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Analysis of Foraminifera Test Chemistry and Sediment Characteristics from Munambam to Kuzhupilly beach, Ernakulam: Implications on the Environmental Anomalies

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ABSTRACT

Thirty sediment samples collected from the Cochin shoreline between Munambam and Kuzhupilly beach addressing the distribution and shell chemistry of foraminifera, sediment characteristics, and the implications for the environmental anomalies is the focus of the current study. The sole recorded foraminifera species from the investigated area is *Ammonia beccarii.* Estimation of Calcium carbonate, sand, silt and clay was cautiously done to analyse the textural characteristics. The calcium carbonate proportion can be attributed to the shattered molluscan shell along with the *Ammonia beccarii* count. Ilmenite, Monazite, Zircon, Pyroxene, Chlorite, Hornblende, Garnet, Staurolite are the significant heavy minerals identified from the area of study. The results for sample number MB19 exhibited anomalies on chemical composition for both foraminifera and heavy mineral grains. MB19 have dominantly dark coloured sediments with a comparatively higher silt percentage, presence of Bromium (Br) mineral in the sediment grains. EDS analysis in *Ammonia beccarii* traced Thulium (Tm), a rarely occurring rare earth element in the test at location MB19. It has been identified that stone revetments installed to defend the coastal erosion undergo weathering, contribute sediments to the beach and influences on the local ecosystem.

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Supplemental data for this article can be accessed online at our website

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1. Introduction

The coastal zone is the area of transition where the sea and land meet, and it is impacted by both marine and terrestrial factors (NCESS, 2023). Furthermore, the coastal zone and adjacent niche are the primary targets of all environmental changes. The top portion of the beach experiences wind-driven coastal sediment transport, but the nearshore region and swash zone experience continuous sediment transport due to oceanographic factors such tides, currents, and waves. This process continues all the way to the continental shelf. Very low oxygen concentrations (<0.2 mg/L) are found in the water column 150 m below the surface along the southwest coast of India (Naqvi, 1987).

Textural analysis in an area decodes the dynamics and features of sediments, and it is a crucial field of study that frequently yields insightful data on the coastal environment (Pradhan et al., 2020). Microfossils are an essential proxy for reconstructing diverse ecosystem. The distribution and abundance of foraminifera are influenced by sedimentological, biological, and physicochemical characteristics of the substrate (Armstrong and Brasier, 2013). Foraminifera are widely used in higher resolution biostratigraphy, stratigraphic correlation, oil exploration, and environmental paleoenvironmental interpretations (Adarsh et al., 2012).

The species diversity of foraminifera is influenced by salinity and open ocean conditions (Gandhi et al., 2017). The growth and shell chemistry of foraminifera is impacted by the hydro as well as the sediment chemistry. The use of foraminifera differs throughout species. Also foraminifera are susceptible to different hydrographic fluctuations like temperature (*Bulimina marginata*), and dissolved oxygen content (*Fursenkoina complanata*) as studied by Nisha and Singh (2012). Heavy minerals are useful in explaining diagenesis and serve as proxies for understanding paleocurrent, sediment correlation, and sediment provenance (Mange and Maurer, 2012). Heavy minerals are the detrital rock components with density higher than 2.90 g/cm^3 and are opaque while observed under a microscope in transmitted light (Eduardo and Sergio 2019).

Climate, source rock, weathering of the source rock, concentration, sediment transport, specific gravity of minerals, deposition, hardness, and chemical characteristics of sediments are the factors that cause heavy mineral deposits (Haldar, 2018). Micro-textural analysis of heavy mineral grains provided insights into both mechanical and chemical erosions affecting grain surfaces (Ali and Dhanamjayarao, 2021). The combination of textural analysis, heavy mineral characterization, and micropaleontological research in the coastal zone might provide valuable insights into the environmental health and regional characteristics. The goal of the current investigation is to understand and address the environmental anomalies found by examining the coastal dynamics and sediment characteristics of the Ernakulam coast from Munambam to Kuzhupilly beach.

2. Study Area

Ernakulam is a district in Kerala state and located to the central part of the state. The district's 46 km of seashore are bordered to the north by the Thrissur coast, to the east by the Periyar-Muvattupuzha Rolling Plain, to the south by the Alappuzha Coast, and to the west by the Arabian Sea (NCESS, 2023). The selected field area's grid encompassed around nine kilometers, encompassing the northern Munambam stretch that extended to Cherai and the southern Kuzhupilly beach on the Ernakulam coast (Fig.1). The longest river in Kerala, Periyar, also referred to as the "lifeline of Kerala"—drains into the Arabian Sea close to Munambam, one of the main tourist attractions in the Ernakulam area is Cherai Beach, whereas Kuzhupilly Beach is an emerging tourist location. Munambam, Cherai and Kuzhupilly beaches have distinct sedimentological and geological features.

3. Materials and Methods

3.1 Field work

Sediment samples were gathered in the field from the Munambam, Cherai, and Kuzhupilly beaches along the Cochin coast in the Kerala state, with the intention of analyzing the foraminifera distribution and comprehending the properties of the sediment. The geographic coordinates were determined with LOCUS GPS software. Thirty samples of surface sediment were obtained, and observations were made. Samples MB1 through MB12 were taken from the beach at Munambam. The samples from Cherai beach (MB13 to MB20) and Kuzhupilly beach (MB20 to MB30) are located to the South of Munambam beach. With the exception of three samples (MB4, MB5, and MB7), the sample collection distances were roughly 300 meters apart.

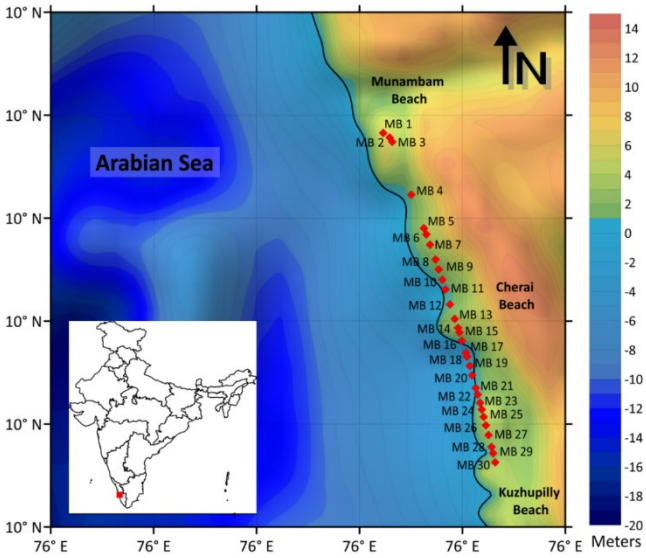

Fig.1. Study area map depicting the sampling locations

3.2 Estimation of Sedimentological Parameters

Sedimentological studies in present work includes $CaCO_3$ estimation, heavy mineral studies, sand, silt and clay analysis. Since the majority of the sediment sample consisted of coarser sand the traditional sieving and pipette (settling tube method) technique described by Krumbein and Pettijohn (1938) was used for the determination of sand, silt, and clay percentage. To remove moisture, sediment samples were oven-dried at 50°C. Subsequently, a 20 g portion of each sample was wet-sieved using a 230 ASTM mesh sieve with 1000 ml of water to separate particles based on size. The analysis of carbonate content is essential, as it serves as an indicator of calcareous organisms within marine and coastal sediments. Rapid titration (Piper, 1947) was the method used in this investigation to estimate the amount of calcium carbonate. Five grams of sediment samples were processed for $CaCO_3$ measurement for the present analysis.

The bromoform gravity separation method is utilized to determine the presence of heavy minerals from other sediments. Bromoform is employed as a density separator in this gravity separation technique. A stopcock was used to separate the heavy minerals, which were then gathered using filter paper. To identify the heavy minerals, these collected particles were dried in an oven after being cleaned with distilled water.

3.3 Micro paleontological studies

A high-resolution stereo microscope is necessary for the separation of the microfossils from the dried residue. Based on the classification suggested by Lobleich and Tappan (1988) the foraminifera identification has been placed in the Taxonomic chart. In this work, microfossils are extracted from sediment samples by means of appropriate washing, drying, wet-sieving, picking, and mounting of foraminifera. The sediments collected from the field are taken in to the laboratory for further processing and to separate the microfossils. The oven dried sediment samples are weighted and taken for micropaleontological studies. We used ASTM 230 to remove silt and clay and picked the microfossils with the help of fine-hair brush. Individual specimens of foraminifera are collected and moved to picking slides for SEM and EDS analysis.

3.4 SEM and EDS analysis

SEM analysis was performed using VSPE G4 in variable pressure mode at 100 kV induced current (EHT) and a working distance (WD) of 10.63 mm. One method for estimating quantitative and semi-quantitative elemental analysis is Energy Dispersive X-ray Spectroscopy (EDS). EDS makes it possible to identify both significant components that make up more than 10% of the weight and minor components that range in weight from 1% to 10% (Nasrazadani and Hassani, 2016). SEM and EDS analyses were performed after ultrasonic washing of heavy mineral grains and the foraminiferal test. Sediments were dried at a temperature lower than 50^0 degrees Celsius. The samples were not coated and had elemental composition analysis performed on them.

3.5 Cluster analysis

In addition to classifying the environment, cluster analysis is utilized to identify regional similarities and contrasts. Putting comparable data together and dissimilar data apart is the process of clustering and has been widely used for a variety of matrices, including soils, sediments, and water (Gholami and Srikantaswamy 2009, Bhuiyan et al., 2010, Lu et al., 2010). PAST (Paleontological Statistics) software version 4.3 is utilized to plot the dendrogram for this experiment, which employs Ward's Hierarchical Cluster Analytic (HCA) approach.

4. Results and Discussion

4.1 Environmental anomalies observed from the study area

The world's present concerns include pollution of the air, water, and marine environment caused by numerous anthropogenic activities (Prasanthan and Vasudevan, 2000). A number of organizations, such as the Kerala University for Fisheries and Ocean Science (KUFOS), Cochin University of Science and Technology (CUSAT), and Kerala State Pollution Control Board (KSPCB), routinely investigate and track the pollution factors along the Ernakulam coast. An observed sea-level rise of approximately 1.8 mm/year along the Ernakulam coast, coupled with localized patterns of coastal accretion and erosion, has been documented at multiple sites, alongside the presence of various pollution indicators (Sreekesh et al., 2018). From Munambam to Kuzhupilly beach, stone revetments have been erected to prevent soil erosion. However, the research did identify the following anomalies from the area of study.

- Stone revetments completely enclose the beach in certain places. In some places where stone revetments are near to the sea, the sediments have a dark color, and MB19 is one of a kind.
- The sediments contain a lot of broken molluscan shells and very few completely preserved molluscs.
- Angular grains predominate on the beach close to stone revetments, but moving towards the sea the percentage of angular fragments are decreasing.
- Only one location, MB19 has a higher percentage of silt than any other; the percentages of silt at all other locations are relatively low.
- At location MB19, there were more angular grains than polished or rounded ones. The zircon grains also have an angular appearance at this location.
- Abnormal and wildly varying composition of heavy mineral and microfossil EDS data at location MB 19.

4.2 Granulometric studies

Sand, silt, and clay are examined as sedimentological parameters in the current study, along with the estimation of calcium carbonate and heavy mineral analysis (Table.1). Sand, silt, and clay analysis is conducted to assess the granulometric measurements. The area under investigation has an average sand percentage of 98.652%; sample number MB 3 has the highest sand percentage of 99.213%, while sample number MB 19 has the lowest sand percentage of 94.427%. The average silt percentage in the sample is 1.101%, with a maximum silt percentage of 5.268% from sample number MB 19 and a minimum of 0.557% from sample number MB 2.

The average clay percentage in the sample is 0.246%, with a maximum clay percentage of 0.345% from sample number MB 23 and a minimum of 0.115% from sample number MB 10. The grading on the study area as per the analysis falls under two categories fine grade sand and coarse-grained sand. In the present study the $CaCO_3$ composition is varying from 2.99 to 9.99% with an average value of 6.72%. Based on the different environmental parameters the $CaCO_3$ composition is shifting from Munambam to Kuzhupilly. In the study $CaCO_3$ percentage of Munambam beach is 2.99 to 8.98 percent. The graph shows the percentage of calcium carbonate is varying lightly in the three beaches. In Cherai beach, the amount of $CaCO_3$ is varying in between 5.02 to 9.82 %. The KuzhupiIly beach recorded $CaCO_3$ percentage from 7.49 to 9.99%. $CaCO_3$ ranges from 7 to 96% in the sediment samples taken from Ernakulam's continental shelf (Mohan and Rajamanickam.,1994). The Cochin backwaters' surface sediment content ranges from 0.5% to 5.5% (Gandhi et al., 2017). Nonetheless, the current study's $CaCO_3$ values are lower than those of the Ernakulam continental shelf and higher than those of the Cochin backwaters. The maximum population size of calcareous microfossils is favored by an increase in $CaCO_3$. The population size of the foraminifera that were retrieved for the study does not correspond with the $CaCO_3$ values. Heavy minerals are separated and identified using the gravitational method with the aid of bromoform. The important heavy minerals identified from the study area are Ilmenite, Monazite, Zircon, Pyroxene, Chlorite, Hornblende, Garnet, Staurolite.

The elemental composition of the identified heavy minerals is ascertained by EDS analysis. C, O, Na, Mg, Al, Si, Cl, K, Ti, Ca, Fe, Zn, and Zr are the elements that are examined for each of the heavy minerals using EDS. Although bromine (Br) is identified as the dominant element in one of the heavy mineral grains in MB19, it could not be identified because of the complex chemical composition displayed. The Munambam and Kuzhupilly regions have comparatively less zircon than Cherai beach. Usually, pyroxene is a rock forming mineral. Though, some varieties have a higher specific gravity and considered as heavy minerals. The predominant texture found in the sediment samples taken from the study area is found to be sand. With the exception of sample MB19 (Fig. 2), 29 of the 30 samples that were taken from the study area had more than 97% sand. While the majority of the sediments from Cherai and Kuzhupilly beaches have a higher range of $CaCO_3$ percentage, the majority of samples from Munambam beach have a lower concentration of $CaCO_3$ (Fig. 3). The percentage of $CaCO_3$ depends not only on the population of foraminifera (*Ammonia beccarii*), but also on the large number of broken molluscan shells that are a result of the region's high turbidity and wave action.

A plot of sand versus silt (Fig. 4) is used to determine which zones show anomalies. Sample number MB19 is identified and shown in the plot as anomalous. With the exception of sample MB19, the percentage of silt in all the other sediments is relatively low.

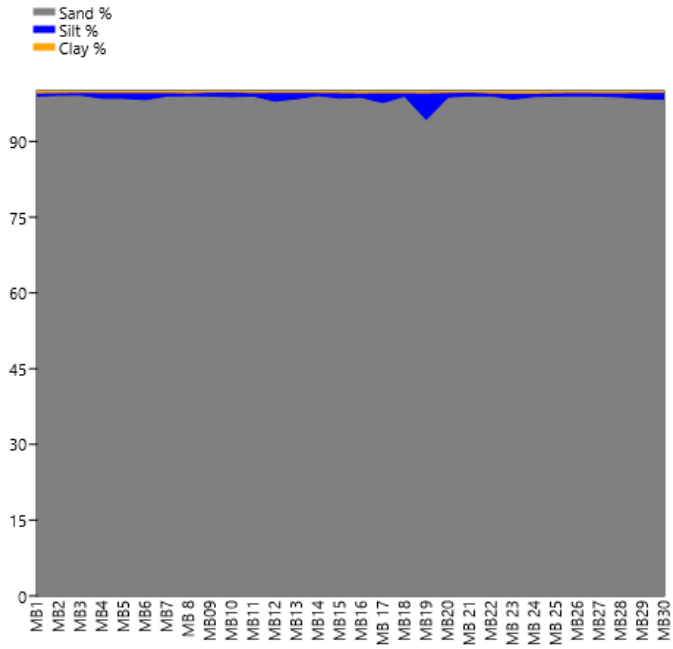

Fig.2. Granulometric measurements of sediments (Y axis-Percentage and X axis-Sample number)

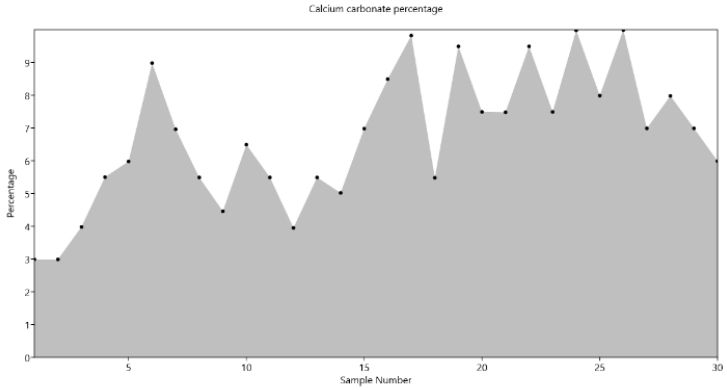

Fig.3. Area graph showing CaCO3 in sediments

Table.1. Textural analysis and foraminifera population from the study area

Sl No.	Sample number	Sand %	Silt %	Clay %	Population of Foraminifera	$CaCO_3$ %	Nature of sediments
1	MB1	99.025	0.665	0.31	93	2.99	Coarse grained Sand
2	MB2	99.188	0.557	0.255	10	2.99	Fine grained sand
3	MB3	99.213	0.612	0.175	30	3.98	Coarse grained sand
4	MB4	98.624	1.136	0.24	200	5.5	Fine grained sand
5	MB5	98.583	1.181	0.235	200	5.98	Fine grained sand
6	MB6	98.317	1.443	0.25	280	8.98	Fine grained sand
7	MB7	99.031	0.749	0.22	200	6.96	Fine grained sand
8	MB 8	99.107	0.577	0.315	150	5.49	Coarse grained sand
9	MB09	99.048	0.787	0.165	80	4.46	Fine grained sand
10	MB10	98.892	0.992	0.115	83	6.49	Fine grained sand
11	MB11	99.065	0.675	0.26	20	5.49	Fine grained sand
12	MB12	98.036	1.764	0.2	50	3.95	Fine grained sand
13	MB13	98.485	1.295	0.22	10	5.49	Fine grained sand
14	MB14	99.125	0.649	0.22	80	5.02	Fine grained sand
15	MB15	98.634	1.105	0.26	80	6.98	Coarse grained sand
16	MB16	98.797	0.903	0.3	200	8.49	Fine grained sand
17	MB 17	97.722	2.033	0.245	60	9.82	Fine grained sand
18	MB18	99.022	0.697	0.28	50	5.48	Fine grained sand
19	MB19	94.427	5.268	0.30	80	9.49	Fine grained sand
20	MB20	98.820	0.954	0.22	120	7.49	Fine grained sand
21	MB 21	99.065	0.79	0.145	130	7.49	Coarse grained sand
22	MB22	99.074	0.626	0.3	100	9.49	Fine grained sand
23	MB 23	98.418	1.237	0.345	110	7.49	Fine grained sand
24	MB 24	98.927	0.732	0.34	50	9.99	Fine grained sand
25	MB 25	99.034	0.691	0.275	150	7.99	Fine grained sand
26	MB26	99.08	0.695	0.22	100	9.99	Fine grained sand
27	MB27	99.029	0.695	0.275	50	6.99	Coarse grained sand
28	MB28	98.852	0.873	0.27	90	7.98	Fine grained sand
29	MB29	98.533	1.257	0.21	20	6.99	Fine grained sand
30	MB30	98.382	1.393	0.22	10	5.99	Fine grained sand

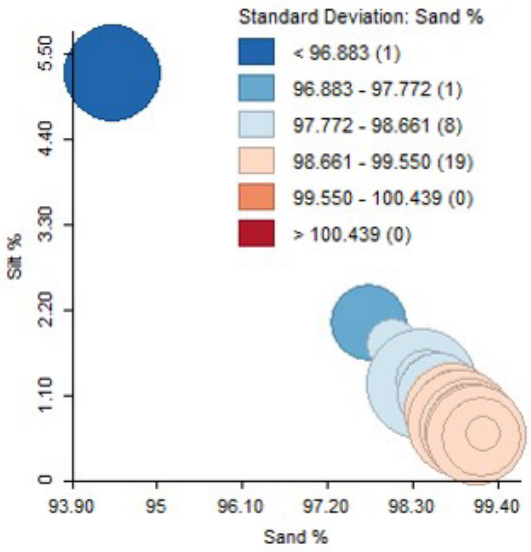

Fig.4. Sand vs silt plot

4.3 Micropaleontological studies

Ammonia beccarii was the only foraminifera species found in the current investigation. *Ammonia beccarii* is a globally occurring foraminifera species and are commonly found in shallow marine habitats, with test sizes of less than 1 mm, and the best substrate for their survival and abundance has been found to be sand (Hussain et al., 2017). *Ammonia beccarii* is an important bioindicator of environmental health because of its ability to thrive in disturbed or contaminated environments. Its resilience to low-oxygen, high-nutrient, and shallow-water environments can indicate the presence of pollution or other environmental stressors. Throughout the thirty-sampling location, a total of 2886 specimens of *Ammonia beccarii* were identified (Fig. 5).

To classify data points into groups or clusters according to their similarities, a variety of mathematical techniques are included in cluster analysis. It's an effective tool for figuring out environmental patterns. The percentage of calcium carbonate, the number of foraminfera in the population, sand, silt, and clay are the parameters used in this analysis for the multivariate cluster analysis. PAST software version 4.3 was utilized to plot dendrograms. Regarding the current study area, three separate biozones were identified (Fig. 6). Samples are contained in biotopes with comparable traits. Under biotope I, the sediment samples MB 6, MB 4, MB 5, MB 7, and MB 16 are categorized. Biotope II includes sample numbers MB 11, MB 13, MB 30, MB 2, MB 3, MB 12, MB 18, MB 27, MB 24, MB 17, and MB 29. Biotype III is represented by sample numbers MB8, MB 25, MB 21MB 9, MB 14, MB 15, MB 19, MB 10, MB 22, MB 26, MB 28, MB 20, MB 1 and MB 23. Every biotype is separated into sub-biotopes and signifies a comparable environmental association. Each of the biotopes I and II has two sub-biotopes. Four sub-biotopes make up Biotope III.

The sample locations in biotope I have more than 98% sand, a higher percentage of calcium carbonate, and a larger population of foraminifera (above 200). This zone has a lower percentage of available oxygen in comparison to other zones, along with higher turbidity and higher energy conditions for deposition. The foraminifera population in the samples from biotope II ranges from 10 to 50, with a sand percentage of more than 99 percent and a variable calcium carbonate percentage. The traits of the third Biotope are moderate. Foraminifera in the zone range in population size from 50 to 200, and their sand and calcium carbonate content vary. MB19 is a lone sub-biotope at biotope III with unusual outcomes.

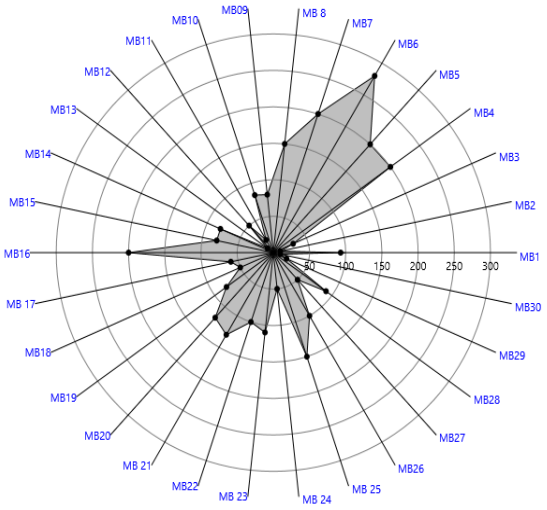

Fig.5. Graph representing the population of *Ammonia beccarii* with respect to sample number

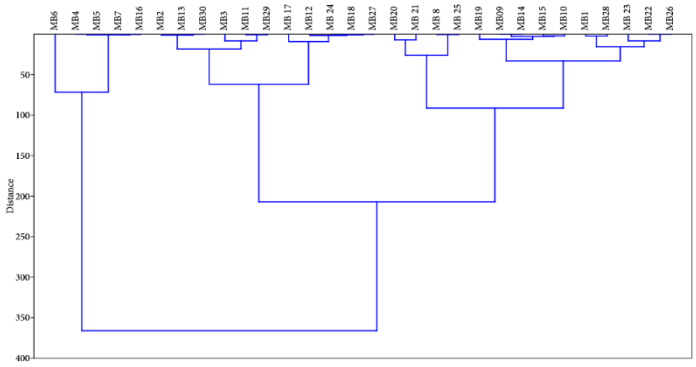

Fig.6. Dendrogram showing different biotypes

The microfauna *Ammonia beccarii* and all the identified heavy mineral grains were subjected to SEM analysis. The *Ammonia beccarii* species recovered from the area are whitish to creamy white in colour (Fig.7A&B). Zircon grains are also illustrated (Fig.7C). Since all the heavy minerals are established and well-studied, for the sake of brevity the detailed characteristics description and SEM images are omitted. EDS analysis of *Ammonia beccarri* and an unidentified grain at location MB19 exhibits anomalous characteristics. The EDS analyses of *Ammonia beccarii* in sample MB19 have the element Thulium (Tm), one of the rarest rare earth elements in the earth crust (Fig.8). At the same location MB19 EDS analysis of heavy mineral grains exhibit Bromine (Br) in considerable concentration (Fig.9). Both these characteristics are believed to be formed from stone revetment dumped near shore to protect the coast from coastal erosion.

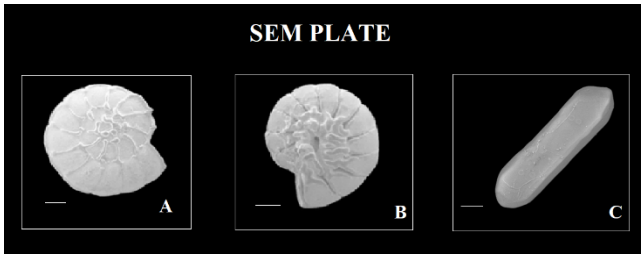

Fig.7. A Dorsal view of *Ammonia beccarii*, B. Ventral view of *Ammonia beccarii*, C. Zircon grain

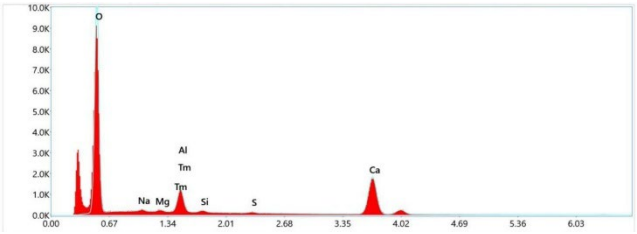

Fig.8. EDS data of *Ammonia beccarii* from MB19 (Y axis-Intensity in a.u., X axis- Energy in KeV)

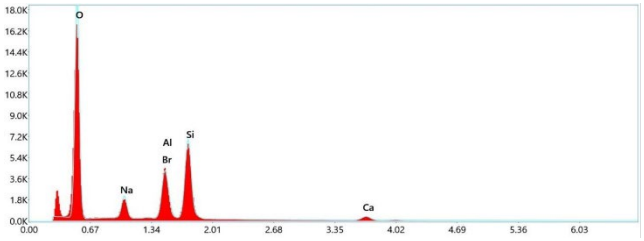

Fig.9. EDS data of unidentified heavy mineral from MB19 (Y axis-Intensity in a.u., X axis- Energy in KeV)

5. Conclusions

Sand is the most dominant substrate in majority of the samples (29 out of 30) which depicts on the higher energy condition of deposition. One sample (MB19) has a comparatively lower sand values with silt exhibit slightly higher values. Variance in calcium carbonate percentage is not because of the count of foraminifera alone. Rather the variation is attributed mainly because of numerous broken molluscan shells found in the sediments. Higher turbidity and dynamicity of the coast is the reason for the presence of numerous broken molluscan shells in the region. The presence of the fractured molluscan shell is caused by the area's extreme turbidity. The size, color, and abundance all indicate a favourable (lower oxygenated) environmental condition for the microfossil to grow in. *Ammonia beccarii*'s ability to absorb elements has been shown to vary with changes in the surrounding environment.

The anomalous discovery of element Thulium (Tm) in sample MB19 was made after the EDS analysis, which examined the foraminifera test for dominant elements. An intermixing of the heavy mineral grains derived from the stone revetments to the riverine and placer deposits are identified. It is found that most of the angulargrains which show anomalous composition are derived from the stone revetments put for the protection of the coast. Obviously, the rock revetment serves the purpose of protecting the coast from further erosion; however, the impacts caused by the revetments due to its weathering and impacts on the microenvironment of Munambam to Kuzhupilly beach need an in-depth study.

CRediT authorship contribution statement.

Mohammed Noohu Nazeer: Field Investigation, Supervision, Formal analysis, Funding acquisition. **Akshay S.:** Field Investigation, Formal Analysis, Writing Original Draft. **Anand S.:** Field Investigation, Formal Analysis, Writing Original Draft. **Honey H. Das:** Methodology, Reviewing and Editing. **Naveen P.U.:** Field Investigation, Data curation, Visualisation.

Declaration of competing interest

The authors declare that they have no known financial or personal conflicts of interest that could have influenced the work reported in this paper.

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References

Ali, M. and Dhanamjayarao, E.N (2021) The impact of seasonal changes on heavy minerals concentration from a part of east coast of India. Malaysian Journal of Geosciences, V.5 (1), pp. 12-21.

Adarsh, P. and Rajeshwara Rao, N (2012) Benthic foraminifera from onshore trench samples at Vengara and Punchakkad, Kannur district, Kerala: Implications for sea-level changes. International Journal of Earth Sciences and

Engineering, V.5 (4) , pp.731-738.

Armstrong, H. and Brasier, M (2013) Microfossils, John Wiley & Sons, 557 p.

Bhuiyan, M.A.H., Lutfar, P.M.A. Islam, S.B. and Shigeyuki, S (2010) Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. Journal of Hazardous Materials, V. 173, (1–3), pp.384-392.

Eduardo, G. and Sergio, A (2019), Heavy Minerals for Junior Woodchucks. Minerals, 9, pp. 1-25.

Gandhi, S.M., Jisha, K., Jeshma, P. and Tharun, R (2017) Foraminiferal and sediment geochemistry studies in and around Cochin backwaters, southwest coast of India. Indian J Geo-Mar Sci, V.46 (11), pp. 2303-2313.

Gholami, S. and Srikantaswamy, S (2009) Statistical Multivariate Analysis in the Assessment of River Water Quality in the Vicinity of KRS Dam, Karnataka, India. Natural Resources Research, V.18, pp.235-247.

Haldar, S.K (2018) Chapter 13 - Mineral Processing. Swapan Kumar Haldar (eds), Mineral Exploration (Second Edition), Elsevier, pp. 259-290.

Hussain, S.M., Ganesan, P., Ravi, G., Mohan, S.P., Sridhar, S.G.D (2007) Distribution of Ostracoda in marine and marginal marine habitats off Tamilnadu and adjoining areas, southern east coast of India and Andaman Islands: Environmental implications, Indian J Geo-Mar Sci, V. 36(4), pp. 369-377.

Hussain, S.M, Rajkumar A., Nishath, M. N. Sakthivel, M and Selvasundaram, S (2017) Distribution of Foraminifera and Ostracoda and their Ecological Conditions in the Beach Sands of Tuticorin, Tamil Nadu, Southeast Coast of India. International Journal of Earth Sciences and Engineering. V. 10. pp. 281-288.

Krumbein, W.C. and Pettijohn, F.J (1938) Manual of Sedimentary Petrography, D. Appleton Century Co. Inc., New York, 549p.

Loeblich, A.R. and Tappan, H (1988), Foraminiferal Genera and Their Classification, Springer New York, NY., 2031p.

Lu X., Lijun, W., Loretta, Y., Li, Kai, Li. and Huang, D.K (2010) Multivariate statistical analysis of heavy metals in street dust of Baoji, NW China. Journal of Hazardous Materials, V. 173, pp. 744-749.

Mange, M.A and Maurer, H.F.W. (2012) Heavy Minerals in Colour, Springer, Dordrecht, 147 p.

Mohan, P. M., & Rajamanickam, G. V. (1994). Organic matter and carbonate in the southwest continental shelf of India. *Journal of the Geological Society of India*, *44*, 575–580.

Naqvi, S.W.A (1987) Some aspects of the oxygen-deficient conditions and denitrification in the Arabian Sea. Jour Mar Res, V.49, pp.1049-1072.

Nasrazadani,S. and Hassani, S (2016) Chapter 2 - Modern analytical techniques in failure analysis of aerospace, chemical, and oil and gas industries. Abdel Salam Hamdy Makhlouf, Mahmood Aliofkhazraei (eds), Handbook of Materials Failure Analysis with Case Studies from the Oil and Gas Industry, Butterworth-Heinemann, pp. 39-54.

National Centre for Earth Science Studies (2023) Draft report on Coastal Zone Management Plan (CZMP) for Ernakulam District – Kerala (Prepared as per CRZ Notification 2019) PP.1-43.

Nisha, N.R and Singh, A.D (2012) Benthic foraminiferal biofacies on the shelf and upper continental slope off North Kerala (Southwest India). J Geol Soc India, V.80, pp. 783-801.

Piper, C.S (1947). Soil and Plant analysis. A monograph. - Waite Agricultural Research Institute, Adelaide, 368 p.

Pradhan, U.K., Sahoo, R.K., Pradhan, S., Mohany, P.K., and Mishra, P (2020) Textural Analysis of Coastal Sediments along East Coast of India. J Geol Soc India, V.95, pp. 67–74.

Prasanthan, V and Vasudevan Nayar, T. (2000) Impact Assessment - Hydrological Studies on Parvathyputhenar. Pollution Research Paper, V.19 (03) pp. 475-479.

Sreekesh,S., Sreerama, S.R and Rani, S (2018) Effect of Sea Level Changes on the Groundwater Quality along the Coast of Ernakulam District, Kerala. Journal of Climate Change. V. 4. pp. 51-6.