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Effect of Seawater intrusion on soil and water quality parameter in vulnerable area of South Andaman Island, India

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Abstract

Sea level rise poses a serious threat to the natural resources of small islands. The effect is manifested as salinization of soil and water in the coastal areas which get aggravated by human activities. The present study attempted to analyze hydro-chemical property of coastal soil and groundwater samples collected from wells located in close proximity to sea. The vulnerability of the coastal aquifer to seawater intrusion and accumulation of Na_2CO_3 and $NaHCO_3$ salt in undrained area was studied. The study revealed that the condition favours sodic soil formation in the study area. The high clay content and presence of $CaCO_3$ concretions result in poor drainage and inundation of the area. The high sodium content resulted in high SAR, soil alkalinity and high pH which necessitate suitable amendment and land management practices to sustain the agricultural production.

Key words: Salinity, Seawater Intrusion, Water quality, Sea level rise, coastal aquifer

Introduction

Salinity is a major problem for agriculture in the coastal region where the soil and water is affected with sea water intrusion. Understanding and assessing of the coastal salinity is different from inland salinity as it comes under the strong influence of sea water. During the December 2004 Indian Ocean tsunami large tracts of agriculture area Andaman and Nicobar Islands was affected. The coastal paddy fields were converted into sea water inundated area which not only affected the standing crop but soil and water quality as well (Velmurugan et al., 2014). The primary process involved in transportation and deposition of salt (Pal et al., 2003; Dasberg et al., 1991) from the coastal creek and the low laying flats are the common topographic zones showing salt infestation along the coast (Manchanda, 1976). This affects the soil quality and results in waterlogging. In this context, water quality assessment is important because poor water quality can pose a health risk for people and the ecosystem. In addition, long-term use of poor quality water for irrigation will reduce soil fertility and crop production. Anthropogenic influences and natural processes (changes in precipitation, erosion, and weathering of crustal materials) degrade water resources and impair their use for drinking, industrial, agricultural, recreation or other purposes (Abrol et al., 1988).

The evaluation soil and water quality in most countries has become a critical issue especially due to concerns that freshwater will be a scarce resource in the future (Singh et al., 2004). Water quality monitoring is a helpful tool not only to evaluate the impacts of pollution sources but also to ensure an efficient management of water resources (Strobl and Robillard, 2008). Water is one of the most critical resource and constraint in an Island ecosystem where only rained agriculture is prevalent. The major ground water sources in Andaman and Nicobar islands are the porous formation consisting of beach sand with coral rags and shells, the thin cover of alluvial or colluvial deposits in the coastal or intermountain valleys and adjoining foothills besides fractured volcanic and igneous rocks (Central Ground water board, 2010). The salinization of this precious resource is a matter of great concern, therefore a study was conducted to assess the hydro-chemical properties of water and soil along the coastal areas of Ograbraj, South Andaman, India.

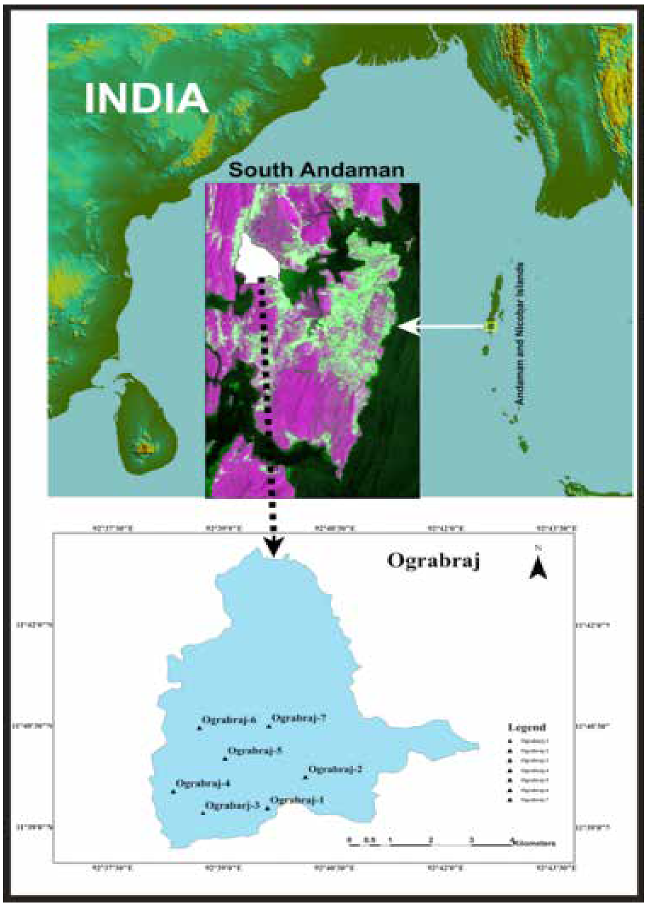

Fig 1. Location of the study area in South Andaman Districts

Material and methods

Assessment of salinization of soil and water along the coastal areas of Ograbraj, South Andaman, India was carried out by way of samples and field verification. The study area lies between *11º39'19.83"* N latitude and *92º39'33.86"* E longitude (Fig.1). A total of seven samples of sodic bulk soil samples were collected from the upper 0 to 90 cm soil depth at Ograbraj by following standard survey procedure. Further, ground water samples were also collected at Ograbraj along the coast during 2015-16 from seawater intruded waterlogged areas. The water sample collection area was close to sea and the soil sampling sites. The samples were collected during the summer month (Jan to May) in capped high-density PVC bottles, fortified with 1 ml of toluene to arrest the any biological activity for various anions and cations for water samples at Ograbraj. Soil was collected and processed according to standard procedure (Page et al., 1982).

Soil pH and EC were determined in saturation extract. The determination of carbonate and bicarbonate concentrations was carried out by titration using 0.01N sulfuric acid and in the presence of the indicators phenolphthalein for the first and methyl-orange for the second. Chloride content was determined with the standard silver nitrate (0.01 N) titration method and in the presence of 1mL of potassium chromate (5%) as an indicator. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) contents were determined by complexation using EDTA (Ethylene diamineteracetate) with the ammonium purpurate as an indicator for the determination of Ca^{2+} content alone, and "Eriochrome Black T" for both Ca^{2+} and Mg^{2+}content (Richards, 1954). Sodium (Na+) and potassium (K+) ion concentrations were determined using a flame-photometer (JENWA PFP7).

Result and Discussion

During the survey of soil and water, samples were collected from the salt affected waterlogged area for physico-chemical characterization and quality appraisal. The data presented in table 1 & 2, indicated the strong relation between nature of salinity and the sea water. Soil morphological characteristic showed that soil were moderate to deep, pale brown to dark yellowish brown colour, sandy loam to sandy clay/ clay loam texture. This was in conformity with the soil characters of the study area earlier described by Mandal (2012). Change in texture or composition close to the sea and severely tsunami affected areas was noticed. It was sandy loam to sandy clay loam and sandy clay loam to clay at Ograbraj-1, Ograbraj-4, Ograbraj-5, Ograbraj-6 and Ograbraj-7 apparently due to clay illuviation. The silt and clay contents were higher than sand content in Ograbraj-2, Ograbraj-3 and Ograbraj-4 due to lower topography positions.

The pH values ranged from 9.1 to 10.7 showing slight to strong alkaline nature of the soil (Table 2). The ECe value showed strong indication for sea water intrusion and presence of soluble salts at the study areas. At Ograbraj -1 ECe varied from 4.6 to 7.4 dS m^{-1} , Ograbraj-5 4.6 to

7.4 dS m^{-1} , Ograbraj -6 4.5 to 5.3 dS $^{m-1}$ and Ogrbaraj-7 4.5 to 5.5 dS m^{-1} is higher than the Ograbraj-2 (1.2 to 6.2 dS m^{-1}), Ograbraj-3 (2.4 to 4.0 dS m^{-1}) and Ograbraj-4 (2.5 to 4.1 dS m^{-1}) due to its physiographic position and upward movement of salt from below. The pH increased with depth at all the sites due to accumulation of salts particularly sodium added from sea water. The higher alkalinity (pH 10.2) in Ograbraj-1, Ograbraj-5 (pH 10.1), Ograbraj –6 (pH 10.1) and Ograbraj-7(pH 10.1) at the sub-surface (40 cm) was due to the local condition and accumulation of salts which resulted in unfavorable soil physical properties and waterlogging at the surface. The higher pH in Ograbraj-1(9.6 to 10.2), Ograbraj-5 (pH 9.6 to 10.1), Ograbraj -6 (pH 9.3 to 10.1) and Ograbraj -7 (9.1 to 9.7) limited its use for arable cropping.

The ionic composition of soil showed the dominance of CO_3^{2-+} and HCO_3^- anion. It is high in Ograbaraj-1(17 to 28.5 me L^{-1}), Ograbraj -5 (18.0 to 30.0 me L^{-1}) , Ograbraj-6(18.0 to 29.0 me L^{-1}) and Ograbraj -7(20.0 to 28.0 me L^{-1}) while ionic composition was low in Ograbraj-2 (5.1 to 10 me L^{-1}), Ograbraj -3(5.0 to 10 me L^{-1}) and Ograbraj-4 (5.9 to 10.1 me L^{-1}). It was reported from several studies that high sodium in subsurface and surface soil causes dispersal of soil particles and waterlogging. In the study area, high Na^+ was recorded in Ograbraj 1,5,6 and 7 which varied from 70.4 to 98.7 me L^{-1} 70.4 to 83.9 me L^{-1} 70.1 to 74.7 me L^{-1} 99.5 to 70.9 me L^{-1}, respectively. This is present in the form of sodium carbonate and bicarbonate in coastal soils. At the same time, significant concentration of $CaCO_3$ at 12 - 58 cm depth in Ograbraj-2 (1.3 to 2.0%), at 12 - 99 cm depth in Ograbraj -3 (1.5 to 3.0%) and at 15 - 79 cm depth in Ograbraj-4 (1.3 to 5.3%) was observed.

The hydro-chemical properties of water samples collected from the coastal areas showed high pH (8.7 to 9.5) and SAR (8.14 to 23.90 me L^{-1}) indicating the sodic nature (Table 2). The salt composition showed dominance of CO_3^{2-} (1.5 to 3.0 me L^{-1}) HCO_3^-(2.5 to 13.4 me L^{-1}) and Na^+(9.10 to 16.9 me L^{-1}) while Ca^{2+}+Mg^{2+}(1.0 to 2.5 me L^{-1}) and Cl^-(1.7 to 10.0 me L^{-1}) were also present. The samples with high RSC should be used after treatment with gypsum. The samples with moderate alkalinity can be used for growing salt resistant varieties.

Recommendation and use of Potential of slat affected soils

Sodic soil of Ograbraj in South Andaman Islands were rich in sodium carbonate and bicarbonate salt and showed strongly sodic soil (Ograbarj-1, Ograbraj- 5, Ograbraj-6 and Ograbraj-7) containing high Na_2CO_3 and $NaHCO_3$ salt. Coarse soil texture with sodic water need gypsum application so as to reduce the alkalinity followed by leaching of excess soluble salt. Moderately sodic soil of Ograbraj-1, Ograbraj-5 and Ograbraj -6 and Ograbraj -7 containing soluble Na_2CO_3 and $NaHCO_3$ salt and fine soil texture can be reclaimed by addition of gypsum and organic matter. Due to high clay content and presence of $CaCO_3$ concretion, Ograbraj -2, Ograbraj -3 and Ograbraj -4 (slightly sodic soil) showed drainage congestion and waterlogging. It may be used for growing deep water rice having tolerance to salt and waterlogging.

Conclusion

Salinization of coastal soil and water is a major concern for sustainable agriculture. In the study area presence of strong alkaline salts (Na_2CO_3 and $NaHCO_3$) lack of natural drainage and waterlogging conditions in sodic soil caused low productivity. The high soil pH, fine soil texture and presence of concretionary calcium carbonate layer at sub-surface depth are primary constraints for arable cropping. Suitable reclamation measures were suggested for strongly and moderately sodic soil using appropriate amendment such as gypsum and organic matter. Delineation of salt affected soil and seawater intruded area at Ograbraj, South Andaman Districts can help to identify the hot spot areas and treat them differently.

Table 2. Physico- chemical characteristics of water in Ograbraj

Location	pHs	EC (dS m^{-1})	Na+ (me/L^{-1})	K^+ (me/L^{-1})	Ca^{2+}+Mg^{2+} (me/L^{-1})	CO_3^- (me/L^{-1})	HCO_3^- (me/L^{-1})	Cl (me/L^{-1})	SAR (me/L^{-1})$^{1/2}$	RSC (me/L^{-1})
Ograbaraj-1	8.8	1.4	13.9	0.1	2.5	2.0	13.4	1.7	12.43	12.9
Ograbaraj-2	8.7	1.1	9.10	0.2	2.5	1.5	10.0	1.7	8.14	9
Ograbaraj-3	9.5	1.4	13.3	0.1	2.0	3.0	11.0	1.7	13.30	12
Ograbaraj-4	9.1	1.3	12.6	0.1	1.5	1.5	2.5	10.0	14.55	2.5
Ograbaraj-5	9.3	1.4	14.0	0.1	1.0	1.3	3.0	6.0	19.80	3.3
Ograbaraj-6	9.1	1.6	16.9	0.1	1.0	0.0	3.0	5.0	23.90	2
Ograbaraj-7	9.5	1.7	15.6	0.3	2.5	0.0	10.0	10.5	13.95	7.5

Table 1. Physico –chemical characteristic of soils in Ograbraj

Location	Depth (cm)	pH	ECe (ds m^{-1})	Na^+ (me/L)	K^+ (me/L)	Ca^{2+} + Mg^{2+} (me/L)	Co_3- +HCO_3 (me/L)	Cl (me/L)	SAR (me/L)	$CaCO_3$
Ograbaraj-1	0-14	9.6	7.4	98.7	0.9	4.0	17.0	31.0	69.79	2.45
	14-40	10.0	5.5	80.0	0.2	4.0	21.0	18.0	56.57	2.45
	40-82	10.2	4.6	70.4	0.1	4.0	28.5	15.0	49.78	0.09
Ograbaraj-2	0-12	9.8	1.2	11.5	0.1	1.0	15.7	3.5	16.26	1.3
	12-28	10.7	5.3	54.0	0.1	1.5	30.3	12.5	62.35	1.0
	28-58	10.6	6.2	60.6	0.1	1.0	27.7	10.5	85.70	2.0
Ograbaraj-3	0-12	9.3	2.4	11.5	0.2	3.0	5.0	4.5	9.39	1.5
	12-28	9.7	2.6	54.0	0.1	2.0	40	14.5	54.00	2.5
	58-99	10.1	4.0	60.6	0.1	2.0	10	13.5	60.60	3.0
Ograbaraj-4	0-15	9.1	2.4	28.6	0.2	1.5	5.9	25.0	33.02	5.3
	15-39	9.6	2.6	33.0	0.1	1.0	45	20.0	46.67	1.7
	39-76	9.7	4.0	53.9	0.1	1.0	15	25.0	76.23	1.3
Ograbaraj-5	0-14	9.6	7.4	70.4	0.9	4.1	18.0	32.0	49.17	2.46
	14-40	10.0	5.5	83.9	0.2	4.1	25.0	20.0	58.60	2.46
	40-82	10.1	4.6	75.8	0.1	4.1	30.0	15.0	52.94	0.10
Ograbaraj-6	0-14	9.3	4.6	28.9	0.2	4.0	18.0	31.0	49.57	2.45
	14-40	9.7	5.3	34.0	0.2	4.0	28.0	19.0	56.71	2.46
	40-82	10.1	4.5	55.9	0.1	4.0	30.0	14.0	52.82	0.09
Ograbaraj-7	0-14	9.1	1.6	96.7	0.2	4.2	20.0	29.0	66.73	2.47
	14-40	9.6	1.7	99.5	0.2	4.2	22.0	18.0	68.66	2.48
	40-82	9.7	1.8	53.9	0.2	4.2	19.0	20.0	48.93	0.09

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