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Saline Water Intrusion in Urban Coastal Area: A Case Study of Kuttiyadi River, Kerala, India

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Abstract The present study focus on the water quality analysis of Kuttiyadi River, Kerala, with special reference to saline water intrusion. Salinity intrusion has a serious effect on the water supply in the Kuttiyadi river basin area in the recent years. Kuttiyadi River is the only source of water for supply during summer in Vadakara Municipality and nearby villages. The upstream sampling point which 22.5 km from the river mouth has salinity of 6.83 ‰ showed the rate of intensity of saline intrusion. Through Water quality analysis it is found that salt water intrusion in the river also leads to contamination ground water in the river sides. In some extent salt water intrusion the reason behind deterioration of surface water and ground water in private wells near river side. The results showed significant correlation with salinity and anions like Chloride, and Sulfate. Cations like Magnesium, Sodium, Calcium and Potassium are also significantly correlated with salinity of both surface water and ground water.

Keywords: *salinity intrusion, Kuttiyadi River, drinking water, water pollution*

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1. Introduction

Water quality has much importance in our life because it is essential to support physiological activities of any biological cell [1]. The lack of water quality will adversely affect health of living beings. Water pollution is the main reason behind deterioration of water quality and makes unsuitable for drinking and other purposes. Pollution is serious problem as almost 70% of India's surface water resources have been contaminated by various contaminants [2]. Environmental factors such as occurrence of highly soluble or easily weathered minerals, distance to the marine environment, aridity, terrestrial primary productivity, ambient temperature, the weathering reaction kinetics and quality of unpolluted waters influences the river water chemistry. River pollution affect adversely on the life of aquatic plants and animals [1].

In the coastal aquifer, seawater lies under fresh water since fresh water is less dense than seawater; consequently, the zone of contact between fresh water and seawater is brackish water [3]. Fresh water is commonly over the top of the heavier seawater and serves to push the seawater interface seaward. The seawater intrusion problem is one of the most important environmental issues that negatively affects groundwater resources significantly since groundwater salinity can lead to a reduction in fresh water availability and the degradation of groundwater quality [4,5]. Therefore, the study of seawater intrusion into coastal aquifers is needed to identify the affected zones where it should be able to prevent problems or remediate such areas efficiently. Processes of saltwater intrusion is the processes of the sea and river water mixing and the estuarine stratifications are the combinations of small-scale turbulent diffusion and large-scale variation of the field of advective mean velocities not constant either in time, space and direction [6].

Normally the inland extent of the saltwater wedge is limited because fresh ground water levels, or the height of the freshwater column, increases as land elevation gets higher. During summer season severity of saltwater intrusion increases with decrease of groundwater recharge and increase of water demand. Water management sectors such as agriculture, domestic and industrial water supply may affect by the salinization of groundwater systems [7]. Reference [8] in their study shares the thing that , increasing salinity from saltwater intrusion which will affects agriculture, aquaculture, infrastructure, coastal ecosystems, and the availability of freshwater for household and commercial use, this will creates negative impact on livelihoods and public health.

The saline water has many connections with fresh water bodies across the coastal belt. It leads to alteration or disturbance in the trophic structure and diversity of shallow fresh water bodies such as increased strength of trophic interactions. As a result, saline water fish are mixed with fresh water species. Freshwater fish species disappear Because of this, the intrusion of saline water in different fresh water bodies [9].

2. Materials and Methods

2.1. Study Area

Kuttiady River originating from the Narikota Ranges on the western slopes of the Wayanad Hills a part of Western Ghats at with a length of 74 km. The River water is used for supply by water authority in Vadakara Municipality and nearby villages. The present study was conducted on different sampling points in the Kuttiady River for surface water analysis (Table 1). Groundwater analysis was also done along the river basin.

Table 1. The location of the sampling stations

Sl. No	Sampling stations	Latitude	Longitude
1	SW1	11°34′18.6"	75°35′36.5"
2	SW 2	11°33′8.47"	75°36′6.07"
3	SW 3	11°31′6.31"	75°39′3.26"
4	SW 4	11°34′2.77"	75°41′06.5"
5	SW 5	11°36′1.50"	75°42′3.47"
6	SW 6	11°36′5.70"	75°44′5.44"
7	SW 7	11°37′5.02"	75°47′6.19"

2.2. Collection and Preservation of Samples

To evaluate the quality of water with special reference to salinity in each sampling stations water samples are collected in 1 L plastic containers and brought to the laboratory in ice box. Before taking the water samples, the containers are washed with distilled water and rinse two times with the water sample. The water samples for the bacteriological analysis are collected separately in sterilized plastic bottles. Ground water samples are collected clustery but network method is followed in order to determine the rate of saline water intrusion with increasing of distance from the River.

Soil samples were collected from the area where ground water samples are collected to understand the influence of salinity on soil mainly to focus on the texture difference and salinity intrusion rate. Soil samples were taken by removing the top soil and collected in plastic samples and followed by air dried in laboratory. Standard methods were used or the analysis of different physico- chemical parameters [10].

3. Results and Discussion

The study is conducted in pre-monsoon season. The results from the analysis were compiled and the values obtained for the physic chemical parameters are given in the Table 2.

pH of the water samples varied from 6.89 -7.7 during pre-monsoon season, with an average 7.3. pH is an important ecological factor that provides an important piece of information in many types of geochemical equilibrium or solubility calculations.

The electrical conductivity (EC) of the water samples varied from 32840 - 31.32 µS/cm with mean value of 14459.5 µS/cm. The sample point SW 1, close to the estuary point about 200 cm distance has the higher EC where the upstream sample has the lowest value. It is clear that as the distance from the sea increases the EC value shows decrease. High conductivity during pre-monsoon might be attributed to saline intrusion from sea [11]. In the month of March, the climatic condition differed and was indicated through higher salinity (EC) and hardness values. The concentration goes down in Monsoon season due to huge fresh water discharge through the river and natural cleaning process remains operating [12]. Total suspended solids that determine the depth to which photosynthetic organisms grow [11]. Maximum TDS found is 50520 and minimum is 20.52 at upstream of the river. EC of SW4 is slighty higher than that of SW 5. SW5 has lower salinity than SW4, but it has slightly higher concentration of chloride and magnesium, it may be due to the considerably influenced by human activities, and it might have derived from domestic effluents, fertilizers, and natural sources, weathering of chloride-bearing minerals [13].

Table 2. Physico-chemical characteristic of surface water of Kuttiady River

Parameter	**SW 1**	**SW 2**	**SW 3**	**SW 4**	**SW 5**	**SW 6**	**SW 7**
pH	7.34	7.7	7.34	7.41	6.89	6.9	6.98
Electrical conductivity (µS/cm)	32840	25620	20140	9232	9222	179	31.32
TDS (mg/l)	50520	39340	14290	14190	14240	115.1	20.52
Salinity (ppt)	33.42	25.23	10.25	8.26	6.83	0.07	0.02
Turbidity (NTU)	5.1	3.3	2.4	0.7	0.4	0.2	0
Sulphate (mg/l)	2296	1492	1464	772	751.2	5.84	2.4
Total Alkalinity (mg/l)	101.92	90.16	43.12	39.2	39.2	19.6	11.6
Chloride (mg/l)	16913	11275	7651.5	4429.8	6242.4	40.27	4.03
Sodium (mg/l)	11162	8672	4205	3080	2025	22.54	2.14
Potassium (mg/l)	490	375	217.5	70	15	1.31	0.33
Iron (mg/l)	0.11	0.24	0.09	0.7	0.08	0	0
Nitrate (mg/l)	2.79	0.66	0.66	0.65	0.13	0.02	0
Phosphate (mg/l)	0.66	0	0	0	0.6	0	0
Total Hardness (mg/l)	5742	4158	3564	1584	2178	31.68	7.92
Calcium Hardness (mg/l)	792	495	475.2	316.8	178.2	11.88	3.96
Magnesium Hardness (mg/l)	4950	3663	3088.8	1267.2	1999.8	19.8	3.96
Calcium (mg/l)	316.8	198	190	126.7	71.28	4.75	0
Magnesium (mg/l)	1202	890.1	750.6	397.9	485.9	4.81	0.96
DO (mg/l)	5.0	5.1	6.60	6.89	7.04	7.48	7.67
BOD (mg/l)	1.7	1.45	1.39	0.95	0.76	0.4	0.22
COD (mg/l)	496.4	496.4	460.9	276.6	85.09	21.27	7.09

The observed values of salinity ranged from 0.02ppt to 33.42 ppt. It is clear that the salinity along the course of the river decreases as on going to upstream portion of the river. It is also due to the influx of sea water into the river. Due to high evaporation, sea water dominance and cessation of freshwater flow from the upper reaches [14].

Chlorides are normally present in water in the form of sodium chloride. Their concentration above 250 mg/L produces a noticeable salt taste in water. SW1 has the maximum chloride value of 16913mg/l and that of upstream sample is 4.03mg/l. The results reveals that chloride content of the samples except sw6 and sw7 are higher than the permissible limit of chloride. Chlorides are toxic to most plants, so they should be checked for irrigation waters. The tolerance limit for surface waters used for irrigation is 600 mg/L, and values in most of samples were found high and so the river water cannot be suitably used for irrigation without any hazard from chlorides [15].

The percentage of sodium (Na) ions is often taken as important parameter deciding the suitability of water for irrigation [16]. Na is one of the important naturally occurring cations and its concentration in fresh waters is generally lower than that of calcium and magnesium [17]. But in the present investigation, the average concentration of Na is comparatively higher than that of Ca and Mg. The concentration of dissolved salts like Sodium chloride and Potassium chloride influence the conductivity of water. Sodium is the most abundant cation in seawater and its concentration generally increases towards the coast. The Na levels were very high ranging from 2.14mg/l to 11162.5mg/l. Here except SW6 and SW7, all samples shows higher sodium concentration. Thus, the water is not suitable for drinking or irrigation. Saltwater intrusion is the reason behind this, and it is clear from results that as the distance increase the concentration of both sodium and potassium decreases. Presence of Potassium in the natural waters is very important since it is an essential nutrient element.

Total hardness is a parameter of water quality used to describe the effect of dissolved mineral (Ca and Mg), determining solubility of water for domestic, industrial and drinking purpose attributed to presence of bicarbonates, sulphate, chloride and nitrates of Calcium and Magnesium [18]. It is found that high total hardness is at the near estuary point value of 5742mg/l and upstream sample has TH of 7.92mg//l (Figure 3).

Calcium content in the water sample ranged between 0 - 316.8mg/l. Mg content is ranged between 0.96mg/l to 1202mg/l. This findings satisfies the Na+ content of surface samples which is high due to intrusion.Sw5 shows high Magnesium content than SW4, it may due to more consumption of river water for irrigation and other purposes, enhances the entering and existence of saline water in the bottom of the river. The Magnesium content in water is generally affected by low levels of dissolved oxygen.

Biological Oxygen Demand (BOD) is used as the index of organic pollution of waste water that can be decomposed by bacteria under anaerobic conditions. Oxygen content of water varies with temperature, salinity, turbulence, photosynthetic activity of algae and higher plants atmospheric pressure. BOD value is low for upstream sample indicating that is less polluted (Figure 2).

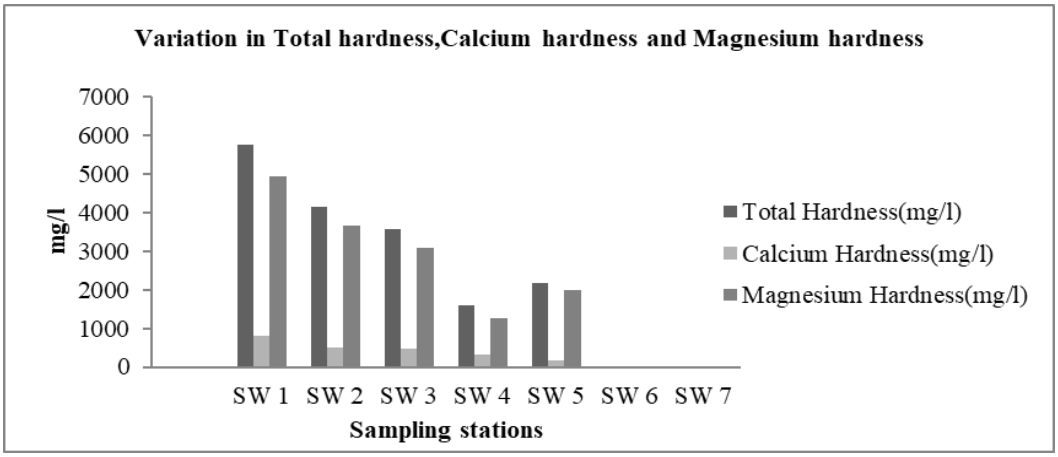

Figure 1. Variation in Total hardness, Calcium hardness and Magnesium hardness of the samples

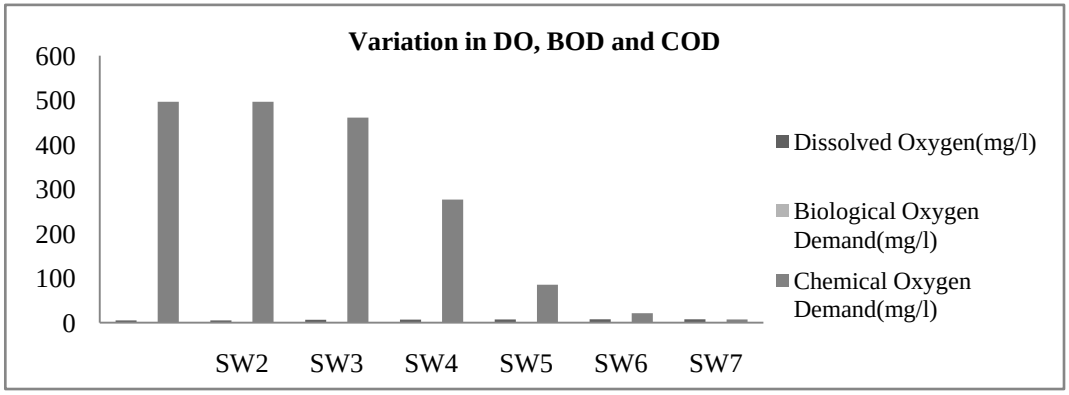

Figure 2. Variation in DO, BOD and COD of the samples

Table 3. Bacteriological analysis of surface water

Stations	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7
Total coliforms (MPN/100ml)	460	240	1100	240	240	240	4
Escherichia coli	Present	Present	Present	Present	Present	Present	Absent

Higher Chemical oxygen demand (COD) values may indicate pollution from domestic sewage and industrial effluents. In the present study COD varies from 7.09 mg/l to 496.4 mg/l. In the present investigation as salinity increased, COD increased significantly. In the coastal zone, estuaries vary from brackish to fully saline, and due to the high concentrations of chloride the COD values are elevated.

All the water samples are found to be contaminated with microbes. The total coliforms count in samples maximum is 1100MPN/100 ml. presence of E.*coli* is found in all samples except the upstream sample (Table 3). Microbial water quality of the river is poor and not suitable for domestic use without treatment. For agricultural purposes there is a possibility of contamination from vegetables and other crops eaten in their raw state. The poor microbiological quality might be due to contamination caused by human activities and livestock.

3.1. Correlation Analysis of Surface Water

The correlation coefficient (r) between various pairs of the physic-chemical parameters of surface water samples Kuttiady River was analyzed. EC shows significant positive correlation with TDS, TH, Salinity, TA, Chloride, Sulphate, Calcium, Magnesium, Sodium, Potassium, and medium correlation with Phosphate and very minute with iron. TDS, Total Hardness (TH), Salinity are significantly correlated with each other. This indicate that the increase of TDS increase the Salinity and Total Hardness of water. Most anions show very significant correlation with Salinity. Among these, Chloride and Sulphate shows very significant correlation with salinity that of phosphate is medium. All cations show also very significant correlation with salinity.

3.2. Ground Water Quality Analysis with Special Reference to Saline Intrusion from the Kuttiady River

The value of TDS plays a vital role in the groundwater whether the water is potable or for domestic use. The dissolved solids refer to any minerals, salts, cations, or anions dissolved in water. Total dissolved salt comprise of inorganic salts like calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates. The value of TDS is found to be in between 105mg/l to 2493mg/l. Average value is 591.2mg/l (Table 4). Even the average value exceeds the desirable limit of TDS and one sample at SW2 sampling station is higher than the permissible limit. EC is directly related to TDS, the locations showing high contents of EC support higher TDS concentration. TDS value of groundwater samples shows that it is much affected by the intrusion from the river. The existence of turbidity in water will affect its acceptability to consumers. Seven samples have higher than permissible limit of 5NTU. It may due to anthropogenic activities and results gives that samples having high turbidity possess high iron content. As distance increases turbidity value decreases [19].

The observed value of salinity ranged from 0.07ppt to 2.02 ppt. The sample GW-B1 has the high salinity (Figure 3).

The concentration of Chloride ranged from 16.11mg/l to 966.5mg/l. The permissible limit of chloride is 1000mg/l. All samples comes under the limit, with an average of 177.37mg/l. Chlorides are toxic to most plants, so they should be checked for irrigation waters.

Soil analysis is done for the surface sample station SW2, SW4 and SW5, named S1, S2, S3 and respectively. Results show that salinity not that much affected the soil samples (Table 5). SW4-S has the higher organic content. Texture analysis of the soil found that S1 and S2 were fine sand and S3 is loamy fine have more clay content. Fine sand having high proportion of sand content may enhances the rate of saltwater intrusion into ground water, where loamy fine sand have little more clay content. Results shows that the soil sample (S1) in the second surface sample point shows high salt content in the ground water where area of S2 and S3 are comparatively low. Ground water in the S3 sample area found little variation in salt content than that of S3; it may be due to difference in geographical conditions of that area. Organic matter of soil is not affected by saline intrusion. Saline intrusion in the selected areas for soil analysis shows that not affected the soil salinity and its organic content.

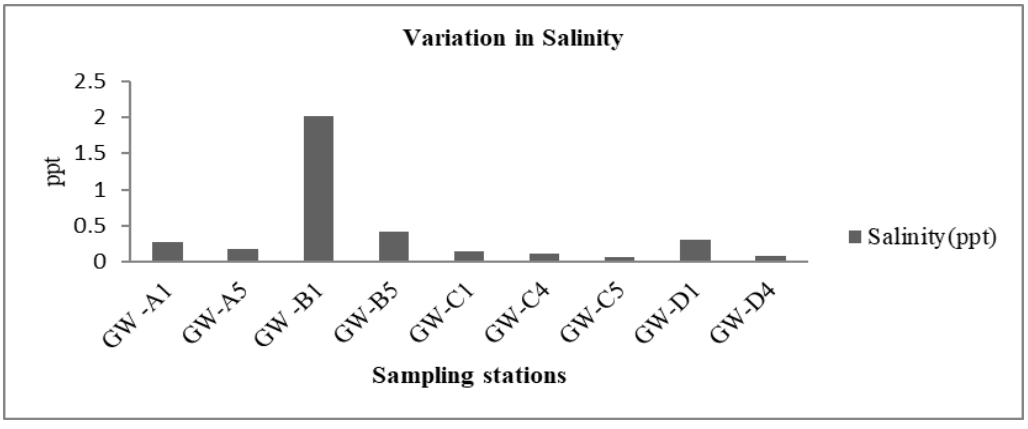

Figure 3. Variation in salinity in Groundwater samples

Table 4. Physico-chemical characteristic of Groundwater

Stations	pH	TDS (mg/l)	Salinity (ppt)	Turbidity (NTU)	Chloride (mg/l)	Sodium (mg/l)	Iron (mg/l)
GW -A1	7.2	365	0.28	0.79	44.3	23.12	0.89
GW -A2	6.33	269.3	0.2	0.97	44.3	23.07	0.05
GW-A3	6.54	338.2	0.29	1.95	56.37	18.81	0.04
GW-A4	7.45	391	0.25	14.55	36.24	35.82	0.07
GW-A5	6.42	246.9	0.18	2.76	36.24	34.18	0
GW -B1	7.63	2493	2.02	8.5	966.5	342.1	1.03
GW-B2	8.15	1744	1.39	1.8	644.33	215.1	0.13
GW-B3	7.85	809	0.62	1.8	221.5	107.7	0.21
GW-B4	7.82	911.4	0.7	5.6	241.6	143.5	0
GW-B5	7.79	544.9	0.41	0	124.84	41.35	0
GW-C1	6.69	257.5	0.15	0.8	20.14	25.25	0.2
GW-C2	6.43	207.5	0.13	0	20.14	33.82	0.71
GW-C3	6.58	154.4	0.09	3.2	16.11	9.66	1.4
GW-C4	6.42	177	0.11	0	20.16	6.27	0.09
GW-C5	6.2	105	0.07	1.2	16.11	9.6	0.5
GW-D1	6.27	478.1	0.3	7.1	169.13	41.4	0.52
GW-D2	6.74	456.7	0.29	0.6	149	35.92	0.08
GW-D3	6.49	166.5	0.1	42.3	36.24	16.02	0.8
GW-D4	6.5	134	0.08	6.6	28.18	10.03	0.31
GW-D5	6.5	158.5	0.1	16	28.18	9.4	0.23

Table 5. Soil textural Analysis

Sampling stations	% of suspension	%Sand	% of clay	% of silt	Organic Carbon%
S1	2.25	97.75	2	0.25	0.35
S2	4.75	95.25	4.5	0.25	0.42
S3	14.75	85.25	12	2.75	0.3

4. Conclusion

The results show that occurrence of significant salt water intrusion in the river. Up to 22.47Km away from river mouth, that is the surface sampling point SW5 has 6.83ppt salinity, means that much of concentration of salt content is exist in the surface water of river. Salinity is reduced to 0.07ppt in the SW6, where the upstream sampling point has salinity value of 0.02 ppt. So up to SW6 significant salinity is reported. It is understood that the significant role of distance, means the salinity is decreases with increasing of distance from the river mouth. Concentration of anions like sulfate, chloride and cations like sodium, potassium, calcium and magnesium has important contribution in the salinity of river, these elements in the river also decreases with increasing of distance from river mouth.

The analysis of ground water quality in the river side reveals that effect of saline intrusion. The salinity in the ground water GW-B1 collected from the second surface sampling point shows high salinity, and by water quality index it is under the very poor water quality. Network method of analysis of ground water sample helps to understand the role of distance, it is clear that when distance from the river side increases the effect of saline intrusion is decreased. Results also reveal that there is deterioration most of ground water samples collected closest to river side. Most of the ground water is contaminated with microbes also. Geographical conditions and anthropogenic actions may be reasons behind some fluctuations in salt concentration. Soil is not that much affected by saline intrusion.

The salinity of river is some extent become a reason of deteriorating quality of river water and may leads to unfit for irrigation, may become a threat of the existence of aquatic fauna and flora. High salt content may leads to replace the aquatic fauna by organism which is more adaptive to saline conditions. The river water is mainly depend for the water supply by water authority, the occurrence of saline intrusion in the river become very intensive during summer season leads to the unavailability of fresh water for water supply. So the implementation of regulator come bridge in the selected points of the river and allowing of the maximum runoff to downstream may help to reduce the intensity of saline intrusion in the river. Strict action should be taken by the government against sand dredging because sand dredging is one of the main reasons behind intrusion of salt water into fresh water bodies like river from the sea.

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