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GROUNDWATER QUALITY OF ANDHAKARANAZHY COAST, ALAPPUZHA, KERALA, INDIA

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ABSTRACT

Andhakaranazhy is a coastal village in Alappuzha district, Kerala, India, identified as one of the 26th December 2004 tsunami affected coastal sections of Kerala. This area is particularly under severe water stress because of having only few dependable fresh water sources. To study the groundwater chemistry and fate of ions, eleven ground water sources (9 dug wells and 2 bore wells) have been monitored and water quality parameters analyzed for a period of time 2012-2016. The results were revealed that total iron exceeds the permissible limits of BIS standards in some of the groundwater sources (2012-2016). Based on the piper plots, the hydro chemical facies of the water is characterized by Ca^{2+}- Mg $^{2+}$-HCO_3^- prominent over the years (2012-2016). Groundwaters mostly are suitable for irrigation purposes based on parameters evaluated. Corrosion indices reveals, the groundwater having scale forming behavior. Gibbs diagrams indicate the groundwater chemical composition of this region is controlled by weathering of rocks and evaporation. This study focuses the overall hydrogeochemistry of groundwater being tested for parameters measured and reported as sodium percent (Na %), sodium adsorption ratio (SAR), Kelly's ratio (KR), permeability index (PI), magnesium adsorption ratio (MAR), Gibb's plots, Langelier saturation index (LSI) and other similar values.

KEYWORDS: Tsunami, Corrosion Indices, Andhakaranazhy, Piper Diagrams, Groundwater

Groundwater is a precious natural resource which is necessary for human health, socio-economic development, and functioning of ecosystems (Steube et al. 2009). Many of the coastal ground water aquifers of Kerala are suffering from sea water intrusion intensified over the years due to over exploitation and natural coastal disasters (Achari et al. 2017). Tsunami induced quality variation and its assessment has been a major research work and many reports are known with respect to pre and post-tsunamic situation. Post-tsunamic study of ground water quality in Kerala coast found that pristine quality has been deteriorated due to the 26th December 2004 Indian Ocean Tsunami impact (Achari et al. 2007; Achari et al. 2017; Achari et al. 2005; Jaison; 2012; Achari et al. 2017; Achari et al. 2017) . The quality of groundwater in Andhakaranazhy depends on hydrological, physical, chemical and biological factors. Present study discusses the hydrochemical characteristics of groundwater sources of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016. Andhakaranazhy, in Alappuzha District, Kerala, India (09° 44' 50N, 76° 17' 07E) is a barrier islet section having the impact of continuous action of scrolling waves, where the backwaters connected tidal flow into the sea through a seasonal sand bar mouth. This coastal area and its beach is one of the emerging tourist and religious destination of Kerala. Two barges operated by large mechanized shutters are there in the tidal canals near north and south end of confluence. These shutters are flow regulators of saline water to prevent and protect the neighboring paddy fields which are well connected to the backwaters. During monsoon, water is released into the sea by lifting these shutters; hence prevent flooding in the location. Fresh water availability is very low regarded as a water stress region due to proximity to sea and other peculiar features connected to backwaters, lagoons and barrier islets. This research focuses to determine the overall groundwater chemistry of this geographically and ecologically significant coastal region of Kerala - a region where fresh water flow in monsoon months intercepts with sea through tidal canals and during lean month. Sea water intrusion is controlled by a flow regulator system. This place is highly populated, ecologically sensitive with a number of settlers, mostly fishermen. The livelihood of the people depends on the flow condition in tidal canal and quality of the groundwater is a rare source for domestic consumption in this narrow islet.

MATERIALS AND METHODS

Eleven ground water sources (9 dug wells and 2 bore wells) have been selected along this coastal section to identify the variability of groundwater chemistry over the years. The sampling and analysis (APHA; 2005) have been done for a period starting from January-December 2012, also in December 2013, 2014, 2015 & 2016. The samples were subjected for drinking water quality analysis as per BIS 10500: 2012 and water quality indices were computed. Hill-Piper-Trilinear plots were made to evaluate the water type of the study area using GW chart software. Irrigation suitability is measured by sodium percent (Na %), sodium adsorption ratio (SAR) and Kelly's ratio (KR), permeability index (PI), magnesium adsorption ratio (MAR), USSL and Wilcox diagrams.

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Gibb's plots were made to the chemical composition of groundwater. Corrosive behavior of the groundwater is determined by Langelier saturation index (LSI), Ryznar stability index (RSI) and aggressiveness index (AI). These indices values will give us an insight into the actual groundwater chemistry of the region. One of our study objective is to investigate this highly vulnerable region extensively and intermittently for a period of 25 years starting from the year 2004. The results are presented with respect to successive months of year 2012 and month of December for years 2013, 2014, 2015 and 2016. This is because to compare the results with 2004 data, the occasion where 26th December 2004 tsunami affected the coast.

RESULTS AND DISCUSSION

Overall water quality parameters of the Andhakaranazhy coast evaluated and reported in this study during the period 2012, obtained as mean of 12 monthly sampling events starting from January - December 2012, consisting of 11 stations. The results are, pH (7.6±0.25), EC (0.8±0.62) mS/cm, TA (330.2±117.23) mg/L, TH (290.0±108.93) mg/L, Ca^{2+} (83.2± 26.46) mg/L, Mg^{2+} (18.5±11.39) mg/L, TDS (576.3 ± 398.92) mg/L, Na^+ (119.2±96.21) mg/L, K^+ (8.3± 8.98) mg/L, Cl^- (161.6±169.9) mg/L, SO_4^{2-} (10.2±14.91) mg/L, NO_3^- (1.3± 1.41) mg/L, PO_4^{3-} (0.2± 0.18) mg/L & Total Iron (0.8± 0.84) mg/L. This unique primary data is used to compute pertinent water quality indices. Similarly for December 2013, the parameters determined are pH (7.9±0.26), EC 2.2±1.91) mS/cm , TA (467.1±226.24) mg/L, TH (331.1±158.17) mg/L, Ca^{2+} (104.3±26.47) mg/L, Mg^{2+} (17±24.08) mg/L, TDS (1469.5 ±1242.62) mg/L, Na^+ (131.6±129.44) mg/L, K^+ (6.7±6.31) mg/L, Cl^- (55.3±153.46) mg/L, SO_4^{2-} (2.3±3.85) mg/L, NO_3^- (1.3±1.43) mg/L, PO_4^{3-} (0.2±0.12) mg/L & Total Iron (0.6±0.47) mg/L. The very purpose of this investigation is to compare the results with available data of past studies that initiated in the post tsunami period after 26th December 2004. pH (7.4±0.23), EC(1.5±1.59) mS/cm, TA (363.3±184.54) mg/L, TH (374.2±253.04) mg/L, Ca^{2+}(93.1±37.5) mg/L, Mg^{2+} (34.2±48.02) mg/L, TDS (985.6±1032.95) mg/L, Na^+(127.8±130.42) mg/L, K^+ (9.3±9.31) mg/L, Cl^-(213.4±242.98) mg/L, SO_4^{2-} (4.7±4.39) mg/L, NO_3^- (1.4±1.38) mg/L, PO_4^{3-} (0.1±0) mg/L & Total Iron (0.6±0.18) mg/L. Physico-chemical parameters of the water qualityof the region for 2015 are pH (7.6±0.29), EC (1.2±0.93) mS/cm, TA (255.7±40.74) mg/L, TH (224.5±107.13) mg/L, Ca^{2+} (58.2±30.1) mg/L, Mg^{2+}(19.1±11.09) mg/L, TDS (801 ±611.92) mg/L, Na^+ (104.8±53.7) mg/L, K^+ (8.9±7.22)mg/L, Cl^- (160.8±113.81) mg/L, SO_4^{2-}(4.4±6.33) mg/L, NO_3^-(1.3±1.42) mg/L, PO_4^{3-}(0.2±0.11) mg/L & Total Iron (1.3±2.93) mg/L. Most recently the water quality parameters for the period December 2016 are given. pH (8.1±0.17), EC(3.1±3.18) mS/cm, TA (290.7±77.01) mg/L, TH (251±111.72) mg/L, Ca^{2+} (96.5±57.82) mg/L, Mg^{2+} (24.5±15.26) mg/L, TDS (2033.7 ±2074.31) mg/L, Na^+ (81.9±60.63) mg/L, K^+ (5.2±6.16) mg/L, Cl^- (69±144.61) mg/L, SO_4^{2-}(3.3±4.06) mg/L, NO_3^- (1.5±1.43) mg/L, PO_4^{3-}(0.2±0.07) mg/L & Total Iron (0.8±0.81) mg/L. The results revealed (Table 1) that total iron exceeds the permissible limits in some of the groundwater sources of the coast (BIS; 2012) during the entire period. The overall behavior of the water seems to be not safe for meeting the drinking water purpose as the evidenced by these parameters. Natural mobilization of iron from alluvial deposition and natural recycling are the sources of iron in the region.

Irrigation Water Quality

There are many indices used to assess the irrigation water quality such as sodium percent (Na%), sodium adsorption ratio (SAR) and Kelly's ratio (KR), permeability index (PI), and magnesium adsorption ratio (MAR). Kelly's ratio is the ratio of Na^+ to Ca^{2+}+Mg^{2+} is an index for Na^+ content with respect to Ca^{2+} and Mg^{2+}. KR is less than 1.0 indicates the irrigation suitability during 2012, December 2013 & 2014. But December 2015 onwards, it becomes unsuitable (KR>1). PI belongs to the class II, marginally safe for irrigation during the entire period. Na% of groundwater of Andhakaranazhy coast is under the class of permissible during 2012, December 2013 & 2015. Although it is good for irrigation in December 2014 & 2016. The groundwater can be used for agricultural purpose, revealed by SAR and MAR (Table 1).

USSL diagram are used to find the irrigation suitability, plotted by SAR against EC. Andhakaranazhy coast showed a high salinity – medium sodium water (C3S2) during the period 2012-2015. But in December 2016 water is changed to very high salinity-high sodium (C4S3 type), which needs adequate drainage to overcome the salinity problem (Figure 2).Wilcox diagram is by plotted EC vs Na%. Figure 3 shows the Wilcox diagram of Andhakaranazhy coast during the period 2012-2016. It reveal that during the period 2012, December 2014 & 2015 groundwater sources are fall in excellent to good region, indicating its irrigation suitability. Although the groundwater sources are fall in doubtful to unsuitable region during December 2013 and December 2016 due to the increased amount of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} ions in ground water. Thus the water is unsuitable for agricultural usage (Ravikumar; 2011).

Gibb's Diagram

The source and ion chemistry of groundwater can be explained by Gibb's diagrams. It is plotted $Na^+/Na^+ + Ca^{2+}$ vs TDS and $Cl^-/Cl^- + HCO_3^-$ vs TDS (Figure 4). Both anion and cation plot indicate that, the major ion chemistry of groundwater of Andhakaranazhy coast which is mainly controlled by weathering of rocks. However, the groundwater chemistry also affected by the evaporation process, evidenced by December 2016 (Ravikumar; 2011).

Hydrochemical Facies

Piper diagram provides very valuable knowledge on the water type, precipitation or solution behaviour, mixing character and ion exchange phenomena. Piper plots of Andhakaranazhy coast showed a temporary hardness behavior throughout the study period (Figure 5). There is no dominating cation and bicarbonate is the anion type. Hence the hydrochemical facies is characterized by Ca^{2+}- Mg^{2+}-HCO_3^- prominent water (Ravikumar; 2011).

Table 1: Water quality parameters of groundwater sources of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016.

Water Quality Parameter	Annual Mean 2012	December 2013	December 2014	December 2015	December 2016	BIS (2012) Permissible limit
pH	7.6±0.25	7.9±0.26	7.4±0.23	7.6±0.29	8.1±0.17	6.5-8.5
EC(mS/cm)	0.8±0.62	2.2±1.91	1.5±1.59	1.2±0.93	3.1±3.18	
TA(mg/L)	330.2±117.23	467.1±226.24	363.3±184.54	255.7±40.74	290.7±77.01	600
TH(mg/L)	290.0±108.93	331.1±158.17	374.2±253.04	224.5±107.13	251±111.72	600
Ca^{2+}(mg/L)	83.2± 26.46	104.3±26.47	93.1±37.5	58.2±30.1	96.5±57.82	200
Mg^{2+}(mg/L)	18.5±11.39	17±24.08	34.2±48.02	19.1±11.09	24.5±15.26	100
TDS(mg/L)	576.3 ± 398.92	1469.5 ±1242.62	985.6± 1032.95	801 ±611.92	2033.7 ±2074.31	2000
Na^{+}(mg/L)	119.2±96.21	131.6±129.44	127.8±130.42	104.8±53.7	81.9±60.63	
K^{+}(mg/L)	8.3± 8.98	6.7±6.31	9.3±9.31	8.9±7.22	5.2±6.16	
Cl^{-}(mg/L)	161.6±169.9	155.3±153.46	213.4±242.98	160.8±113.81	169±144.61	1000
SO_4^{2-}(mg/L)	10.2±14.91	2.3±3.85	4.7±4.39	4.4±6.33	3.3±4.06	400
NO_3^{-}(mg/L)	1.3± 1.41	1.3±1.43	1.4±1.38	1.3±1.42	1.5±1.43	45
PO_4^{3-}(mg/L)	0.2± 0.18	0.2±0.12	0.1±0	0.2±0.11	0.2±0.07	
Total Iron(mg/L)	0.8± 0.84	0.6±0.47	0.6±0.18	1.3±2.93	0.8±0.81	0.3
KR	0.9±0.61	0.8±0.41	0.7±0.58	1.1±0.55	1±1.48	<1.0
PI	70.1±7.74	71.7±10.19	64.5±12.59	78±11.45	67.5±26.02	Class I or II
Na%	43.8±14.3	41.4±12.4	37.9±16.81	50.5±11.18	39.1±21.4	<20 or 20–40
SAR	3±2.09	2.9±2.08	2.7±2.31	3.1±1.39	2.5±2.45	<10 or 10–18
MAR	26.5±12.24	17.2±13.05	3.6±5.54	3±3.51	3.2±6.46	<50
LSI	0.4±0.44	0.9±0.32	0.3±0.27	0.2±0.36	0.9±0.44	
RSI	6.8±0.65	6.0±0.49	6.7±0.61	7.2±0.54	6.3±0.85	
AI	12.4±0.41	12.9±0.31	12.3±0.30	12.1±0.37	12.8±0.48	

Table 2: Classification of irrigation water quality parameters

Parameter	Range	Class
$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	0-10	Excellent(E)
	10-18	Good(G)
	18-26	Fair(F)
	>26	Poor(P)
$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Na^+ + Ca^{2+} + Mg^{2+}} \times 100$	>75%(Class I)	Safe(S)
	25-75%(Class II)	Marginally Safe(MS)
	<25%(Class III)	Unsafe(U)
$Na\% = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$	< 20	Excellent(E)
	20-40	Good(G)
	40-60	Permissible(P)
	60-80	Doubtful(D)
	>80	Unsuitable(US)
$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$	<1	Suitable(S)
	>1	Unsuitable(US)
$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$	<50	Suitable(S)
	>50	Unsuitable(US)

Table 3: Classification of corrosion indices

Parameter	Range	Water Tendency
LSI	< -2	Intolerable corrosion (IC)
	-2 - -0.5	Serious corrosion (SC)
	-0.5 - 0	Slightly corrosive but non scale forming(SCNSF)
	0	Balanced but pitting(BP)
	0 – 0.5	Slightly scale forming and corrosive (SSFC)
	0.5 - 2	Scale forming but non corrosive (SFNC)
RSI	4.0 – 5.0	Heavy scale(HS)
	5.0 – 6.0	Light scale(LS)
	6.0 – 7.0	Little scale or corrosion(LSC)
	7.0 – 7.5	Corrosion significant(CS)
	7.5 – 9.0	Heavy corrosion(HC)
AI	< 10.0	Highly aggressive(HA)
	10.0-11.9	Moderately aggressive(MA)
	> 12.0	Non-aggressive(NA)

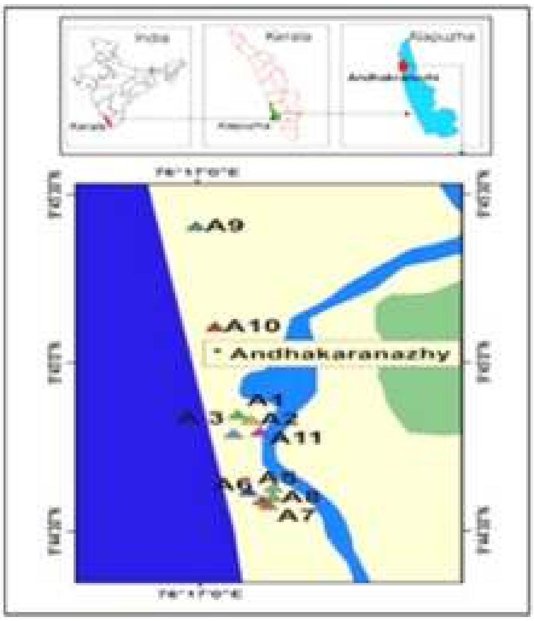

Figure 1: Location map of Andhakaranazhy coast, Alappuzha, Kerala, India, which has been subjected to inundation by 26th December 2004 Indian Ocean Tsunami

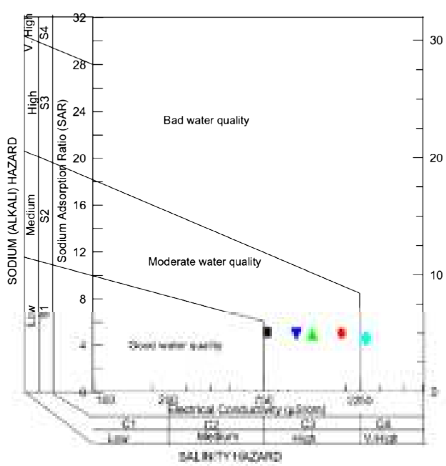

Figure 2: USSL Diagram of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016

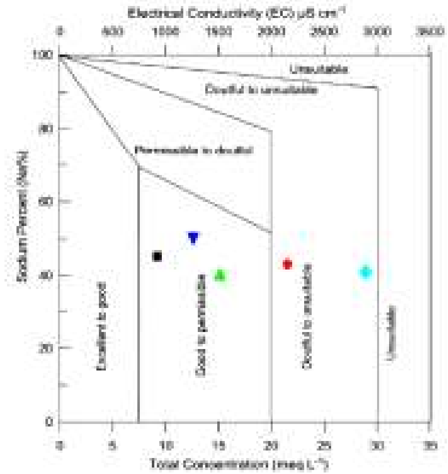

Figure 3: Wilcox Diagram of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016

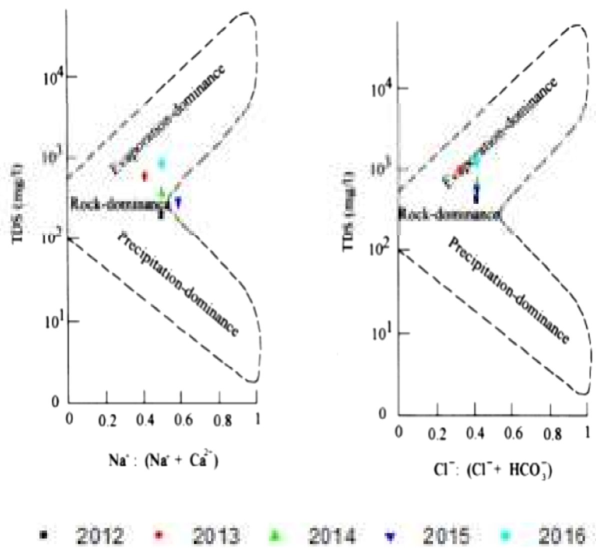

Figure 4: Gibb's Diagram of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016

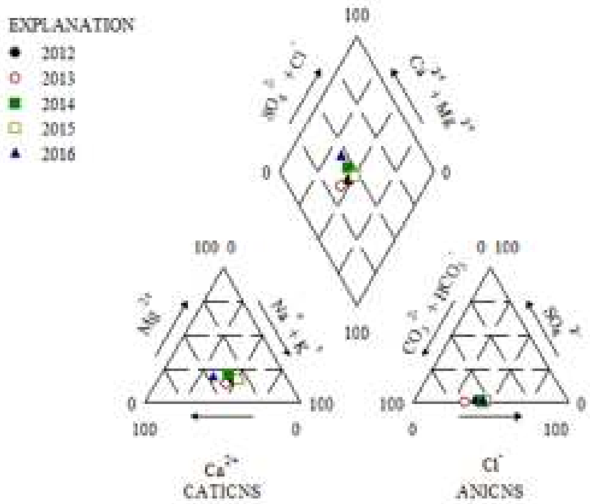

Figure 5: Piper Diagram of Andhakaranazhy coast, Alappuzha, Kerala, India during the period 2012-2016

Industrial Water Quality

Industrial water quality is mainly depends on the corrosion or scaling potential of groundwater. Some of the indices were used to compute the industrial suitability of groundwater sources of Andhakaranazhy coast such as Langelier saturation index (LSI), Ryznar stability index (RSI) and aggressiveness index (AI). LSI and RSI are more suitable to find the scaling tendency of groundwater. AI is mostly used for predicting the corrosion behavior of the water. These indices were calculated by following equations.

$$\mathbf{LSI = pH - pH_s \ .... (1)}$$

$$\mathbf{pH_s = pK_2 - pK_s + pCa^{2+} + pHCO_3^- \ ...... (2)}$$

$$\mathbf{RSI = 2pH_s - pH \ ...... (3)}$$

$$\mathbf{AI = pH + \log(AH) \ ..... (4)}$$

Where pH = actual pH of water

pH_s = pH of saturation for $CaCO_3$

pCa^{2+} = equilibrium calcium content

pK_2 = second protolysis constant for H_2CO_3

pK_s = solubility product constant for $CaCO_{3(s)}$

$pHCO_3^-$ = total alkalinity when pH>9.5

LSI of Andhakaranazhy coast during 2012, December 2014 & 2015 is slightly scale forming and corrosive behavior (SSFC). But December 2013 & 2016, water is scale forming and non-corrosive (SFNC). In 2012, December 2013, 2014 & 2016 Andhakaranazhy coast RSI indicates little scale forming or corrosive (LSC) character. However, in December 2015 water shows significant corrosion (CS). AI of the coast during the whole period reveals, groundwater is non-aggressive (NA) in nature (Table 1). Hence, the water shows scale forming and little corrosion behavior during the study period (2012-2016). But the scale forming nature is prevalent because of the increased concentration of calcium and magnesium ions in groundwater aquifer (Shankar; 2014).

CONCLUSION

The study areas chemical composition is mainly controlled by many processes such as weathering of rock forming minerals, evaporation, sea water intrusion, rock-water interaction and sulphate reduction. Salt water intrusion is a major problem affecting the study area because of the peculiarities such as lying below mean sea level, proximity to the sea and aquifer nature. Factors such as pH, temperature, total dissolved solids, alkalinity and hardness affecting the groundwater quality of the coast leads to the corrosion or scale forming behavior. Sulphate reduction mechanism is contributing bicarbonate ion concentration to the groundwater thus by causing the temporary hardness behavior of the region.

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REFERENCES

Achari V. S., Jaison C. A., Alex P. M., Pradeepkumar A. P., Seralathan P. and Shaji E.; 2007. Tsunami on Kerala Coast: A Study of Ground Water Quality along Arattupuzha and Alappad Coast. ICFAI Journal of Environmental Sciences., 43-54.

Achari V. S., Deepa P., Ambili M. S and Regi T. G.; 2017. Corrosion Indices, Drinking and Irrigation Water Quality of Andhakaranazhy and Cherai Coastal Regions of Kerala. Journal of the Academy of Chemistry Teachers., 3(1): 10-14.

Achari V.S., Ambili M. S., Jaison C. A., Deepa P and Regi T. G.; 2017. Groundwater hydrochemical facies of tsunami affected Alappad coast of Kollam, Kerala, India. Journal of the Academy of Chemistry Teachers, 3: 40-44.

Achari V.S., George T Regi., Deepa, P., Ambili, M. S., Jayasree, S., Rajalakshmi, A.S and Raichel Mary Lopez.; 2017. Indian Journal of Geo-Marine Sciences., **46**: 1765-1779.

Achari V.S.; 2005. Water Quality Assessment in the Tsunami Affected Coastal Areas of Kerala. The final project report submitted to Department of Science and Technology.

APHA. AWWA and WPCF.; 2005. Standard method for the examination of Water and Waste Water. 21st edition. APHA, Washington D C.

BIS 2012. Specifications for drinking water. Bureau of Indian Standards IS: 10500, New Delhi.

Jaison C.A.; 2012. Assessment of Water Quality along the Coastal Areas of Kerala: A Study of the Tsunami Impact on Groundwater .Ph.D. Thesis, CUSAT, Kerala.

Ravikumar P and Somashekar R.K.; 2011.Geochemistry of groundwater, Markandeya River Basin, Belgaum district, Karnataka State, India. Chinese J Geochemistry., **30**: 51-74.

Shankar B.S.; 2014. Determination of Scaling and corrosion tendencies of water through the use of Langelier and Ryznar Indices. Sch. J. Eng. Tech., **2**:123-127.

Steube C., Richter S and Griebler C.; 2009. First attempts towards an integrative concept for the ecological assessment of groundwater ecosystems. Hydrogeol. J., **17**: 23–35.