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Ground Water Quality Index of Patna, the Capital City of Bihar, India

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Abstract Groundwater is the most preferred source of water in various user sectors in India on account of its near universal availability, dependability and low capital cost. The present study mainly focus on the drinking water quality index of one of the fast growing city of India, Patna. The city has a population of 58.3lakhs of people which mainly relay ground water for drinking. The ground water from fourteen stations was analysed. Even though the Water Quality Index (WQI) put the water into 'good water' category, none of the samples were found suitable because all the samples were found high concentration of total and faecal coliform. Alkalinity, Total Dissolved Solids (TDS) and Nitrate concentrations in some stations were found above the drinking water standards.

Keywords: *ground water, water quality index, faecal coliform, total coliform, Bihar*

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1. Introduction

Groundwater resources are dynamic in nature and are affected by different factors such as, irrigation activities, industrialization and urbanization. The process is slow but its effects are very dreadful [1]. Thus, whatever the nature of the physical pollution, be it chemical [2] or bacteriological (bacteria, viruses) [3], the aquifers are affected. Hence, monitoring and conserving this important resource is essential [4]. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO organization, about 80% of all the diseases in human beings are caused by water [5].

Ground water is also very important to many agricultural areas. Since it is filtered through the ground, it is usually cleaner than surface water. Unfortunately, it is threatened every day by public who do not even realize how important it is or how they are affecting it. All forms of life on earth draw their prolong and growth from nature's most rich and free available reserve of water. But in many parts of the world humans have no access to the clean drinking. Water is polluted with germs, worms, or toxic chemicals and this can lead to many illnesses. In developing countries, about 80% of urban wastewater is used for irrigation paying to 70-80% food security and livelihood of urban and peri-urban communities. In agricultural areas, an excessive use of fertilizers has directly or indirectly affected the groundwater quality [6]. But beyond the quantitative aspect, it is also advisable to remain vigilant on the level of the water quality consumed by the populations [7].

Groundwater is the backbone of India's agriculture and drinking water security in urban and rural areas. Ground water is also important for the industrial sector in a large measure and, should be regulated, otherwise may lead to serious inter-sectoral conflicts. A serious groundwater crisis prevails currently in India due to excessive overdraft and groundwater contamination covering nearly 60 percent of all districts in India and posing a risk to drinking water security of the population, as more than 80 percent of India's drinking water needs are serviced by groundwater resources. In addition to overdraft and biological and chemical pollution, water logging is also a serious problem in many regions, impacting livelihood security of large sections of society [8].

Bihar is undergoing fast economic development with its impact on life style, natural resources and environment. But economic growth has persisting inadequacies. One such challenging area is agriculture, which has the key role in poverty alleviation in Bihar, where 90% population is rural. Though the state is bestowed with water and land, the state needs to substantially increase the cropping intensity and also the irrigation intensity. Assured availability of water for drinking, agriculture and industries are the key factors to determine the future economic scenario. During the last six decades, the remarkable feature in irrigation development is the conspicuous growth in the use of groundwater. However, in Bihar at present, the groundwater meets the irrigation to only about 65 % of the gross irrigated area. It has affected the agricultural production for want of irrigations. The major credit for increase in groundwater use goes to a large extent to the farmers' own investment and spread of groundwater market. There are about 0.9 million shallow and about 1700 deep tube wells in operation in the state. Even then, the stage of groundwater development is only 39%. To enhance the irrigation potential ground water can safely be developed at least to the level of 60-70% as groundwater irrigation is under the direct control of the farmers and is amenable to precision agriculture and higher irrigation efficiency [9].

Although industrialization is inevitable, various devastating ecological and human disasters which have continuously occurred over the last four decades, implicate industries as major contributors to environmental degradation and pollution problems of various magnitude [10]. The unplanned and non-scientific development of ground water resources, mostly driven by individual initiatives has led to an increasing stress on the available resources. The adverse impacts can be observed in the form of long-term decline of ground water levels, de-saturation of aquifer zones, increased energy consumption for lifting water from progressively deeper levels and quality deterioration due to saline water intrusion in coastal areas in different parts of the country. Surprisingly the three major States occupying the alluvial plains i.e. Uttar Pradesh, Bihar and West Bengal, has a share of the in storage ground water resources to the tune of 7652 bcm which is more than 70% of the total resource. Fragmented land holdings, poor socio-economic status, poor infrastructure facilities, lack of knowledge of modern technologies are some of the reasons for the under-utilization of ground water resources in these areas, in spite of the growing need for boosting agricultural production [11]. In this context there is an urgent need to explore various befitting options for optimal utilization of these resources.

2. Materials and Methods

2.1. Study Area

The study area lies between 25°21'45.83"N, 85°42'19.54"E and 25°28'22.78"N 83°51'51.40"E in the state of Bihar in India.

2.2. Sample Collection and Analysis

The samples were collected during winter. Water samples from bore well were collected in glass containers. Before collecting samples, water from bore well was pumped out for about 5-10 minutes or until water temperature is stabilized. Samples were collected in different containers at each point to add necessary preservatives as per standard procedure. The samples were preserved in icebox and transported to laboratory within 3 hours from the time of collection and analyses.

The samples were analysed as per Standard methods for the examination of water and waste water, [12]. The results obtained were compared with the drinking water standards as specified by World Health Organisatio (WHO) [13] and Bureau of Indian Standards(BIS) [14].

2.3. Microbiological Analyses

For microbiological analyses, 100 ml water samples were collected from sixteen study sites of the river stations. The samples were subjected to serial dilution in nutrient water containing potassium dihydrogen phosphate and magnesium chloride and inoculated in multiple tubes as per the maximum probable number method. The tubes contained 10 ml of lauryl tryptose broth for the detection of total coliform and faecal coliform were incubated at 35 ± 0.5°C for three hour in A1 broth. For faecal coliform, the tubes were inoculated serially and were incubated for three hour at 35 ± 0.5°C for three hours and transferred to a water bath at 44.5 ± 0.2°C and incubated for an additional 21 ± 2 hour. Production of an acidic reaction or gas production in any A-1 broth culture within 24 hours or less is a positive reaction indicating the presence of faecal coliform [13].

2.4. Statistical Analysis

The data obtained on the physicochemical and microbiological parameters of the ground water were subjected to correlation analysis. The correlation was carried on statistical software SPSS version 18.

3. Results

pH of the water ranged from 6.59 to 7.69 and TDS 174 mg/l to 1283.6mg/l. The conductivity of the samples were found between 229 µS/cm to 2010 µS/cm. Alkalinity ranged between 140 mg/l to 572 mg/l. Chloride ranged from 2.0 mg/l to 247.9 mg/l. Total dissolved solids in samples ranged from 174 mg/l to 1284 mg/l. Total hardness of the samples have a wide range in the samples (156 mg/l to 760mg/l) Calcium 44.2 mg/l to 212.6 mg/l. Magnesium from 10.2 mg/l to 68.8 mg/l. Nitrate ranged from 0.06 mg/l to 13.71 mg/l. Sulphate from 2.27 to 78.4 mg/l. Fluoride from 0.24 to 0.76 mg/l. Total and faecal coliform ranged from 1.1 MPN/100ml to 8 MPN/100ml.

3.1. Water Quality Index

For computing water quality index three steps are followed. In the first step, each of the nine parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment [15]. Magnesium which is given weight of 2 as magnesium by itself may not be that harmful [12]

Second step, relative weight (Wi) is computed from the following equation:

$$Wi = wi + \sum_{i=1}^{n} wi$$

Where (Wi) is the relative weight, (wi) is the weight of each parameter and ‘n’ is the number of parameters. The Calculated Water Quality Index of drinking water in Patna is also given in the Table 1.

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result is multiplied by 100:

$$qi = (Ci/Si) * 100$$

Where **qi** is the quality rating, **Ci** is the concentration of each chemical parameter in each water sample in mg/l, and **Si** is the BIS (Bureau of Indian standards) water standard for each chemical parameter in mg/l according to the guidelines of the BIS and WHO.

For computing the **WQI**, the **SIi** is first determined for each chemical parameter, which is then used to determine the **WQI** as per the following equation

$$SIi = Wi * qi$$

$$WQI = \sum SIi$$

SIi is the sub index of Ith parameter, qi is the rating based on concentration of ith parameter and **n** is the number of parameter. The computed WQI values are classified into five types "excellent water", "good water", "poor water" "very poor water" and "water unsuitable for drinking" as shown in the Table 2

Table 1. The Water Quality Index of Patna, Bihar

	Concentration of parameters (mg/l) (Ci)	Weightage (wi)	Relative weight (Wi)	Standard Concentration (mg/l) (Si)	Quality Rating (qi)	Sub Index (SIi)
TDS	544.50	4	0.13	500	108.9	14.5
Chloride	63.18	3	0.10	250	25.3	2.5
Total hardness	345.86	3	0.10	300	115.3	11.5
Calcium	92.52	2	0.07	75	123.4	8.2
Magnesium	28.04	2	0.07	30	93.5	6.2
Nitrate	7.71	5	0.26	45	17.1	4.5
Sulphate	19.99	4	0.13	200	10.0	1.3
Fluoride	0.53	4	0.13	1	52.6	7.0
Alkalinity	354.29	3	0.10	200	177.1	17.7
					WQI= 73.5	

Table 2. Water quality classification based on WQI value [16]

WQI Value	Water Quality
<50	Excellent
50 – 100	Good water
100 – 200	Poor water
200 – 300	Very poor water
>300	Water unsuitable for drinking

4. Discussion

pH usually has direct effects on biotic environment. For satisfactory water disinfection and clarification at all stages the control of pH is very necessary. Effective disinfection with chlorine, the pH should preferably be less than 8. pH of all the stations in Patna were found within the range of Indian standards (6.5-8.5). The Total dissolved solids (TDS) of five stations were higher than the standard. Craun et al. [17] reported that increase TDS concentrations in drinking water cause of cancer, coronary heart disease, arteriosclerotic heart disease and cardiovascular disease. The concentration and relationship Alkalinity and TDS is shown in Figure 1.

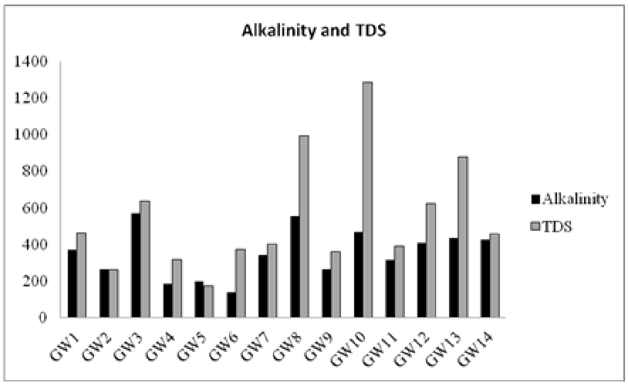

Figure 1. Concentration and relationship between Alkalinity and TDS

The Total Hardness is an important parameter of water quality whether it is to be used for domestic, industrial or agricultural purposes. Total hardness of the seven stations of was above the Indian standards for drinking water. Total hardness has a high significant correlation ($p<0.01$) between Total Dissolved solids (TDS). The calcium concentration in three stations was found above the standards. In case of magnesium, eight stations have high amount of magnesium concentration. The concentration and relationship between Total Hardness, Calcium and Magnesium is shown in Figure 2.

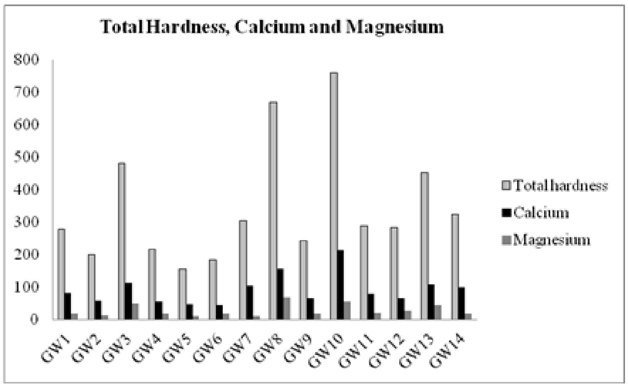

Figure 2. Concentration and relationship between Total Hardness, Calcium and Magnesium

The nitrate concentration in all the water samples were well within the limit of standards except in one station where the concentration is 60 mg/l. Nitrate losses from non point agricultural sources, mainly originated by fertilizers application, have been recognized as one of the most serious threats for pollution of groundwater [18]. An improvement of knowledge is however essential to make the water services more powerful and to reinforce the policy for the access to safe water in the country [7]. Nitrates and nitrites may themselves be carcinogens or may be converted in the body to a class of compounds known as the nitrosamines, compounds that are known to be carcinogens [19]. Nitrate-nitrogen levels below 90 mg/L and nitrite levels below 0.5 mg/L seem to have no effect on warm-water fish, but salmon and other cold-water fish are more sensitive [20].

Chloride concentration of one station was found above the standards. Chloride has a high significant correlation ($p<0.01$) between TDS and Total hardness. A report showed that people drinking chlorinated water over long periods have a 21% increase in the risk of contracting bladder cancer and a 38% increase in the risk of rectal cancer [19]. Due to urbanization and heavy industrialization the ground water of our country becomes unpleasant for drinking [21]. The factors which control the fluoride concentration includes the climate of the area and the presence of accessory minerals in the rock mineral assemblage through which the ground water is circulating [22]. In the present study the concentration of fluoride is within the permissible limits of WHO.

Most waterborne pathogens are introduced into drinking-water supplies in human or animal faeces, do not grow in water and initiate infection in the gastrointestinal tract following ingestion [13]. In all the stations, the total and faecal coliform exceeds the standards for drinking water [12,13] which put the groundwater unfit for drinking but lack of other drinking water sources people are forced to drink the water. This is a matter of serious concern in the state of Bihar in which the largest reservoir of ground water in the country exists.

Water Quality Index (WQI) is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status of a certain time and location [23]. The WQI of Patna city is 73.5 which categorises the ground water in the "good water" category as per the water quality classification based on WQI value. But the presence of faecal and total coliforms in water make them unfit for drinking. The single parameter which has high significance in determining the quality of drinking water has to be thoroughly studied and to be checked.

5. Conclusion

Groundwater is one of the major sources of potable water in Patna City. Over abstraction of this limited resource, in addition to erratic waste disposal in surface waters, enhances the contamination of groundwater. It thus becomes obligatory to identify suitable management strategies to balance development without compromising on environment or public health. Groundwater pollution will increase regional water scarcity; leading to a humanitarian crisis. The successful implementation of projects requires an intensive, daily investment in coordination between the parties. The responsibility for this coordination lies with all parties.

Preventive management is the preferred approach to drinking-water safety and should take account of the characteristics of the drinking-water supply from catchment and source to its use by consumers. As many aspects of drinking-water quality management are often outside the direct responsibility of the water supplier, it is essential that a collaborative multiagency approach be adopted to ensure that agencies with responsibility for specific areas within the water cycle are involved in the management of water quality.

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References

[1] Baghvand, A., Nasrabadi, T., Nabibidhendi, G., Vosoogh, A., Karbassi, A. and Mehradadi, N., 2010. "Groundwater quality degradation of an aquifer in Iran central desert". Desalination 260(3), 264-275.

[2] Attoui, B., Kherci, N. and Bousnoubra, H., 2012. "State of vulnerability to pollution of the big reservoirs of groundwater in the region of Annaba-Bouteldja (NE Algeria)". Geographia Technica. 2:1-13

[3] Schijven, J.F., Hassnizadeh S.M. and Husman, A.M., 2010. "Vulnerability of unconfined aquifers to virus contamination". Water Res., 44(4):1170-1181.

[4] Suvarna T., Mohammad J. S. and Rushikesh S., 2012. "Spatial Distribution of Ground Water Quality In Some Selected Parts of Pune City, Maharashtra, India Using GIS". Current World Environment, 7(2), 281-286.

[5] Shivasharanappa, Padaki S. and Mallikarjun S. H., 2011. "Assessment of ground water quality characteristics and Water Quality Index (WQI) of Bidar city and its industrial area, Karnataka State, India". International Journal of Environmental Sciences, 2(2), 965-976.

[6] Huang, T., Pang, Z. and Edmunds, W.M., 2012. "Soil profile evolution following land-use change: Implications for groundwater quantity and quality". Hydrol. Process 27(8), 1238-1252.

[7] Diodato, N., Esposito, L., Bellocchi, G., Vernacchia, L., Fiorillo, F. and Guadagno, F.M., 2013. "Assessment of the Spatial Uncertainty of Nitrates in the Aquifers of the Campania Plain (Italy)". Am. J. Clim. Chang. 2, 128-137.

[8] Jain, S. K. and Sharma, V., 2011. Report on Contamination of Ground Water by Sewage, Central Ground Water Board, Government of India.

[9] Vijay Shankar, P.S., Kulkarni, H. and Krishnan, S., 2011. "India's groundwater challenge and the way forward". Economic and Political Weekly, 56 (2), 37-45.

[10] Velagaleti, R. and Burns, P. K., 2006. "The Industrial ecology of pharmaceutical raw materials and finished products with emphasis on supply chain management activities", http://www.epa.gov/esd/chemistry/ppcp/images/ecology.pdf

[11] Report of the Working Group, 2011. Sustainable Groundwater Management as input to 12th Plan, Government of India, New Delhi.

[12] APHA, 2005. Standard methods for the examination of water and waste water, 21st Edn, American Public Health Association, Washington.

[13] WHO, 2006. Guidelines of drinking water quality Recommendation: the 3rd edition. Geneva: World Health Organisation, 2nd ed.

[14] Bureau of Indian Standards, 2012. Drinking Water-Specification, IS 10500:2012, Second Revision, Government of India, New Delhi.

[15] Ramakrishniah, C.R., Sadashivam, C. and Ranganna, G., 2009. "Assessment of Water Quality Index for the Groundwater in Tumkur, Karnataka State", India. E. Journal of Chemistry, 6(2), 523 530.

[16] Kavita, P. and Vineeta, P., 2010. "Evaluation Water quality Index for drinking purpose of river Subenarekha in Singhbhum District", International Journal of Environmental Sciences, 1(1), 77-81.

[17] Craun, G.F. and Mccabe, L.J., 1975. "Problems associated with metals in drinking water". Journal of the American Water Works Association, 67, 593.

[18] Salemi E., Mastrocicco M., Colombani N. and Aschonitis V.G., 2012. "Comparison of Three Different Methods for Groundwater Intrinsic vulnerability Mapping in the Ferrara Province", Italy. BALWOIS 2012-Ohrid, Republic of Macedonia.

[19] Howard, D., 2007. "Chemical Speciation Analysis of Sports Drinks by Acid–Base Titrimetry and Ion Chromatography: A Challenging Beverage Formulation Project" Journal of Chemical Education 84 (1), 124.

[20] USGS, 2002. United States Geological Survey: Study and Interpretation of the Chemical Characteristics of Natural Water: Water Supply Paper, 1473.

[21] Parihar, S.S., Kumar, A., Kumar, A., Gupta, R.N., Pathak, M., Shrivastav, A. and Pandey A.C., 2012. "Physico Chemical and microbiological analysis of underground water in and ground Gwalior city, M.P., India", Res. J. Recent Sci., 1(6), 62-65

[22] Rahman, S., 2002. "Groundwater quality of Oman", Groundwater Quality, London, 122-128.

[23] Amadi, A. N., Olasehinde, P.I., Okosun, E.A. and Yisa, J., 2010. "Assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers", Physics International 1 (2), 116-123.