Ingress of saline water in Coastal aquifers of Junagadh, Gujarat

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ABSTRACT: Junagadh coastal area is one of the salinity affected area mainly due to sea-water intrusion from last two-three decades. A study had been conducted in 1977 by High Level Commission (HLC-I); Government of Gujarat (GOG) to assess salinity scenarios for betterment of situation. The main objective of this study is to construct salinity ingress profile in 2006 pre-monsoon period. A comparison of salinity scenario within intervened and non-intervened sites is carried out to understand the effect of intervention. In addition to that, attempt has been made to identify the probable governing factors of salinity. In order to achieve these objectives, water samples are taken from ninety wells in pre-monsoon period (May). The study shows the salinity ingress profile in 2006 is within 7.5 km to 9.5 km inland in an average. While in 1977 it was observed within 5 km to 7.5 km. Therefore, the intervention is not much effective in macro scale but there is some influence of structure in micro-scale.

1 INTRODUCTION

Salinity in coastal groundwater is a widespread problem in many parts of India. Main causes of increase in salinity on the coastal plain may be due to individual or combined effects of inherent salinity, tidal effect, irrigation by saltwater and by seawater intrusion due to extensive pumping. Junagadh coastal area is one of the salinity affected areas mainly due to sea-water intrusion from last two-three decades.

The main objective of this study is to construct salinity ingress profile in the year of 2006 on Junagadh coastal area. A comparison of salinity scenario within intervened and non-intervened sites is to be carried out to understand the effect of intervention. In addition to that, probable governing factors of salinity are tried to identify. In order to achieve those objectives, water samples are taken from 90 wells in pre-monsoon period (May) from this area. Geo-chemical analysis is performed to construct ingress profile. Comparison of salinity ingress trend with respect to distance and intensity is also carried out of intervened and non-intervened sites.

2 BACKGROUNDS

Considering the history of water resources scenarios of Junagadh coastal area, it is found that in the mid 1950s, introduction of pumping technologies in the area made the agriculture production very high. As a result in the 1960s, the withdrawal rate of groundwater became 10 to 25 times more than that of previous. This extensive pumping caused unbalance in recharge and withdrawal phenomenon that resulted in sea-water intrusion. Therefore, there was a requirement of a study for salinity assessment and recommendation for betterment of situation in the late 1970s. A High Level Commission (HLC-I) was formed by Government of Gujarat (GOG) for this purpose. After an extensive study on geo-chemistry and hydro-geology of Juangadh coastal area some recommendations were proposed by HLC-I. According to those recommendations, management techniques like changing crop pattern, regulation of groundwater extraction etc, Recharge Techniques such as check dam, recharge well etc, and salinity control techniques like tidal regulator, fresh water barrier etc were proposed as the preventive measures for adoption. Partial measures are adopted in some of those areas (Kodinar). So, after three decades of implementation of the measures proposed in the study, an attempt has been made to conduct a fresh study with the same objectives and similar activities in order to have some comparison and assessment of the change in situation with respect to time.

3 DETAILS OF STUDY AREA

3.1 Geographic and Physiographic details:

Junagadh coastal area comprising of Una (T1 and T2), Kodinar (T3), Sutrapada (T4), Veraval (T5 and T6), Malina and Mangrol (T7 and T8, reference Figure-1) talukas serioally from easts of Junagadh, has been considered as the study area. This area is the middle part of saurashtra coast, extended from Diu (Una) to Jamnagar (Mangrol). The study area with well locations is shown in Figure 1.

The continental slope is very moderate near shore and therefore very wide. It is around 100km wide with an average slope of 6'. Veraval to Dwaraka, there is emergent aspect of shore with a number of bars and spits in the stream mouths. 2-3 parallel beach ridges of 10m to 20m height can be noticed with a gentle slope towards low land behind it. The coastal plain consists of plain low land behind the shore zone. In the transition between the shore and the coast, an alluvium or sandy ridge of 5m to 15m height, stretches for miles. The coastal soil is overlying on basaltic base rock, which appears 15 km away from the shore line and at the transition of coastal zone and main land.

Mangrol-Chowrad-Sil, the western most part of study area lies in a depression. From Madhavpur to Una, the coastal depression varies from 30m to 7m in elevation within few meters. Mangrol to Sil, North of this coastal ridge another depression can be noticed. In the Eastern most part (till Una) the direction of coastal slope is NE-SW and then clearly from North to South. Una-Dwarka slope direction is from NW-SE. (from Madhavpur toward Una). From west to east Netravati, Devka, Hiran, Saraswati, Singwadi, Singwada are the major intermittent type river.

Figure 1 Junagadh coast as study area with well location

3.2 Hydro-geology

The main aquifer materials in eastern part are mainly recent alluvium with a thickness of 5-20m. The main components of this alluvium are soil, coastal sand, saline marshy land and oyster beds. Recent alluvium is having a greater thickness toward kodinar and Una. Milliolite lime stone is mostly consisted with white or pale brown oolotic sandy lime stone with occasional grits and conglomerate. The water flows through lime stone cavities and pores, which is very difficult to estimate. Milliolite limestone is having a thickness of 15m to more than 20m in places. It is predominant in western side of the study area such as Mangrol area. Gaj formation consists of impermeable clay and compacted lime stone with grit in some places. Therefore over all permeability gets reduced. Gaj-Milliolite limestone interface shows an inclination of about 4^0 toward sea. Beyond and below Gaj formation Deccan trap bed rock can be found. Weathered Deccan Trap and Gaj formation is more productive in eastern side at Kodinar and Una area

3.3 Meteorology

Annual rainfall in Junagadh Coastal plain is estimated at approximately 674 mm; and again the variability coefficient of rainfall is very high; varying within an annual range of 29 to 35. Maximum variability of rainfall coefficient is obtained at the month of July as 53. Therefore the reliability of availability of water from rainfall is very uncertain. This is one of the phenomenons which make the water management problem the most critical in saurashtra coastal plain. Seasonal fluctuation of rainfall along with evapo-transpiration and the variation of wind speed are shown in Figure 2A and 2B respectively.

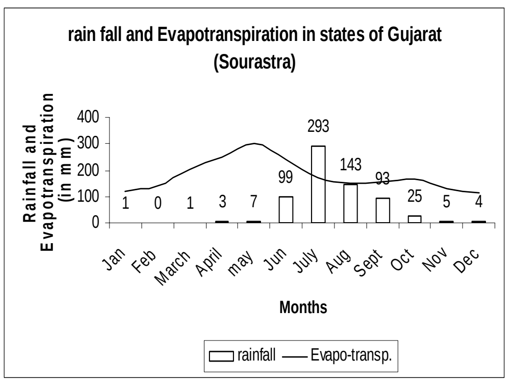


Figure 2A. Seasonal Fluctuation of rainfall

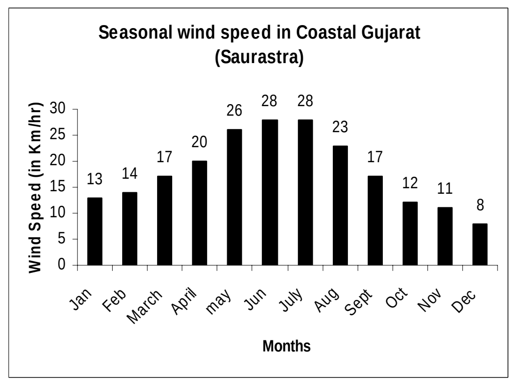


Figure 2B. Seasonal Fluctuation of ET

From the Figure 2A and 2B it can be noticed that the evapotranspiration in this coast is very high compared to total available rain. Only in the month of July there is some gain in water due to rainfall. In addition to that high wind speed with a range of 26km/hr at the month of May, when evaporation is maximum with a negligible amount of rainfall may result in salt accumulation in the coastal soil. All these meteorological aspects are favorable to intensify salinity problem in Coastal Junagadh.

4 ANALYSIS AND DISCUSSION OF DIFFERENT OBJECTIVES:

4.1 Salinity ingress profile:

Nearly 105 wells were selected for regular monitoring of water level and water sampling by High Level Commission–I (HLC-I) between Una to Madhavpur area in Junagadh in 1970s. Water sample having 1500 ppm TDS is considered as saline water in late 1970s. Therefore, with this limiting concentration salinity ingress distance was found out. Now with this available information, same kind of methodology has been adopted to assess the salinity scenario in 2006 after three decades of that study. In order to achieve that, around 90 wells are taken for groundwater level monitoring and water sampling. Water sample having TDS within 1750ppm to 2000 ppm is considered as saline water depending on Indian standards (2000 ppm) as of today. With this specification salinity ingress distance and profile has been found out and is given in Table-1 and shown in Figure-3 respectively.

From the table it is observed that the extension of salinity ingress in 1977 was minimum 5 km in (Veraval) area and maximum nearly 7.5 km in Una and Kodinar area. And salinity ingress in 2006 is approximately 7.5 km in Veraval area and 9.6 km in Una area

Table 1 Salinity Ingress Distance in Different Talukas

Talikas	1971	1973	1975	1977	2006
Una	4.5	6	6.5	7.5	9.6
Kodinar	4.5	6	7	7.5	9.5
Veraval	2.5	3	4	5	7.5
Mangrol	3	4	5	6	8.25

* Unit of distance is in kilometer (km)

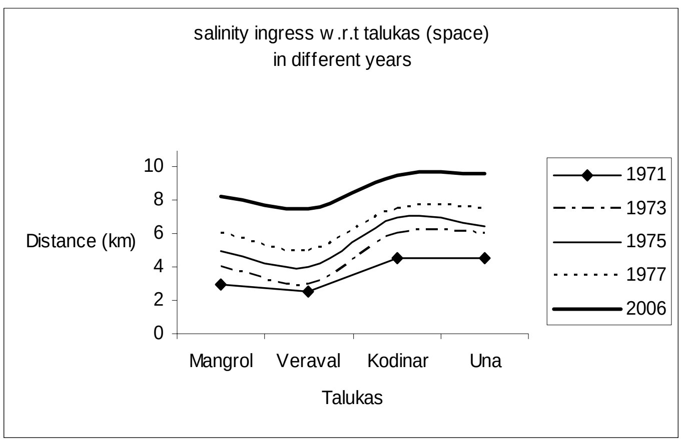


Figure 3: Salinity Ingress profile in Different Talukas of Junagadh district.

From the graph it is observed that though the ingress profiles in different zones are following same kind of trend but yet rate of ingress has changed slightly. That result shows that the salinity ingress distance is maximum in Una zone in 2006 while in 1977; Kodinar and Una both were showing the same ingress distance. In addition to that it can be observed that the Veraval region is showing less ingress distance compared to others historically. This observation can be explained by the high altitude of Veraval near coast as well as difference in local geological formation.

4.2 Comparison of intervened and non-intervened sites: Observation, Analysis and Discussion.

In order to understand the effect of intervention, two different zones are considered. One is Kodinar Taluka where many different types of recharge and salinity control techniques were adopted and another is Veraval taluka where no such interventions have been adopted. Salinity ingress distance of two places (intervened and non-intervened) are compared before and after intervention. In addition to that salinity intensity trend between intervened and non-intervened zones are compared in terms of TDS concentration with time (where location is fixed) and with space (where time is fixed) to understand the extension and scale of effect of intervention with respect to time and space.

4.2.1 Salinity ingress rate

Salinity ingress distances of two different zones, one is Veraval (non-intervened) and another is Kodinar (intervened), are shown in Figure 4.

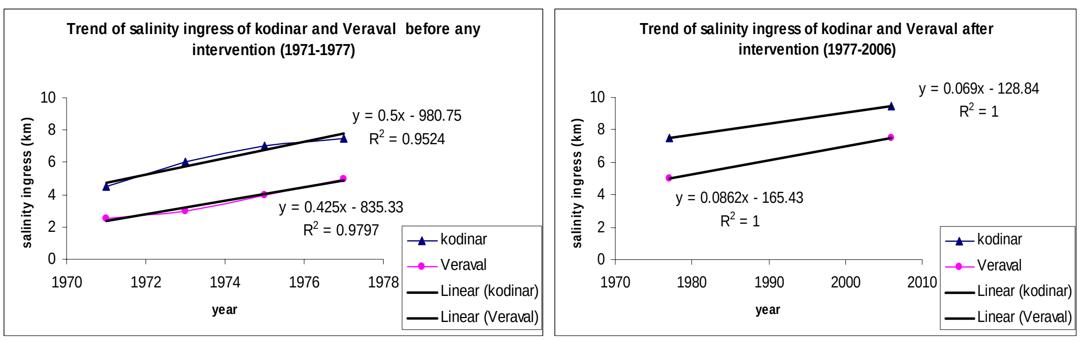


Figure 4A: before intervention Figure 4B: after intervention
Figure 4: salinity ingress distance of intervened and non-intervened sites.

From Figure 4A, it can be observed clearly that salinity ingress distance and rate, both are higher in Kodinar area during 1970 to 1977. Ingress rate of kodinar was found as 0.5 km per year while it was less as 0.425 km per year in veraval area before any intervention in any of these areas. From the trend line it can be clearly observed that the salinity ingress trend lines are diverging during that period. This phenomenon imparted that the Veraval is having a lesser ingress rate with compared to Kodinar area traditionally.

From Figure 4B, salinity ingress trend lines of non-intervened and intervened zone are converging during the period 1977 to 2006. Though Kodinar area is having a higher ingress distance from past but salinity ingress rate of Kodinar (intervened) are observed as 0.069 km per year while Veraval is having a rate of 0.0862 km per year. Comparing the salinity ingress rates within intervened and non-intervened sites, it is found by a simplified calculation that the salinity ingress rate are deduced in Kodinar area as 30m per year with respect to Veraval. Without considering accuracy of analysis it can be clearly concluded that the deduction rate is not much effective at intervened areas in macro scale. Therefore, salinity intensity trend with respect to time and space are required to analyze in order to understand the effectiveness of intervention and its feasibility in different scale.

4.2.2 Salinity intensity trend with respect to Time

Salinity intensity trends with respect to time during 1988 to 2004 of two specific locations, one is in intervened site and another is in non-intervened site are shown in Figure 5. Salinity is represented by TDS concentration in parts per million (ppm). Figure 5A is showing salinity intensity of village Devli in Kodinar Taluka which is a bit far from sea and some small intervention like recharge tank, canal etc can be observed. Whereas, village Lati in Veraval taluka is just adjacent to the sea and no intervention is observed. Salinity intensity trend (in ppm) of Lati is shown in Figure 5B.

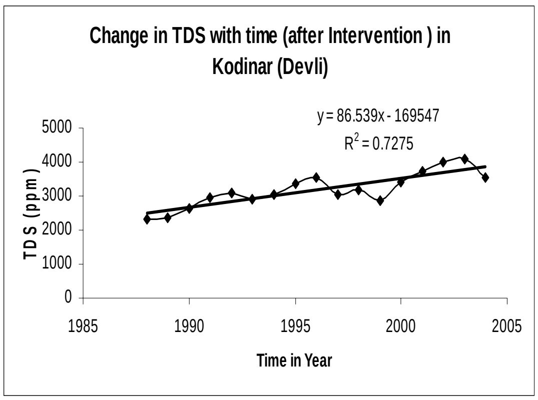


Figure 5A: Kodinar as Intervened area

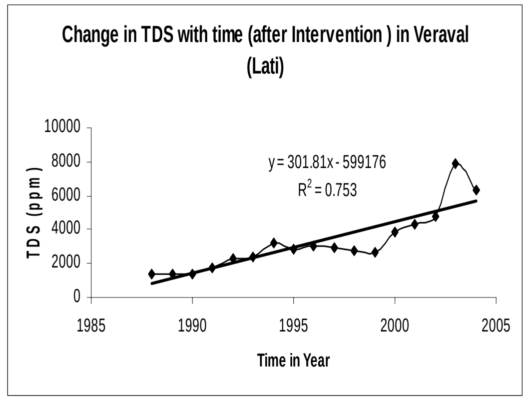


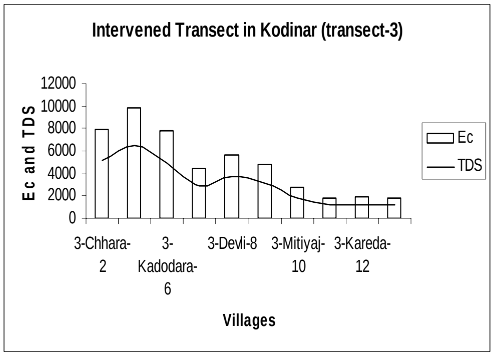
Figure 5B: Veraval as non-Intervened area

Figure 5: Salinity intensity trend of intervened and non-intervened sites during 1988-2004.

From Figure 5 it can be observed that the intensity and variation of salinity (TDS) is less in Devli when compared to Lati. Whereas the TDS of Devli varied within a range of minimum 2500 ppm in 1988 to 5000 ppm in 2004, the variation of TDS in Veraval at the same time is from 1500 ppm to 9500 ppm. The reason of it might be combined effect of distance from sea, effect of local geology and presence of interventions. Comparisons of intensity trends are also supporting the same fact. The slope of intensity trend of Figure 5B is much steeper than that of Figure 5A. From this observation it can be implied that the intensity of salinity in micro-scale is a function of both distance from sea and local geology as well as effect of intervention. In addition to that, it can be noticed that the TDS of each locations have not increased steadily with time. There are some depressions in TDS in some year. For example, 1999 is showing lower TDS while 2003 is showing a sudden increase in TDS in both the locations. That phenomenon can be explained as a result of rainfall variability.

4.2.3 Salinity intensity trend with respect to space

Salinity intensity trends with respect to space in a fixed time (pre-monsoon period of 2006) are shown through Figure 6. Figure 6A and 6B are showing Ec (microohm/cm and TDS (ppm) perpendicular to the sea in Kodinar taluka along transect T3 and in Veraval Taluka along transect T5 (refer Figure 1) respectively. It can be observed from Figure 6A that transect-3 or Kodinar area is having an undulating TDS trend from sea side to inland. While the trend of TDS is steep and steady in Veraval area along transect -3 as shown in Figure 6B. This observation can be explained by local effect of interventions. As 4^{th} location from sea side (khadodora village) in Figure 6A is showing a depression in TDS. This lowering of salinity is an effect of intervention in local scale. But Figure 6B is not showing such kind of variability in its trend and no intervention is also observed along this transect.



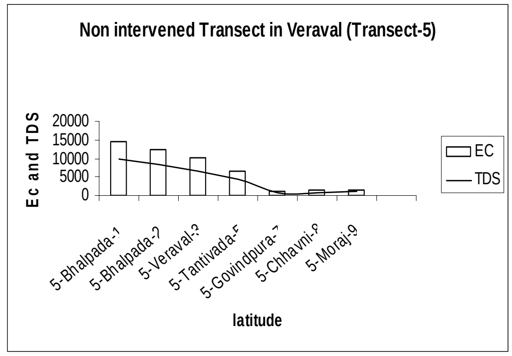


Figure 6A: Kodinar (transect T3) Figure 6B: Veraval (transect T5)

Figure 6: Salinity intensity trend perpendicular to coast (T3 and T5) of intervened and non intervened zone in 2006 (pre-monsoon period)

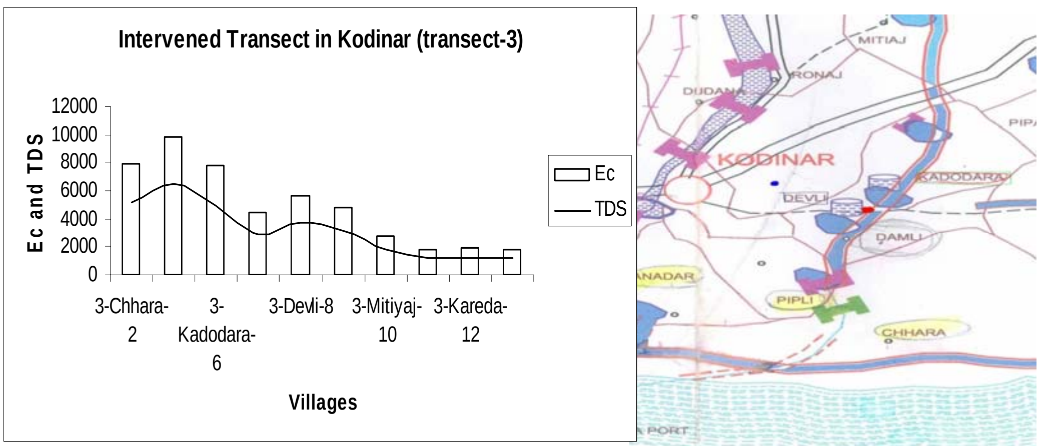


Figure 7: distribution and effectiveness of intervention in salinity along transect-3 (T3) in Kodinar taluka

Effectiveness of intervention in local scale can also be supported by Figure 7. In this Figure Intervention location and type of intervention are shown along transect 5 (T5). Therefore comparing the TDS concentration with intervention locations some concept about the effectiveness of scale of intervention can be achieved.

5 CONCLUSION AND FUTURE SCOPE

From field observation data collection and analysis it is noticed that the salinity ingress in coastal Junagadh area are extended from past three decades in different rate. In 2006 pre-monsoon period this ingress distance is found in a range of 7.5 km to 9.6 km on an average. Salinity ingress distance and rates are not uniform along the coast. This phenomenon is very much dependent on local altitude and geological feature. Transect 5 Veraval is showing less ingress distance historically. It is because this region is having a higher altitude with compared to other places. This intermediate region is having Milliolite formation extension more than Kodinar (Una) area but less than that of Mangrol. And Gaj formation is also found at a depth shallower than in Mangrol areas. This combined complex geological formation may be facilitating salinity ingress in Veraval area while compared to others. Comparison of intervened and non intervened sites shows that intervention is not bringing much change in salinity ingress scenario in macro scale. But in local scale there is some effect of structural intervention on salinity intensity.

From field observation it is found that the hydro-geological formation is very much diversified locally. Flow of water occurs through pores and caverns of recent alluvium, Milliolite and Gaj lime stone formation. Therefore there is a requirement of understanding distribution of those different classified geo-formation in micro scale. Effectiveness of intervened structures is also governed by small scale distribution of geological formation. Therefore, spatial distribution of aquifer diversity, hydrological aspect, rainfall variability, geochemical property and structural efficiency should be understood and integrated in a normalized scale. Based on those understanding type, location and capacity of further preventive measures should be adopted accordingly.

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