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DEVELOPMENT OF WATER QUALITY INDEX FOR GROUNDWATER IN KOLKATA CITY, WEST BENGAL, INDIA

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ABSTRACT

Water Quality Index is a tool not only to identify the status of the present water quality scenario with respect to priority of parameter against weight value but also to assess the allocation wise suitability towards quality of water. In this paper, water quality index is developed to assess the groundwater scenario of Kolkata city, West Bengal State, India. Eighteen groundwater samples were collected from different locations of the selected site spreading over a period of two year from January 2011 to December 2012 and accordingly physico-chemical parameters have been analyzed as per standard procedure. Six parameters have been considered to calculate Water Quality Index such as pH, Turbidity, Total Dissolved Solids, Total Hardness, Chloride and Iron. The tool WQI results show that out of eighteen samples only six water samples are suitable to fit for drinking.

Keywords: water quality index, groundwater, Kolkata City, physico-chemical parameters, quality rating.

1. INTRODUCTION

Most of the groundwater in Kolkata city, West Bengal, India occurs under confined to semi-confined condition. In the major part of the area fresh groundwater overlies the brackish groundwater except in the western part starting from Fort William in the central part on the bank of river Hugli and Kalighat in the south and in a localized body around Kasipur, west of Dumdum in the north, where brackish groundwater overlies the fresh groundwater. In the levee deposit on the bank of Hugli River thin lens of shallow aquifer occur within 12 m below ground level (bgl), where groundwater occurs under water Table condition. Groundwater also occurs under unconfined condition within 17 m below ground level in the marshy/swampy lands around Ballyganj, Tollyganj, Tiljola, Dhakuria, Kasba, Santoshpur, Garia, Behala, Barisha and Thakurpur [1].

The city receives its supply of water both from surface (80%) and subsurface (20%) sources. Industries in and around the city generate considerable toxic effluents, which contaminate groundwater. Groundwater quality from deep tubewells show high concentrations of chlorides and the chemical composition is not satisfactory, but free of bacterial contamination. In some wards of the city, groundwater has been found to contain impermissible amounts of arsenic, lead and cadmium. Steps are being taken to assure potable drinking water to the citizens of all the areas [2]. Keeping in view, the overall objective of the present work is to develop a tool of Water Quality Index (WQI) against contours to assess the suitability of groundwater for drinking purpose prescribed by APHA guidelines [3] in Kolkata city, West Bengal State, India.

Study area

Kolkata is the capital city of West Bengal, which lies in eastern India, bordering Bangladesh. The city is centered on latitude 22 º 34' North and longitude 88 º 24' east, elevations ranging from 1.5 to 9.0 m above sea level. The city is about 30 km from the Bay of Bengal and river tides at Kolkata range over 4 m. The river Hooghly is the principal waterway, forming the western boundary of the city. Lying within the tidal reaches of the Ganges, the city area is mostly flat and sloping from north to south. There are numerous low-lying areas, marshes, wetlands, and shallow lakes in the region. The East Kolkata Wetlands (EKW), now declared a Ramsar site, was originally formed from tidal action leaving salt lakes and marshes. The agro-climatic zone characterization of the area is Gangetic alluvium group of soils and the city and its neighboring areas are represented predominately by clay soils. The climate is hot and humid. The monsoon starts in mid-June and goes up to September, and even October. On average, the city receives 1600 mm of rainfall annually. Relative humidity ranges between 84% in August to 68% in March. During winter (November to February) fog is frequent, indicating a high humidity and presence of aerosols in abundance. Frequent inversion layers restrict the vertical motion of the atmosphere to a great extent [2].

The study area is located between Latitudes 22 º 07' to 22 º 11' North and Longitudes 88 º 05' to 88 º 08' east, covering an area of approximately 153.084 km^2 shown in Figure-1.

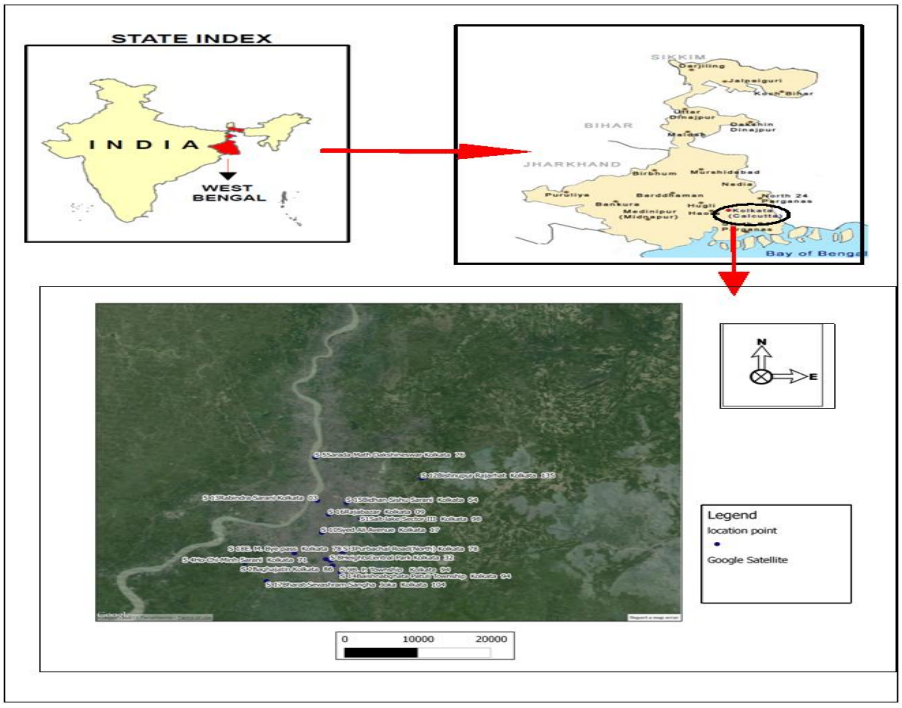

Figure-1. Study area locations.

3. MATERIALS AND METHOD

Drinking water samples of eighteen (18) different locations of the Kolkata City of India were collected spreading over a period of two year from January 2011 to December 2012. Water samples were mainly collected from tube wells and were analyzed as per standard procedure described by APHA (2012). The sampling locations are arranged in Figure-1.

For calculating the Water Quality Index (WQI), the method followed by Tiwari and Mishra [4], Singh [5], Das *et al*., [6] have been employed. In the present study, six parameters have been considered for calculating the WQI such as pH, Turbidity, Total Dissolved Solids (TDS), Total Hardness, Chloride and Iron. The quality rating scale and accordingly the weight values have been assigned to the selected parameters to estimate the overall water quality index. Based on the actual groundwater scenario most of the researchers have been established the weight value to assess the water quality depends on criteria and standard. However in this study the weight value of the said parameters pH, TDS, Turbidity, Total Hardness Chloride and Iron are considered as four for first two parameters, two for other three parameters and rest for one to establish the overall water quality index. The standards of the water quality parameter as per IS - 10500 (1991), [7] and their respective weight used in the present study are highlighted in Table-1.

Table-1. Water quality parameter, standards and weight used in the present study.

S. No.	**Parameters**	**Standards** (IS-10500) (1991)	**Weight** (W_t)	**Unit weight** (W_i)
1.	pH	6.5-8.5	4	0.266667
2.	Turbidity (in NTU)	5-10	2	0.133333
3.	Total dissolved solids (TDS) (in mg / L)	500-2000	4	0.266667
4.	Hardness as $CaCo_3$ (in mg / L)	300-600	2	0.133333
5.	Chloride as Cl^- (in mg / L)	250-1000	2	0.133333
6.	Iron as Fe (in mg / L)	0.3-1.0	1	0.066667
			$\sum W_t = 15$	$\sum W_i = 1$

4. WATER QUALITY INDEX (WQI) AND ITS CALCULATION

Water Quality Index (WQI) is a mathematical tool to integrate the complex water quality data into a numerical score that describes the overall water quality status. WQI may be used as indicator to measure the watershed pollution as recommended by Enrique Sanchez *et al*., [8]. Lai *et al*., [9] developed a water quality model to trace the extent of pollution of lake and river. Water quality index could be used as simple indicator of aquaculture effects on aquatic bodies (Fabiano dos Santos Simoes *et al*., [10]). Marta Terrado *et al*., [11] established surface water quality indices for the analysis of data generated by automated sampling networks. An innovative approach has been undertaken by Ramesh S. *et al*., [12] to describe the drinking water quality index of Southern Tamil Nadu. Stigter *et al*., [13] was also pointed out the quality index could be used for groundwater to assess the scenario in a distributed manner and subsequently a communication tool has been developed for adaptation strategy towards agro-environment at policy level.

Calculation of water quality index (WQI)

The unit weight of each parameter calculated by the formula,

$$W_i = \frac{(w_i)^i}{\sum(w_i)^i} \quad \text{as} \quad \sum wi = 1$$

The quality rating scale (q_i) for six physico-chemical parameters is given in Table-2.

Table-2. Quality rating scale for water quality parameters (q_i).

S. No.	Degree of pollution rating (q_i)	Normal (100)	Slight (80)	Stress (50)	Famine (0)
1.	pH	6.5 - 7.5	7.51 - 8.0	8.01 - 8.5	>8.5
2.	Turbidity	0 - 5.0	5.1 - 7.5	7.5 - 10.0	> 10
3.	TDS	0 - 500	501 - 1250	1251 - 2000	> 2000
4.	Hardness	0 - 300	301 - 450	451 - 600	> 600
5.	Chloride	0 - 250	251 - 600	601 - 1000	> 1000
6.	Iron	0 - 0.3	0.31 - 0.70	0.71 - 1.0	> 1.0

The value for the parameters have been divided into four stages viz. Normal, slight, Stress and Famine for which quality rating (qi) ranges from 100 to 0. Average values of physico-chemical parameters to assign WQI value for different samples have been used in the present study depicted in Table-3. The sub index (SI) has been calculated for each parameter by applying the multiplication of weight value and the rating scale of individual quality and therefore the formula of WQI is

$$WQI = \frac{\sum(SI)_i}{\sum w_i}$$

So, $WQI = \sum (q_i w_i)$ as $w_i = 1$

Table-3. Average values of physico-chemical parameters and assign WQI value of different samples used in the present study.

		Physico-chemical parameters						WQI
S. No.	Sampling source number	pH	Turbidity	TDS	Hardness	Chloride	Iron	
1.	S - 1	7.38	1.16	720	360	285	0.15	89.33
2.	S - 2	7.70	2.00	2570	960	1590	2.17	40.00
3.	S - 3	7.87	0.73	1015	640	370	0.54	72.00
4.	S - 4	7.06	3.70	383	280	96	0.08	100.00
5.	S - 5	6.70	2.00	780	376	130	0.09	92.00
6.	S - 6	7.51	2.00	2500	788	1410	1.06	34.67
7.	S - 7	6.70	3.00	560	240	48	0.75	94.67
8.	S - 8	6.68	2.00	1340	612	721	0.13	66.67

9.	S - 9	6.70	6.00	3570	1040	1160	2.16	37.33
10.	S - 10	7.20	5.00	1350	420	325	0.31	79.99
11.	S - 11	8.00	3.10	910	592	312	0.74	76.67
12	S - 12	7.38	5.00	740	360	370	0.50	88.00
13.	S - 13	7.50	2.50	1020	740	270	0.47	77.33
14.	S - 14	7.60	3.20	2740	840	1140	0.65	40.00
15.	S - 15	7.45	2.00	1345	560	780	0.18	73.33
16.	S - 16	7.20	1.58	1250	580	570	0.89	82.00
17.	S - 17	7.06	6.00	2424	688	1320	5.70	37.33
18.	S - 18	7.80	2.80	1095	500	410	1.25	73.33

5. RESULTS AND DISCUSSIONS

The average value of physico-chemical parameters and WQI of eighteen samples is given in Table-3. The results observed that the maximum and minimum value of WQI has been found to be 100.00 and 34.67 delineated as S-4 and S-6 respectively.

In the present study it is observed that nearly sixty six percentage of water samples consists of 33% of each sample are having poor and very poor status. Nearly 34% of water samples are being fallen under good and excellent category as highlighted in Table-4.

Table-4. Status categories of WQI and number of sample come under the status.

WQI	Status	Sampling source number under the status	Total number of sample comes under the status	Percentage of sample comes under the status
0-70	Very Poor	S-2, S-6, S-8, S-9, S-14, S -17	Six	33
71-80	Poor	S-3, S-10, S-11, S-13, S-15, S-18	Six	33
81-90	Good	S-1, S-12, S-16	Three	17
> 90	Excellent	S-4, S-5, S-7	Three	17

6. CONCLUSIONS

WQI has been computed to assess the suitability of groundwater of six different parameters for drinking purposes in and around Kolkata region. In this paper, eighteen groundwater samples were collected and accordingly analyzed at the laboratory of School of Water Resources Engineering, Jadavpur University during the period of January, 2011 to December, 2012. About 17% is under the category of excellent so far drinking water quality is concerned followed by another 17% which exhibits good category. This paper concludes only six groundwater samples can be treated as drinking standard. It may also be opined that about 66% of groundwater sample are not fit for drinking due to obtaining lesser WQI value i.e., WQI $\leq$ 80. It may also be reflected that two parameters particularly chloride and hardness are found to be higher compared to permissible level resulting TDS value at higher order owing to salt water intrusion which might take place in the vicinity of eastern and southern part of Kolkata.

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