Role of Electrical Conductivity on Salinity and Mineralization due to Groundwater Level Fluctuations in Kolkata City

B John¹ and S Das²

¹ Senior Research Fellow, School of Water Resources Engineering, Jadavpur University, India
² Assistant Professor, School of Water Resources Engineering, Jadavpur University, India
E-mail: bernadettejohn.rs@jadavpuruniversity.in

Abstract. This paper attempts to explain the relationship between the falling Groundwater level and the rising electrical conductivity of the Kolkata Metropolitan City. The groundwater level of the city is on the fall, and if it further depreciates, then it will lead to the flow of toxic elements from the Dhapa areas leading to increased minerals and dissolved salts in the groundwater, rendering the groundwater unfit for consumption. It is seen that the salinity of the groundwater is on the rise in Kolkata. The salinity or the degree of dissolved salts was tested using electrical conductivity parameter. The water level and electrical conductivity data was collected from different Government organisation and the EC for post 2018 was collected through field measurement using a TLC metre. Maps were prepared using GIS techniques and both the parameters (groundwater level and electrical conductivity) were correlated. It shows a positive correlation between groundwater level and electrical conductivity and maximum fall in the level is seen in the northern part of the city. If artificial recharge is done in the trough areas then only the problem can be solved to a greater extent.

1. Introduction
Groundwater (GW) is a natural resource occurring in varied rock types and since this water percolated through different soil layers finally to form the groundwater reservoir, it is considered to be pure and much treatment is not required for its use. The deterioration in the quality of groundwater occurs mainly due to human intervention like municipal waste disposal, industrial waste disposal, use of pesticide and other factors. Thus, a thorough evaluation of groundwater quality and quantity is vital for a systematic planning and handling of the asset [1-3]. The quality of groundwater cannot be considered to be static with a given aquifer and there is a spatial variation in the quality of groundwater within the aquifer [4-6].

The presence of salt in the lower layers of the soil profile is an indication of its movement in rainwater or from weathering of the rocks containing salt in the strata. The clayey soil has more clayey content than those of sandy soil [7]. Salinization involves both the physical and chemical processes and the entire process of salinization is related to the transportation of salts in dissolved form in groundwater flow directions.

The river Hooghly has varied characteristics along its entire length. The salinity in the river closely follows the addition of freshwater from its upper reaches as the quantum of freshwater increases in its upstream, the salinity of its water decreases even in downstream [8-9]. The salinity of the river affects the groundwater of Kolkata to a greater extent.
The distribution of saline water spatially, closely follows the groundwater flow systems. The salinity of groundwater is because of the mineralization of the groundwater, physical transport of salt and saline base flow into other water bodies and the precipitation of salts within the zone [10]. Since pure water is a weak electrolyte, and the electrical conductivity (EC) of aqueous solutions will thus depend on the presence of charged ions. EC increases with the number of ions in solution. Thus EC is a good parameter to judge the increasing salinity and dissolved salts in groundwater. This paper attempts to study the increasing salinity of Kolkata’s groundwater and its relation with groundwater exploitation in the city.

2. Study area
Kolkata, the gateway of Eastern India, is the capital of the Indian state of West Bengal, India. Extending from 22°28'00" N to 22°37'30" N and positioned on the left bank of the river Hooghly as seen in figure 1 and is nearly 120 km away from Bay of Bengal. The natural drainage of the Kolkata-Municipal-Corporation (KMC) area is towards the eastern and southern part of Kolkata [11-12]. The subsoil mainly consists of clay, silt, different grades of sand gravels and pebbles. Climatically it is of hot and humid type. The Kolkata Municipal Area occupies an area of 187.33 sq. km divided into 144 wards and 16 boroughs. Originally the city grew in the North-South direction over a length of 50 km and due to the rising population pressures especially due to the influx of refugee from Bangladesh the former East Pakistan after partition. The nearby wetland has been encroached upon, especially Salt lake and Rajarhat areas.

![Figure 1. Location of the study area.](image)

2.1 Occurrence of groundwater
In general groundwater in KMC area is mainly present under confined condition and in some parts as semi-confined aquifers. In major parts of the city the freshwater is present above the brackish water exception being the western part of the city from Fort William to Kalighat and in Dumdum area where freshwater is present below the brackish water. In some parts of the region where there are old levee deposits, especially in the southern part of the city, groundwater also occurs in unconfined condition as seen in figure 2. Groundwater also occurs under unconfined condition in the marshy/swampy lands around Tollyganj, Dhakuria, Tijlola, Ballyganj, Santoshpur, Kasba, Garia, Barish, Behala and Thakurpukur because of
the nature of availability of groundwater at different places different levels of ground water is tapped which is clear from the figure below [11].

Figure 2. Aquifer map of Kolkata city.

Due to the presence of saline water in majority of wards in Kolkata the tubewells bored by KMC is done around 90 m, exception being few wards in the west and south-western part, where saline water is overlying freshwater, the water has been tapped at a greater depth of around 120 and 220 m (source: KMC). But, even tapping the freshwater zone the EC values is showing a rise which is an indicator of Increasing mineralization and salinization of the groundwater in the city as seen in figure 3.

3. Methodology
The present study is based on primary data collected through ground investigation and secondary data collected from government sources. The data for electrical conductivity for the year 2010 was collected from West Bengal Pollution Control Board, Kolkata. The data on groundwater level for the year 2010 and 2018 was collected from Central Ground Water Board, Kolkata and the electrical conductivity for the post monsoon period, 2018 was measured at different locations in Kolkata using a TLC metre. The data thus collected was interpolated using GIS tools and the result was further analysed and interpreted.

4. Results and discussion

4.1. Spatial and temporal variations in groundwater level
A study of changes in groundwater resources over time and space helps to have an overall idea of the condition of the resources and exactly which places needs immediate attention. The analysis of groundwater level (GWL) for the Kolkata city shows a lower level of groundwater. A comparative
analysis of GWL for 2010 and 2018 shows a negative fluctuation in GWL. The pre monsoon 2010 shows GWL fluctuation within 10 to 17.5 metre below ground level (mbgl), a value indeed low for a deltaic plain region. There is a huge spatial difference in the level of groundwater in the city. The north and central part of Kolkata has a lower GWL than its southern counterparts. The southern part of the city has a higher level of groundwater, which is a clear reflection of its geology. For post monsoon period for the same period, it is seen that at some places, there has been an increase in GWL and at some places the level has declined, it is evident from this that there has not been equal recharge at all places owing to the slope and geology of the area. The GWL during the given period varies between 7-20 mbgl. The maximum depletion is seen in the northern part of the city. Places like Shyambazar, Sinthi, Manicktala, Sealdah, Rajabazar all show a water level of 16.5-19.37 mbgl, such a low level for a deltaic lowland is quite alarming. Majority of places in the city showed a water level of 14-16.5 mbgl. Places in the south-eastern part of the city show a better GWL, comparatively. Around Garia, Anandapur, Mukundapur, the GWL ranges from 7-13 mbgl.

Figure 3. The depth of tubewells for groundwater withdrawal in different wards of Kolkata.

The temporal variation of GWL in the city shows that the GWL has depleted over the decade. Overall there has not been much of a variation in the GWL. The level for pre monsoon 2018 fluctuates within 6-21 mbgl, for post monsoon period the variation is between 5.5-20 mbgl as seen in figure 4. Thus, over the years there has not been such depletion of groundwater in the city, this is due to the steps taken by Kolkata Municipal Corporation in providing treated surface water to maximum areas of the region. Though the dependency on groundwater is not totally eliminated but the problem has much been arrested, which is clearly reflected in the GWL of the city.
4.2. Electrical conductivity

Electrical conductivity (EC) is a physico-chemical parameter, used to access the quality of water. The electrical conductivity of groundwater for the city was measured at 15 locations spread all over the city. The data thus obtained was interpolated using IDW (Inverse Distance Weightage) maps were drawn. The map of EC values provides information on groundwater mineralization and its correlation with groundwater exploitation. EC is a parameter for assessing the dissolved salts in water and hence its salinity. The EC values of the KMC area show that maximum EC is seen in the eastern and northern part of the city. In Cossipore the EC value is 2340 µS/cm, values slightly lower than this is found in Bantala which is around 2100 µS/cm. In the surrounding areas the EC value is comparatively lower. The lowest value is seen in the western and south-western part of the city i.e. around Hastings, Behala, Sarsuna, Haridebpur, where the quality of water is better due to lower EC value. Even places at central Kolkata- Entally, Tangra show a lower EC value. The groundwater EC usually ranges from 500-1000 µS/cm and values higher than that indicate anthropogenic influence [13].

Figure 4. Groundwater level map for (a) Pre Monsoon 2010 (b) Post Monsoon 2018 (c) Pre Monsoon 2018 (d) Post Monsoon 2018.
Barring a few places in the south western part of the city including Behala, Sarsuna, Haridebpur and the adjoining areas all show values greater than 1000 µS/cm as seen in figure 5.

The post monsoon EC value of groundwater is more or else same with little variation due to addition of water through groundwater recharge. The recharge is quite low to bring about a significant change in the EC value. Eight years down in time series the EC value shows a slight rise. The pre monsoon values at Topsia rises to as high as 6000µS/cm, this might be due to the increasing groundwater withdrawal but at other places the values remain more or else same. The lowest value remains around Behala, Sarsuna, Haridebpur, Garia and the highest value around north Kolkata. The post monsoon shows a better EC value which proves the fact that dilution of water leads to lower EC values. Thus, with better recharge or lowering of groundwater exploitation the dissolved salts can be controlled. The salinity value for the city increases upward from south to north. The conductivity remains high around Beadon Street, Bagbazar area.

Figure 5. Electrical conductivity map of Kolkata for (a) Pre Monsoon 2010 (b) Post Monsoon 2010 (c) Pre Monsoon 2018 (d) Post Monsoon 2018.

A close correlation between salinity and groundwater level is seen, in majority of places, the area with lower groundwater level shows higher EC value. In the past, there was too much of withdrawal of groundwater, because of which the lowered water table gave rise to higher EC value. Though with
governmental intervention and high rate of awareness there has been a shift from groundwater to surface water because of which the groundwater level has been arrested to some extent, though there are usage of groundwater in the south but their dependency has been reduced. If we see the geomorphological setting of the city, the lower EC value for the southern part can be explained, the presence of Adi Ganga or Tolly nalah in the south which adds water to the ground. There are many jhils and khals in the southern part of the city. Though the mineral content is high in these areas but is less in comparison to other parts of the city. The higher EC value in the groundwater owes its origin also due to its origin i.e. the city has been formed by the alluvial deposition [10]. The EC value is higher in the eastern part of the city owing to the presence of dumping ground near Dhapa, which is unlined and there is absence of leachate collection system.

The groundwater samples of this area showed the presence of heavy metals [14]. The wastewater generated in the city which is the mixture of domestic and industrial effluent which carries heavy metals. These are fed into the wetland and the outlet from this wetland contains lot of pollutants. Leaching of pollutants may be accelerated due to over exploitation of groundwater for different sectors. The contamination of the aquifers might lead to the transportation of these pollutants inward towards the heart of the city [15]. Thus, if further the groundwater withdrawal is accelerated the pollutants will get transported further inward, as the dissolved metals or salts increases the EC value increases, thus, rendering the water unfit.

5. Conclusions
The rising awareness in the field of groundwater raises concern about its quantitative and qualitative aspect. Over the years the GWL of the city is falling leading to other qualitative problem. Thus, it is clear that with more withdrawal of groundwater and with greater trough creation the intrusion of pollutants from the nearby area increases. The northern part of the city shows higher EC value due to lower GWL. The higher withdrawal of groundwater would lead to the change in aquifer condition from confined to unconfined which will further pollute the groundwater. This problem can only be solved if only the withdrawal is controlled and further groundwater recharge is done. The illegal and uncountable withdrawal needs to be checked with strict legislation. Artificial Recharge Scheme was taken under Central Sector Scheme at All India Soil and Land Use Building which was constructed in a Recharge trench now shows an increasing trend. Thus artificial groundwater recharge is the prime need of the hour. A regular monitoring of the GWL and quality needs to be done on a regular basis to prevent any hazardous situation in the city. People should be taught the worth of water by levying water tax. The study highlights the chances of saline intrusion in the city which should be further correlated with the litho-logs of the city and surrounding area. Even the study of groundwater resources should be addressed in an integrated manner since the geology does not follow any administrative boundary thus; the adjoining districts’ water condition needs to be assessed to understand the problem related to the study area in concern.

6. References
[1] Adhikary P P, Chandrasekaran H, Dubey S K and Trivedi S M 2015 Electrical resistivity tomography for assessment of groundwater salinity in west Delhi, India, Arabian Journal of Geosciences 8 5 pp 2687-2698. DOI: 10.1007/s12517-014-1406-y.
[2] Chakraborty S, Maity P K and Das S 2020 Investigation, simulation, identification and prediction of groundwater levels in coastal areas of Purba Midnapur, India, using MODFLOW, Environment, Development and Sustainability 22 4 pp 3805-3837. DOI: 10.1007/s10668-019-00344-1.
[3] Chakraborty S, Maity P K, John B and Das S 2020 Overexploitation of groundwater causing seawater intrusion in the coastal aquifer of Egra in West Bengal, Indian Journal of Environmental Protection, accepted.
[4] Maity P K, Das S and Das R 2017 Methodology for Groundwater Extraction in the Coastal Aquifers of Purba Midnapur District of West Bengal in India under the Constraint of Saline
Water Intrusion, *Asian Journal of Water, Environment and Pollution* **14** 2 pp 1-12. DOI: 10.3233/AJW-170011.

[5] Jeihouni M, Delirhasannia R, Kazem S, Alavipanah S K, Shahabi M and Samadianfard S 2015 Spatial analysis of groundwater electrical conductivity using ordinary kriging and artificial intelligence methods (Case study: Tabriz plain, Iran), *Geofizika* **32** pp 191-207. DOI: 10.15233/gfz.2015.32.9.

[6] Maity P K, Das S and Das R 2018 A geochemical investigation and control management of saline water intrusion in the coastal aquifer of Purba Midnapur district in West Bengal, India, *Journal of the Indian Chemical Society* **95** 3 pp 205-210.

[7] Salama R B, Otto C J and Fitzpatrick R W 1999 Contributions of groundwater conditions to soil and water salinization, *Hydrogeology Journal* **7** pp. 46-64.

[8] Gole C V and Vaidyaraman P P 1966 *Salinity Distribution and Effect of Freshwater Flows in the Hooghly River*, Central Water and Power Research Station, Poona, India

[9] John B and Das S 2020 Identification of risk zone area of declining piezometric level in the urbanized regions around the City of Kolkata based on ground investigation and GIS techniques, *Groundwater for Sustainable Development*. DOI: 10.1016/j.gsd.2020.100354.

[10] Das D and Chattopadhyay B C 2009 Characterization of soil over Kolkata Municipal Area, Indian Geotechnical Conference, Guntur India 1.

[11] *Groundwater Information Booklet* 2007 Kolkata Municipal Corporation, West Bengal.

[12] John B, Das S and Das R 2020 Effect of changing Land Use Scenario in Kolkata Metropolitan on the Variation in Volume of Runoff using Multi-Temporal Satellite Images, *Journal of the Indian Chemical Society*. accepted.

[13] Marechal J C, Ahmed S, Engerrand C, Galeazzi L and Touchard F 2006 Threatened groundwater resources in rural India: an example of monitoring, *Asian Journal of Water Environment and Pollution* **3** 2 pp 15-21.

[14] De S, Maiti S K, Hazra T, Debsarkar A and Dutta A 2015 Assessment of groundwater pollution by municipal saolid waste (MSW) landfill leachate: A case studt in Kolkata, India, *International Journal of Computer and Mathematical Sciences* **4** pp.12-20.

[15] Sahu P, Michael H A, Voss C I and Sikdar P K 2013 Impacts of groundwater recharge areas of megacity pumping: analysis of potential contamination of Kolkata, India, water supply, *Hydrological Sciences Journal* **58** 6 pp 1-21. DOI: 10.1080/02626667.2013.813946.

**Acknowledgements**

We are highly grateful to Mr. Amlanjyoti Kar, Head, Eastern Region, Central Ground Water Board for providing us with the GWL data for our research. We are thankful to UGC for funding the research and to our University for providing funding support under RUSA 2.0 of Government of India.