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Assessment of Groundwater Quality in Andaman and Nicobar Islands

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Abstract

In an island ecosystem, assessment of groundwater for its quality is very essential for understanding salinization and judicious use of water. Groundwater occurs in three different geological formations in which marine sediment formation in the coastal areas can be judiciously exploited only by rings well. Stratified random water samples (496) were collected covering all the three districts and analyzed for its hydro-chemical properties. The results showed that water samples from only three blocks exceeded EC value of more than 5.0 dS m^{-1} accounting for 15% while none of the sample found to contain RSC. The distribution of samples in different water quality categories indicated that 80% samples were good in quality and 4% samples were saline while 5% samples found to be high SAR saline.

Key words: Water quality, Tropical islands, Seasonal variation, Salinity, SAR, RSC

Introduction

Groundwater is the most important source of fresh water in an island ecosystem at the same time retaining its level in the underground storage structures is very critical for maintaining the balance with the sea water in the fresh water-sea water interface. Challenges for shallow aquifer of small coral islands include salt-water intrusion due to groundwater overexploitation, tidal influence, seasonal recharge variability, and subsurface groundwater discharge (Bear *et al.*, 1999). Thus, the hydro-chemical properties of ground water are influenced by supply of various mineral elements from both natural and anthropogenic sources. This necessitates the sustainable development of the limited groundwater resources particularly in the tropical islands which requires a thorough understanding of hydro-geological regime including the hydro-chemical behavior of groundwater (Banerjee *et al.*, 2012).

In Andaman and Nicobar Islands the coastal areas are affected by salinity primarily due to sea water intrusion and capillary rise of saline water (Velmurugan *et al.*, 2015). The area under agriculture cannot be increased to meet the growing demand for vegetables, fruits and other food items. At the same time the demand for intensification of agriculture and irrigation water for vegetable cultivation during dry season has been increasing. In addition, due to the subsidence of land masses during the December 2004 due to Indian Ocean tsunami sea water intrusion increased resulting in movement of sea water into the shallow wells located along the coastline (CGWB, 2010). Understanding the importance of groundwater resource, several studies have been carried out on groundwater quality for drinking and irrigation purposes in different parts of India besides innumerable global studies. However, there was no systematic study on the coastal ground water resources with the focus on salinization. Therefore, a study was conducted in Andaman and Nicobar Islands to assess the quality of ground water and its spatio-temporal variations.

Material and Methods

Study area

Andaman and Nicobar Islands are located in the Bay of Bengal, about 1,200 km from the Indian

mainland between the geographical location of 8° to 14°N and 92° to 94°E. The Islands experience hot and humid climate with distinct dry (Jan/Feb to Apr/May) and wet seasons (June to November). The annual rainfall varies from 2900 to 3100 mm with mean maximum and minimum temperature of 32°C and 22°C, respectively. As these islands are situated close to the equator intensive solar radiation is received which results in high evapo-transpiration. For the most part during dry period (Jan/Feb to Apr/May) it far exceeds precipitation creating water deficit of 300-400 mm (Fig. 1). Further the coastal areas experiences inundation of sea water during high tide. Thus, the geographical and climatic conditions of these islands besides demand for diversified food production exert pressure on the limited fresh water resources.

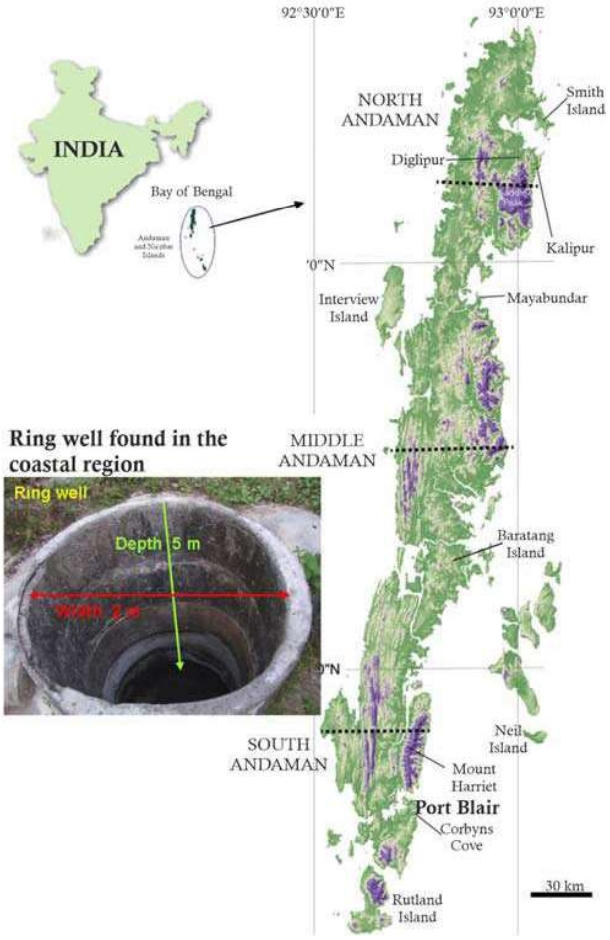

Fig. 1 Location and physiography of the study area

Groundwater sampling

Groundwater sampling was carried out in all the three districts of Andaman and Nicobar (A&N) Islands by following stratified random sampling in such a way to cover all the major inhabited islands. Before undertaking field survey, geological map of Geological Survey of India topo sheets were overlaid on LISS-IV image in a GIS environment. Probable sampling grids were marked on a field map which was used for sampling (Fig. 1). The survey was carried out during post-monsoon (Oct-Nov 2015 and 2016) and pre-monsoon period (Mar-April in 2015, 2016). A total of 248 samples during pre-monsoon and same number during post-monsoon period were collected by revisiting the same site in order to study the seasonal variation in ground water quality. The samples (496 in number) were collected from the shallow wells located in the coastal areas which are mostly under multiple uses. The results were grouped by blocks and presented in tables after analyzing for required water quality parameters.

Determination of hydro-chemical properties

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. The most important factors to determine the suitability of groundwater use in agriculture are the following:

- pH
- Salinity hazard - total soluble salt content
- Sodium hazard - relative proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions
- Alkalinity - carbonate and bicarbonate
- Specific ions: chloride (Cl^-), sulfate (SO_4^{2-}), boron (B), and nitrate-nitrogen (NO_3^-N)

The samples were analyzed by following standard procedures (Jackson, 1973). Subsequently residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) were calculated for these samples as;

$$RSC\ (meq\ l^{-}) = (HCO_2^- + CO_3^{2-}) - (Ca^{2+}+Mg^{2+}) \quad \text{- Eq. 1}$$

$$SAR = Na^+ / Sqrt\ (Ca^{2+}+Mg^{2+}/2) \quad \text{- Eq. 2}$$

Based on EC, SAR and RSC water samples were classified into different categories as per the classification suggested by AICRP on management of salt affected soils and use of saline water in agriculture (Gupta *et al.,* 1994).

Results and Discussion

Ground water formation

Groundwater is the main source of drinking water supply in rural and tribal areas in A & N Islands. Further, farm and semi-feral animals also depend on this source for drinking water during dry season. These islands are underlain by Late Cretaceous igneous rocks - the 'Ophiolite Suite', marine sedimentary group of Palaeocene to Oligocene age and Recent to Subrecent beach sand, mangrove clay, alluvium and coralline formations (CGWB, 2009). Marine sedimentary rocks are located to an anomalous admixture of sand and clay where clayey residue are predominating and do not form well developed potential aquifer system both in shallow and deeper horizons. This is mostly found in the coastal areas. Extraction of groundwater by making bore wells are not feasible in marine sedimentary formations whereas dug wells of 4-5 m diameter to 6 m depth may yield 3000-5000 litres water per day. Excess extraction of water may lead to upward movement of saline water. The igneous rocks also do not form potential aquifers but in comparison to the sedimentary they yield moderately. These rocks form aquifer both in weathered mantle and fractured basement rocks which are generally developed through dug well, ponds and bore wells (Srivastava and Ambast, 2009). The coralline limestone formations as in the case of Nicobar Islands form potential aquifer in shallow horizon and can be developed as 4-5 diameter dug wells to 6 m depth with a yield varying between 15000-90000 litres per day.

Ground water quality

The range and mean of EC, pH, SAR and RSC are presented in Table 1. Although EC of water sample ranged from 0.1 to 13.7 dS m^{-1}, the mean value showed that only at Ferrargunj, Prothrapur and Mayabunder blocks it exceeded 2.0 dS m^{-1}. In other blocks EC was within permissible limit both for irrigation as well drinking. Among the districts the salinity level was lowest in Car Nicobar followed by North & Middle Andaman and highest was observed in South Andaman district. This showed that in the granitic formation of South Andaman, due to over exploitation of groundwater at certain pockets resulted in upward or lateral movement of saline water into the fresh water aquifers. The pH is an important quality parameter for determining acidity, neutrality or alkalinity of water. The pH ranged from strongly acidic to moderately alkaline in different blocks however, the mean pH indicated from slightly acidic to mildly alkaline. Therefore, the mean value for large number of samples collected is misleading. If salinization is not occurring all over the district but observed only in the coastal or areas

Table 1. Mean and range of ground water quality parameters in different block of A & N Islands

Name of the Block	Year of sampling	EC (dS m^{-1})		pH		RSC (meq l^{-1})		SAR (mmol $l^{-1})^{1/2}$	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
South Andaman District									
Ferrargunj	2016	0.1-13.68	2.10	6.10-8.09	7.10	0.0-0.1	0.0	0.04-3.52	0.56
Prothrapur	2016	0.02-12.69	1.36	5.29-8.05	7.35	0.0-0.0	0.0	0.01-5.46	0.46
Little Andaman	2015	0.20-4.62	1.80	5.52-7.86	6.82	0.0-0.2	0.0	0.02-4.62	0.42
North & Middle Andaman District									
Diglipur	2016	0.63-3.1	1.13	6.05-7.65	7.08	0.0-0.1	0.0	0.12-0.47	0.27
Mayabunder	2016	0.76-4.23	2.04	6.88-7.38	7.33	0.0-0.0	0.0	0.18-0.46	0.31
Rangat	2015	0.73-3.40	1.38	6.4-7.70	7.14	0.0-0.2	0.0	0.28-0.67	0.47
Car Nicobar District									
Car Nicobar	2015	0.23-3.65	0.93	7.23-8.31	7.78	0.0-9.2	0.0	0.03-3.78	0.72
Nancowry	2016	0.65-2.31	1.02	7.08-8.24	7.66	0.0-0.0	0.0	0.12-0.56	0.29
Campbell Bay	2015	0.4-2.15	1.10	6.90-7.70	7.80	0.0-0.0	0.0	0.20-0.46	0.35

Table 2. Water quality classification in different blocks of Andaman and Nicobar Islands (%)

District	Block	EC dS m^{-1}					SAR		RSC
		0.05-1.5	1.5-3.0	3.0-5.0	5.0 -10.0	>10.0	0.0-2.5	2.5-5.0	(meq l^{-1})
South Andaman	Ferrargunj	81.3	3.1	6.25	3.13	6.25	93.75	6.25	Absent
	Prothrapur	81.1	2.7	8.11	2.70	2.7	94.59	5.41	Absent
	Little Andaman	75.0	12.5	12.5	-	-	93.80	6.32	Absent
North & Middle	Rangat	37.5	50.0	12.50	-	-	100.00	-	Absent
Andaman	Mayabunder	75.0	25.0	0.00	-	6.25	100.00	-	Absent
	Diglipur	68.8	25.0	6.25	-	-	100.00	-	Absent
Nicobar	Car Nicobar	72.7	22.7	4.55	-	-	90.91	9.09	Absent
	Nancowry	75.0	25.0	-	-	-	100.00	0.00	Absent
	Campbell Bay	72.2	27.8	-	-	-	94.44	5.56	Absent

adjoining the creeks, then more sampling in those areas are preferable. This may help to identify hotspot areas of salinization particularly in islands. In general, the mean values showed that RSC and SAR were within the permissible limits for irrigation. However, at block level Prothrapur and Little Andaman recorded SAR more than 4.0. This was due to sodium addition from sea water either through surface or subsurface intrusion.

Based on EC, SAR and RSC the samples were grouped into different salinity categories. The results showed that water samples from Ferrargunj and Prothrapur and Mayabunder blocks exceeded EC value of more than 5.0 dS m^{-1} accounting for 15% while none of the sample found to contain RSC (Table 2). The distribution of samples in different water quality categories (Gupta *et al.*, 1994) indicated that on an average more than 80% samples were good in quality and 4% samples were saline while 5% samples from South Andaman district found to be high SAR saline (Table 3). Among different blocks Nancowry found to have largest percentage of sample (92%) under good category while Prothrapur had 8.1% of samples under high SAR saline category.

Seasonal variations in water quality

A significant variation in salinity was observed between dry and wet season. Based on the EC, SAR and RSC values salinity of groundwater increased only at some locations during summer period (Fig. 2). Among the three districts seasonal variation in pH and EC was higher in Nicobar Islands probably due to porous nature of soils and bedrocks. Further when compared to Andaman Islands, the mean elevation is lower for Nicobar

Table 3. Distribution of water samples in different water quality categories (%)

District	Block	Total number of samples	Quality			
			Good	Marginally saline	Saline	High SAR saline
South Andaman	Ferrargunj	63	81.25	3.13	9.38	6.25
	Prothrapur	47	86.49	2.70	2.70	8.11
	Little Andaman	16	75.00	12.50	12.50	0.00
	Average		80.91	6.11	8.19	4.79
North & Middle	Rangat	18	87.50	12.50	0.00	0.00
Andaman	Mayabunder	14	75.00	25.00	0.00	0.00
	Diglipur	24	87.50	6.25	6.25	0.00
	Average		83.33	14.58	2.08	0.00
Nicobar	Car Nicobar	26	86.36	9.09	4.55	0.00
	Nancowry	22	91.67	8.33	0.00	0.00
	Campbell Bay	18	72.22	27.78	0.00	0.00
	Average		83.42	15.07	1.52	0.00

*EC, SAR, RSC: Good : < 2,<10,<2.5; Moderately 2.4, < 10, <2.5; Saline:- 4, <10,<2.5; High SAR saline >4,>10>2.5

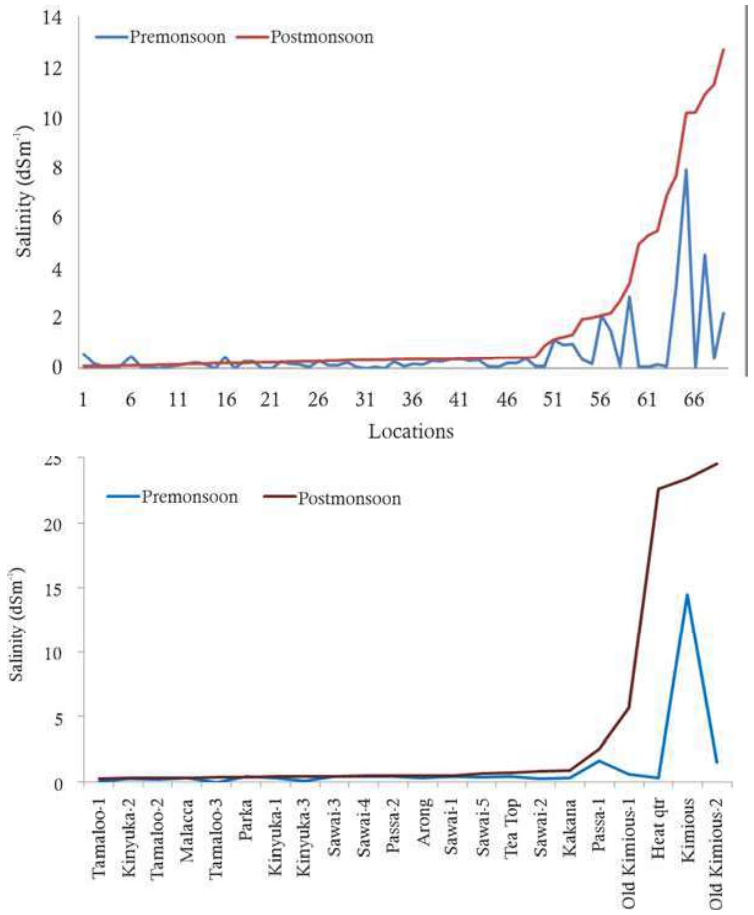

Fig. 2. Seasonal variation in salinity of ground water (a) South Andaman (b) Nicobar District

group of islands except Great Nicobar. These islands are having large part of the coastal zone under less than 5 m AMSL resulting in sea water intrusion. These areas are highly vulnerable to salinization due to sea water intrusion and over exploitation.

Conclusion

The groundwater analysis showed that majority of the samples were good in quality and only 5% was highly SAR saline. Except in few identifiable pockets covering two blocks, water quality for most of the parameters tested were good and can safely be used for irrigation purpose. At the same time seasonal variation in salinity was observed. This showed possibility of sea water intrusion by surface flooding or capillary rise. Hence, over exploitation should be avoided particularly in the coastal areas having aquifers in the marine sediments. Detailed analysis of hydro-chemical properties of groundwater helps in assessing the spatial distribution of soil salinity and scope for its judicious use. However, the most important contemporary and projected challenges for the coastal/island aquifer management are identification, measurement, and periodic monitoring of saline water and freshwater interaction.

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References

Banerjee P, Singh VS, Singh A, Prasad RK and Rangarajan R (2012) Hydrochemical analysis to evaluate the seawater ingress in a small coral island of India. *Environ Monit Assess*. **184:** 3929–3942.

Bear J, Cheng AHD, Sorek S, Ouazar D and Herrera I (1999) *Seawater Intrusion in Coastal Aquifers—Concepts, Methods and Practices*. Dordrecht: Kluwer Academic.

CGWB (2010) Approach paper on ground water quality issues in islands. Central Ground Water Board, Ministry of Water Resources, GOI. p.69

Gupta RK, Singh NT and Sethi M (1994) *Water Quality for Irrigation in India. Technical Bulletin* 19, CSSRI, Karnal, India.

Richards LA (1954) *Diagnosis and Improvement of Saline and Alkali soils*. USDA Handbook No.60. US Govt Printers Office, Washington DC.

Srivastava RC and Ambast SK (2009) *Water Policy for Andaman & Nicobar Islands: A Scientific Perspective*. CARI, Port Blair, p 20.

Velmurugan A, Swarnam TP, Ambast SK, Meena RL and Subramani T (2015) Soil salinity dynamics in raised bed and furrow (RBF) system and its effect on alleviating waterlogging in the coastal lowlands. *Journal of Soil Salinity and Water Quality* **7(2):** 90–97.

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