Eco. Env. & Cons. 27 (February Suppl. Issue) : 2021; pp. (S88-S93)
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ISSN 0971–765X

Environmental implications of the soil settlement in Munroe Island, Kollam, Kerala, India

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(Received 11 July, 2020; Accepted 10 August, 2020)

ABSTRACT

The Munroe island in the Ashtamudi estuary of Kollam district in Kerala is facing the threat of sinking and soil settlement. The main objective of this study is to find out the reasons for the soil settlement in the island. The soil samples were collected from different parts of the island and the organic carbon content in the soil was estimated. An attempt was also made to study the soil breathing in the island. Based on these, the hypothesis that the main reason for soil settling is the near surface oxidation of carbon in the organic soil of the deltaic island was tested and proved correct. The higher concentrations of carbon dioxide emission from the soil were mostly from the locations affected by soil settlement.

Key words: *Soil settlement, Deltaic island, Soil breathing, Organic carbon.*

Introduction

Munroe island or Munrothuruthu is located at the confluence of Ashtamudi Lake and the Kallada River, in Kollam district, Kerala, South India. The island, accessible by road, rail and inland water navigation, is about 25 kilometers from Kollam by road. As per the 2011 census, the administrative village of Munrothuruthu (which includes nearby small villages as well) has a total population of 9599.

The island is about 13.4 square kilometers in area. The villagers depended on traditional industries like coir for livelihood. This tiny island in the southern state of Kerala is being submerged due to the rising sea levels and erosion. Also it is under the growing threat of soil settlement.

The area surrounding the Munroe island is a part of Ashtamudi estuary which forms an important geological segment of the South Indian peninsular shield; both crystalline rocks and tertiary sediments are major components of the estuary (Kurian *et al.*, 2001). Sedimentary rocks belonging to the Warkalli and Quilon formation constitute the dominant lithology of the main island and nearby area. The quaternary sediments are of marine and fluvial origin and are seen in the low lying areas, mostly by the side of Kallada River and to the western part in proximity with the Ashtamudi Lake and the numerous tidally active creeks. The lithological association and thickness of quaternary strata in the area are as reported by Padmalal *et al.* (2013).

The Munrothuruthu core is composed of a silt and clay dominated sequence inter layered by sand. The sand lies over thick mud-clay inter-layered sequence with low content of sand fraction and fairly high contents of silt and clay fractions (Mohan *et al.*, 2014).

The Sacramento-San Joaquin River Delta of California once was a great tidal freshwater marsh blanketed by peat and peaty alluvium. Beginning in the late 1800s, levees were built along the stream channels, and the land thus protected from flooding was drained, cleared, and planted. Exposing this partially decayed organic matter to oxygen caused (aerobic) decomposition, the process whereby the metabolic activity of microbial organisms converts organic carbon solids to carbon dioxide and other gases. As peat decomposed, new surfaces were exposed, resulting in further decomposition and land subsidence (Ingebritsen and Ikehara, 1991).

Hatala *et al*. (2012) found that the grazed degraded peat land emitted 175 to 299 g-C m^{-2} yr^{-1} as CO_2 and 3.3 g-C m^{-2} yr^{-1} as CH_4, while the rice paddy sequestered 84 to 283 g-C m^{-2} yr^{-1} of CO_2 from the atmosphere and released 2.5 to 6.6 g-C m^{-2} yr^{-1} as CH_4. The rice paddy evaporated 45 to 95% more water than the grazed degraded peat land. Annual photosynthesis was similar between sites, but flooding at the rice paddy inhibited ecosystem respiration, making it a net CO_2 sink. The rice paddy had reduced rates of soil subsidence due to oxidation compared with the drained peat land, but did not completely reverse subsidence.

Brown and Nicholls (2015) documented and analyzed the rates of subsidence and related these findings to human influences. Rates differed by locality, methodology and period of measurement. Continued development might have caused rates to locally increase (e.g. due to groundwater abstraction and or drainage). Improved monitoring was required over a wider area, to determine long-term trends, particularly as short-term records were highly variable.

Studies and ground reports (Dandekar and Thakkar, 2014) are warning that most of the deltas around the world are shrinking due to catastrophic sea level rise. According to several independent scientific studies, the major reason behind this effective sea level rise is delta subsidence. The direct impacts of delta subsidence and effective sea level rise abetted by dams include inundation of coastal areas, saltwater intrusion into coastal aquifers, increased rates of coastal erosion, an increased exposure to storm surges, etc, in addition to the threat to food security, livelihood security, water security to millions and huge loss of biodiversity (Dandekar and Thakkar, 2014).

The objective of this study is to find out the reasons of the settlement of soil in this deltaic island and the main hypothesis of this study is that near surface oxidation of peat soil of the island is one of the reasons for the settlement processes in the area. Under water logged conditions, the deltaic soil might have accumulated anaerobic organic carbon compared to its decomposition in the drained situations. Drainage for agriculture might have led to aerobic conditions in the island. Under aerobic conditions, microbial activity oxidizes the carbon in the peat soil quite rapidly. Microbes like bacteria consume organic carbon and the metabolic activity in the bacteria converts organic carbon to carbon dioxide. In other parts of the world, under similar situations, minimal subsidence has been identified in un-reclaimed areas.

Materials and Methods

Samples of soils were collected and soil organic carbon content was studied for different areas. An attempt was made to study the soil breathing of carbon dioxide also. Based on these, the hypothesis on the subsidence was tested. For measuring soil organic carbon CHNS analyzer in Sophisticated Analytical Instrument Facility, IIT Bombay was used. Determination of C, H, and N was done using a "2400 CHN Elemental Analyzer" by Perkin Elmer.

The CHNS (O) Analyzer find utility in determining the percentages of carbon, hydrogen, nitrogen, sulphur and oxygen of organic compounds, based on the principle of "Dumas method" which involves the complete and instantaneous oxidation of the sample by "flash combustion". The combustion products are separated by a chromatographic column and detected by the thermal conductivity detector (T.C.D.), which gives an output signal proportional to the concentration of the individual components of the mixture.

To measure the rate of oxidation of carbon by soil breathing, soda lime test (Simmons, 2009) was used. One of the most common methods for measuring soil respiration is the soda-lime method; this method is able to remove water vapor from the air in a reversible reaction. The water produced by this reaction remains temporarily adsorbed to the soda lime. Drying oven, analytical balance (0.001 g range), soil thermometers and digital thermometers were the equipments which were used.

The materials used in the field experiment were soda lime, granular glass jars (15 mL), spatulas desiccator, plastic ziploc sandwich bags and aluminum weighing boat chambers (500 mL).

First step is the preparation of soda lime. Label each glass jar with a piece of tape and permanent marker. Add approximately 8 grams of soda lime to each jar (Fig.1). Place the jars with soda lime in an oven at 105 °C for at least 24 hours to evaporate the water from the granules. Remove jars from the oven and place in a desiccator to cool for 2 to 5 minutes. Remove jars from desiccators one at a time, weigh to the nearest tenth-milligram (0.0001g) and cover immediately. Record this as the initial dry mass that includes the soda lime and jar.

Select the sampling locations. Clean and level the soil surface. Place a chamber upside down on a relatively flat area of the floor.

The rim of the chamber must make an air tight seal with the soil surface, so carefully remove twigs, small rocks that are in the way without disturbing the leaves and soil surface under the chamber. Leave the chamber loose on the surface. Obtain a jar containing soda lime. Remove the cap and place the jar under the chamber resting on the soil. Slowly and carefully push down on and rotate the chamber to force the edges about 0.5 to 1 cm into the floor (Fig. 1).

Fig. 1. Preparation of samples and placing of sample on the ground

Place a weight on the chamber (like a medium-sized rock or branch) to maintain pressure and keep it from getting blown away (Fig. 1). Record the number of the soda lime jar and the number and location of the chamber. Repeat these steps for each of the chambers at each site.

At one of the sites, place an open jar of soda lime in an upright chamber and seal the chamber with a lid. This will serve as a blank to document the amount of CO_2 absorbed from the air in the chamber and during the opening and closing of the jars. Let all chambers be incubated for 24 to 48 hours.

Return to the field to retrieve the chambers. Remove the chamber and cover the soda lime jar immediately. Measure and record the date, time, air temperature, and soil water content. Measure air temperature at 0.5 m. Soil water content varies significantly, so take at least four soil samples from each sampling location. Back at the lab, place all the jars uncovered in the oven at 105 °C. Dry for at least 24 hours to evaporate water from the soda lime. Remove the dry soda lime from the oven and place in a desiccator to cool for 5 minutes. Remove jars one at a time from the desiccator, weigh to the nearest tenth-milligram. Record this as the post-incubation dry mass (which includes the mass of the jar).

Drying the soda lime after the incubation drives off the water that was absorbed and also the water that was produced by CO_2 absorption. In order to compensate for this underestimation, multiply it by a correction factor (1.69). Find out initial dry mass of soda lime and final dry mass of soda lime. Then mass change of blank is calculated. From these 3 values, mass change of sample is calculated. Finally CO_2 absorbed by soda lime is obtained by introducing the factor 1.69. Then soil respiration in (mg CO_2 / m^2 / d) can be calculated.

Results and Discussion

Results of CHNS Analysis include percentage of carbon, hydrogen, nitrogen, sulphur in the soil samples which were collected from 15 locations of the soil settlement affected areas of Munroe island. The organic carbon content in percentage are marked in the map of Munroe island and it is given in Fig. 2.

Percentage of organic carbon in the 15 locations are given in the form of a histogram (Fig. 3)

Highest value of carbon is 13.054 % and lowest value is 0.371. The average value of carbon is 3.10%. In Sacramento-San Joaquin Delta, the organic carbon content varies between 0.14 and 2.1 % (Wakeham and Canuel, 2016). The carbon content of the study area has an average value of 3.10%. In the case of Munroe island, the carbon content varies from 0.371% to 13.054%. This shows that the soils of Munroe island are more carbonaceous than that in California.

The highest content of organic carbon (13.054%) is present in the soil samples collected from the Pattamthuruthu East area. The minimum content of organic carbon (0.371%) is present in the soil of Pattamthuruthu-Pooppani region. Soil respiration data of 28 samples as obtained by the method discussed above is presented in Table 1.

Soil breathing test was mainly conducted at 26 locations in the study area. The location map of the

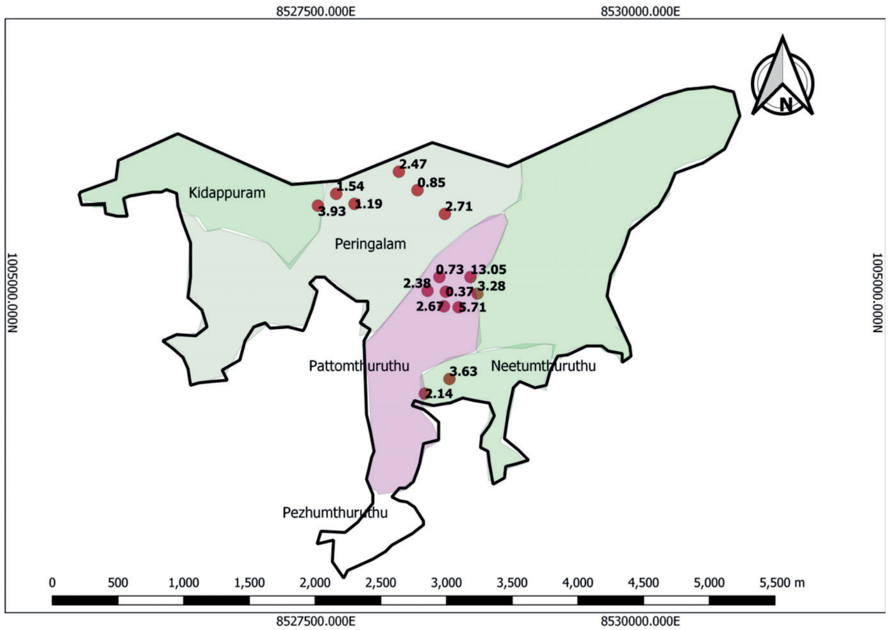

Fig. 2. Map showing values organic carbon content in the area

Table 1. Results of Soil Respiration Experiment at Munroe island

Sl. No.	Lattitude Longitude	Locality	Water Content (%)	Temperature (^{0}C)	Soil Breathing ($gCO_2/m_2/day$)
1	8.997,76.604	Kidapparam 1	30.28	34	5.883759
2	8.9919,76.609	Kidapparam 2	55.49	33	4.561314
3	8.997,76.611	Kandrankani 1	62.91	32	4.707007
4	9.00015,76.609	Pattamthuruthu 1	54.87	32	12.260633
BLANK 1	9.0007,76.609	Pattamthuruthu 2	-	32	-
5	8.991,76.611	Pattamthuruthu 3	48.11	32.5	5.805309
6	8.9898,76.6105	Pattamthuruthu 4	27.32	32	12.30546
7	8.9837,76.6108	Pattamthuruthu 5	27.56	32	5.4018513
8	8.9843,76.608	Pattamthuruthu 6	36.49	32	9.649365
9	8.9851,76.613	Panchayath office	5	32	4.76304
10	8.99714,76.605459	Kidapparam 3	45.25	33	26.984
11	8.997936,76.610865	Kandrankani 2	15	35	20.93165
12	8.997579,76.611176	Kandrankani 3	44.13	35	3.312077
13	8.990719,76.6122165	Pattamthuruthu 7	14.59	35	5.31277
14	8.991905,76.612303	Pattamthuruthu 8	11.95	35	5.68265
15	8.991827,76.611624	Pattamthuruthu 9	48.97	35	7.46478
16	8.989986,76.613747	Pattamthuruthu 10	120	33	22.22622
BLANK 2	8.989986,76.614183	Pattamthuruthu 11	-	33	-
17	8.997914,76.605459	Kidapparam 4	-	33	5.76671
18	8.996399,76.612787	Kandrankani 4	28.11	35	6.4728
19	8.996399,76.61278	Kandrankani 5	24.52	35	5.59858
20	8.996437,76.612704	Kandrankani 6	18.3	35	7.80103
21	8.990039,76.612629	Pattamthuruthu 12	22.14	33	4.87564
22	8.992058,76.614532	Pattamthuruthu 13	42.99	33	7.96916
23	8.990995,76.614712	Pattamthuruthu 14	26.34	33	33.05352
24	8.997881,76.602972	Kidapparam 5	19.09	33	6.775467
25	8.997618,76.603182	Kidapparam 6	58.22	33	8.97791
26	8.997048,76.606484	Kandrankani 7	17.62	33	3.44657

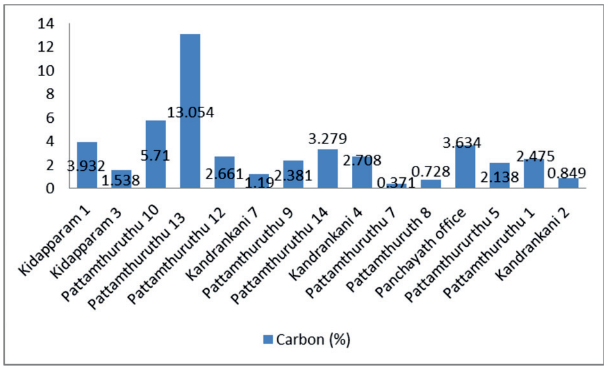

Fig. 3. Histogram showing organic carbon of soils in the selected locations

study area is shown in Fig. 5. Carbon dioxide emission in Munroe Island varies from 3.312 g/m^2/day at Kandrankani to 33.05 g /m^2/day at Pattamthuruthu East area. The lowest value of soil breathing is at the place Kandrankani and highest value is at the place Pattamthuruthu East (Fig. 4).

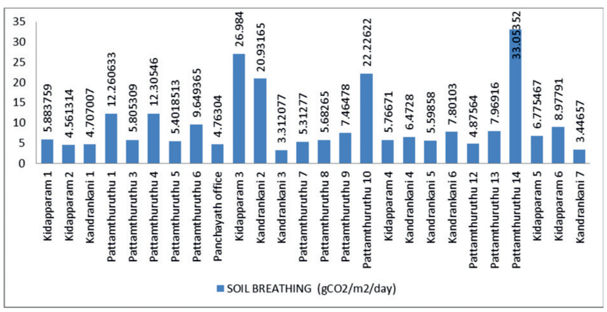

Fig. 4. Soil breathing in the study area in g CO_2/m^2/day.

Panchayath office area which is not affected by soil settling has a lower value of 4.76 g CO_2/m^2/day. An average value of 9.53 g CO_2/m^2/day is obtained from the study area.

From Fig. 5, it can be seen that most of the higher values of CO_2 emission from the soil like 33.05, 26.98, 22.22, 20.93, 12.30, 8.97 etc are all falling in the affected areas. This shows that soil settling in this area is part of natural soil degradation by near surface oxidation of carbon in the carbonaceous soil of the island.

Fig. 6 shows that soil breathing is maximum at optimum moisture content. It decreases as water content increases or decreases. This confirms the idea that soil breathing rate is low at comparatively less and high moisture conditions in the soil.

Soil breathing becomes high at an optimum temperature. It goes on decreasing as temperature increases or decreases (Fig.7). This result also is in agreement with the established fact about optimum

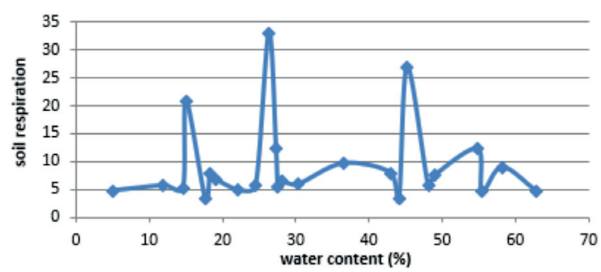

Fig. 6. Variation of Soil breathing with moisture

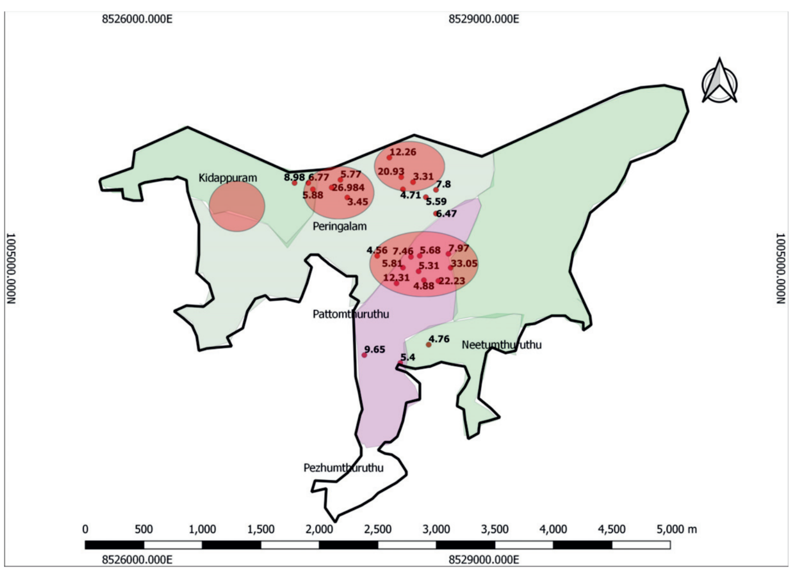

Fig. 5. Map showing the locations of soil respiration tests done in the area. The circles show the area affected by soil settling

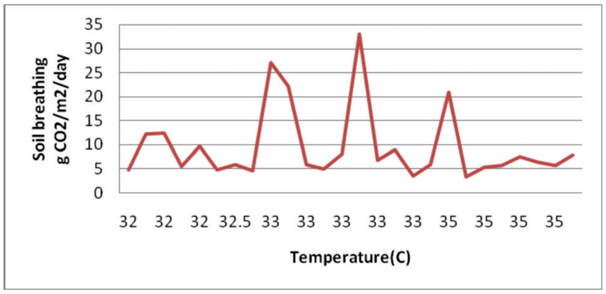

Fig. 7. Variation of soil breathing with soil temperature

temperature of soil breathing.

Fig. 8 shows that there exists no linear relationship between carbon content and soil breathing. Normally one would expect a proportional increase in the amount of CO_2 releases from the soil with the organic carbon content. But, since other factors like temperature, moisture content and nitrogen content of soil randomly change soil breathing rates, CO_2 also varies randomly.

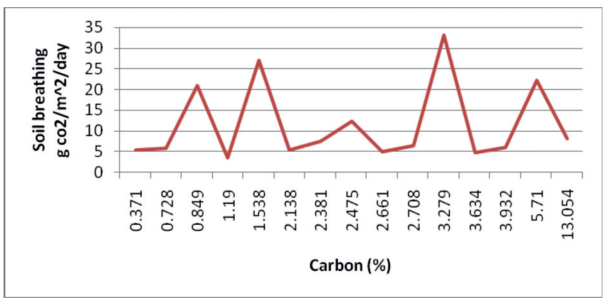

Fig. 8. Variation of soil breathing with organic carbon

Conclusion

When comparing the values of soil breathing in Munroe island with other areas, it can be seen that soil breathing is very high in Munroe island. Soil breathing values are very high in the areas affected by soil settlement like Nenmeni, Pattamthuruth, Kandrankani etc. So, it can be inferred that one of the main reasons for soil settlement in Munroe island is soil breathing. An average value of soil respiration of 9.53 g $CO_2/m^2/day$ is obtained in Munroe island, which is very high compared to other deltas. The Sacramento – San Joaquin Delta which faces similar subsidence issue as Munroe island has an average value of 8g-C m^{-2} d^{-1} only.

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