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An attempt to identify and estimate the subsurface groundwater discharge in the south east coast of India

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Abstract

An attempt has been made to study the subsurface groundwater discharge (SGD) in the coastal Cuddalore region of south east India. Measurement for Radon, water level, Electrical Conductivity (EC) and pH in surface water for a total of twenty hours by hourly interval has been attempted and further correlated with tidal values calculated by WX Tide 32 software. The SGD measurements were made by using a modified seepage meter. The study reveals a match with water level variation and tide with minor variation due to influx of surface water. Saline discharges, fresh groundwater discharges and surface water mixing processes were identified along the coast. Lower SGD (37.24–79.16 cm/day) was observed during fresh groundwater discharge.

Keywords: Groundwater; Discharge; Radon; Tide; Coast

1. Introduction

The Submarine groundwater discharge (SGD) has been defined as the flow of water through continental margins from the seabed to the coastal ocean, regardless of fluid composition or driving force with spatial scale lengths of meter to kilometers (Burnett and Dulaiova, 2003; Moore, 2010). The importance of submarine groundwater discharge (SGD) as a source of dissolved solids to coastal waters has become increasingly recognized, with recent studies suggesting SGD derived chemical loading may rival surface water inputs in many coastal areas (Moore, 1996; Bugna et al., 1996; Kim et al., 2003). It represents all direct discharge of subsurface fluids across the land–ocean interface (Taniguchi, 2002), including discharging of fresh groundwater from coastal aquifers to oceans under pressure differences between the hydrostatic head (Church, 1996; Li et al., 1999). SGD has become an important factor for understanding and instituting sustainable management practices in coastal areas, particularly in highly populated

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areas of the world (Kontar, 2002). Some of the earliest research on SGD sought to quantify its role in the delivery of nutrients to the coastal ocean (e.g. Valiela and D'Elia, 1990; Giblin and Gaines, 1990). Subsequently, Valiela et al. (1992, 2002) has pointed out the influencing factors for SGD as: (1) the hydraulic gradient due to water flowing down gradient across the continent; (2) precipitation and human influence; (3) tidal and wave pumping, storm or current-induced pressure gradients in the near shore zone; (4) density variation by temperature and salinity differences; (5) convection (salt-fingering) induced by saline water overlying fresh groundwater in some near shore environments; (6) seasonal inflow and outflow of seawater into the aquifer resulting due to the movement of freshwater-seawater interface in response to annual recharge cycles; and (7) geothermal heating for coastal aquifers' dynamics. Since then, most submarine groundwater research has been motivated by the possibility of ground water discharge partially responsible for nutrient loading (Byrne, 1999; Uchiyama et al., 2000; Masterson and Walter, 2001) or pollutant contamination (Johannes, 1980; Li et al., 1999) to coastal regions. Many studies have pointed out that SGD may carry elevated quantities of nutrients and trace metals to the oceans (Krest et al., 2000; Montlucon and Sanudo-Wilhelmy, 2001; Burnett and Dulaiova, 2003; Aureli et al., 2006; Burnett and Dulaiova, 2006). Numerical groundwater flow modeling is another method used to estimate the rates of SGD (Langevin, 2001; Kaleris et al., 2002), but not often used due to limitations in computer speed, data availability and availability of a simulation tool that can minimize numerical dispersion. In recent years it is significant that SGD has a significant impact on the coastal environment (Moore, 1996; Burnett and Dulaiova, 2003). In various cases, SGD may contain contamination from land-based activities in the near shore marine environment (Burnett and Dulaiova, 2006; Cable et al., 2006; Moore, 2010). SGD is now recognized as an important biogeochemical pathway between land and sea and represents an important component of the hydrological cycle (IAEA, 2007). The direct discharge of the groundwater in the coastal zone has received attention in last few decade and it is found to influence chemical and biological processes of the ocean (Burnett, 1999; Kontar and Zektser, 1999) and also as a potential path way of dissolved ions to diffuse pollution (Burnett et al., 1996, 2001a). The natural radioactive ^{222}Rn has been adopted to identify SGD (Moore, 1996; Cable et al., 1996; Hussain et al., 1999; Burnett et al., 2001b). The radon is about 3–4 order of magnitude more concentrated in groundwater than in coastal surfing surface water with a $t^{1/2}$ of 3.82 days comparable to the time scale of circulation in many coastal settings (Cable et al., 1996; Corbett et al., 1999; Hussain et al., 1999). The first attempt of SGD in this part of India was attempted by Diksha et al. (2014), using Radium isotope. Fewer attempts to understand the SGD dynamics in the south west coast of India has been proposed by Suresh babu et al., 2009; Jacob et al., 2009. But there are several studies to understand the variation of groundwater geochemistry (Chidambaram et al., 2008; Srinivasamoorthy et al., 2012) of this region. Since river discharge is the main source of freshwater to the sea through surface or subsurface an attempt has also been made to quantify the amount of SGD along the Uppanar river mouth located along the south of Cuddalore. The present study focuses on tidal influenced SGD at the river mouth, by understanding the influences of tidal activities using parameters like EC, Water Level (WL), and Radon. Further it also aims to understand the nature and process governing the release along with quantification of SGD.

2. Study area

The study area is located along south Cuddalore which is bounded by North latitudes 11°71′94″ East longitudes 79°77′44″ (Fig. 1). The study area forms a part of coastal region composed of coastal alluvium located along the south eastern coast of India. The land is completely flat with large deposits of black and alluvial soil in inlands and coarse sand near the seashore.

The mean annual rainfall, in Cuddalore district, from 1994 to 2014 (Fig. 2) was found to be 111.1 mm with the maximum of 167 mm in 2005 and minimum of 54.3 mm in 2014. The contribution from the North-East monsoon (NEM) rainfall was about two-thirds of the annual rainfall in many years. The mean rainfall during NEM was found to be 796.6 mm. The rainfall, during South-West monsoon (SWM) (June–September), contributed to about one-third of the annual rainfall in many years. The mean rainfall during the SWM was found to be 372.5 mm.

Uppanar River which originates from the southern part of Perumal Eri, flows NE and joins the sea along the south of Cuddalore. The location of observation site is on the Uppanar River mouth, North latitudes 11°42′10″ East longitudes 79°46′42″ which fall North of Pichavaram mangrove. This river is ephemeral and floods during monsoon. It generally flows from west toward east and drains in Bay of Bengal. It has an elevation of about 3 m above mean sea level (amsl). The other major river Ponnaiyar River runs north of the town, while Gadilam River runs across Cuddalore. The groundwater level ranges between 0.004 and 17.54 m below ground level (mbgl) (CGWB, 2009). The Storativity of this region is 7.72×10^{-5}–9.5×10^{-3} and the Transmissivity is between 438 and 1900 m^2/day. The maximum temperature varies between 43.3 °C and 39.60 °C during 2009 and 2004, respectively (Srinivasamoorthy et al., 2011a,b). The relative humidity recorded in Cuddalore ranges from 60 to 80%. Higher rates of humidity are observed during the North-East monsoon period. The relative humidity observed during the North-East monsoon period is high and low during summer.

The wind prevailing in the region is generally moderate in strength with mean velocity variation from 6 to 14 km/h. Wind speed is higher in May and lower in October. South

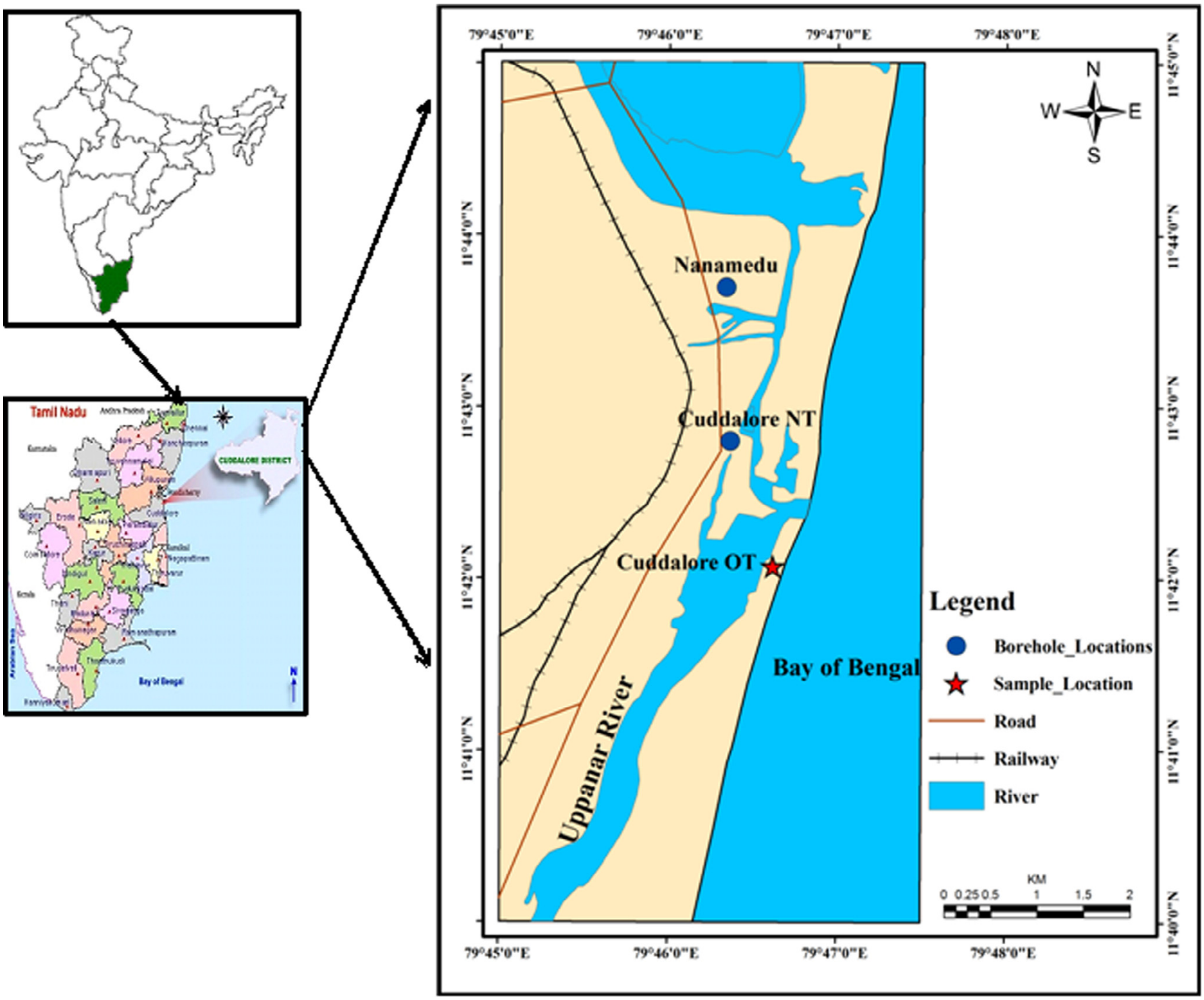


Fig. 1. Location map of the study area with sampling location.

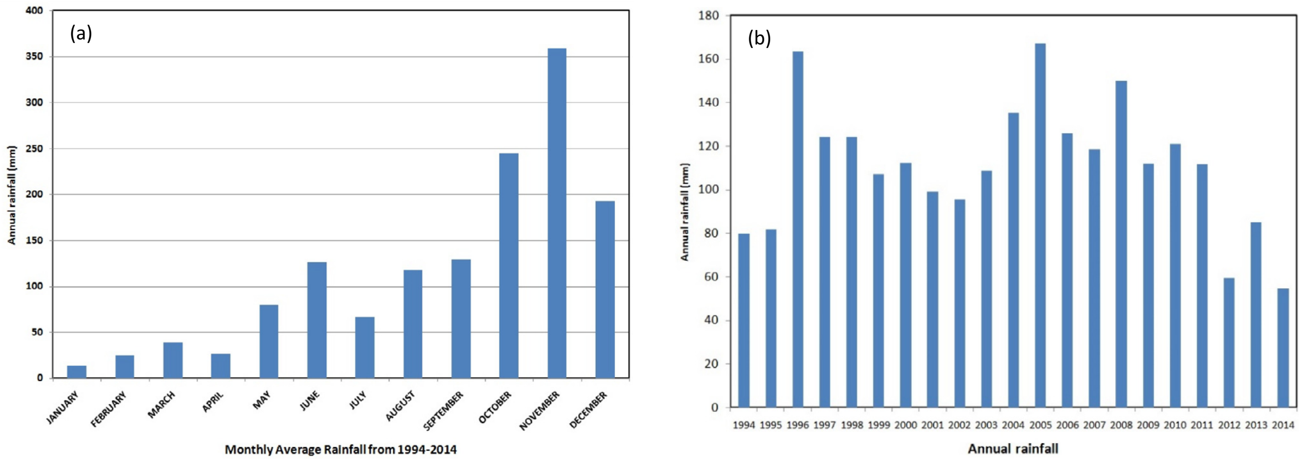


Fig. 2. (a) Monthly average rainfall for ten years; (b) Average rainfall for 1994–2014.

westerly wind prevails over 33% of days in a year and Northeasterly wind over 32% of the days (Gowrishanker et al., 1980).

Fig. 3 shows the resistivity and self potential (SP) log with lithological identifications. It indicates Clay and Sand in the top layers of 0–20 m. Fine to Coarse Sand is dominant in the litholog. Lignite is identified at the depth of 125 m. Potential aquifer is identified in Coarse sand of 40–60 m in Cuddalore. It may indicate the possibilities of submarine ground water discharge (SGD) in Cuddalore. The study of resistivity and SP log indicate the saline water intrusion at 150 m depth in Cuddalore. The resistivity and SP logging mainly indicate the possibilities of SGD and saline water intrusion in Cuddalore.

The distribution of the resistivity and litholog of Cuddalore and Nanamedu falling just north of the observation point has been studied in the depth of fresh/saline waters. Fig. 4 shows the contrasting resistivity values at Cuddalore and Nanamedu. The litholog section for these two locations are located North-West of the observation station at a distance of the borehole 3–5 km in the shallow aquifers from 0 to 100 mbgl. The resistivity profile when compared with the lithology of the region shows that shallow aquifers at Cuddalore are comparatively fresh and those of Nanamedu are saline (Thilagavathi et al., 2013). The deeper aquifer at Cuddalore shows lesser resistivity with greater thickness with saline groundwater. The deeper and shallow aquifers are demarcated by intervening Clay layer. It is also evident that the thickness of the top Clay is less at Cuddalore than at Nanamedu (Thilagavathi et al., 2013). The litholog at Nanamedu has lesser resistivity from 0 to 100 m of the borehole. The depth range is represented by Coarse Sand and Sand by lithology reflecting low resistivity indicating invasion of sea water as they form a part of the

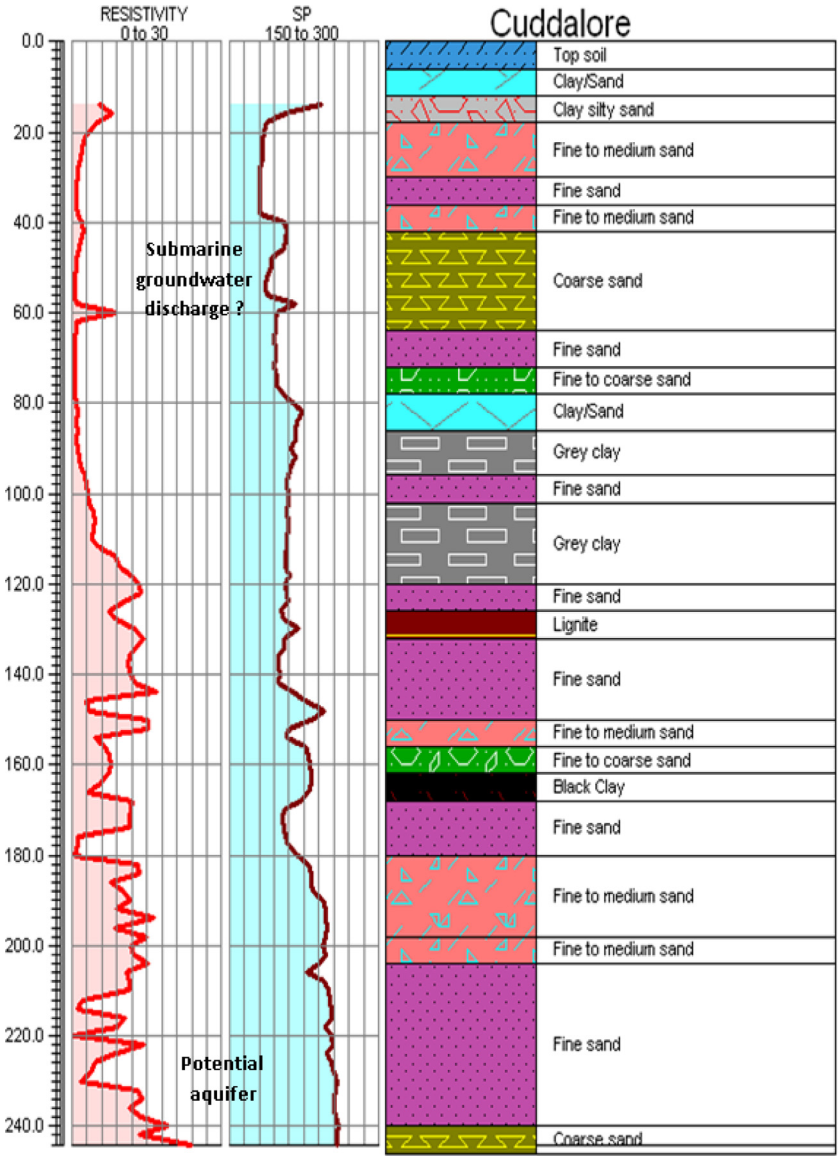


Fig. 3. Resistivity, self-potential and Litho-logging for Cuddalore.

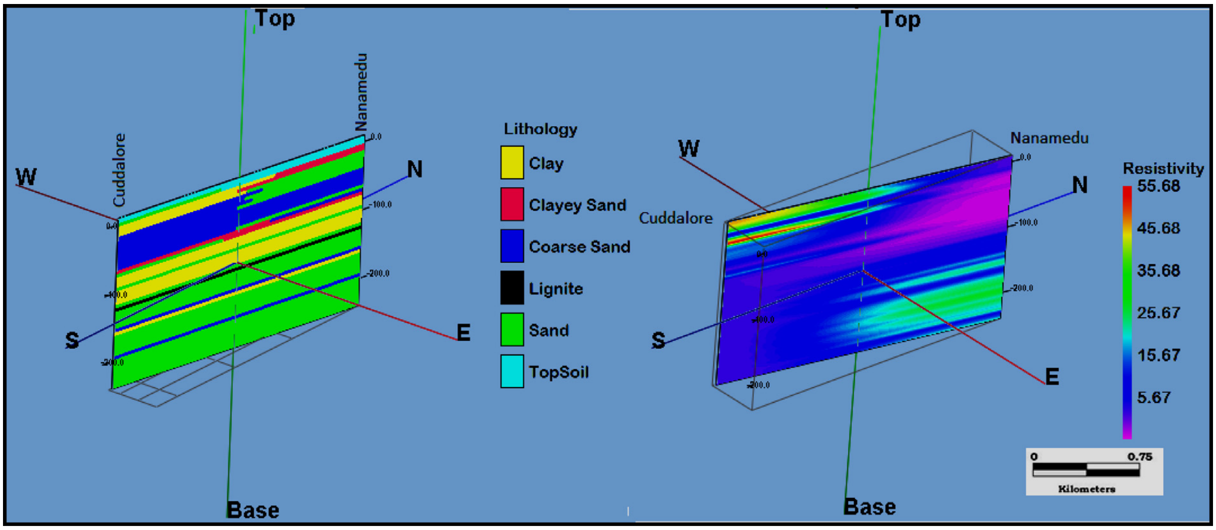


Fig. 4. Two dimensional view of the subsurface lithology and geophysical resistivity log.

coastal aquifer at Nanamedu. It has not spread below to the deeper aquifer above 150 m (approx.) due to the presence of an impermeable layer. The deep aquifer of Nanamedu is relatively fresh compared to deeper aquifers of the Cuddalore. Hence, the resistivity and litholog cross section of these two locations reveals that the prevalence of lesser resistivity value and coarse sand in the corresponding depth indicate that there is a positive flow of SGD in this region. This has to be investigated further to delineate the zone of SGD and to estimate the flux.

3. Methodology

Tide-affected Cuddalore region were selected for the field monitoring. The observations were carried out in 1h interval for 24 h (Indian Standard Time) IST, in the field. The study is mainly based on the in situ measurements and the estimation of SGD is based on the values of EC, water level (WL), radon and tide. The time-wise measurements were made for Water level, pH, EC and salinity for every one hour during the month of August (South-West monsoon period) using Standard IntelliCAL LDO Hach probes. Automated Radon monitoring was carried out by RAD7 (Durridge make). The RAD7 was fixed on the river bank and water was pumped using a peristaltic pump (Fig. 5) to circulate water from river mouth. ^{222}Rn values were measured as a function of tide levels and EC. For the in situ measurement of ^{222}Rn in the coastal region, seawater is continuously pumped from 1 m above the sea bed using a peristaltic pump and sprayed as a jet into an air–water exchanger (Fig. 5).

The circuit has a desiccant and the purpose of desiccant is to absorb moisture, since detection efficiency decreases at higher humidity (AboJassim and Shitake, 2013). The equilibrium of ^{222}Rn between the liquid and gaseous phase is established within 30 min. The radon monitor (RAD-7) uses a high electric field above a silicon semiconductor detector at ground potential to attract the positively charged polonium daughters, ^{218}Po (half-life = 3.1 min; alpha energy = 6.00 MeV) and ^{214}Po+ (half life = 164 μs;

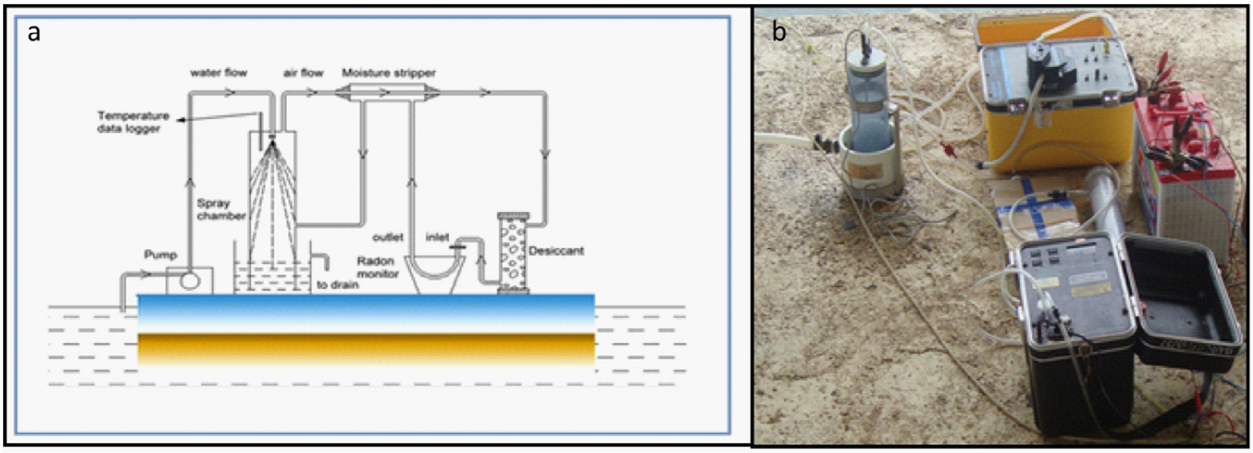


Fig. 5. The radon thus stripped out from the water is circulated through a closed air-loop via a desiccant tube into a ^{222}Rn counting system.

alpha energy = 7.67 MeV), which are counted as a measure of ^{222}Rn concentration in air. An air filter at the inlet of the radon monitor prevents dust particles and charged ions from entering into the alpha detector. The ions are collected in energy specific windows which eliminate interference and maintain very low background. ^{222}Rn activities are expressed in Bq/m^3 (disintegration per second perm^3) with 2 s uncertainties. At room temperature, since the radon in air is about four times more than that in water at equilibrium, the measured radon concentrations in air are corrected accordingly (Weigel, 1978). SGD was directly measured by the modified seepage meter (Fig. 6). Seepage meter was placed on to the floor filled with 250 ml of water. The EC of the water filled in was noted before and after the SGD measurements. The filled water is measured as liter/hour to find the SGD.

4. Results and discussion

The maximum, minimum and average values for pH, EC, Radon, Water level and SGD are shown in the Table 1.

4.1. Tides and water level

This coastal interface shows interaction between the surface water and groundwater as sea water intrusion. Several forcing mechanisms, such as waves, tides, dispersive circulation (Taniguchi, 2002; Burnett and Dulaiova, 2003) and changes in upland recharge (Michael et al., 2005), affect the rate of fluid flow for both fresh and saline groundwater, which are ultimately important in controlling the submarine discharge of which tidal variation plays a significant role. Tidal calculations were made by WX Tide 32 software by providing, the time, date and geographical location of the study area.

Fig. 6. Seepage meter used to measure the SGD.

Table 1
Maximum, minimum and average values for EC, pH, W.L, ^{222}Rn and SGD.

	EC (ms/cm)	pH	W.L (ft)	^{222}Rn (Bq/m^3)	SGD (l/h)
Maximum	44.76	8.98	2.80	125	2370
Minimum	39.72	8.25	1.60	43.2	1910
Average	43.29	8.60	2.36	74.25	2057.14

The coastal environments are more dynamic with frequent invasion of the tides into the river mouth. This part of coastal India has a minimum level of 90 cm and maximum level of 120 cm tides. The rivers of these regions are ephemeral and excess fresh water flow is noted during monsoon period.

The tidal curve shows, the low tide is noted at 6.00 am and 7.00 pm of the study period and the high tide was calculated to be at 1.00 am and at 1.00 pm. The tidal behavior shows that it is in a diurnal pattern (Fig. 7). The recorded water level depths also show the maximum water level of 1.60 ft below the measuring point during high tide and the minimum water level is 2.8 ft below the measuring point during low tide (Fig. 7). The figure shows that the calculated tidal values match with the in situ water level observation. It is also stated that the tidal cycle is a major driver for periodic changes in the SGD rate. During low tide with low water level, the hydraulic gradient between land and sea is higher compared to high tide. This steeper gradient allows more groundwater to discharge from the hydraulically connected aquifer (Santos et al., 2009; Mulligan and Charette, 2006).

4.2. pH, Radon, SGD

Continuous radon activity ranges from 125 Bq/m^3 to 43.2 Bq/m^3. The highest value was noted at 9.00 pm and that of the lowest was at 4.00 pm. The variation of radon value in the surface water may be due to the surfing of sea water and due to greater influence of fresh water influx or due to SGD in these regions (Nepolian, 2013). EC varies from 39.72 to 44.76 ms/cm with a lowest at 4.00 am and highest EC recorded during 10. 00 am. The pH ranges from 8.25 to 8.98 with highest values noted at 10.00 am and the lowest observed at 5.00 am. The maximum and minimum SGD is observed as 2.03 and 0.9 l/h at 12:00 and 20:00 respectively. The small rise in the WL preceding both the Low Tide conditions may be due to the inflow of Uppanar river water (Nepolian, 2013).

4.3. Radon as tracer for SGD

Radon in seawater ranging from 1.3 to 1.7 Bq l^{-1} (Ghose et al., 2000) shows only a few Bq/m^3 in Bay of Ben-

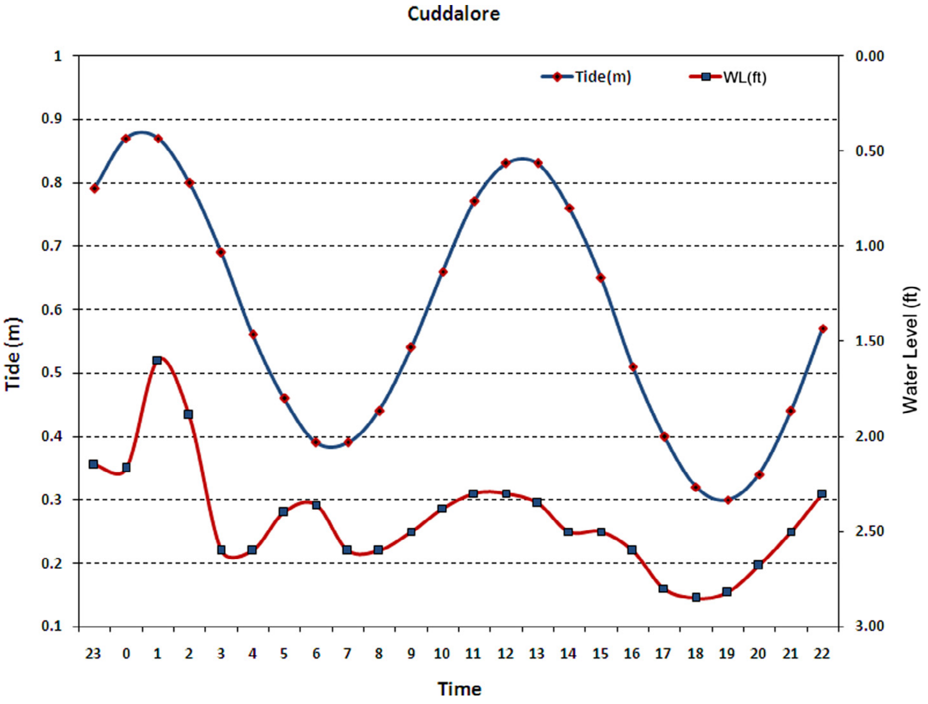


Fig. 7. The variation of WL to Tidal variation, depicting a direct relation.

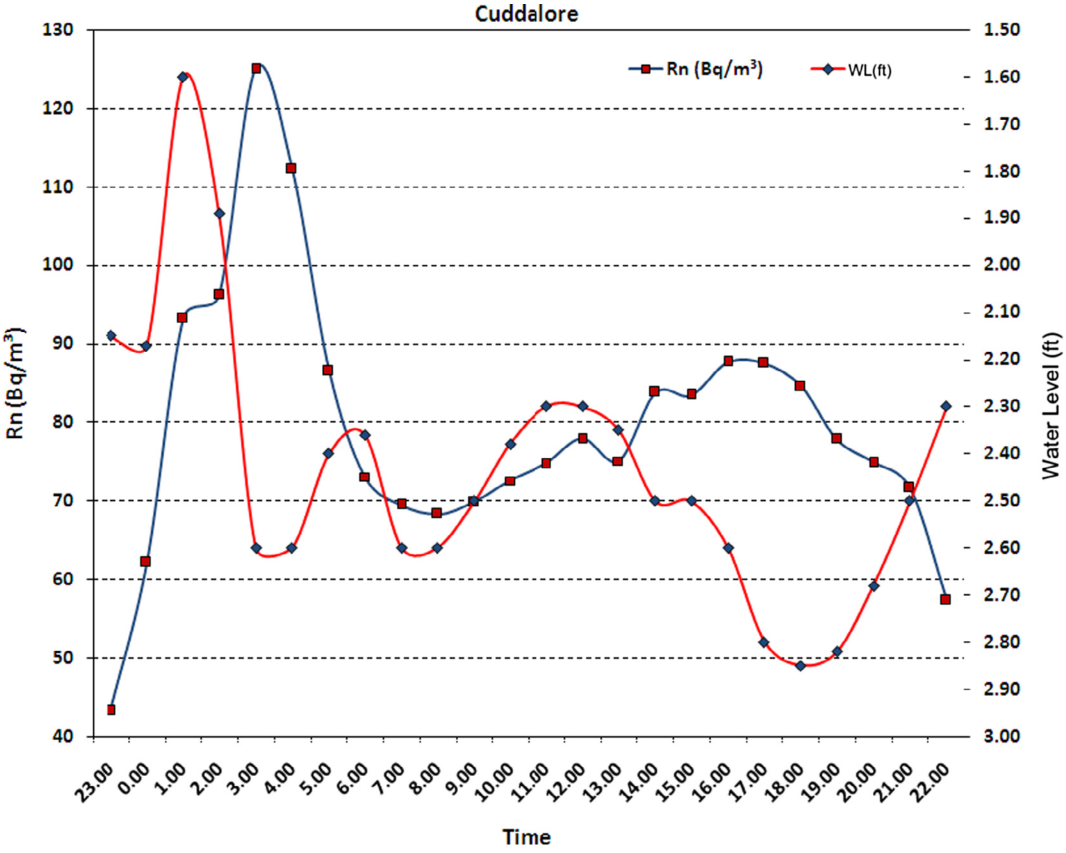


Fig. 8. Relationship of surface water level to Radon during the 24 h observation.

gal water. But in groundwater, concentrations reach up to 20 kBq/m^3 and more (Schubert et al., 2014). The strong gradient at the groundwater/seawater interface results in an inverse correlation between seawater depth and radon concentration in the coastal sea, i.e., in high concentrations during low tides (due to intense SGD) (Fig. 8) and vice versa as at 5–6 IST and 15–16 IST (Tsabaris et al., 2010). The relation between the Radon and water level of the Cuddalore illustrate the inverse correlation between radon and water depth observed from 16:00 until the end of the monitoring period. At the beginning of the day at 0:00, this relationship appears to be reversed. Similarly at 7:00–8:00, low water depths are associated with low radon concentrations in the water column. The most likely reason for this unusual radon pattern is the high water turbulence (Schubert et al., 2014) or may be due to the influence of Uppanar River water input during the Low Tide (at 6.00 am). While radon gets degassed from every open water surface, this gas evasion is strongly enforced if the water is very turbulent and contains many air bubbles. The sea water releases radon due to intense water mixing between seawater and discharging groundwater. During low tide this pressure is released by a fall in water table and the groundwater can migrate further seaward, inducing mixing within a zone of enhanced SGD that extends toward the shore.

The fluctuation of the radon with the WL observation shows that they are indirectly proportional to each others. The increase in Rn during 3.00 am and from 13.00 to 16.00 h corresponds to the decrease in the WL condition and similar situation is also reflected during 18.00–22.00 h.

4.4. EC and radon

Radon is an excellent tracer of SGD (Burnett et al., 1996; Cable et al., 1996; Corbett et al., 1997). The very large enrichment of ^{222}Rn concentration in groundwaters over surface waters (typically 1000-fold or greater), its unreactive nature, and short half-life ($t^{1/2} = 3.83$ d) make ^{222}Rn an excellent tracer to identify areas of significant groundwater discharge. Groundwater-surface water interaction has increased dramatically in the last few years; there is actually very little documentation available as of now. The knowledge on the origin, pattern and scale of radon migration in the groundwater environment are used to find the type of waters involving the presence of high radon concentrations.

Based on our field observations and analysis of data and literature review, the following assumptions were made to understand the different conditions and process based on the relationship between EC and Radon in groundwater to determine the SGD (Fig. 9)

1. Increase in Radon and decrease in EC representing Fresh water SGD

From the continuous monitoring of ^{222}Rn in coastal waters, it is possible to identify SGD (Kim et al., 2003;

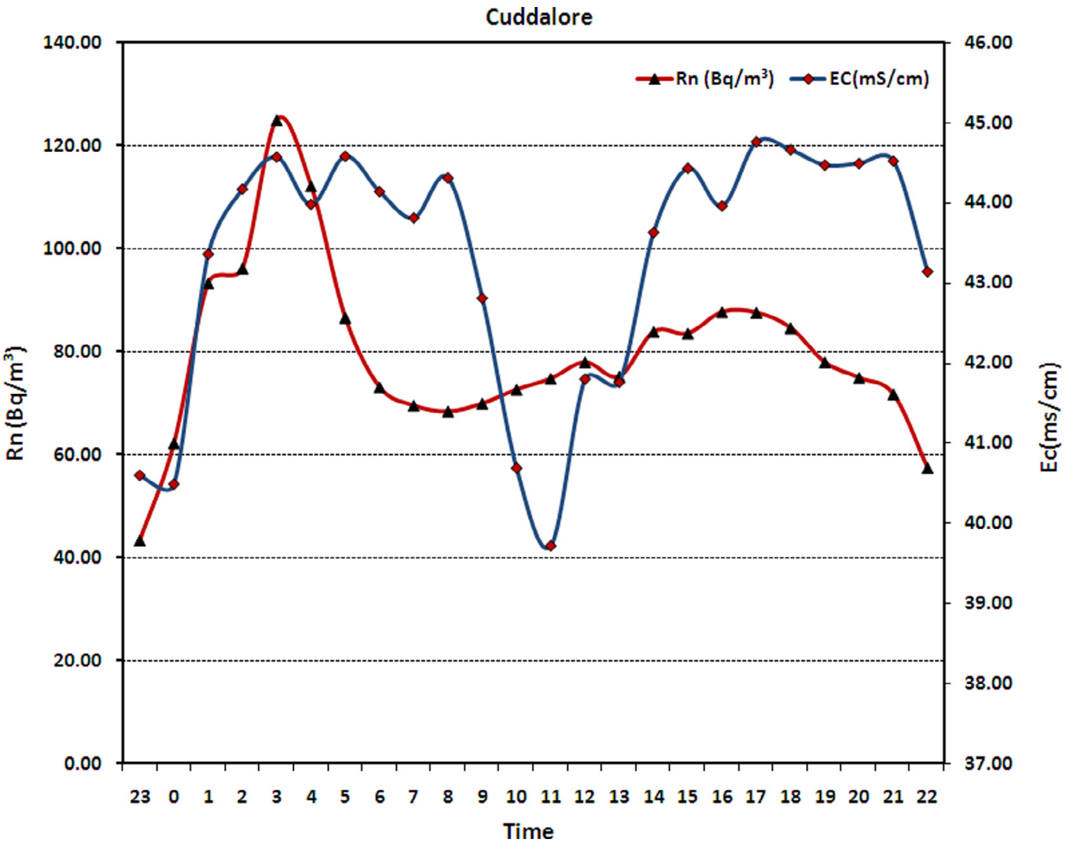


Fig. 9. Relationship of Electrical Conductivity to Radon.

Cable et al., 1996; Corbett et al., 2000; Burnett and Dulaiova, 2006). The lowering of EC is mainly either due to the increased freshwater input or decreased sea water input; in either case it represents SGD.

2. Increase in Radon and increase in EC representing Saline SGD

At the second situation the increase in SGD is due to the groundwater discharge with high salinity due to the expelling of sea water intruded into the aquifer during the early high tide period.

3. Decrease in Radon and decrease in EC representing Fresh Surface water

In the third condition the decrease in radon (ie) due to surface action of tide/surface waters. The value range of concentration activity of water-dissolved ^{222}Rn is very wide. The concentration of this gas in surface waters decreases very fast, as it is released into the atmosphere. Its concentration in the waters of streams and rivers oscillates from a fraction of a Becquerel to a few dozen Becquerel's in a liter. Moreover, the lesser EC value indicates contribution from river water as freshwater flow.

4. Decrease in Radon and increase in EC representing Sea water

The fourth condition assumes that the decrease in Radon is due to the influence of surface water and the increase in EC adds to the fact that it's due to the influence of sea water.

Observed Radon concentration in Cuddalore was inversely correlated with tide, indicating that groundwater was being added to the system when the hydraulic gradient was the greatest (low tide). Seepage rates are inversely proportional to tidal height. Studies have been conducted by several authors about Radon and tides on the occurrence of radon, particularly ^{222}Rn isotope in groundwater environment (Przylibski, 2000a,b,c, 2005, 2007; Przylibski and Zebrowski, 1996, 1999; Przylibski et al., 2001, 2002, 2004).

Radon is SGD tracer and hence generally be stated that Radon reveals robust data due to its distinct gradient at the groundwater/seawater interface, due to its inert behavior and its straight forward detectability on site (Mulligan and Charette, 2006). However, in the case of rough seas intense radon degassing may limit its applicability as a tracer. Lower tide could result in increased seepage (and thus higher radon) representing the fresh groundwater at 17:00.

The shallow sandy aquifer has higher permeability. Generally, the permeability for Sand is, 10^{-5} to 10^{-3} cm/s (Fetter, 1994) which enhances the saline/fresh water movement along the pores during the HT and LT condition. The observation of the EC values show that higher EC was observed at 03.00 h, which started to increase from 0.00 h. Further it gets decreased till 10.00 h and later it shows an increasing trend with a small drop at 16.00 h and it decreases after 21.00 h.

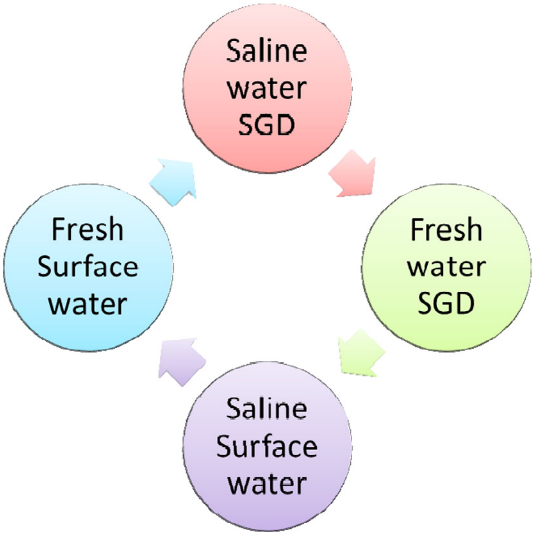
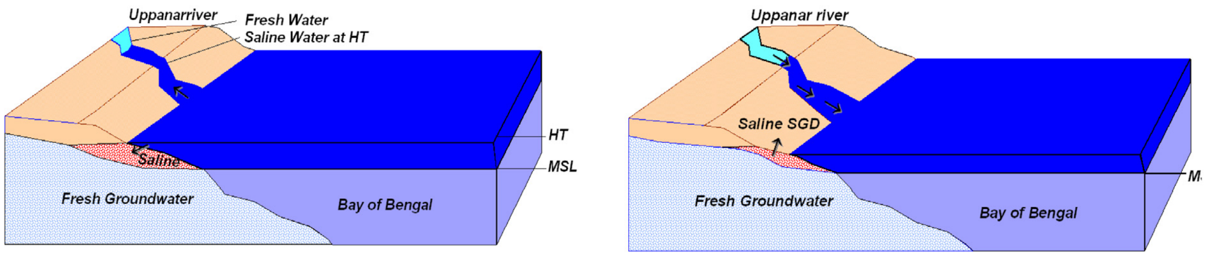


Fig. 10. The cyclic process inferred from the present study.

The Radon value shows an increasing trend at 3.00IST along with higher EC due to the saline SGD (Process 1), (Figs. 10 and 11b), and is comparable to the interpretation of the salinity data. Another potential explanation is that seawater, which was pushed into the conduit system earlier, discharged again after the sea gets to calm down. Further drop in EC and decrease in Radon indicates mixing of freshwater inflow from subsurface groundwater discharge. Hence resulting in lesser radon value due to the turbulence of the sea by wind action during 4.00–7.00 IST i.e., Process 2 (Figs. 10 and 11c), Then 8.00–9.00 IST tide retreat and the saline water entered the river during the high tide (9.00–10.00 IST), Process 3 (Figs. 10 and 11d). There is a drastic drop in EC and Radon at 10.00 IST and at 18.00 IST may be due to the mixing of fresh water and sea water surfing process in open sea, which results in the reduction of Radon, Process (4) (Figs. 10 and 11e). Subsequently there is an increase in EC with radon indicating saline SGD at 14.00 h. Further a drop in EC at 15.00 IST and high Radon indicate freshwaters SGD and hence this process keeps continuing in this region (Table 2).

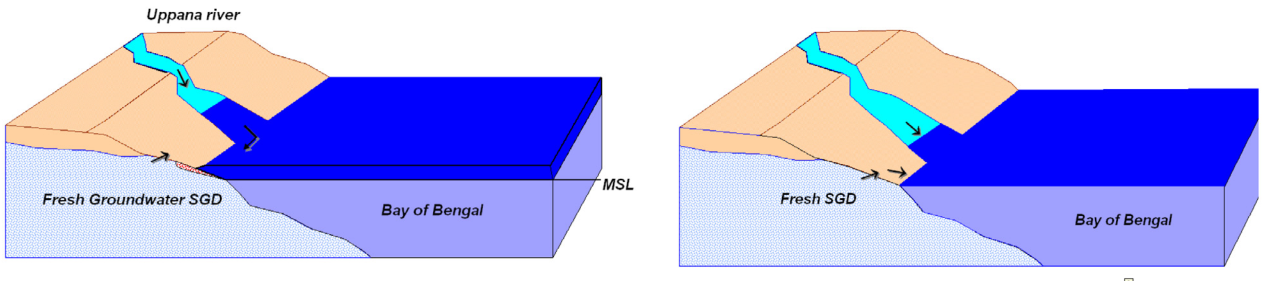
4.5. Quantification

Studies have focused on methods to quantify SGD, either through point measurements (e.g., Bokuniewicz, 1980; Michael et al., 2003), hydrologic models (e.g., Smith and Zawadzki, 2003; Destouni and Prieto, 2003), or by using geochemical tracers that provide a spatially integrated estimate of total flux (e.g., Moore, 1996; Cable et al., 1996; Gramling et al., 2003). There are other methods for SGD estimation, by calculation, modeling of water balance, direct measurement by seepage meter and using natural or artificial tracers (Burnett et al., 2001a; Burnett and Dulaiova, 2006; Moore, 1996; Cable et al., 1996;



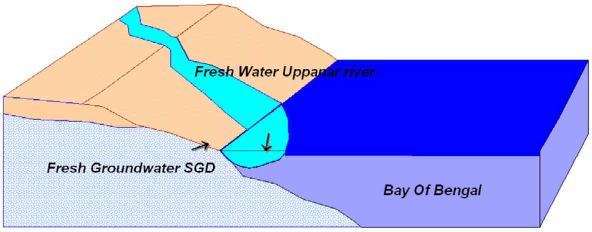
(a) High tide condition

(b) High Tide retreating (Process 1)



(c) High tide retreating (Process 2)

(d) Low tide condition (Process 3)



(e) Mixing of the fresh surface water with the saline water in the low tide condition (Process 4)

Fig. 11. A schematic conceptualization of the process between HT and LT in the study area (not to scale). (a) High tide condition. (b) High Tide retreating (Process 1). (c) High tide retreating (Process 2). (d) Low tide condition (Process 3). (e) Mixing of the fresh surface water with the saline water in the low tide condition (Process 4).

Table 2
Sum up of the processes inferred from the above study.

S.No	Time IST	Process
1	2–3	SGD of Saline groundwater
2.	4–7	SGD of Fresh groundwater
3.	8–9	Influence of saline surface water from Uppanar river
4.	9–11	Mixing of fresh Uppanar River water with sea water
5.	14–15	SGD of Saline groundwater
6.	15–16	SGD of Fresh groundwater
7.	16–17	Influence of saline surface water from Uppanar river
8.	18–22	Mixing of fresh Uppanar River water with sea water

Gramling et al., 2003). Seepage meters have been used to quantify groundwater discharge below the water surface for many years (Lee, 1997).

The direct seepage water measurements were made 7 times during the period of observation. The EC of the water were observed before and after the measurement period. It reflects the trend of normal surface water EC with minor variation. But it is interesting to note the variation in the quantity of the water released from the aquifer collected as SGD (Table 3). So, while the volume of water discharged as SGD may be small relative to surface discharge, the input of dissolved solids from SGD can surpass that of surface water inputs. For example, SGD often represents a major source of nutrients in estuaries and embayments (Krest et al., 2000; Charette et al., 2001). The amount of water was noted to be higher during the low tide condition and the rate of SGD was also higher. Moreover, the SGD at 16–17 h shows the lowest rate of SGD (i.e. 37–24 cm/day). This also reveals the fact that the EC of the water present in the seepage meter after the experiment has been reduced from 44.76 to 42.86 ms/cm, indicating the fresh water discharge and the quantity of water released is lesser due to the fact that the fresh water flow in the saline medium is apprehended due to density of sea water.

Table 3
Summary of the seepage meter measurements during the study period.

S.NO	Time (Indian Standard Time IST)	Initial volume SGD (L)	Before EC (ms/cm)	SGD final Volume (L)	After EC (ms/cm)	SGD Volume (cm/day)
1.	7–8	250	43.81	2030	44.31	79.16
2.	12–13	250	41.80	1005	42.26	39.19
3.	14–15	250	43.63	1030	44.43	40.16
4.	16–17	250	44.76	955	42.86	37.24
5.	18–19	250	44.96	2010	44.47	78.38
6.	20–21	250	44.46	1580	44.52	61.61
7.	22–23	250	43.14	1005	40.60	39.19

5. Conclusion

The study broadly brings out the major geochemical process occurring in this coastal environment zone. The study further reveals the fact that the water level measurements fall in line with the calculated tidal value and further the deviation during the low tide is inferred mainly due to the fresh surface water inflow. The Radon measurements indicate the difference in fresh water-groundwater interface in this region. The EC variation has been studied throughout the tidal cycle period and compared with parameters measured in the field like Radon, pH and Water levels. The relationship of EC and Radon revealed four possible different conditions and process that may exist and is used to determine the SGD status. This study identified four cyclic processes that are dominant in the region as saline SGD, Fresh water SGD, Saline surface water interference and the mixing of fresh Uppanar river with sea. The seepage studies conducted at the specific intervals also reveal the impact of the above said process and the rate of discharge was found to be lesser during the fresh water SGD. The maximum rate of discharge was observed during the saline water discharge period. Further studies are needed focusing on different season of the same area that will give insight into the holistic processes governing this coastal fresh-saline surface water interface. It helps to exactly delineate the influence of SGD on the coastal productivity, which are depleting in the recent years.

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