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# SURFACE WATER QUALITY WITH PAINSTAKING HUMAN IMPACTS-A CASE STUDY OF THE WAINGANGA RIVER, BHANDARA, MAHARASHTRA, INDIA

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**Abstract:** The present paper ardently deals with the surface water vulnerability assessment of River Wainganga in Tahsil Bhandara of Bhandara District of Maharashtra State, India. The surface water vulnerability assessment of River Wainganga in Tahsil Bhandara is analyzed according to the guidelines provided by the Central Pollution Control Board, New Delhi, APHE, IHP and WHO. A total number of 36 surface water samples collected from drainage and sub-drainages of River Wainganga in Tahsil Bhandara of Bhandara District, Maharashtra State during 2010-11 were analyzed for pH, EC, Fe, Zn and Cu. The pH was found in the alkaline range (7.21-8.32), while conductance was obtained in the range of 221-3364 µmhos/cm. Fe, Zn and Cu were detected enormously higher than the permissible limit for the samples in the range of 5.50-55.85, 2.12-39.18 and 12.6-418.30mg/l respectively. Overall seasonal variation was significant for Fe, Zn and Cu. The maximum mean concentration of Fe (55.85 mg/l) was observed in summer, Zn (39.18 mg/l) in monsoon. Fe, Zn and Cu concentrations also varied with the change of sampling locations. The highest mean on concentrations (mg/l) of Fe (55.85) and Zn (39.18) was observed at Warthi near Sunflag Iron Steel Plant. Whereas the Cu (418.3 mg/l) was obtained at the downstream station, Bhandara Bridge. All in all, the dominance of various heavy metals in the surface water of the river Wainganga followed the sequence: Cu > Fe > Zn. A significant positive correlation was exhibited for conductivity of water with Cu and Zn.

**Keywords**: River Wainganga (RW), Spatial and Temporal Changes (STC), Heavy Metal (HM), Water Quality (WQ).

## INTRODUCTION

There are many different situations where surface water quality is threatened by the existing industries in the district. There is one Ordnance factory at Bhandara town, which discharges hazardous and toxic wastes in to the streams. There are about 180 Rice Mills, 4 Oil Extraction Plants, 3 Steel & Alloys units, 2 Paper & Pulps unit, 1 Sugar and about 70 Cottage Brass utensils manufacturing units in the district. The wastewater disposed by these industries contains hazardous elements and contaminates surface water and later on contaminates groundwater [16]. The type, extent, and duration of induced changes of groundwater quality are controlled by the type of human influence; the geo-chemical, physical and biological processes occurring in the ground; and the existing hydrogeological conditions. These parameters are controlled by the volume and flux of water in the system which, in turn, depends on climate, topography, and hydraulic conductivity [18].

The source streams of the Wainganga rise in the Chhindwara and Seoni Plateaus of Madhya Pradesh; the river flows south through the Balaghat district before entering Bhandara district at its northern extreme [7]. It initially flows west along the northern boundary, and then turns south-west and gradually southwards through the Bhandara tahsil. Before leaving the district to enter Chandrapur, the river runs south-east. Thus, the Wainganga drains mainly the western parts of the district.

River Wainganga, the most sacred and important river of Bhandara District, is regarded as the life-line of Bhandara district. About 140 Km of the river stream gives life to 6 cities and about 250 of river site villages out of total 870 in the district. These villages contaminate the river by polluting million liters of water per day. Although the Wainganga River's annual flow regime is subject to local variations, the predominant pattern is for a low-flow dry season from February to May and a wet season from mid June to January, with peak flows usually occurring in July. Among the inorganic contaminants of the river water, heavy metals are getting importance for their non-degradable nature which, often accumulate through tropic level causing a deleterious biological effect [9]. Anthropogenic activities like mining, ultimate disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates from different industries, such as Steel plants, Utensil industries [2], Thermal power plants etc. and also the indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture resulted in deterioration of surface water quality rendering serious environmental problems posing threat on human beings [12-14-21], and sustaining aquatic biodiversity [6-8]. Though some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in plants and microorganisms, while many other metals like Cd, Cr and Pb have no known physiological activity, but they are proved detrimental beyond a certain limit [5-13], which is very much narrow for some elements like Cd (0.01 mg/L), Pb (0.10 mg/L) (ISI, 1982) and Cu (0.050 mg/L). The deadlier diseases like edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented [1-10-22]. Therefore, monitoring these metals is important for safety assessment of the environment and human health in particular. With reference to this background, this study monitored the surface water in the Bhandara Tahsil stretch of the river Wainganga in Maharashtra State, India, considering the spatial and temporal variations in heavy metal content and also to evaluate the status of the river water quality with respect to drinking and agricultural irrigation purposes.

In India, while there are some very large rivers, there are many others which have only a meager flow. Even in the case of River Wainganga, because of extraction of water for irrigation purposes, the flow is considerably reduced. This is particularly true during low flow season and when the demand of water for agriculture is high. In many cases, because of impoundments and abstractions and also the seasonal nature of the river, in some places the channel may be dry for 1 to 2 months in the year. Further, water quality planning also has to take into account the fact that for a large fraction of rural population living on the banks of the river, the river water is the only source for domestic water requirements [4]. The utilization of assimilative capacity of a river for waste disposal is therefore not considered a viable approach in setting discharge limits. Under the Environment Pollution Control Act 1986, effluent standards have been set for different industries uniformly throughout the country. Only in cases when the effluent is disposed in the sea or estuary, location specific discharge limits may be allowed. Most of the pollution of rivers in the country can be attributed to the discharge of untreated municipal wastes. The Government of India (National River Conservation Directorate, Ministry of Environment & Forests) co-ordinates the pollution control program identified under the action plan. In the case of municipalities, the Government also gives subsidy to create necessary infrastructure for pollution control measures. Maharashtra State Pollution Control Board is to take action against the industries, which do not meet their waste discharge standards [23].

## METHODOLOGY

In order to mitigate the problem, the following approach and methodology is adopted in the presented paper:

- Water quality analysis is carried out as per APHA norms in river stretches to establish the existing water quality [3].
- Surveys are also carried out to determine the existing and planned beneficial uses of the stream in different reaches, such as abstraction for drinking water supply as per WHO norms.
- The existing water quality in a river reach is then compared with the water quality standards for the beneficial use in the reach requiring the most stringent water quality.

**Location of Study Area:**

Bhandara is a town and district of British India, in the Nagpur division of the Central Provinces. The town is situated on the left bank of the River Wainganga, 7 Km from the Bhandara Road railway station on the Bengal-Nagpur railway. Bhandara district is encircled by Balaghat district (Madhaya Pradesh) in North, Gondia in East, Chandrapur, in South, and Nagpur in the West. The district of Bhandara is situated 21° 09' north and 79° 42' East on the world map. Its area is 3716 sq.kms. The climate is moderate with 1,470mm of annual rainfall. The rain fall generally increases from the west towards the east. It varies from 1312mm (51-69) at Chandpur near the western border of the district to 1578mm (62-15) at Gondia near the north eastern border of the district [15]. The south-west monsoon arrives over the district by about second week of June. The rainfall during the period from June to September constitutes about 90 percent of the annual normal rainfall. July and August are the months with heavy rainfall, July being the rainiest month. The variation in the annual rainfall from year to year is small [16]. Hilly region of the northern side consists of Satpuda range, Bhivsen Koka are small hillocks in this range. Gaymukh, Ambagad, are the prominent hills in northern hilly region. The district is bounded on the North, North East and East by lofty hills, while the West and North-West are comparatively open. Small branches of the Satpura range make their way into the interior of the district. The Ambagarh or Sendurjhari hills, which skirt the south of the Chandpur-Pargana, have an average height between 300 and 400 ft. above the level of the plain. There are 3648 small lakes and tanks in Bhandara district, whence it is called the lake region of Nagpur [7]. The district is traversed by the national high way No.6

from Nagpur to the east, and also by the Bengal-Nagpur railway Fig. No. 1 shows location map of the study area.


**Fig.1:** Shows the location map of Bhandara District of Maharashtra State [Curtsey mapsofindia.com].

Bhandara is also known as 'Brass City' as it is the largest brass producing industrial base. The district is also very famous for the Ordnance Factory Estate which is commonly known as Jawaharnagar colony. The Sunflag Iron Steel Company and Shivmangal Ispat Pvt. Ltd. are the major industrial undertakings in Bhandara [17].

## RESULT AND DISCUSSION

Almost major area in the district has naturally poor surface water quality and in many places the natural quality of the surface water has been altered by human activities. Large portion of the surface water in the district is under threat due to organic/biological matter from various agro-industries; whereas some portion of the surface water is being contaminated due to non-biodegradable organic and inorganic compounds from the industries [18-19-20]. The demand for freshwater has increased, that mainly consists of surface water, for potable, domestic, irrigation, and industrial uses. It is a well-known fact that clean water is absolutely essential for healthy living. Adequate supply of fresh and clean drinking water is a basic need for all the inhabitants of this Tahsil, yet it has been observed that freshwater resources are threatened not only by over exploitation and poor management but also by ecological degradation. The main source of freshwater pollution can be attributed to discharge of untreated waste, dumping of industrial effluent, and run-off from agricultural fields. Industrial growth, urbanization and the increasing use of synthetic organic substances have serious and adverse impacts on freshwater bodies. It is a generally accepted fact that the developed countries suffer from problems of chemical discharge into the water sources mainly groundwater, while developing countries face problems of agricultural run-off in water sources. Drinking water polluted with chemical causes problem to health and leads to water-borne diseases, which can be prevented by taking measures even at the household level. The increased demand and related supply has caused the water storage to decline and surface water quality to deteriorate. The results of analysis of hydrochemical data from 36 surface water samples from selected locations in the areas of the Bhandara Tahsil have been evaluated to determine the temporal changes in Surface water quality.

The water samples are collected from the upstream (before the river enters the town), downstream (after the river has left the town) and midstream (somewhere in the town). The water samples are collected from the midstream and one-fourth from the river bank. But no one goes either to midstream or one-fourth distance from the bank to have a dip. Also the water intake points are on the bank. So the river water quality should be analyzed at the users' points e.g., bathing Ghats and intake points. The parameters for which the river water quality is analyzed are Iron, Zinc, Copper, TDS, Color, Electrical Conductivity, Alkalinity, and Hardness which don't reflect the true water quality. Hydro-chemical changes associated with land use change of the affected spots (Exceeding Desirable Limits of Iron, Zinc, Copper, TDS, Color, Electrical Conductivity, Alkalinity, and Hardness, are shown in the Table No. 1, 2, 3 and 4. The tables summarize the average concentration of Iron, Zinc, Copper, TDS, Color, Electrical Conductivity, Alkalinity, and Hardness for River Wainganga water. Iron, Zinc, and Copper have been used in this paper as an indicator of surface water contamination in Bhandara Tahsil .TDS, Electrical Conductivity, Alkalinity, and Hardness have been used as an indicator of River Wainganga water salinity contamination. High levels of TDS, Electrical Conductivity, Alkalinity, and Hardness in the surface water cause high salinity in the water supply. The average higher side TDS concentration is 1572.89mg/l in some part of Tahsil, which is not within the permissible limit.

Table No.1 Showing Water Quality Status near Sunflag Iron Industry, Warathi, Bhandara.

| Month of sampling | Iron (Fe) (mg/l) | Color (Hazen Unit) | pH | Electrical Conductivity (µmhos/cm) | TDS (mg/l) | Alkalinity (mg CaCO3/l) | Turbidity (NTU) | Total Hardness (mg CaCO3/l) |
|---|---|---|---|---|---|---|---|---|
| Sept. 10 | 55.85 | 4 | 8.1 | 363 | 224 | 148 | 210 | 140 |
| Oct. 10 | 50.87 | 4 | 8.4 | 372 | 265 | 165 | 187 | 157 |
| Nov. 10 | 57.98 | 4 | 7.3 | 356 | 209 | 136 | 165 | 198 |
| Dec. 10 | 45.00 | 3 | 7.9 | 324 | 217 | 190 | 143 | 154 |
| Jan. 11 | 23.98 | 4 | 8.3 | 398 | 365 | 168 | 129 | 243 |
| Feb.11 | 19.70 | 4 | 7.1 | 465 | 275 | 154 | 94 | 287 |
| Mar. 11 | 12.80 | 3 | 7.6 | 653 | 367 | 209 | 63 | 297 |
| Apr.11 | 1.70 | 2 | 7.8 | 647 | 402 | 208 | 5 | 220 |
| May.11 | 3.80 | 2 | 8.1 | 476 | 436 | 243 | 5 | 198 |
| Average | 30.18 | 3.11 | 7.84 | 450.44 | 306.66 | 180.11 | 111.22 | 210.44 |

Table No.2 Showing Water Quality Status near Sun flag Pandhrabodi nala, Warthi, Bhandara.

| Month of sampling | Iron (Fe) (mg/l) | Color (Hazen Unit) | pH | Elec. Conductivity (µmhos/cm) | TDS (mg/l) | Alkalinity (mg CaCO3/l) | Turbidity (NTU) | Total Hardness (mg CaCO3/l) |
|---|---|---|---|---|---|---|---|---|
| Sept. 10 | 167.50 | 3 | 8.4 | 442 | 276 | 188 | 45 | 144 |
| Oct. 10 | 159.23 | 3 | 8.6 | 465 | 324 | 199 | 57 | 176 |
| Nov. 10 | 169.20 | 3 | 8.3 | 487 | 329 | 210 | 53 | 165 |
| Dec. 10 | 155.20 | 4 | 8.4 | 426 | 357 | 243 | 43 | 198 |
| Jan. 11 | 128.30 | 2 | 7.9 | 547 | 398 | 214 | 47 | 254 |
| Feb.11 | 111.98 | 2 | 7.3 | 543 | 435 | 266 | 37 | 244 |
| Mar. 11 | 54.87 | 3 | 8.8 | 643 | 476 | 213 | 32 | 265 |
| Apr.11 | 2.70 | 1 | 8.1 | 787 | 496 | 280 | 26 | 276 |
| May.11 | 2.50 | 1 | 8.1 | 675 | 466 | 298 | 25 | 287 |
| Average | 105.72 | 2.44 | 8.21 | 557.22 | 395.22 | 234.55 | 40.55 | 223.22 |

Table No.3 Showing Water Quality Status near Brass Industry, Satyam Theater, Warthi Road Bhandara.

| Month of sampling | Copper (Cu) (mg/l) | Zinc (Zn) (mg/l) | Color (Hazen Unit) | pH | Elec. Conductivity (µmhos/cm) | TDS (mg/l) | Alkalinity (mg CaCO3/l) | Turbidity (NTU) | Total Hardness (mg CaCO3/l) |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 10 | 418.3o | 3.918 | 20 | 8.7 | 3350 | 2110 | 1780 | 790 | 1550 |
| Oct. 10 | 478.98 | 2.344 | 21 | 8.7 | 3360 | 2115 | 1759 | 798 | 1511 |
| Nov. 10 | 438.76 | 2.477 | 20 | 8.5 | 3364 | 2170 | 1727 | 732 | 1528 |
| Dec. 10 | 350.32 | 3.543 | 21 | 8.2 | 3278 | 1987 | 1403 | 760 | 1387 |
| Jan. 11 | 349.00 | 3.834 | 22 | 8.3 | 3298 | 1594 | 1298 | 683 | 1372 |
| Feb.11 | 320.34 | 5.432 | 15 | 8.2 | 2856 | 1392 | 1175 | 654 | 1245 |
| Mar. 11 | 240.87 | 34.58 | 12 | 7.7 | 2393 | 1235 | 942 | 543 | 862 |
| Apr.11 | 183.27 | 80.00 | 3 | 7 | 1108 | 720 | 328 | 52 | 440 |
| May.11 | 184.72 | 71.00 | 7 | 7 | 1125 | 833 | 349 | 76 | 476 |
| Average | 329.39 | 23.01 | 15.66 | 8.03 | 2681.33 | 1572.89 | 1195.66 | 565.33 | 1152.33 |

Table No.4 Showing Water Quality Status near Intake Well, Wainganga River, Kardha, Bhandara.

| Month of sampling | Iron (Fe) (mg/l) | Copper (Cu) (mg/l) | Zinc (Zn) (mg/l) | pH | Elec. Conductivity (µmhos/cm) | TDS (mg/l) | Alkalinity (mg CaCO3/l) | Turbidity (NTU) | Total Hardness (mg CaCO3/l) |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 10 | 26.90 | 257.2 | 2.87 | 8.3 | 221 | 134 | 164 | 760 | 96 |
| Oct. 10 | 25.90 | 244.9 | 3.87 | 8.3 | 287 | 183 | 172 | 654 | 104 |
| Nov. 10 | 21.30 | 218 | 3.98 | 8.2 | 254 | 152 | 156 | 609 | 139 |
| Dec. 10 | 17.90 | 165.2 | 39.7 | 8 | 297 | 143 | 176 | 537 | 162 |
| Jan. 11 | 11.90 | 152.9 | 39.2 | 7.9 | 398 | 265 | 139 | 432 | 198 |
| Feb.11 | 6.21 | 187.9 | 42 | 7.3 | 410 | 289 | 201 | 328 | 201 |
| Mar. 11 | 2.30 | 98.67 | 44.87 | 7.5 | 490 | 329 | 228 | 123 | 228 |
| Apr.11 | 0.8 | 59.4 | 46 | 7.4 | 605 | 372 | 236 | 4 | 244 |
| May.11 | 0.8 | 38.2 | 49.8 | 7.2 | 610 | 429 | 239 | 10 | 265 |
| Average | 12.66 | 158.04 | 30.25 | 7.78 | 396.88 | 255.11 | 190.11 | 384.11 | 181.88 |

The average Iron (Fe) concentration is 49.5 mg/l in some part of Tahsil. The average concentration of Copper (Cu) is 243.71 mg/l in some part of Tahsil. The average concentration of Zinc (Zn) is 26.63 mg/l in some part of Tahsil. As shown in Table No.1, 2, 3, & 4 & Fig. No. 2, 3, 4 & 5 level of TDS, Fe, Cu, Zn, Turbidity, Total Hardness and pH were higher than APHE/WHO/IS:10500 standard, i.e., 1000, 5 mg/l, 2 mg/l, 3 mg/l, 10 NTU, 600 mg/l and 8.5, respectively. Furthermore, in some part of Tahsil, the concentration of TDS was less than standards.

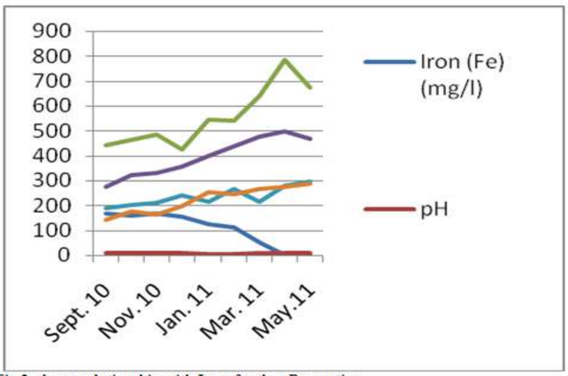


Fig.2. shows relationship with Iron & other Properties.

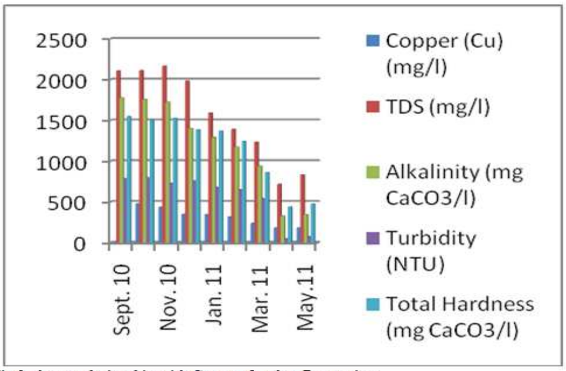


Fig.3. shows relationship with Copper & other Properties.

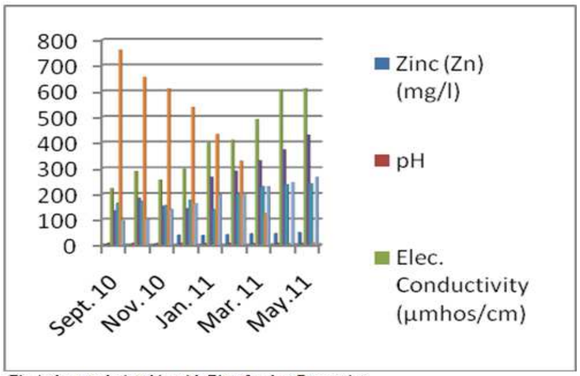


Fig.4. shows relationship with Zinc & other Properties.

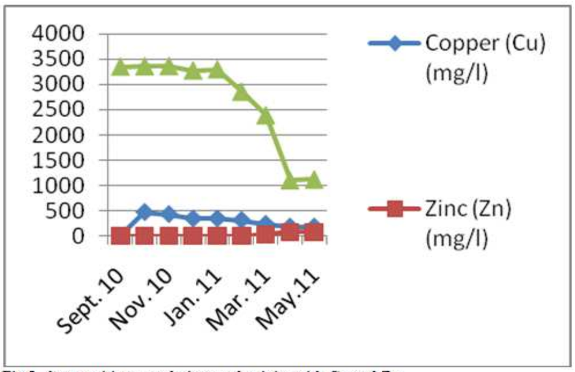


Fig.5. show positive correlation conductivity with Cu and Zn.

Physico-chemical characteristics for Wainganga River samples downstream and upstream show little or no impact of any discharge in this area. Results would be considered typical for this river at this time of year. Samples were collected directly from surface water when actively discharging. The effluent proved highly toxic to aquatic organisms and comprised elevated Turbidity, Alkalinity, Total Hardness, pH, EC and Heavy Metals [11] levels and a significantly elevated concentration of Iron (55.85mg/l.). Iron is generally present in natural waters, though in very small amounts. When present in natural waters in levels above 2.5mg/l, sewage or industrial contamination may be indicated.

Samples were collected from Wainganga River downstream of Bhandara city surface water when the discharge was active. The results contrast notably with upstream samples and downstream sample prior to the discharge. This context represents an alteration of physico-chemical conditions within the Wainganga River under the influence of the discharge. River water was highly contaminated and displayed breach of limits for Turbidity, Alkalinity, Total Hardness, pH, EC, Suspended Solids, and Total metallic substance and other physico-chemical properties is as stated under Table No.1, 2, 3 and 4. Most notable of these breaches was the level of total Copper content which is about 1200 times the upper limit for surface waters at time of sampling. The concentration of heavy metal form is considerably more toxic to organisms such as fish and, therefore, we pay considerable attention to the relative concentration of this particular contaminant. In the Wainganga River, total Copper concentration in water of 478.98 mg/l at pH 8.7 and a temperature of 25°C would have resulted highly toxic to freshwater aquatic organisms including all fish and most invertebrate species and represents a level approximately 1200 times that specified as the upper limit for surface waters to be conformed with, by 80% of samples over a 12 month period.

**Copper (Cu) and River Wainganga water:**

Copper is commonly used in the Bhandara Tahsil to make Brass utensils. All living organisms including humans need copper to survive; therefore, a trace amount of copper in our diet is necessary for good health. However, some forms of copper or excess amounts can also cause health problems. The level of copper in surface water is generally very low. High levels of copper may get into the environment through farming, manufacturing operations, and municipal or industrial wastewater releases into Wainganga River in the study area. Copper can be found in many kinds of food, in drinking water and in air. Because of that we absorb eminent quantities of copper each day by eating, drinking and breathing. The absorption of copper is necessary, because copper is a trace element that is essential for human health. Although, humans can handle proportionally large concentrations of copper, yet too much of copper can still cause eminent health problems. Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachaches, dizziness, vomiting and diarrhea. Intentionally high uptakes of copper may cause liver and kidney damage and even death.

**Zinc (Zn) and River Wainganga water:**

Zinc is naturally present in water. The average zinc concentration in Rivers generally contain between 5 and 10 ppb zinc. The World Health Organization stated a legal limit of 5 mg Zn/L. Zinc salts cause a milky turbidity in water in higher concentrations. Additionally, zinc may add an unwanted flavor to water. The solubility of zinc depends on temperature and pH of the water in question. When the pH is fairly neutral, zinc in water is insoluble. Solubility increases with increasing acidity. Zinc was not attributed to a water hazard class, because it is not considered a hazard. Zinc is a dietary mineral for humans and animals. Still, its overdose may negatively influence human and animal health and over a certain boundary concentration, zinc may even be toxic. Toxicity is low for humans and animals, but phyto-toxicity may not be underestimated. Current zinc values are not a very extensive environmental risk. Zinc concentrations in the river Wainganga at Bhandara town have reached optimal values. Unfortunately, locations of historical contamination still exist. The human body contains approximately 2-3 g zinc, and zinc has a dietary value as a trace element. Minimum daily intake is 2-3 g prevents deficiencies. The human body only absorbs 20-40% of zinc present in food; consequently many people drink mineral water rich in zinc. Symptoms of zinc deficiencies are tastelessness and loss of appetite. Children's immune systems and enzyme systems may be affected. One may also absorb zinc overdoses. This does not occur very regularly. Symptoms include nausea, vomiting, dizziness, colic's, fevers and diarrhea and mostly occur after intake of 4-8 g of zinc.

**Iron (Fe) and River Wainganga water:**

Wainganga Rivers contain an average 30.18 mg/l of iron, at Bhandara Tahsil. Iron may be harmful to plants at feed concentrations of between 5 to 200 ppm. The total amount of iron in the human body is approximately 4 g, of which 70% is present in red blood coloring agents. Iron is a dietary requirement for humans, just as it is for many other organisms. Men require approximately 7 mg iron on a daily basis, whereas women require 11 mg. The difference is determined by menstrual cycles. When people feed, normally these amounts can be obtained rapidly. Iron is a central component of hemoglobin. When iron exceeds the required amount, it is stored in the liver. The bone marrow contains high amounts of iron, because it produces hemoglobin. When high concentrations of iron are absorbed, for example by Haemochromatose patients, iron is stored in the pancreas, the liver, the spleen and the heart. This may damage these vital organs. Healthy people are generally not affected by iron overdose, which is also generally rare. It may occur when one drinks water with iron concentrations 50ppm.

## CONCLUSION

Water is essential for life. No living being can survive without it. It is a prerequisite for human health and well-being as well as for the preservation of the environment. Water challenges will increase significantly in the coming years. Continuing population growth, coupled with its mobility, and rising incomes will lead to greater water consumption, as well as more waste. The urban population in developing cities will grow dramatically, generating demand well beyond the capacity of already inadequate water supply and sanitation infrastructure and services. Hence, it's highly recommended that before discharging waste water into surface, waste water should be treated before discharging into natural stream. The recommended strategy provides the focus for water management in the Wainganga River. Successful implementation of the strategy will require the commitment of and substantial resources from the Department of Water and Environment and other institutions. The interdependency of the Wainganga River will require coordinated and synchronized planning in future to ensure coherent management of the water resources. Cooperation among water service providers, municipalities, industries and the Department of Water and Environment in the implementation of the strategy will be essential to foster the principles of integrated water resource management and to achieve the objectives of the strategy for sustainable development.

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