Review on Present Situation of Groundwater Scenario on Kolkata Municipal Area

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Abstract: Kolkata is one of the most important city in Asian subcontinent. River Ganga is on its west. Kolkata located on gangetic deltaic plain. It is situated on Bengal basin. A typical groundwater situation exists in Kolkata municipality area. The presence of semi confined and confined aquifers can be observed. Different types of study on the scenario of groundwater on Kolkata municipal area has already been discussed they have contributed their valuable observation regarding this. A certain amount of daily consumption of water is to be fulfilled by extraction of groundwater. Urban development in this city is making an adverse effect on groundwater. Several types of hydro chemical composition can be observed in groundwater. There is possibility of presence of harmful arsenic in certain places. Due to extensive extraction of groundwater, possibility of land subsidence can affect as consequence. As for further study, there is limited scope due to unavailability of updated dataset. There should be strict governance and fruitful implementation to maintain sustainability of groundwater. This paper further studies on groundwater situation on municipal area of Kolkata with overall perspective and informative manner.

1. Introduction

Kolkata is a metropolitan city, constituted as a district under west Bengal the eastern part state of India. It has been established and proved as city since 17th century. British emperor had put their stone in India from this city towards India, it has been India’s capital until 1911. With the passage of time Kolkata has changed its shape. Growth of the city has increased with population in time. Kolkata has an historical background in economic and cultural perspective Kolkata has become saturated for last fifty years because of sudden infiltration of population due to political disturbances. Kolkata has been exploited for living and other purposes in terms of natural resources. Ground water is one of the most valuable resources’ that has been rigorously extracted to serve different purpose. This paper is trying to find, the aspect of groundwater exploitation in Kolkata from the past years and what is the current situation of groundwater in Kolkata.

The study area mainly focuses on the area under Kolkata Municipal Corporation (Figure 1). Specifically to the district of Kolkata (88° 30'E - 22° 33' N.). With 205 sq. km area holding 24,306 people as population density[1]. Eminent scholars has put an immense effort to understand the situation of groundwater of Kolkata. different planning and different steps has been taken for understanding and approaching towards groundwater. In this paper, previous researches regarding
ground in this specified study area has been tried to discuss briefly to establish present condition regarding groundwater.

Figure 1. Satellite image of Kolkata Corporation

Figure 2. Geomorphological map of Kolkata

Source: CGWB; Kolkata (KMC) district profile
2. Geomorphology
Kolkata is situated upon Bengal basin. A large peri-tectonic tertiary basin of fluvio marine sediments with enormous thickness in it [2]. Kolkata is located over the western part of the hinge zone across which sediment thickness and facies significantly varies from shelf area in the west to the deep basinal part in the east [3]. Kolkata is located on the lower deltaic plain of the composite Ganga Bhagirathi delta and the sediment deposited by the river system flowing through the area during the quaternary era covers it. The subsurface geology of the area is completely obscured by the blanket of recent sediments (Figure 2). The upper strata of 300 meters below the ground level belongs to quaternary era and is primarily an alteration of clay, silt and sands of various grades, gravels with occasional pebble beds. The formation the quaternary era is the principle respiratory of groundwater in the area [4].

3. Aquifers in Kolkata
The sub-surface disposition of the aquifers indicates that the clay (10 to 60 m thick) at the top of the sedimentary sequence imparts confined to semi-confined condition to groundwater occurring in the aquifers below this clay blanket. The aquifers below this clay bed consist of fine to coarse sand, which are occasionally mixed with gravel (Figure 3). The sediments show facies variation at a few places, which is characteristic of typical deltaic deposition and the top clay bed, shows a transition from aquiclude to aquitard. The thickness of the aquifer varies from place to place with the frequent occurrence of clay lens within them. (Table 1) In most cases this unconfined aquifer is hydraulically connected with the surface water bodies like ponds, unlined nals and stagnant water in the low-lying marshy lands and the open wells get a constant supply of surface water. As a result the open wells which are hydraulically connected with the surface water bodies do not dry even in the peak summer season[5]. (Figure 4)

![Figure 3. Hydrological map of KMC area](image-url)
Figure 4. Aquifer diagram of KMC area
Source: CGWB; Kolkata (KMC) district profile

Table 1. Status of aquifers in kolkata[6]

| formation       | Quaternary alluvium |
|-----------------|---------------------|
| Aquifer condition | 600m bgl have been established. The fresh group of aquifers is sandwiched between saline/brackish aquifer. The top saline/brackish aquifer lies within the depth span of 20-180m with maximum depth of 320mbgl in the extreme south. Suitably constructed tubewell tapping 35m cumulative thicknesses can yield 100-150m3/hr. |

4. Occurrence of Ground Water
A certain hydro chemical situation can be observed in KMC area [7,8]. In certain places brackish water lies over the fresh groundwater, such places area western part starting from the fort William in the central part of the bank of the river hoogli, kalighat in the south and in a localized body around kashipur, west of dumdum in the north. but in contrast major part of the Kolkata, fresh groundwater overlies the brackish water (Table 2)
Table 2. Locations of water level

| Occurrence  | Status                          | Places                                                                 |
|-------------|---------------------------------|------------------------------------------------------------------------|
| Within 12 m bgl | thin lens of shallow aquifer  | Around the levee deposit on the bank of Hugli River and surroundings   |
|             | water table condition           |                                                                        |
| Within 17 m bgl | unconfined condition           | marshy/swampy lands around Ballyganj, Tollyganj, Tiljola, Dhakuria, Kasba, Santoshpur, Garia, Behala, Barisha and Thakurpur |

5. Groundwater resources

Due to semi confined to confined nature of aquifers estimation of ground water resource by water table fluctuation method could not be done. Depending upon the available data a total quantum of 204 million litres per day of ground water is entering into the central depressed zone. Ground water in the localized water table aquifers in Ballyganj, Tollyganj, Tiljola, Dhakuria, Kasba, Santoshpur, Garia, Behala, Barisha and Thakurpur area and in the levee deposits along the bank of Hugli river has got limited yield prospects but estimation of ground water resources is not possible due to paucity of data as the aerial extension of the aquifer cannot be determined due to cover by urban agglomeration.

6. Scenario of water levels in Kolkata city during the groundwater yearbook 2013-2014

The piezometric surface of the confined fresh ground water in KMC area was initially flat before the large-scale development of ground water started. The flow of ground water initially followed the slope of land and movement of ground water was towards south and southeast. Withdrawal of more and more ground water in excess of replenishment has created adverse effect on ground water regime in KMC area and it is reflecting in the pattern of piezo metric surface(Table 3). Groundwater occurs mainly under confined condition. Piezo metric level is significantly deep ranging between 10.92&19.03mbgl during pre-monsoon period and between 8.08 and 17.74 m bgl during post monsoon period.in the major part of the city, generally piezo metric level varies from 14.50-16.50m bgl. This is due to huge withdrawal of groundwater for domestic and industrial uses.

Table 3. Piezometric level trend

| Trend (m/yr.) | Pre monsoon | Post monsoon | Annual |
|---------------|-------------|--------------|--------|
| Rising        | 0.033-0.437 | 0.152*       | 0.079-0.346 |
| Falling       | 0.113-0.164 | 0.005-0.691  | 0.011-0.451 |

* Singular observation

Source: GWYB 2013-2014

Declining of water level in 45 years

1958-2003

| Yearly declining trend | 7 to 11 meter |
|------------------------|---------------|
|                        | 0.33 meter at core |
|                        | 0.11 meter at periphery |

Source: CGWB; Kolkata (KMC) district profile
7. Kolkata’s water supply

Groundwater provides 25% of the city’s water supply and is drawn by private motorized wells operated by industry, housing estates, and high-rise apartments. Another 10% is groundwater drawn from ~260 electrically pumped municipal wells that are typically 100 to 150 m deep. Some 10,000 public hand-pumped shallow wells are also estimated to exist in the KMC [9]. The volume abstracted by public wells is insignificant compared to that abstracted by motorized municipal and private wells but their importance to public supply of water is great. Decades of high-capacity pumping of groundwater has lowered the groundwater level in parts of the city by up to 14 m, creating cones-of-depression in the east, west and north of KMC the groundwater high between the eastern and western depressions arises because recharge is occurring from Tolly’s Nala [10] 1838, a deep borehole was drilled down to a depth of 52 m extracting freshwater, for the first time, from the city aquifer. Subsequently, between 1918 and 1940, several tube wells were installed with an average discharge of 655 m$^3$/d. A trend of increasing groundwater development in Kolkata has continued from the middle of 1950s to the present day. In 1956, the groundwater-pumping rate was about $55 \times 10^3$ m$^3$/d. This increased by 1989 to about $182 \times 10^3$ m$^3$/d. As of 2010, the screens of the drinking water wells a replaced within a depth interval of 100 to 140 whereas some shallow wells, constructed by small land owners for domestic use, have their screens placed at depths of between 30 and 60 m. Kolkata now pumps about $310 \times 10^3$ m$^3$/d of groundwater. In Kolkata City, it is anticipated that, by 2025, an additional $75 \times 10^3$ m$^3$/d of groundwater may be required for drinking, domestic and industrial purposes. This rate was calculated by projecting the past trends of groundwater abstraction at Kolkata for the period 1956–2006[11] by the projected population in 2025. It is also noticed that big housing complexes generally needs considerable bulk quantity of water. Therefore, the surface water source alone cannot meet up fully the overall requirement of domestic water. Hence, this necessitates setting up for bore well pump within the particular premises under the private capacity of flat owners’ association. The bore well pump has some limitation for withdrawal of ground water keeping in mind of Aquifer condition in the particular area. Therefore, over withdrawal may affect adversely in the quality of water and existing piezometric level with the fluctuation in water level[12] The past and current withdrawals in Kolkata and the surrounding areas may have led to changes in groundwater flow patterns, declines in ground water quality, land subsidence and increased pumping costs.

8. Groundwater quality

The quality of ground water, although being utilized for domestic, commercial and industrial uses, is considered by the users as problematic particularly in Bidhannagar in the east to Baghajatin in the south, where mineralisation increases depth wise. Ground water in the south-western part is fresh and is suitable for all purposes. The mineralisation is due to relict salinity of deltaic alluvium formed at the time of deposition and simultaneous dilution/ flushing of the seawater. Presence of Mn (manganese) in ground water may be harmful to Kolkata. There is presence of Fe (Ferrous) in certain parts of Kolkata in groundwater. There is also the presence of Mg (magnesium), which can be hazardous for health, which are certainly present in late Pleistocene and deltaic aquifers [13]

| Locations under KMC | Behala, khiddirpoe, Alipore, chetla etc. | Bullygunjne, tiljola, garia, tolygunjne santoshpur, manicktala, razabazar etc. |
|---------------------|----------------------------------------|---------------------------------------------|

**Table 4.** Quality compositions of ground water

| hydro chemical | Bicarbonate type | Chloride type |
|----------------|------------------|---------------|
| anionic        | Ca-Mg-HCO$_3$    | Ca-Mg-Cl      |
|                | Na-HCO$_3$       | Na-Cl         |

Source: CGWB; Kolkata (KMC) district profile
KMC has reported sporadic occurrence of arsenic beyond permissible limit (0.05mg/l) to groundwater in few places. [14] The groundwater in late Pleistocene aquifers across the Bengal basin the groundwater in the late Pleistocene aquifer beneath Kolkata is not polluted by naturally occurring As. [15] the groundwater arsenic contamination of Kolkata has changed drastically since 2009. The wards under arsenic contamination threat have increased in number, and the situation in most part of Kolkata has become seriously alarming [16] a confusion regarding the presence and vulnerability of As in groundwater is still on between researchers. [17]

9. Issue of land subsidence
Due to rapid urbanization it has been observed more population consumption in Kolkata, this causes more consumption of groundwater also as groundwater provides 25% of total consumption. It can cause the situation of land subsidence the estimated land subsidence varies between 1.12 and 43.8 mm/year (Table 4) with a mean of 13.53 mm/year. The estimated land subsidence for 1 m drop in the piezometric head varies from 1.79 to 10 cm with an average of 3.28 cm. Visible evidences of land subsidence yet been recorded because of the presence of a thick layer of very low permeable material at the top of the geological column.[18]

10. Conclusions
In this paper, detailed secondary data studies has been done. Research work of different researchers has been incorporated in this paper. On the present situation of groundwater studies there is ample scope in it due to rapid urbanisation and accumulation of population, groundwater exploitation is increasing day by day. Already decline in groundwater level has already been observed. If this situation continues, in future there will be a shortage of groundwater along with there is a possibility of contamination of harmful elements. In case of groundwater recharge and discharge, a negative anomaly has been observed, it may lead to the vulnerable cause of land subsidence. There is lack of availability about further documentation regarding groundwater studies. Proper governance and monitoring of the alarming situations on groundwater are yet to be developed.

11. References:
[1] https://www.kmcgov.in/KMCPortal/jsp/KolkataStatistics.jsp
[2] Alam M et al 2003 An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. Sedimentary Geology 155:179-208.
[3] Nath Sankar et al 2014 Earthquake scenario in West Bengal with emphasis on seismic hazard microzonation of the city of Kolkata, India. Natural Hazards and Earth System Sciences. 14. 2549-2575. 10.5194/nhess-14-2549-2014
[4] http://wbdmd.gov.in/writereaddata/Chapter-7.pdfChatterjee A 2014 Water Supply system in Kolkata city and adjoining areas. https://medium.com/@anjan.chatterjee/water-supply-system-in-kolkata-city-and-adjoining-areasb199099a4517#.trpdgul6z
[5] Chatterjee A 2014 Water Supply system in Kolkata city and adjoining areas. https://medium.com/@anjan.chatterjee/water-supply-system-in-kolkata-city-and-adjoining-areasb199099a4517#.trpdgul6z
[6] Ground Water Year Book of West Bengal&Andaman & Nicobar Islands (2013-2014)
[7] http://cgwb.gov.in/District_Profile/WestBangal/Kolkata%20Municipal%20Corporation.pdf
[8] http://cgwb.gov.in/District_Profile/WestBangal/Kolkata%20Municipal%20Corporation.pdf
[9] Maity B K Management of Urban Water Cycle in Kolkata Municipal Corporation. http://www.bengalchamber.com/energyconclave/year2012/b-k-maity.pdf, 2012, Accessed on 23/07/2016
[10] Sahu P and Sikdar P K Effect of pumping on hydrologic system of a young satellite city in south Bengal Basin through numerical modelling: past, present and future. Sustain. Water Resour. Manag.2017, 3 (3), 321
[11] Sikdar 2000 personal communication with Dr A.K. Misra, Central Ground Water Board, CGWB, Eastern Region)
[12] Chatterjee A 2014 Water Supply system in Kolkata city and adjoining areas. https://medium.com/@anjan.chatterjee/water-supply-system-in-kolkata-city-and-adjoining-areasb199099a4517#.trpdgu16z
[13] http://cgwb.gov.in/District_Profile/WestBangal/Kolkata%20Municipal%20Corporation.pdf
[14] McArthur et al 2018 Groundwater Quality beneath an Asian Megacity on a Delta: Kolkata’s (Calcutta’s) Disappearing Arsenic and Present Manganese. Environmental Science & Technology. 52. 10.1021/acs.est.7b04996
[15] http://cgwb.gov.in/District_Profile/WestBangal/Kolkata%20Municipal%20Corporation.pdf
[16] McArthur et al 2018 Groundwater Quality beneath an Asian Megacity on a Delta: Kolkata’s (Calcutta’s) Disappearing Arsenic and Present Manganese. Environmental Science & Technology. 52. 10.1021/acs.est.7b04996.
[17] Malakar A et al 2016 Rapid decadal evolution in the groundwater arsenic content of Kolkata, India and its correlation with the practices of her dwellers. Environmental Monitoring and Assessment, 188(10).
[18] Sahu P and Sikdar P 2011 Threat of land subsidence in and around Kolkata City and East Kolkata Wetlands, West Bengal, India. Journal of Earth System Science. 120. 435-446. 10.1007/s12040-011-0077-2.