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# Examining the extent of seawater intrusion from groundwater quality analysis at Purba Medinipur coast of India

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Water is mostly used for drinking water supply, irrigation water, and industrial supply. Purba Medinipur coast has been chosen as the study area which has small number of rivers and limited other surface water sources. Due to increasing population, industrialisation and irrigation groundwater is practised regularly instead. It is evident that if groundwater levels decline then seawater will intrude into fresh aquifer. To examine such condition, fourteen sampling locations have been chosen from coastal Purba Medinipur. Water quality parameters like pH, chloride, sodium chloride, magnesium chloride, magnesium carbonate, total dissolved solids, iron and total hardness are monitored for these selected locations. These water quality parameters are compared with international standards being used for specification of drinking water and is used for water quality reference for food industry. Central Pollution Control Board guidelines for water quality management for irrigation are considered as a reference for chemical analysis also.

Keywords: Seawater intrusion, groundwater, drinking water, irrigation.

## Introduction

Several studies are available worldwide which describe the extent of seawater intrusion effect on surrounding local groundwater quality. In Turkey, seawater intrusion ranged radially one kilometer coastal sites[1]. In Italy, several reasons of sweater intrusion were investigated[2]. In USA, both groundwater extraction and seawater-level rise were denoted as the cause of seawater intrusion[3]. The aquifers of low-lying coastal areas are polluted by seawater intrusion due to high rate of abstraction and small gradient of head[4]. In India, few analyses were done outside West Bengal to determine the quality of groundwater after seawater intrusion[5,6]. In West Bengal, also few studies ware made on this groundwater-seawater intrusion issues[7–15].

Purba Medinipur is located in eastern coast line of India. Latitude and longitude of Purba Medinipur is 87°46′44.87″ E and 21°56′21.25″ N (Fig. 1). Purba Medinipur is extreme south district of Medinipur division. Odisha is in the south west of Purba Medinipur, Bay-of-Bengal is located in the south. Hoogly River and South 24-Parganas district lies to the east. Howrah district lies to the northeast of it. Due to lack of rainfall partially filled surface water, water resource management is not sufficient. To fulfill domestic, industrial, irrigation water people are dependent on groundwater. Therefore groundwater level is declining[13]. According to Ghyben-Herzberg principle if the groundwater level declines by half meter then the seawater intrusion will intrude around twenty meter towards the inland areas.

The coastal area of Purba Medinipur is receiving influenced by seawater ingression through the aquifers and nearby canals. Therefore fresh water aquifer of Purba Medinipur is contaminated with seawater intrusion. Owing to salinity effect in soil, the yields of local crop are gradually decreasing. It gives a concern to future agricultural economy of Medinipur coastal areas.

Geological study conducted in previous studies show that since many years before Medinipur coastal areas was sited close to the Bay-of-Bengal at lower section of Singbhum and

Rajmahal. In reality, the West Bengal coastal areas were progressively made by stratified stratums that were structured through sediment and subsequent stone depositions in many decades carried by Ganga, Vagirathi and other rivers. Due to natural adversity, many trees and lives are covered up under soil stratums formation since long resulting; the soil, here, is acidic. Normally stratified soils have more permeability towards horizontal entrance direction of seawater from Bay-of-Bengal. So the soil herein coastal areas are highly saline. Mainly four types of soil are found in the coastal areas which are: (i) saline, (ii) saline alkali, (iii) non saline alkali and (iv) degraded saline. The soil configuration of Purba Medinipur coastal area is immature.

In rainy season there is no salinity effect on local crops because such local crops are mostly grown up by rainfed water. However, in summer all local crops are grossly affected by salinity. Several salt tolerant local crops may be cultivated successfully in summer like chilli, sunflower, cotton, etc. So groundwater quality is a very important issue for local summer crops in Medinipur coasts.Therefore, present study attempts to find out a link between seawater intrusion and subsequent effect on groundwater quality on coastal parts of Mediniupur.

## Materials and methods

For the present study fourteen (14) locations were chosen in such a way that those are spatially varied all over the coastal belt of Purba Medinipur. So the groundwater collected from these locations would give the clear picture of the extent of saline water intrusion over entire Purba Medinipur on the analysis of groundwater. The locations of groundwater sampling points are shown in Table 1.

As stated earlier groundwater from fourteen locations of Purba Medinipur were taken in a closed container. These containers were transferred to Surface Water Investigation Department (SWID) for the analysis of water quality parameters such as pH, sodium chloride, magnesium chloride, total hardness, chloride, magnesium carbonate, total dissolved solids (TDS), iron. The results obtained from SWID were noted down and tabulated.

**Table 1.** Locations of sampling points

| Sl. No. | Block/Area | North | East |
|---|---|---|---|
| 1. | Basantia High School | 21°48′16″ | 87°48′50″ |
| 2. | Pichabani | 21°43′05″ | 87°40′53″ |
| 3. | Amarshi Kasba | 22°03′35″ | 87°36′13″ |
| 4. | Kalindi headwork | 23°4′50″ | 87°18′10″ |
| 5. | Serkhanchak | 21°55′49″ | 87°55′51″ |
| 6. | Kumirda | 21°52′47″ | 87°43′28″ |
| 7. | Bagmari/Pataspur, Block-II | 22°35′13″ | 88°23′15″ |
| 8. | Dhanghora | 22°31′49″ | 86°59′28″ |
| 9. | Bara Subarnanagar/Contai-II | 21°48′39″ | 87°50′′49″ |
| 10. | Bhajachowlee | 21°51′38″ | 87°41′09″ |
| 11. | Barchunfuli/Contai-I | 21°46′33″ | 87°44′59″ |
| 12. | Bankiput/Contai-II | 21°45′51″ | 87°52′02″ |
| 13. | Badalpur/Ramnagar-II | 21°47′51″ | 87°37′48″ |
| 14. | Astichwak/Egra-I, Pump House-2 | 21°54′22″ | 87°40′10″ |

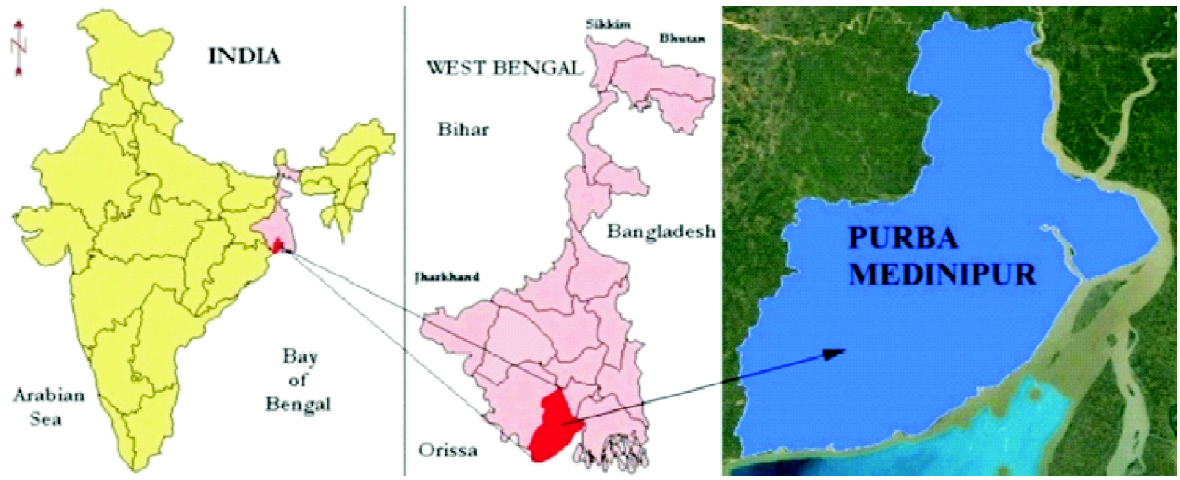


**Fig. 1.** Study area.

Also with the help of ArcGIS 10.3, contour map of each of the groundwater quality parameters was drawn. Based on the table and contour maps the groundwater quality parameters values were analysed with the help of (IS) 10500: 2012 for drinking water specification[16], IS 4251.1967 for food industry specification[17] and also Central Pollution Control Board (CPCB) manual for irrigation to identify whether groundwater parameters were safe to use for this intended purpose or exceeded the permissible limit.

Through water quality parameter analysis it is examined whether the fresh water aquifer of Purba Medinipur is contaminated with seawater intrusion or not. A pathline of seawater into the mainland may also be predicted from this study. The prevention for seawater intrusion is suggested as well.

## Results and discussion

The results of the chemical analysis of groundwater samples collected from 14 tubewells are shown in Table 2. The contour maps of each of the water quality parameter is drawn which will be helpful for analysis.

According to (IS) 10500:2012 acceptable limits for pH is 6.5–8.5. It is seen from Fig. 2 that pH level of all locations is within acceptable limit. So groundwater from Purba Medinipur is fit for domestic use from pH level. According to IS 4251: 1967, pH level for food processing industry is 6.5–9.2. So similarly groundwater from study area is fit for industrial purpose from pH level. According to CPCB guideline permissible pH in irrigation water is 6.5–8.5.Since from Fig. 2, it is seen that groundwater is fit from pH for irrigation purpose.

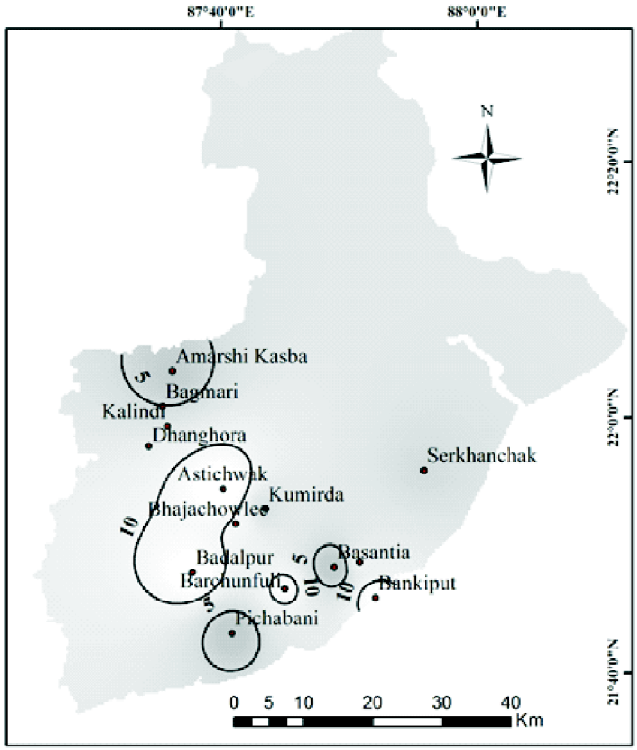


**Fig. 2.** Contour map of pH.

**Table 2.** Chemical properties of water sample at various location of Purba Medinipur district

| Sl. No. | Block/Area | pH | Sodium chloride (ppm) | Chloride ($Cl^-$) (ppm) | Total Hardness $CaCO_3$ (ppm) | Magnesium carbonate (ppm) | Magnesium chloride (ppm) | Iron (ppm) | TDS (ppm) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Basantia High School | 7.80 | 369 | 231 | 218.1 | 115 | 8.7 | 0.50 | 756 |
| 2. | Pichabani | 7.60 | 102 | 62 | 105.5 | 63 | 21 | 0.60 | 463 |
| 3. | Amarshi Kasba | 7.00 | 110 | 43 | 262 | 125 | 46 | 0.40 | 399 |
| 4. | Kalindi Head Work | 7.60 | 136 | 103 | 199 | 94 | 27 | 1.00 | 502 |
| 5. | Serkhanchak | 7.90 | 1219 | 1064 | 410 | 211 | 346 | 0.40 | 2621 |
| 6. | Kumirda | 7.10 | 215 | 44 | 254 | 142 | 109 | 0.36 | 250 |
| 7. | Bagmari/Pataspur, Block-II | 7.50 | 157 | 227 | 318 | 187 | 104 | 0.69 | 412 |
| 8. | Dhanghora | 7.20 | 1300 | 1900 | 650 | 210 | 489 | 4.40 | 1811 |
| 9. | Bara Subarnanagar/Contai-II | 7.30 | 219 | 800 | 285 | 365 | 108 | 0.65 | 780 |
| 10. | Bhajachowlee | 7.15 | 198 | 600 | 252 | 189 | 102 | 0.75 | 597 |
| 11. | Barchunfuli/Contai-I | 7.10 | 310 | 996 | 1010 | 245 | 265 | 1.90 | 1410 |
| 12. | Bankiput/Contai-II | 7.60 | 104 | 71 | 350 | 112 | 102 | 0.66 | 410 |
| 13. | Badalpur/Ramnagar-II | 7.91 | 1340 | 2600 | 504 | 430 | 510 | 0.46 | 2660 |
| 14. | Astichwak/Egra-I/Pump House-2 | 7.30 | 1100 | 800 | 540 | 320 | 210 | 0.05 | 1389 |

But it is seen that groundwater in south portion of Purba Medinipur like Badalpur, Bankiput are containing higher value of pH compared to other places. From the analysis it can be predicted that if indiscriminate usage of groundwater continues then pH level of groundwater in every location of Purba Medinipur will increase due to seawater intrusion movement in groundwater. So at some places in Purba Medinipur, on the basis of pH values groundwater are not fit for an alternative of drinking water supply.

According to water quality standard acceptable limits for sodium chloride is 250 ppm. It is seen from Fig. 3 that sodium chloride levels of Pichabani, Amarshi Kasba, Kalindi headwork and few other places are within acceptable limit. But places like Serkhanchak, Dhanghora are possessing high values of sodium chloride. According to the World-Health-Organization (WHO), sodium chloride concentration upper level for food processing industry is 230 ppm. So similarly, all the places in coastal Purba Medinipur areas are not fit for industrial purpose from sodium chloride viewpoint. So it is seen that most of the places like Serkhanchak, Dhanghora are highly affected by saline water intrusion. From the map it is seen that Sherkhanchak is east side of study area and very close to Bay-of-Bengal. So this place is heavily affected by seawater intrusion. Danghora is North West location of study area. This place is affected due to saline water movement through the aquifer.

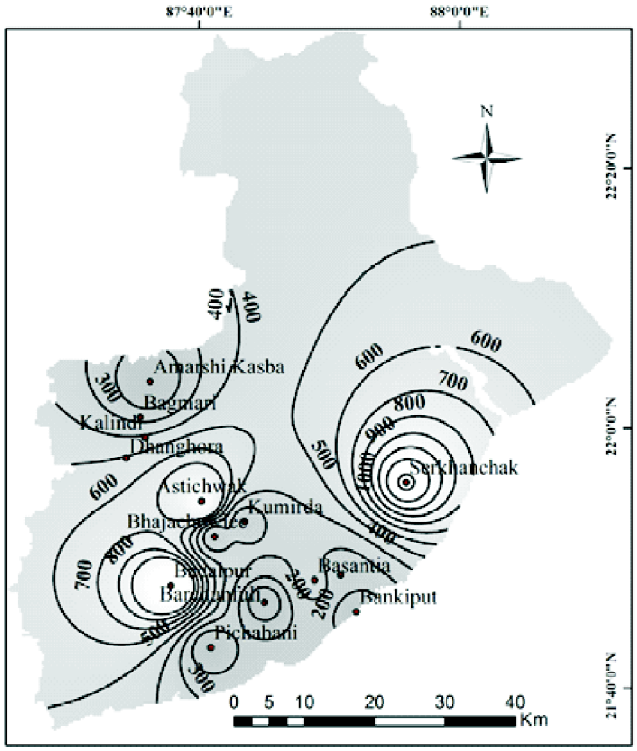


**Fig. 3.** Contour map of sodium chloride.

According to (IS) 10500:2012 acceptable limits for chloride is 75 ppm and permissible limit is 200 ppm. It is seen from Fig. 4 that chloride level of Basantia High School, Serkhanchak, Bara Subarnanagar, Bhajachowlee, Barchunfuli, Badalpur, Astichwak in Purba Medinipur is higher than permissible limit. So these places are highly affected by seawater intrusion from chloride viewpoint. According to (IS) 4251:1967 permissible limit for chloride is 250 ppm. From Fig. 4 it is seen that the locations in Purba Medinipur mentioned above is unacceptable from chloride viewpoint for food industry.

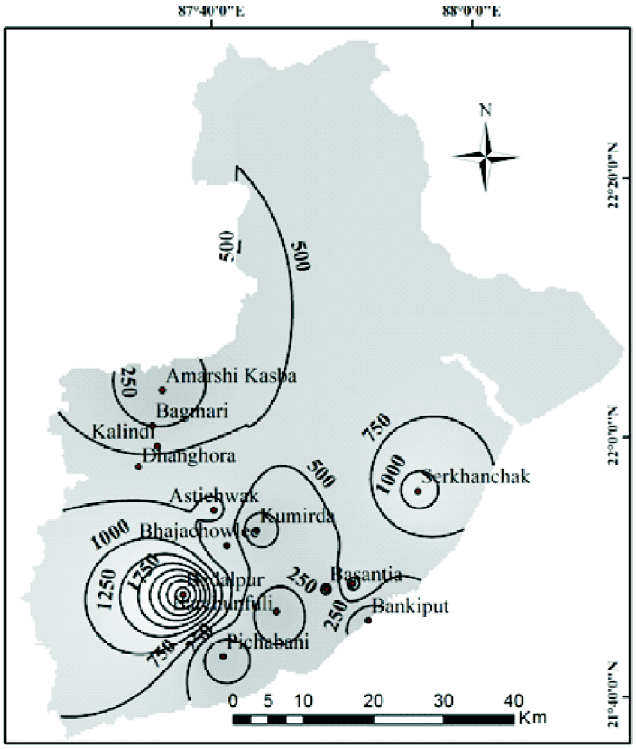


**Fig. 4.** Contour map of chloride.

Those places of Purba Medinipur which are mentioned above are located west side of study area. These places are near to the sea. Due to over exploitation of groundwater, seawater intrudes into aquifer of these places. That is why

these places are highly affected by groundwater contamination through seawater intrusion. Astichawk, Bhajachowlee and other places mentioned above are located in the west side of Purba Medinipur and near to sea. So these places are highly affected by seawater intrusion. According to (IS) 10500:2012 acceptable limits for total hardness 40–80 ppm.

It is seen from Fig. 5 that total hardness of all locations of Purba Medinipur is unfit for drinking water purpose. According to (IS) 4251:1967 permissible limits for total hardness is 30 ppm. From Fig. 5 it is seen that groundwater from all places like are not fit for industrial purpose. Total hardness for irrigation purpose is of 100 to 150 mg/L is considered ideal for plant growth. But from Fig. 4, it is evident that all coastal places in Purba Medinipur especially south and west portion which are near Bay-of-Bengal are mostly affected by seawater intrusion.

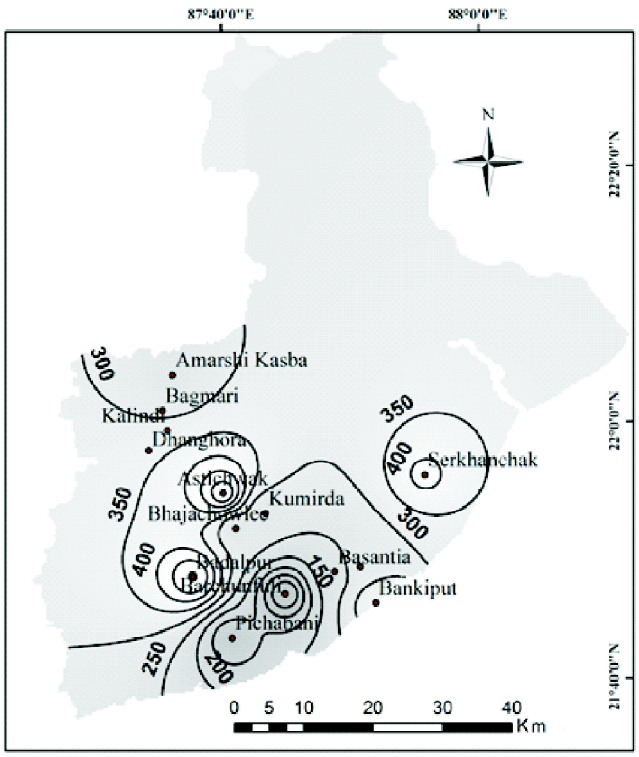


**Fig. 5.** Contour map of total hardness.

Although it is seen that all the places within Purba Medinipur are within safer zone from total hardness viewpoint but few places at western side and southern side are within alarming zone like Sherkhanchak, Bankiput and Pichabani. In near future these places may be highly affected by seawater intrusion from total hardness viewpoint.

According to (IS) 10500:2012 acceptable limits for sodium chloride is 600 ppm. It is seen from Fig. 6 that magnesium carbonate level of all coastal places in Purba Medinipur is not affected by seawater intrusion from magnesium carbonate viewpoint. According to IS 4251:1967 permissible limits for magnesium carbonate is 60–90 ppm.

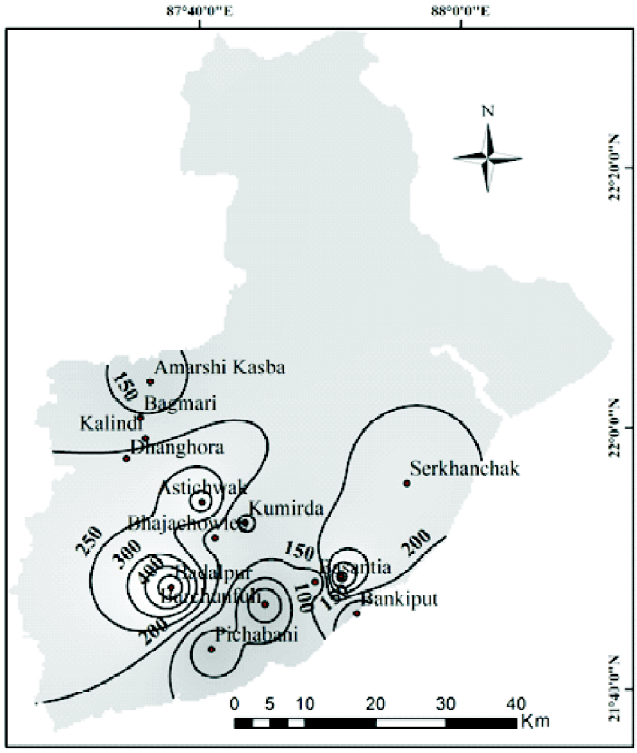


**Fig. 6.** Contour map of magnesium carbonate.

From Fig. 6, it is seen that most of the coastal places are within magnesium carbonate limit but few coastal places like Pichabani which is near Bay-of-Bengal contain high value of magnesium carbonate. So these places are contaminated with seawater intrusion. Pichabani is located in south portion of Purba Medinipur. It is generally seen that south portion and west portion of Purba Medinipur which are near the sea are highly affected by seawater intrusion.

According to (IS) 10500:2012 acceptable limits for magnesium chloride is 250 ppm. It is seen from Fig. 7 that magnesium chloride level of most of the places in Purba Medinipur

which are far away from sea are not affected by seawater intrusion. But the places like Serkhanchak, Dhanghora which are near sea shore - are affected by seawater intrusion from magnesium chloride viewpoint. According to (IS) 4251:1967 permissible limits for magnesium carbonate is 60–90 ppm.

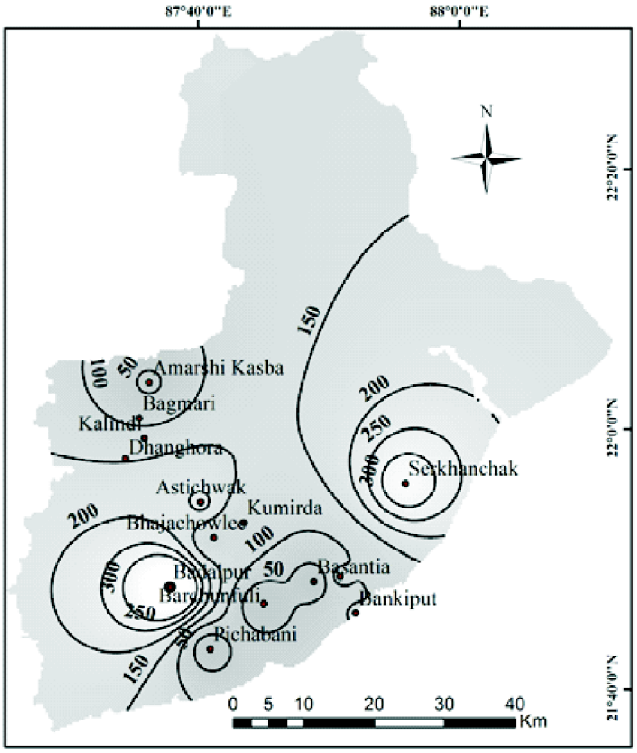


**Fig. 7.** Contour map of magnesium chloride.

From Fig. 7, it is seen that most of the places are within magnesium chloride limit but few places like Pichabani which is near Bay-of-Bengal contains high value of magnesium chloride. So these places are contaminated with seawater intrusion. Sherkhanchak and Pichabani are located very near to sea. So groundwater of these places is highly affected by seawater intrusion. Since Dhanghora is also affected so it indicates that seawater intrusion is spreading from south and west to north.

According to (IS) 10500:2012 acceptable limits for iron is 0.3 ppm. It is seen from Fig. 8, that iron level of Astichwak, Kumirda, Badalpur in Purba Medinipur safe limit for drinking water purpose. Rest of the places are highly affected by seawater intrusion. So these places are highly affected by seawater intrusion from iron viewpoint.

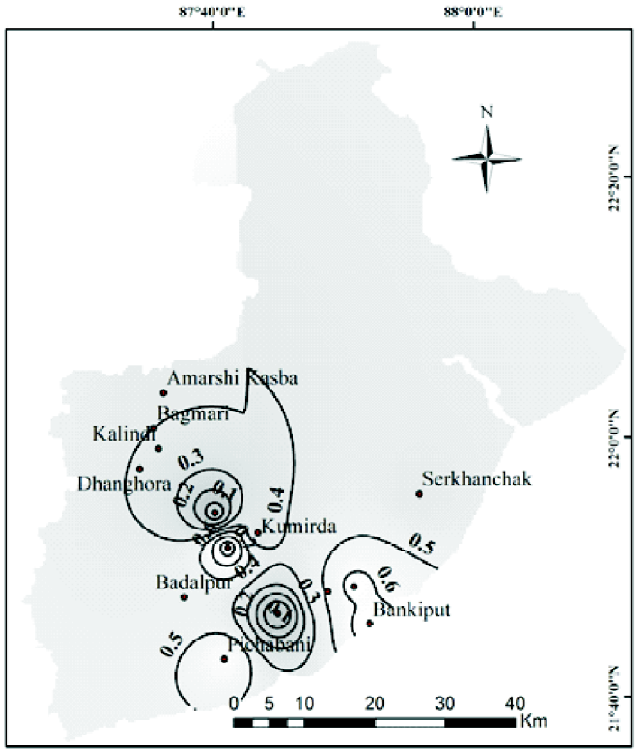


**Fig. 8.** Contour map of iron.

According to (IS) 4251:1967 permissible limits for chloride is 0.3 ppm. From Fig. 8 the same analysis, as done previously, can be inferred from food industry viewpoint.

The places mentioned above are in the western coastal side of Purba Medinipur. The places mentioned above are western coastal side of study area and proximity to the sea. So due to seawater intrusion these places are heavily affected.

Fig. 9 highlights the contour map of TDS. According to (IS) 10500:2012, acceptable limits for magnesium chloride is 1000 ppm and permissible limit is 2000 ppm. It is seen from Fig. 9 that magnesium chloride levels of Sherkhanchak, Dangora Astichwak, Kumirda, Badalpur in coastal Purba Medinipur have exceeded their permissible limit of TDS. So these places are highly affected by seawater intrusion. From the location map and contour map it is seen that all places of Purba Medinipur are highly affected. West side, north side of Purba Medinipur are heavily affected due to proximity to the sea. Northern portion is also affected due to geological formation and seawater movement through groundwater aquifer.

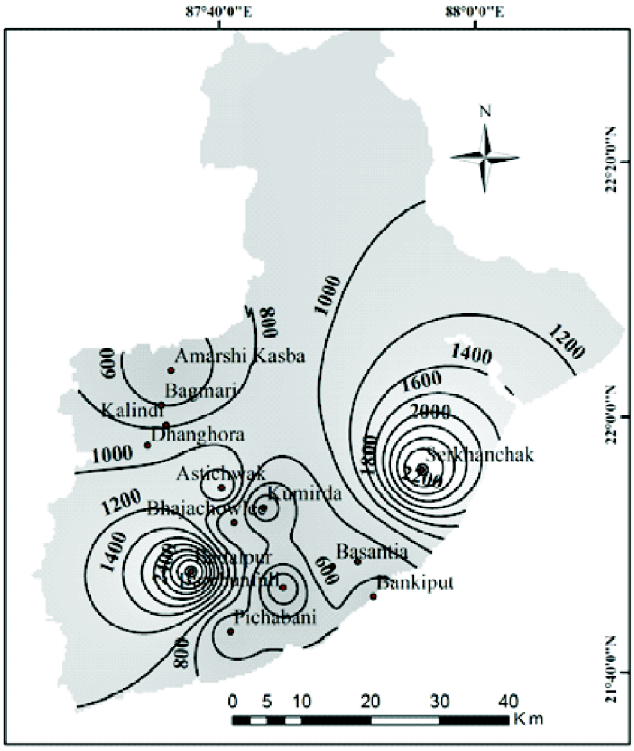


**Fig. 9.** Contour map of TDS.

## Conclusion

From the above results and analysis it has been found that pH value of all places are within permissible value according to of (IS) 10500:2012 for drinking water specification, IS 4251:1967 for food industry specification and also CPCB manual for irrigation. But if such an indiscriminate usage of groundwater extraction is taken place then pH value will exceed the permissible value laid down by standards taken. Areas like Serkhanchak, Dhanghora and other places are possessing high values of sodium chloride on comparison with standards of reference taken. Also chloride of large number of places have been exceeded the permissible limit of the chosen standards. Few places of Purba Medinipur is also affected by high value of magnesium carbonate. It has also been observed that most of the places of Purba Medinipur are affected from iron point of view. All locations of Purba Medinipur are highly affected by total hardness point of view. Serkhanchak, Dhanghora areas which are near Bay-of-Bengal are affected by magnesium chloride point of view. So it has been found that Purba Medinipur is highly affected by seawater intrusion which results enhancement of groundwater quality parameter values. If without any restriction such an indiscriminate usage of groundwater continues than no fresh water will be available at the Purba Medinipur and lithological character, groundwater, surface water will be fully saturated with saline water intruded from sea.

To remediate seawater intrusion the following methods can be adopted. Surface water height may be maintained at a higher level than the seawater. A high water ridge may be adopted near sea level. During extraction of groundwater through pumping, contaminant should be excluded. Rain water harvesting may also be provided.

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