Chapter 5:

Bibliography
CHAPTER – 5
BIBLIOGRAPHY


2. A Hand Book of Hygiene and Health for medical and Public health students; by Bedi, Yash Pal, Ch – 9, P – 9, 10, 11\textsuperscript{th} edition, 1971).


6. BIS: IS: 3025. Methods of Sampling and Test (Physical and Chemical) for water and wastewater.


23. Metcalls & Eddy, Wastewater Engineering Treatment, Disposal and Reuse, 3rd edition,


29. Salomons, W., Forstner, U., 1980. Trace metal analysis on Polluted sediments. Part II:


34. Singh, Kunwar. Petal, 2005, Studies on distribution and fractionation of heavy Metals
in Gomti river sediments a tributary of the Ganges, India. J. Hydrology, 312 (2005), 14-27.

35. Stumm, W; “Aquatic Surface Chemistry”. Chemical Process at the Particle Water Interface; John Willy and Sons, New Yark, 1987).


List of Author's Publications

1. Ganga Water Quality at Patna with Reference to Physico-Chemical and Bacteriological Parameters.
   Vol.49, No.1, P.28-32, January 2007

2. Distribution of Heavy Metals in Ganga Water and its Bed Sediments along the Patna Stretch
   ..... In Press

3. Assessment of Ganga Water and its Bed Sediments along the Patna Stretch with reference to Physico-Chemical Parameters and Heavy Metals
   ..... In Press
Ganga Water Quality at Patna with Reference to Physico-chemical and Bacteriological Parameters

RAM, PARASHURAM* AND SINGH, A.K**

The studies to assess the Ganga water quality at Patna was carried out in terms of physico-chemical and bacteriological parameters to determine its suitability for various purposes. Based on this study, this paper provides the scientific information to the concerned for the implementation of River-Action-Plan and conservation of water body.

Introduction

The holy Ganga originates from Gomukh glacier above Gortri and after travelling a distance of 2525 km, it joins the sea along the Patna. It is one of the major rivers of India. Population of Patna is approximately 17.07 lacs and spread over an area of 110 sq. km. The river Ganga receives pollution due to discharge of sewage, industrial effluent, disposal of solid waste and agricultural run-off water from its catchment area. A total of 190 MLD sewage is generated from the Patna area. The Ganga water is widely used for organized fishing at many places along its stretch. The maintenance and protection of wholesomeness and pristine quality of Ganga is responsibility of individual, social and state as well.

Although, a few project works have been carried out seriously on the study on pollution of river Ganga with heavy metals at different stretches, but the studies have not specifically carried out along the Patna stretch as such. As per latest reports of UNICEF and Govt. of Bihar, the arsenic and fluoride concentrations have been observed in the ground water within 10 km along the Ganga river from Buxar to Gagalpur. These alarming observations prompted the study on Ganga water with reference to physico-chemical parameters including heavy metals.

Water quality monitoring

Considering the outfall drains, human interferences, biological features and to have representative samples of water, grab samples were collected from U/S - Patna (Kurji - Gha), near P.M.C.H and D/S - Patna (Gaighat). The samples were collected during pre-monsoon and monsoon season from midstream as well as from two meters away from the bank. The meter below surface was taken as the standard depth for sampling to avoid surface micro layer. The samples were collected in plastic and glass bottles. The samples for analysis of heavy metals were collected in 250 mL polythene, narrow mouth bottles and preserved by adding 1mL HNO₃ to have final pH < 2. The spot test for temperature, pH and DO were done instantly just after collection of samples at the sampling sites.

Materials and methodology

All the chemicals used in the study were of analytical grades. Double distilled water was used throughout the study. All glasswares and sample containers were thoroughly cleaned and finally rinsed with double distilled water. Standard methods for the examination of water and wastewater (17th Edition) published by American Public Health Association (APHA, 1989) and Bureau of Indian Standards (BIS) Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater (I.S - 3025) were adopted as reference manual for analytical procedures.

Temperature was measured by mercury thermometer. The pH meter (WTW – 320 Model) was used to measure the pH value. Electrical conductivity was measured by conductivity meter (Century – CC 601). Solids were analyzed gravimetrically. DO was analyzed at the spot by the Iodometric with azide modification method. This also forms the basis of BOD estimation by incubation method using BOD incubator at 27°C. The COD values were determined by refluxing the samples with mixture of standard potassium dichromate and conc. sulfuric acid. Total hardness was estimated by the conventional EDTA titration method. Sulphate was analyzed by turbidity method using Spectrophotometer (Spectronic – 20). The amount of chloride ion was analysed by argentometric method, which involved titration with standard AgNO₃ solution using potassium chromate as an indicator. Fluorides and phosphates were also estimated spectrophotometrically. The fluoride estimation involved treatment of water sample with Zirconium – SPADNS solution, whereas the phosphate estimation involved the colour development by treating water sample with ammonium molybdate and SnCl₂ in acidic condition. Na and K

*hairman, Bihar State Pollution Control Board, Patna.


28
Table 1: The values obtained for various parameters to assess the Ganga water quality at Patna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ganga Water Quality at Kurji U/S Patna</th>
<th>Ganga Water Quality at PMCH, Patna</th>
<th>Ganga Water Quality at Gajibhat DDS, Patna</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sampling Location</td>
<td>2 meter away from Bank</td>
<td>Mid Stream</td>
<td>2 meter away from Bank</td>
</tr>
<tr>
<td>3. Temperature °C</td>
<td>19 24 22 19 24 22</td>
<td>19 22 21 19 22 21</td>
<td>19 22 21 19 22 21</td>
</tr>
<tr>
<td>4. pH</td>
<td>8.32 8.99 8.30 8.30 8.60 8.28</td>
<td>8.32 8.50 8.30 8.32 8.50 8.40</td>
<td>8.31 8.52 8.31 8.33 8.50 8.30</td>
</tr>
<tr>
<td>5. Conductivity, μmhos/cm</td>
<td>366 668 170 385 465 162</td>
<td>395 450 182 387 442 190</td>
<td>397 445 175 396 450 180</td>
</tr>
<tr>
<td>6. D.O., mg/L</td>
<td>9.1 8.7 8.0 9.2 9.0 7.7</td>
<td>9.2 8.7 7.8 9.0 8.8 7.8</td>
<td>9.3 8.8 7.5 9.1 9.0 7.8</td>
</tr>
<tr>
<td>7. B.O.D., mg/L</td>
<td>1.3 2.0 1.8 1.7 1.5 2.1</td>
<td>1.8 2.0 2.0 1.8 2.0 1.8</td>
<td>1.9 2.2 2.2 1.8 1.8 2.0</td>
</tr>
<tr>
<td>8. C.O.D., mg/L</td>
<td>12 16 12 4 12 12</td>
<td>20 12 16 12 12 16 20</td>
<td>20 12 20 8 16 16</td>
</tr>
<tr>
<td>9. TSS, mg/L</td>
<td>16 16 20 12 15 22</td>
<td>32 25 20 30 24 24</td>
<td>30 24 23 24 20 22</td>
</tr>
<tr>
<td>10. TDS, mg/L</td>
<td>168 274 164 261 190</td>
<td>132 167 182 166 260 263</td>
<td>134 286 292 174 252 270</td>
</tr>
<tr>
<td>11. TS, mg/L</td>
<td>184 290 176 276 312</td>
<td>164 292 302 196 280 287</td>
<td>154 310 315 194 272 292</td>
</tr>
<tr>
<td>12. Total Hardness, mg/L</td>
<td>178 168 92 180 164 92</td>
<td>172 180 90 172 182 92</td>
<td>180 172 80 174 168 90</td>
</tr>
<tr>
<td>13. Chloride, mg/L</td>
<td>18 22 8 19 20 6</td>
<td>16 20 10 15 18 12</td>
<td>16 23 8 15 18 10</td>
</tr>
<tr>
<td>14. Fluoride, mg/L</td>
<td>0.20 0.18 0.24 0.18 0.18 0.22</td>
<td>0.28 0.40 0.24 0.22 0.46 0.24</td>
<td>0.22 0.58 0.24 0.20 0.50 0.26</td>
</tr>
<tr>
<td>15. Phosphate, mg/L</td>
<td>0.03 0.05 0.04 0.02 0.03 0.040</td>
<td>0.04 0.028 0.04 0.04 0.03 0.04</td>
<td>0.03 0.027 0.04 0.03 0.03 0.045</td>
</tr>
<tr>
<td>16. Sulphate, mg/L</td>
<td>10 9 12 12 10 11</td>
<td>10 9 10 10 12 12</td>
<td>10 10 12 10 9 12</td>
</tr>
<tr>
<td>17. Iron (Fe), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>18. Zinc (Zn), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>19. Copper (Cu), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>20. Chromium (Cr), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>21. Nickel (Ni), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>22. Lead (Pb), mg/L</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
<td>BDL BDL BDL BDL BDL BDL</td>
</tr>
<tr>
<td>23. Sodium (Na), mg/L</td>
<td>15.3 17.5 16 16.0 14.0 13.0</td>
<td>14.0 18.0 16.2 14.0 13.0 14.0</td>
<td>13.0 19.0 16.0 14.0 14.5 14.0</td>
</tr>
<tr>
<td>24. Potassium (K), mg/L</td>
<td>1.8 2.0 2 2.0 1.6 1.0</td>
<td>2.3 2.2 2.3 2.0 1.5 1.8</td>
<td>2.0 2.1 2.2 2.0 1.8 2.0</td>
</tr>
<tr>
<td>25. Total Coliform (TC), MPN/100 ml</td>
<td>2200 1700 160,000 1700 1400 90,000 2800 3200 1,600,000 1500 2500 90,000</td>
<td>2200 3000 1,600,000 1700 2800 90,000</td>
<td>2200 3000 1,600,000 1700 2800 90,000</td>
</tr>
<tr>
<td>26. Faecal Coliform (FC), MNV+1</td>
<td>1700 1100 24,000 700 900 24,000 1100 1400 30,000 500 1200 22,000 1100 1500 22,000 800 1100 22,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ram, Parashuram and Singh, A. K

: The ranges of values obtained for different parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ranges of values at Kurji, U/S Patna</th>
<th>PMCH, Patna</th>
<th>Gaighat D/S. Patna</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.28 - 8.60</td>
<td>8.30 - 8.50</td>
<td>8.30 - 8.52</td>
</tr>
<tr>
<td>Conductivity, $\mu$ mhos/cm</td>
<td>162 - 468</td>
<td>182 - 442</td>
<td>175 - 450</td>
</tr>
<tr>
<td>D.O, mg/L</td>
<td>7.7 - 9.2</td>
<td>7.8 - 9.2</td>
<td>7.5 - 9.3</td>
</tr>
<tr>
<td>B.O.D. mg/L</td>
<td>1.3 - 2.1</td>
<td>1.8 - 2.2</td>
<td>1.8 - 2.2</td>
</tr>
<tr>
<td>C.O.D. mg/L</td>
<td>4 - 16</td>
<td>12 - 20</td>
<td>8 - 20</td>
</tr>
<tr>
<td>T.S.S. mg/L</td>
<td>12 - 22</td>
<td>20 - 32</td>
<td>20 - 30</td>
</tr>
<tr>
<td>T.D.S. mg/L</td>
<td>164 - 274</td>
<td>132 - 263</td>
<td>134 - 292</td>
</tr>
<tr>
<td>T.S. mg/L</td>
<td>176 - 290</td>
<td>164 - 292</td>
<td>154 - 315</td>
</tr>
<tr>
<td>T.H. (as CaCO3), mg/L</td>
<td>92 - 178</td>
<td>90 - 182</td>
<td>80 - 180</td>
</tr>
<tr>
<td>Chloride, mg/L</td>
<td>6 - 22</td>
<td>10 - 20</td>
<td>8 - 23</td>
</tr>
<tr>
<td>Fluoride, mg/L</td>
<td>0.18 - 0.24</td>
<td>0.22 - 0.46</td>
<td>0.22 - 0.58</td>
</tr>
<tr>
<td>Phosphate, mg/L</td>
<td>0.03 - 0.04</td>
<td>0.028 - 0.04</td>
<td>0.027 - 0.045</td>
</tr>
<tr>
<td>Sulphate, mg/L</td>
<td>9 - 12</td>
<td>9 - 12</td>
<td>9 - 12</td>
</tr>
<tr>
<td>Sodium, mg/L</td>
<td>13 - 17.6</td>
<td>13 - 18</td>
<td>13 - 19</td>
</tr>
<tr>
<td>Potassium, mg/L</td>
<td>1.0 - 2.0</td>
<td>1.5 - 2.8</td>
<td>1.8 - 2.2</td>
</tr>
<tr>
<td>T.C. MPN/100ml</td>
<td>1400 - 1,60,000</td>
<td>1300 - 1,60,000</td>
<td>1700 - 1,60,000</td>
</tr>
<tr>
<td>F.C. MPN/100ml</td>
<td>700 - 24,000</td>
<td>1500 - 30,000</td>
<td>800 - 22,000</td>
</tr>
</tbody>
</table>

estimated by Flamephotometer (Systronic – 121). Biological parameters – TC and FC were estimated through dilution method.

and discussion

The analytical results of samples collected on different sampling locations viz. Kurji, U/S Patna and Gaighat, D/S Patna are given in Table 1. Ranges of values obtained for different parameters have tabulated in Table 2.

The pH was observed in the range of 8.2 to 8.6 along the Ganga. This indicates that the Ganga water is slightly alkaline in nature at Patna.

Conductivity of an aqueous solution is a measure of its ability to carry out an electric current. Electrical conductivity in the range of 162 to 468 $\mu$ mhos/cm along the Ganga indicates that water has less content of inorganic acids, bases and compounds which are good conductors.

The concentration of dissolved oxygen (DO) in water is affected by temperature, pressure and concentrations of ions. Due to pollution load, the concentration of dissolved oxygen depletes and poses threat on the aquatic life. It was measured through iodometric method with azide modification. The DO level was recorded in the range of 7.7 to 9.3 mg/L. The higher level of oxygen at midstream is a result of constant aeration due to water current and free from impact due to human activities. The DO level of water indicates that water is favourable for aquatic life (wild life propagation, fisheries, etc.) Low oxygen in water can be detrimental to fishes and many other organisms present in the aquatic system. Organisms have specific requirement of oxygen, for example, a minimum of 3 mg/L of dissolved oxygen is required to support life of fishes in a aquatic ecosystem (Tazwell, 1957).

Biochemical Oxygen Demand (BOD) is the amount of oxygen utilized by microorganisms in stabilizing the organic matter in aerobic condition. DO measurement forms the basis of BOD analysis. It gives an indication of load of biodegradable organic materials present in the water body. The level of BOD depends on temperature, density of plankton, concentration of organic matter and other related factors (Boyd et al., 1978).

In the present study, the BOD was observed in the range of 1.3 to 2.2 mg/L. The maximum value of BOD was recorded as
Ganga water quality at Patna

The minimum value of BOD was observed as 1.3 mg/L at U/S Patna, a station having lesser load of organic pollutants. This lowest value was recorded in January 2005, which may be due to low temperature during this winter period consequently, low bacterial activity and higher DO levels. This finding also confirms that BOD increases with a concomitant decrease in DO.

Chemical Oxygen Demand (COD) is the amount of oxygen required for oxidation of organic constituents with strong oxidizing agent (acidified potassium dichromate). Thus, it is used as a measure of oxygen equivalent of the organic matter present in the sample (APHA, 1989). The COD value was observed in the range of 4 to 20 mg/L. The minimum value was recorded at U/S Patna and maximum at PMCH and D/S Patna. In the present investigation, the ratio of BOD and COD was always more than one, showing the organic load of pollution in river Ganga in this stretch.

Solids include suspended and dissolved solids. Suspended solids represent the floating material (bacteria, algae) and undissolved particles. TDS values were observed in the range of 132 to 292 mg/L. TSS, TDS and TS were assessed gravimetrically.

The hardness of Ganga water was observed in the range of 50 - 182 mg/L. It indicates that the Ganga water is neither hard nor very soft.

Chloride was observed in the range of 6 to 23 mg/L. The minimum value was recorded in the month of August at U/S Patna stretch, whereas, normally the concentration of chloride was observed almost constant, i.e. in the range of 6 - 23 mg/L. Water having chloride concentration > 200 - 300 mg/L gives a taste salty. The chloride ions are non-biodegradable. This is why chloride concentration appeared in the constant range.

Fluoride concentration was observed in the range of 0.18 - 0.58 mg/L along the stretch. The minimum value was recorded at U/S Patna, whereas, the maximum value (0.58) at D/S Patna. The fluoride concentration in water plays a significant role for human health. Excess concentration of fluoride causes dental fluorosis. At the same time, fluoride concentration of approximately 1.0 mg/L in drinking water reduces dental caries without harmful effects on health. The observed concentrations of fluoride in Ganga water indicate that it is not harmful for human health.

The presence of phosphates in large quantity in water body indicates sewage or industrial pollution load. The dissolved phosphate was observed in the low range 0.027 to 0.045 mg/L. The maximum value was recorded in August 2005 at D/S Patna. This might be due to receiving runoff water of the catchment areas as well as from the sewage load of Patna city.

Heavy metals like Fe, Zn, Cd, Pb, Cu, Cr, and Ni were found below detectable limits (BDL). This requires further investigation. The heavy metals exist in aquatic environment due to geo-chemical sources and discharges of various effluents.

Total coliform (TC) and fecal coliform (FC) in river water samples of Ganga were estimated through multiple tube dilution method. TC was observed in the range of 1300 - 1, 60,000 MPN / 100 mL, whereas FC found in the range of 700 - 30,000 MPN / 100 mL. The high values of TC and FC indicate the micro biological population in Ganga water. This indicates that this water may not be useful for domestic purpose without conventional treatment.

Conclusion

As discussed above, the physico-chemical characteristics of river water in the stretch suggest that there is no harmful chemical contamination in it. Presence of toxic metals below detection limits also indicate that there are no toxic metals present in the river water in the stretch. High DO and low BOD values were recorded during January to April, whereas decreased values of DO and increased value of BOD were recorded in August, i.e. during the monsoon season. The BOI values in the range of 1.3 mg/L to 2.2 mg/L, are also suggestive of the fact that the organic material load in the stretch is not alarming. However, the presence of higher population of microbial fauna indicates that the water is contaminated and cannot be used for organized bathing and as a source of drinking water without conventional treatment. However, the water may be used for propagation of wild life, fishery, industrial cooling and irrigation purposes. This river stretch receives a sewage load of approximately 190 MLD, out of which only 62 MLD sewage is treated, whereas, 128 MI remains untreated and is allowed to discharge into river Ganga. If proper measures are taken for the treatment of untreated sewage and restriction of various anthropogenic activities, the wholesomeness and pristine quality of the river Ganga will be restored and its environmental health be improved.

References

Bureau of Indian Standards – IS: 3025, Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater.


In the present study, the distribution of "heavy metals" in Ganga water and its bed sediments were studied at three sampling stations along the stretch of Patna. The samples were collected, preserved, digested with HNO₃ – HClO₄ and analyzed by Atomic Absorption Spectrometer (AAS). The heavy metals were not detected in the dissolved form in Ganga water. The reason may be alkaline nature of water. These were detected in trace quantity in Ganga water and its bed sediments samples as total metals. The heavy metals exist in the aqueous phase due to their absorption on particulate. The sources may be attributed to geo chemical transformation, weathering of soils and anthropogenic activities. The presence of heavy metals in the bed sediments and in the suspended phase indicates that Ganga riverine system act as both carrier and sink for heavy metals in trace levels.

Key Words: Ganga, Sediments, Heavy Metals, AAS

Introduction

Riverine sediments play an important role as pollutants and reflect the history of river pollution. Sediments act as both carriers and sinks for contaminants in aquatic environment. The trace elements having density greater than 5.0 gram per cm³ are commonly referred as "heavy metals" which include elements like Cr, Mn, Fe, Ni, Cu, Zn, Cd, Pb, and Hg etc. The effects of these metals in water and wastewater range from beneficial through troublesome to dangerously toxic depending on their concentration and level intake. These are considered as environmental pollutants depending on their concentration. Their occurrence in water and biota indicate the presence of natural or anthropogenic sources. The main sources of metals in the aquatic environment are weathering of soils, rocks and from anthropogenic activities whereby industrial and urban wastes are discharged into water bodies (Pardo et al., 1990). The metals can be either adsorbed on sediments or accumulated in benthic organism, some times to toxic level. Heavy metals are distributed between the aqueous phase and the suspended sediments. The presence of heavy metals in sediments is affected by the particle size and composition of the sediments (Sakai et al., 1986). Riverine suspended load and sediments play important function in buffering heavy metals concentration particularly by adsorption or precipitation (Forestner and Muller, 1973). More than 97% of the mass transport of heavy metals to the oceans is associated with river sediments (Jain and Sharma, 2001).

The Ganga is one of the major rivers of India. It originates from Gomukh glacier above Gangotri and after traveling a distance of 2525 km, it joins the Bay of Bengal. Thus it travels a distance of 445 km in Bihar and passes along the Patna. The River Ganga receives pollution load due to discharge of sewage, industrial effluent (indirectly), disposal of solid wastes and agricultural run-off water from its catchment area. A total of 190 MLD sewage is generated from Patna urban area. The Ganga water is widely used for organized bathing at many places along the stretch. Only a few studies have been reported on the assessment and distribution of heavy metals in Ganga water, but to the best of the knowledge the studies have not been specifically...
carried out in bed sediments of river Ganga along the Patna stretch. Thus it is of value to study
the same in Ganga river for the determination of eco-toxicological potential of the metals in the
aquatic environment nearby Patna.

2. Materials & Methods

Double distilled water and the analytical grades chemicals were used throughout the
study. Atomic Absorption Spectrometer (AAS) - GBC, Avanta S Model was used for analytical
published by American Public Health Association (APHA), and instruction manual of the
instrument (AAS) were adopted as reference manual for the analytical procedures.

Considering the outfall drains, human interferences, geological features and to have
representative sample of Ganga, grab samples were collected from U/S - Patna (Kurj - Digha),
near P.M.C.H and D/S - Patna (Gaighat). The samples were collected during Summer,
Monsoon (Rainy) and Winter seasons from the midstream as well as from two meters away from
the Bank. The 0.3 meter below the surface was taken as standard depth for sampling to avoid
surface micro layer. The Samples were collected in plastic and glass bottles. The samples for
analysis of heavy metals were collected in 1000 ml polythene, narrow mouth bottles.
Approximately, 250 ml sample was filtered and filtrate was preserved by adding 1 – 2 mL HN03
to have final pH < 2 for the analysis of dissolved metals. The remaining unfiltered sample was
preserved by adding Conc HN03 to have final pH < 2 for the analysis of total metals. Under this
condition metal samples can be made stable for six months.

The ‘bed sediments’ samples were collected from the bed of river’s bank at the depth of
10 cm. They were air dried, sealed in clean polyethylene bags and stored in a refrigerator for
analytical works.

The metals include all metals, inorganically and organically bound, both dissolved and
particulate. River water samples were filtered and filtrate was preserved for dissolved metals.
Water and bed sediments sample were digested with HN03 - HClO4 (Ref. APHA – 3030 II) for
the analysis of total metals.

The bed sediment samples were dried below < 40°C in hot air oven. One gram of each
of the dried sediment sample was dissolved in the double distilled water and diluted to 100 mL for
the digestion with HN03 – HClO4 (Nitric acid perchloric acid). A portion of this solution was taken
for required metal determination through Atomic Absorption Spectrometer (AAS). Direct Air –
Acetylene Flame Method (Ref. 3111, APHA, 17th Edition, 1989) was used.

3. Results and Discussion

The range of the analytical results of heavy metals observed in the collected samples
from different sample locations have been presented in Table – 1.

Heavy Metals (Fe, Cr, Cu, Mn, Ni, Cd & Pb) were not detected in the dissolved form in
Ganga water along the stretch of Patna. Heavy metals can only leach in acidic condition. The
Ganga water was found slightly alkaline in nature (pH 7.68 to 8.60). The chemical abiotic factor
(pH) supports & confirms the non detectable status of heavy metals in dissolved form.

Total metals (which include all metals inorganically and organically bound, both dissolved
and suspended) were detected in the water samples of Ganga in the trace quantities. It indicates
that detected heavy metals were distributed in suspended phase. Metals were also observed in
the bed sediments samples of Ganga river. The presence of heavy metals in bed sediments and
in the suspended phase indicates that Ganga riverine system act as both carrier and sink for heavy metals in trace levels.

The **Iron (Fe)** was recorded in the range of 0.072 to 0.210 mg/L in the aqueous phase. The minimum value was recorded at U/s Patna and maximum at D/s Patna. The concentration of Fe was recorded in the range of 2510 to 3060 mg/kg in the bed sediments of river. The minimum value was recorded at U/s Patna in the rainy season and maximum value near PMCH during summer season.

The **chromium (Cr)** was observed in the range of 0.022 to 0.037 mg/L in the river water samples. The minimum value was found at U/s Patna and near PMCH and maximum value at D/s Patna during summer season. Chromium was recorded in the range of 32.86 to 45.34 mg/kg in the bed sediments samples. The maximum value was recorded at D/s Patna during winter season.

The **Copper (Cu)** was observed in the range of 0.015 to 0.030 mg/L in the water samples. The concentration of copper in the bed sediments samples was recorded in the range of 23.6 to 30.25 mg/kg. The minimum value was observed at U/s Patna during rainy season and maximum at D/s Patna during winter season.

The **Manganese (Mn)** was recorded in the range of 0.028 to 0.052 mg/L and 48.36 to 56.52 mg/kg in the aqueous phase and bed sediments samples respectively. The minimum value was recorded at U/s Patna and maximum near PMCH.

The **Nickel (Ni)** was observed in the range of 0.022 to 0.042 mg/L in the water samples. The same was recorded in the range of 20.50 to 35.89 mg/kg, in the bed sediments samples along the stretch of Patna.

The **Zinc (Zn)** was found in the range of 0.03 to 0.066 mg/L and 28.62 to 46.25 mg/kg in the water and bed sediments samples respectively.

The **Lead (Pb)** was observed in the range of 0.061 to 0.095 mg/L in the water samples as total lead and in the range of 40.36 to 62.67 mg/kg in the bed sediments sample along the study stretch of Patna.

The observation on heavy metals indicated that they were not present in the dissolved form. They were present in trace quantity in the bed sediments samples and aqueous phase as total metals. This indicated that heavy metals existed in the aqueous phase due to their absorption on particulates. The presence and distribution of heavy metals in the aqueous phase and bed sediments reflects that Ganga water is also being polluted by the anthropogenic activities of Patna urban area. The domestic effluents are being discharged in to the Ganga river through different outlets drains viz. Kurji, Rajapur, Mandiri, Antaghat, etc. The main sources of these heavy metals may be due to natural activities such as geochemical transformation, weathering of soils and excretions by the human being through urine and faeces.

The concentration of studied heavy metals in the water samples of Ganga along the stretch of Patna was observed in the following range and order; Fe(0.072 – 0.210 mg/L); Pb(0.061 – 0.095 mg/L); Zn(0.03 – 0.066 mg/L); Mn(0.028 – 0.052 mg/L); Ni(0.022 – 0.042 mg/L); Cr(0.022 – 0.037 mg/L); Cu(0.015 – 0.030 mg/L); Cd BDL i.e. Fe>Pb>Zn>Mn>Ni>Cr>Cu>Cd

---


The concentration of studied heavy metals in the bed sediments samples of Ganga river along the stretch of Patna was recorded in the following range and order:

- Fe(2510 – 3060 mg/kg.)
- Pb(40.36 – 62.67 mg/kg.)
- Mn (48.36 – 56.52 mg/kg.)
- Zn(28.62 – 40.25 mg/kg.)
- Cr(32.06 – 45.34 mg/kg.)
- Ni(20.50 – 35.89 mg/kg.)
- Cu(23.60 – 30.25 mg/kg.)
- Cd(2.54 – 3.12 mg/kg.)

i.e. Fe>Pb>Mn>Zn>Cr>Ni>Cu>Cd

4. Conclusion

Riverine sediments play an important role as pollutants and reflect the history of river pollution. Sediments act as both carriers and sinks for contaminants in aquatic environment.

Heavy metals were not detected in the dissolved form in Ganga water along the study stretch. The reason may be the alkaline nature of Ganga water. The heavy metals can only leach in the acidic condition. On the other hand those were indicated in the Ganga water as well as in bed sediments of river as total metals. Those were present in trace quantity in the bed sediments samples and aqueous phase as total metals. This indicates that heavy metals exist in the aqueous phase due to their absorption on particulates. The domestic effluents are being discharged in to the Ganga river through different outfalls drains viz. Kurji, Rajapur, Mandiri, Anlaghat, etc. The sources of these heavy metals may be due to natural activities such as geochemical transformation, weathering of soils and excretions by the human being through urine and faeces.

5. Acknowledgement

The authors would like to express their sincere thanks to Bihar State Pollution Control Board for providing laboratory facilities. The support provided by Sri S.N. Rao, Sri S.N. Jayaswal and Dr. Naveen Kumar of BSPCB for successful completion of the study is also deeply acknowledged.

6. References


### Table - 1

Range of Heavy Metals in Ganga water & Bed sediments along the stretch of Patna

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Heavy Metals as (Total metal)</th>
<th>Sampling Stations</th>
<th>In Ganga Water (in mg/L)</th>
<th>In Bed sediments (in mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>S1 (U/S Patna)</td>
<td>S2 (Near PMCH)</td>
<td>S3 (D/S Patna)</td>
</tr>
<tr>
<td>1</td>
<td>Iron (as Fe)</td>
<td>0.072 - 0.124</td>
<td>0.080 - 0.183</td>
<td>0.123 - 0.210</td>
</tr>
<tr>
<td>2</td>
<td>Chromium (as Cr)</td>
<td>0.022 - 0.032</td>
<td>0.022 - 0.032</td>
<td>0.030 - 0.037</td>
</tr>
<tr>
<td>3</td>
<td>Copper (as Cu)</td>
<td>0.015 - 0.020</td>
<td>0.020 - 0.023</td>
<td>0.015 - 0.030</td>
</tr>
<tr>
<td>4</td>
<td>Manganese (as Mn)</td>
<td>0.028 - 0.040</td>
<td>0.090 - 0.047</td>
<td>0.032 - 0.052</td>
</tr>
<tr>
<td>5</td>
<td>Nickel (as Ni)</td>
<td>0.022 - 0.025</td>
<td>0.030 - 0.032</td>
<td>0.025 - 0.042</td>
</tr>
<tr>
<td>6</td>
<td>Zinc (as Zn)</td>
<td>0.03 - 0.039</td>
<td>0.040 - 0.044</td>
<td>0.045 - 0.066</td>
</tr>
<tr>
<td>7</td>
<td>Cadmium (as Cd)</td>
<td>BDL - BDL</td>
<td>BDL - BDL</td>
<td>BDL - BDL</td>
</tr>
<tr>
<td>8</td>
<td>Lead (as Pb)</td>
<td>0.061 - 0.072</td>
<td>0.068 - 0.082</td>
<td>0.085 - 0.095</td>
</tr>
</tbody>
</table>