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Assessment of Water Quality of Three Different Aquatic Environments Over Three Seasons

Tandra Mohanta[1+] and Sudha Goel[2]

[1] Junior Research Fellow, Department of Civil Engineering, Indian Institute of Technology, Kharagpur.
[2] Associate Professor, Department of Civil Engineering, Indian Institute of Technology, Kharagpur.

Abstract. A three season study of water qualities of river Hooghly within the stretch between Dakshineswar and Nazirgunj, Kolkata, river Kangsabati and groundwater in Kharagpur was done during the period 2012-2013. The water quality of river Hooghly was found to be moderately bad compared to river Kangsabati and groundwater. Cadmium was the only heavy metal detected above the recommended permissible limit in Hooghly river water and phosphate anions were 5-7 times above safe levels in Kangsabati river water. Most other elements were within safe limits. Levels of dissolved oxygen were high in all three sources throughout the year. Lowest antibiotic resistance index (ARI) value of 0.08 was calculated for river Kangsabati while Metiabruj sampling location of river Hooghly exhibited highest ARI value of 0.63 (threshold value=0.2) indicating greater exposure to antibiotics. ARI values of groundwater were in the range of 0.1-0.17. This implies that the burden of antibiotics being released via wastewater discharges and agricultural runoff into river Hooghly is greater than in river Kangsabati. In general, concentrations of all pollutants and other elements exhibited significant variation with respect to sampling location as well as change in seasons. Concentrations generally were in the order: post-monsoon > winter > summer.

Keywords: Physico-chemical, anions, cations, heavy metals, Antibiotic Resistance Index (ARI).

1. Introduction

Rapid growth in population, industrialization and urbanization has resulted in an enormous increase in wastewater generation. Municipal and often, industrial wastewaters are directly released into water bodies such as rivers, with or without treatment. In addition, other anthropogenic activities such as agriculture result in non-point discharges of pollutants into rivers causing serious environmental problems and therefore posing a threat to human health. This has led to deterioration in water quality rendering it unsuitable for human consumption and sustenance of aquatic life.

Water quality parameters assessed were dissolved oxygen (DO), total organic carbon (TOC), electrical conductivity (EC), various anions, cations and heavy metals. Heavy metals such as Cu, Fe, Zn, Ni, Mn are essential micronutrients for plants and microorganisms while metals such as Pb, Cr and Cd have no physiological activity and are toxic even if present in trace quantities [1]. Many studies have been conducted in India in recent years to examine water quality of aquatic environments [2]. Therefore, the objective of this study was to assess water quality of three different water sources: River Hooghly in Kolkata, untreated river Kangsabati water and groundwater from Kharagpur, West Bengal, and evaluate the impact of pollution on these aquatic environments over three seasons. River Hooghly in Kolkata represents an aquatic environment that is severely impacted by urban and industrial activity while river and ground water samples from Kharagpur represent environments that are relatively unpolluted by urban or industrial activities.

[+] Corresponding author. Tel.: +91(03222-283436); fax +91 (03222-282254)
Email address: tandramohanta1102@gmail.com

2. Materials and Methods

2.1. Study area

The study area included a total of 11 sampling locations, 9 in river Hooghly, Kolkata city and two in Kharagpur, West Bengal. The nine sampling locations on river Hooghly further comprised of six near the river banks (on either side of the river) while the other three were located in the centre of the river or mid-stream. The two remaining locations were in Kharagpur: untreated water from the water works plant (River Kangsabati) and ground water from a pump house in Indian Institute of Technology Kharagpur campus. It is important to note that water from the treatment plant is approximately 70% River Kangsabati and 30% groundwater from campus.

2.2. Sample collection

Surface and ground water samples were collected during the three seasons - post-monsoon (September), winter (January) and summer (May) in 2012-2013. Aseptic plastic bottles were used for sample collection and were carried to the laboratory in an ice box using ice gel packs and kept in a refrigerator at 4°C until analysis.

2.3. Physico-chemical assessment of water

Physico-chemical assessment of water is necessary to determine water quality. The different physico-chemical parameters measured were pH, dissolved oxygen (DO), total organic carbon (TOC), various heavy metals, cations and anions.

pH: pH of all water samples were measured by a pH meter (Toshcon Industries Pvt. Ltd, Hardwar) using two point calibration. According to ISI 10500 the pH should be within 6.5-8.5.

Dissolved oxygen (DO): DO was measured using a DO meter (Digital Instruments, Model PDO-519).

Total Organic Carbon (TOC): TOC is a non-specific indicator of water quality and is a measure of the amount of carbon bound in all organic compounds present in a sample. TOC of all water samples over the three season study was measured using Aurora TOC 1030 auto-analyzer (OI Analytical, USA).

Conductivity: Conductivity is a measure of the ability of water to pass an electrical current. Higher ionic strength will result in higher conductivity of the solution. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminium cations.

Heavy metals: Quantitative estimation of heavy metals like Cu, Cr, Cd, Co, Fe, Mn, Ni, Pb and Zn were done by atomic absorption spectrophotometer (Varian AA240FS fast sequential AAS) using different cathode lamps with air acetylene flame method.

Ion chromatography: Both anions and cations were measured using ion chromatography (Metrohm 761 Compact IC). Water samples were acidified prior to ion chromatography analysis.

3. Results and Discussion

3.1. pH, DO, TOC and conductivity

pH: pH of all water samples over the three season study were in the range of 6.6 - 8.1 and the mean ranged between 6.8-7.9. The optimum pH range according to Indian standard drinking water specifications is 6.5-8.5 [3]. Water samples from river Hooghly exhibited neutral to alkaline pH of 7.2-8.1. On the other hand, ground water samples were slightly acidic to neutral pH of 6.6-7.01 while River Kangsabati water samples were at near neutral pH of 7.1-7.2.

DO: The mean dissolved oxygen (DO) concentrations of all water samples ranged from 5.27 - 7.17 mg/L which is higher than the minimum permissible range (4 - 6 mg/L) provided as per WHO and Indian standard

drinking water specifications [4, 3]. Dissolved oxygen concentration was highest in water samples from river Kangsabati in all three seasons with mean of 7.17 mg/L while groundwater samples exhibited the lowest mean DO content of 5.27 mg/L. The mean DO of water samples from river Hooghly ranged between 6.53 - 6.70 mg/L. The quality of the water in terms of DO content appears to be good. DO levels are sufficiently high to allow aerobic oxidation of wastes and sustenance of aquatic life.

TOC: River Hooghly water samples had the highest TOC concentrations ranging from 4.221 - 12.078 mg/L followed by river Kangsabati samples which ranged from 4.171-5.066 mg/L. Ground water samples exhibited the lowest TOC range of 0.447-0.65 mg/L. However, a significant difference was observed in TOC levels with change in seasons. About 8 sampling locations among 11 (6 among 9 sampling locations on river Hooghly) displayed a greater TOC level in the post-monsoon sampling as compared to the other two seasons.

Conductivity: Conductivity or electric conductance is a measure of ionic strength of a solution and varied between 177.1-248.5 µS/cm for all water samples while their mean conductance ranged between 198.4-227.7 µS/cm. Ground water samples showed lowest mean conductivity of 198.4 µS/cm. River Kangsabati samples showed a mean conductivity of 217.7 µS/cm. Conductivity was lowest in post-monsoon sampling and highest in summer.

3.2. Heavy metals

Seasonal variations of different heavy metals in water from river Hooghly, river Kangsabati and groundwater were studied. About 8 heavy metals were detected out of nine tested. The concentrations of these metals were monitored for three seasons to determine correlations with other water quality parameters including ARI values. Pb was not detected in any of the three seasons in all samples analyzed. Cr was detected only in summer from the sampling locations H3A, H3B and H3C of river Hooghly. It may be related to industrial/commercial activities during this season. Heavy metals Mn and Cu were observed in greater concentrations in post-monsoon and Fe and Ni in winter. Likewise, Cd, Zn and Co were maximum in summer. Higher concentrations were observed for all metals in post-monsoon sampling and may be due to greater solubility effect. In addition, pH was also observed to be comparatively lower in post-monsoon and winter than in summer which also may be responsible for the solubility of heavy metals.

Cd was the only heavy metal detected above the permissible limit in river water from Hooghly and Kangsabati. Effluent discharge standards for inland surface waters for Cd are 2 mg/L [5] while drinking water standards are 0.01 mg/L (desirable and permissible levels) [3]. Cd level was within permissible limits in groundwater. Cd is not a micronutrient and is a toxic heavy metal. Therefore, its presence in concentrations above the permissible limit is a matter of serious public health concern.

3.3. Cations-anions

Dissolved inorganic ions, i.e., both cations and anions were measured using ion chromatography and the results obtained are discussed below.

River Hooghly

Calcium and sodium were the dominant cations and sulphate and chloride were the dominant anions among all ionic species assessed. Sodium was the 2nd most dominant cation and was in the range 8.278-11.640 mg/L, 3.177-14.613 mg/L and 3.560-6.010 mg/L in post-monsoon, winter and summer respectively. Potassium concentrations ranged between 1.324-3.368 mg/L in post-monsoon. Potassium was not detected in the winter and summer sampling. Concentrations of calcium ranged between 7.872-36.638 mg/L and were below the specified permissible levels. Magnesium was detected below the permissible level and was in the range 1.179-6.924 mg/L and followed the order post-monsoon>winter>summer. WHO drinking water quality standard for Mg is 50 mg/L while it is 30 mg/L according to Indian standard (desirable and permissible levels) [3]. Ammonium was detected only in 1 (H1A), 3 and 8 sampling locations in post-monsoon, winter and summer respectively and ranged between 0.191-6.015 mg/L. Dilution effects are greatest in post-monsoon sampling and least in summer samples. Manganese wasn't detected in post-monsoon in water samples from river Hooghly. However, Mn concentrations in winter and summer varied between 0.381-0.530 mg/L which were above the specified permissible level. Effluent discharge standards for Mn are 2 mg/L [5] while drinking water standards are 0.1 (desirable) and 0.3 (permissible) mg/L [3].

Exposure to high concentrations of manganese for years can lead to nervous disorders. High concentrations of manganese can be attributed to its use in the manufacture of dry cell batteries and in the steel industry. In addition, untreated or partially treated waste inputs of municipal and industrial effluents of the city also account for its higher concentrations in surface waters.

Fluoride concentrations ranged between ND-0.238 mg/L and were below the recommended permissible level. WHO and Indian drinking water quality standards for Fluoride are 0.9 mg/L, 1.2 mg/L and 1.5 mg/L (desirable and permissible levels), respectively [3]. Higher chloride concentrations (2.868-53.755 mg/L) were detected in river Hooghly compared to river Kangsabati and groundwater. Effluent discharge standards for chloride are 1000 mg/L [5] while drinking water standards are 250 (desirable) and 1000 (permissible) mg/L [3]. Bromide concentrations were in the range 0.136-0.697 mg/L. Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrite and nitrate concentrations were in the range of 0.153-3.064 mg/L and 0.964-6.905 mg/L, respectively. Effluent discharge standard for nitrate is 100 mg/L [5] while drinking water standard is 45 mg/L (desirable and permissible) [3]. Phosphate and sulphate concentrations ranged between 0.125-5.278 mg/L and 3.658-42.295 mg/L, respectively. Effluent discharge standards for phosphates and sulphates are 5 mg/L and 400 mg/L [5] while drinking water standards are 150 (desirable) and 400 (permissible) mg/L [3] and therefore were below the recommended safe limit.

River Kangsabati

Sodium concentrations were in the range of 6.196-7.435 mg/L for river Kangsabati, and were highest in post-monsoon followed by winter and then summer. Potassium and ammonium concentrations ranged between 1.023-1.367 mg/L and 0.039-0.145 mg/L, respectively and were highest in winter. Calcium and manganese concentrations were in the range of 21.539-23.572 mg/L and 0.039-0.275 mg/L with maximum in post-monsoon. Both, calcium and manganese concentrations were detected at levels lower than the permissible levels specified [3, 5]. Magnesium, fluoride, chloride and bromide concentrations were maximum in summer and were in the range of 12.469-14.207 mg/L, 0.156-0.195 mg/L, 9.456-10.231 mg/L and 0.567-0.617 mg/L respectively. This may be due to the concentrating effect of increased temperature and evaporation. Nitrites were not detected in river Kangsabati samples in any season. On the other hand, nitrate was measured in the range 1.066-1.134 mg/L and is below the permissible limit. Phosphates were maximum (25.067 mg/L-36.214 mg/L) in river Kangsabati samples and were 5-7 times greater than the recommended permissible limit. This can be attributed to the increased use of inorganic fertilisers that are swept along with agricultural runoff. On the other hand, sulphates were below the permissible limit and were in the range of 0.107-0.167 mg/L.

Groundwater

Unlike river Hooghly and Kangsabati, sodium concentrations in groundwater followed a slightly different order: winter > post-monsoon > summer and was in the range 18.953-20.475 mg/L. Potassium, calcium and magnesium concentrations were in the range of 2.687-2.73 mg/L, 21.781-29.798 mg/L and 6.737-9.002 mg/L, respectively with maximum in winter. Ammonium ions were not detected in groundwater in any of the three seasons studied. Manganese was detected only in post-monsoon (1.732 mg/L) and winter (2.692 mg/L) sampling which was beyond the recommended permissible levels and was higher than river Hooghly and Kangsabati. High fluoride concentrations in the range 0.676-0.786 mg/L were detected in groundwater which is below the safe limit. Chloride concentrations were lowest in groundwater and ranged between 3.014-3.281 mg/L. Nitrites were not detected in groundwater in post-monsoon and winter. In summer, nitrites were measured as 0.112 mg/L. On the other hand, nitrates measured were in the range of 0.47-0.884 mg/L. Phosphates and sulphates in groundwater ranged between 3.068-3.167 mg/L and 3.106-8.296 mg/L respectively.

Correlation of ARI with environmental parameters

Antibiotic resistance index (ARI) of each sampling location is a measure of the extent of exposure to antibiotics which can be referred in [6]. When locations are exposed to high antibiotics pollution, an ARI value > 0:2 is observed. When antibiotics are seldom or never used, an ARI value of 0.2 is observed [7]. ARI values for all sampling locations were calculated and found to be in the range of 0.08 to 0.63 (lowest 0.08 for river Kangsabati while highest 0.63 for Metiabruj sampling location on river Hooghly). ARI values of groundwater was in the range 0.1-0.17. This implies that the burden of antibiotics being released via wastewater discharges and agricultural runoff into river Hooghly is greater than in river Kangsabati and is

therefore severely impacted by urban and industrial activity while river and ground water samples from Kharagpur are relatively least polluted by urban or industrial activities.

4. Conclusion

Water quality was assessed for three different aquatic environments over 3 seasons. Major conclusions are as follows-

- **pH, dissolved oxygen (DO) and total organic carbon (TOC) concentrations of all water samples over the three season study were in the range of 6.6-8.1, 5.27-7.17 mg/L and 0.447-12.078 mg/L, respectively. However, groundwater was acidic (mean pH = 6.8) while average pH were 7.2-8.1 and 7.2 for Hooghly and Kangsabati river waters respectively.**
- Cd was the only heavy metal detected above the permissible limit in river water from Hooghly and Kangsabati. All other heavy metals were within permissible limits.
- Calcium, sodium, sulphate and chloride were the dominant cations and anions among all ionic species assessed.
- Nitrites were not detected in river Kangsabati samples in any season. Phosphates were maximum (25.067 mg/L-36.214 mg/L) in river Kangsabati samples and were 5-7 times greater than the recommended permissible limit, probably due to fertilizer inputs along with surface runoff.
- Ammonium ions were not detected in groundwater in any of the three seasons studied.
- High fluoride concentrations in the range 0.676-0.786 mg/L were detected in groundwater. Mean fluoride concentration of 0.179 mg/L and 0.176-0.206 mg/L were detected for river Kangsabati and Hooghly respectively.

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