) Regional tectonic framework, structure and evolution of the western marginal basins of India. Tectonophysics, 135: 307–327.
BUREAU OF INDIA STANDARDS (BIS)10500, (2012) Specification for drinking water, Indian Standard Institution, (Bureau of Indian Standard), New Delhi, 1-5.
CENTRAL POLLUTION CONTROL BOARD (CPCB) (1994) Basin Sub-basin inventory of water pollution -The Narmada Basin, CPCB New Delhi.
CENTRAL WATER COMMISSION (CWC) (2012) Water Quality Hot Spots in Indian River, Report CWC pp-12
GORE J.A. (1985) The Restoration of Rivers and Streams. 1st edn, London Blackwell Science Ltd.
GUPTA H., CHAKRAPANI G.J. (2005) Temporal and spatial variations in water flow and sediment load in Narmada river basin, India: Natural and manmade factors. Environmental Geology, 48(4–5):579–589.
INTER PRESS SERVICE (IPS) (1999) Most Rivers in the World are polluted Wastington D.C Inter-press Service Wire Service. pp. 38-41
JAIN C.K., GUPTA H., CHAKRAPANI G.J. (2008) Enrichment and fractionation of heavy metals in bed sediments of River Narmada, India. Environ Monit Assess., 141:35–47
MINISTRY OF ENVIRONMENTAL FORESTS (1994) Yamuna Action Plan, Govt of India, New Delhi, P-2
RODIER J. (1975) Analysis of Water. Jerusalem. Halsted Press.
WHO (2006) Guidelines for Drinking Water Quality. First Addendum to the Third Edition Volume 1. Recommendations. pp. 491-493.

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