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ESSO

NCESS

ई एस एस ओ-राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
ESSO-National Centre for Earth Science Studies
(पृथ्वी विज्ञान मंत्रालय, भारत सरकार)
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From the Director's Desk

The National Centre for Earth Science Studies (NCESS) has witnessed significant growth during the year 2018-19 with the evolution of major research programs and collaborations at the national and international levels, a record investment on infrastructure, field and lab equipments, and a quality rise in research publications. The Institute procured the state-of-the-art MC-ICPMS facility which is being coupled with the existing LA-ICPMS, and is all set for procuring new EPMA and IRMS facilities to strengthen the analytical capability of the Institute. The Central Chemical Laboratory has been completely renovated and upgraded with many modern sophisticated analytical facilities and was inaugurated by Dr. M. Rajeevan, Hon'ble Secretary, MoES. The Clean Chemistry Lab (class 10000 with class 100 work stations) is under preparation and with this, NCESS is poised to be one of the best centres in the country today for advanced research in the fields of Geochemistry, Geochronology and Isotope studies.

For the first time, NCESS has two exclusive cruises coming up, to be carried out in the Arabian Sea. The first one is charted for October 2019 and the second one for February 2020, both onboard Sagar-Kanya. The program aims at deciphering various aspects of air-sea interaction, paleo-climate change, sediment geochemistry, nutrient dynamics and isotope geochemistry. Also, for the first time NCESS team is all set to join the Antarctica expedition to study the correlation between East Antarctica and India, their connection prior to break-up and models of their geodynamic evolution. Further, new initiatives are embarked to unfold the continental evolution of Eastern Ghats Belt, Himalayas and Archean Cratons like Bundelkhand. As a part of the supracrustal research activities, studies have been taken up to unfold the phenomena of landslides and soil piping in the southern Peninsular India.

The frequent occurrence of coastal flood hazard along the sea coast of India, particularly during non-monsoon period, has always been a matter of concern to the coastal community as well as the government. Lack of adequate information on this unique phenomena is a major lacunae challenging decision making to contain its adversities. Therefore, NCESS has taken up investigations on coastal flooding with an aim to build in house capability for its prediction and management.

The Submarine Groundwater Discharge (SGD) project has evolved as an important national network program involving 12 institutes and government agencies in the country. In the first phase, the program is addressing the south-western coast of India and a multi-disciplinary approach is being adopted, involving hydrogeological and hydrochemical analyses including isotope studies, remote sensing, infra-red thermal imaging using drone survey, etc., to identify and understand the zones of ground water discharge and nutrients into the ocean realm.

Video beach monitoring in collaboration with University of Lisbon, Portugal, has opened up new avenues to understand the ocean wave phenomenon. The Varkala cliff, north of Thiruvananthapuram is an Area of Outstanding Natural Beauty (AONB) and a Geo-heritage site that need to be protected and safeguarded from coastal erosion. Under a project taken up with the Kerala State Government, in collaboration with NCCR, Chennai, it is proposed to study the sub-surface structure, stability of the cliff in order to take appropriate measures for shore protection of this unique coast.

As one of the five Institutes in the country today authorized to carry out CRZ work, NCESS has carried out major studies for the Government of Maharashtra, Kerala, and several smaller consultancy projects for others.

NCESS has initiated studies to understand the cloud microphysics and precipitation systems of Peninsular India. Lightning detection network and S-band Doppler Weather Radar in Kochi are used to examine the radar reflectivity characteristics in southwest India prior to the thunderstorms and lightning in the region during 2018 post monsoon season. The internal dynamics in cloud layers create a seeder-feeder mechanism which plays a major role in determining the drop size distribution (DSD) spectra and precipitation at higher elevations in Western Ghats. NCESS has taken up in-depth studies to unfold all these atmospheric phenomena in the changing climate scenarios of the country.

The rapidly changing water scenario of India needs a thorough investigation with regard to its near surface terrestrial environment called the Critical Zone. The Critical Zone of the country is under immense stress due to rapid urbanization, economic developments and climate change issues. NCESS has already initiated establishment of two CZOs in Kerala – one at Attappadi and the other at Munnar. The network of these observatories will be expanded further in the coming years.

During the reporting period, NCESS has organized many important meetings which include Brainstorming session on Coastal Flooding, Interaction meeting of project participants of the National Network Project – Mission SGD, Mastermind session on landslide hazard, Training programme on regional ocean modelling system etc. Also conducted workshops for Hindi, Official language rules and Prevention of sexual harassment of women at workplace.

The hard work of scientists and research scholars of NCESS has resulted in enhanced standards of publications, with four papers published in Nature Scientific reports, four in Atmospheric Research, and also in journals like JGR, Geophysics and Precambrian Research. The scientists and young researchers of NCESS have contributed in a big way to the forthcoming IGC 2020 to be held in New Delhi in March 2020. It gives me great pleasure to see that several sessions are going to be chaired by young scientists of NCESS. Some are members in various committees like GeoHost, providing a very visible participation from this Institute.

NCESS is also preparing to procure and install state-of-the-art Visual Desktop Infrastructure (VDI) to optimise and enhance the computational facilities of the Institute. The Institute is also working towards development of a National Geoscience data portal for the Ministry of Earth Sciences.

Dr. N. Purnachandra Rao
Director

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Preface

The Indian lithosphere, particularly the south Indian shield, is characterized by a rich geological heritage with a protracted history of igneous activities, deposition, deformation and metamorphism, covering the whole geological period from Archaean to the Recent times. The geological framework includes the Precambrian high-grade granulites (charnockites and gneisses) surrounding the cratonic regions, deep faults and shear zones, several igneous units, sedimentary cover sequences, and one of the largest escarpments, the Great Escarpment of India (Western Ghats). Geological evidence suggests that the Western Ghat escarpment formed as a result of the final phase of rifting and breakup of the supercontinent of Gondwana. The rifting and breakup of continental fragments are also linked with mantle plume activity and formation of large igneous provinces. The Western Ghat escarpment also presents a long history of evolution up to the Recent in the form of plateau uplift, escarpment retreat to the east and eustatic changes of regression/transgression and changes in their depositional environments. This history is well preserved in the Cenozoic sedimentary sequences that are proved to host hydrocarbon reservoirs. Therefore, an excellent opportunity exists in solid Earth science for detailed studies on a variety of geological processes that relate igneous activity, metamorphism, deep internal lithospheric processes through Precambrian and development of the escarpment.

A long coast line, the west coast of India, runs parallel to the Western Ghats. Various natural processes and human interventions in the coastal environment have been affecting its ecosystem. The processes of coastal erosion/accretion and sediment deposition, periodic storms, and sea level changes contribute to continuously modify the shoreline and its morphology. Occurrences of placer mineral deposits and mud bank formation are also well known on this coast. Therefore, monitoring and understanding spatio-temporal changes of shoreline along the coast, through morpho- and hydrodynamic and sedimentological studies become very essential.

The Western Ghats is catchment for many river systems and several water bodies are distributed throughout the coast. Monitoring and estimating the physico-chemical quality of the lakes, rivers and other water bodies, which are under constant attack from human interferences, are important to regulate the environmental degradation and to ensure their sustenance. The Western Ghats and the coastal region are in continuous threat of natural hazards by virtue of tectonic adjustments, surface processes linked to the huge overburden of laterite and thick weathered profiles, copious rainfall and orography and beach dynamics. The problems which need immediate attention are the landslides, soil piping, lightening, beach erosion, coastal flooding, storm surge etc. Thus, studies are aimed to reveal the nature of distribution, identification of vulnerable areas, causative factors and develop prediction capabilities to assist disaster preparedness and formulate viable management plans.

The R&D activities of NCESS are focused under the following four core scientific programmes.

- Geodynamics of Indian subcontinent and landscape evolution (Evolution of Western Ghats and lithosphere through Precambrian)
- Water and Environment (River basins and rivers having their catchment in Western Ghats)
- Coastal morphology and hydrodynamics along the west coast of India
- Natural Hazards (Landslides/land subsidence, cloud processes and lightning in Western Ghats, coastal flooding in west coast)

1. Crustal Processes

"Evolution of Indian lithosphere through Precambrian" aims to understand the evolution of the continental crust (Archean to present) over time and to characterize lower crustal melting in the realm of HT/UHT metamorphism through petrological, phase equilibria modeling, geochemical and geochronological studies with focus on Southern Granulite Terrain (SGT). The data thus generated are being compared with other granulite terrains, viz. Eastern Ghats Belt (EGB), Himalayas and Archean cratons like Bundelkhand. A new initiative has been launched to work on the conjugate Precambrian terrains of East Antarctica and EGB to understand the tectonic reconstruction of different crustal blocks. For understanding the evolution of Western Ghats as a passive continental margin and the role it played in the amalgamation of different crustal blocks like Deccan Volcanic Province, Dharwar Craton, and Southern Granulite Terrain, scientists in CrP are in the process of working out moho variations in the regions. Also trying to prepare a detailed 3D architecture of the Achankovil Shear Zone using joint modelling of gravity and magnetic data. The cause of Indian Ocean Geoid Low was explained in terms of thinning of mantle transition zone using global seismological data. Research in understanding the nature of hydrocarbon fluids generated in the Kerala offshore sedimentary basin is also progressing. As part of supra crustal research activities, the landslides and soil piping phenomena are being investigated. For assessing global environmental changes in the Western Ghats (Sahyadris), a coordinated research based on river basin covering the topics of climate, GHG emissions, land and land resources, soil and water resources and their quality and resource utilization has been undertaken. It is aimed to work-out plans for the environmental sustainability, human development and sustainable development

1.1 Granulite facies metamorphism: Petrology, geochemistry and isotopic studies to constrain timing of emplacement of granitoids; UHT metamorphism, melting and crustal evolution

The present study aims to address the following:

(i) Understanding of the evolution of the continental crust with emphasis on Archean cratons (Bundelkhand), Southern Granulite Terrain (SGT), Eastern Ghats Belt (EGB), and Himalayas.

(ii) Understanding of the quantum of addition of juvenile material through time and recycling of crustal and mantle material.

(iii) Assessment of factors triggering the melting in lower - middle crust and their implications on the rock system.

(iv) Assessment of timing of melting and metamorphism.

(i) Southern Granulite Terrain (SGT), South India:

A number of field studies were carried out in different locations in Nagercoil, Kerala Khondalite Belt (KKB) and Madurai Blocks. Representative rock samples of granulites (migmatitic garnet-cordierite gneiss, quartzofeldspathic gneiss, metapelites, charnokites) and intrusions (granites, carbonatite and syenites) were collected from different locations for detailed petrographic, geochemical and geochronological studies.

A study on garnet-cordierite gneiss from the KKB using phase equilibria modelling revealed signature of partial melting event in the realm of high to ultra-high temperature metamorphism. The petrologic data suggest clockwise P-T evolution from peak

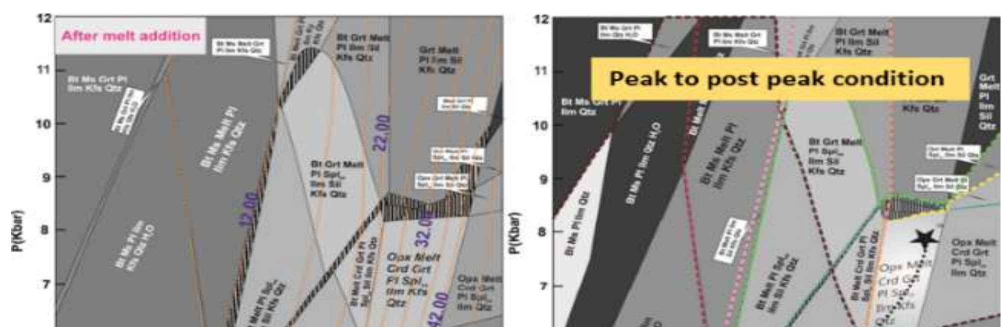


Fig: 1.1.1: P-T pseudosections constructed in, a) pre-peak; b) post-peak metamorphic conditions of grt-crd gneiss of KKB, India high temperature-moderate pressure stage (~900 °C at 7.5 - 8 kbar) followed by decompression and cooling under specific P-T conditions (450-480 °C at 5-5 kbar) (Fig. 1.1.1). These results correlate with burial, heating and eventual exhumation of moderately thickened crust. Modelling of phase equilibria in partially molten rocks in KKB, shows that melt productivity gradually increases with melt addition; but the maximum of 35% granitic melt can be generated in the temperature interval of 740 °C to 950 °C. Further, the chemical ages from monazites point towards a complex tectono-metamorphic evolution in the terrain with the clear indication of a Tonian (~941 Ma) metamorphic event subsequently overprinted by Cambrian (~540 Ma) tectono-thermal episode.

In addition, to probe the evolution of garnet-bearing quartzofeldspathic gneiss from KKB, detailed studies on accessory phases such as monazite and zircon from one locality (Poikamukku) were carried out. Petrographic analysis suggests the presence of melt. In the leucolayers of the rock, narrow rim of plagioclase within the layer of quartz also indicates evidence of melt migration. Compositional variation of garnets is being studied to evaluate growths of garnet with time. Mineral chemistry of various phases, and chemical age dating of texturally controlled monazites were obtained using EPMA. U-Pb geochronology data of these samples have been generated at the Institute of Geosciences, UNICAMP. A total of 77 points were measured in the melt domains which gave 207Pb/206Pb peak ages of Archean (ca. 2.8-3.3 Ga), Palaeoproterozoic (ca. 1.7-2.3 Ga), Mesoproterozoic (ca. 1.2 Ga), Neoproterozoic (ca. 0.6-0.7 Ga) and Devonian to Cambrian (ca. 0.35-0.45 Ga). On the other hand, 80 points were measured in the host which gave dominantly 207Pb/206Pb peaks of Palaeoproterozoic ages (ca. 1.7-2.3 Ga) and a few ranging from Cambrian to Neoproterozoic (ca. 0.5-0.7 Ga).

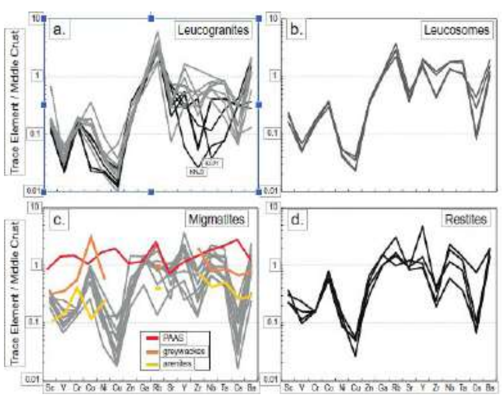


Fig. 1.1.2: Geochemical plots for leucogranites, leucosomes, migmatites and restites

On a similar note, geochemical data on migmatites, leucosomes and leucogranites, and residual (restitic) rocks from eleven localities (working quarries) from the Trivandrum Block of the KKB were analysed with respect to the scales over which near-source processes control the chemical signatures of the melts extracted. The results reveal that the source rocks for the Trivandrum Block migmatitic gneisses were semipelitic sediments characterised by Ga, Rb, Nb, Ta, Y and Ba contents that are lower than or similar to post-Archaean shales and average model middle crust, and by significant relative depletions in the transition metals (Sc, V, Cr, Ni, Cu and Zn), Zr and Cs that bear strong similarities to average arenites (Fig. 1.1.2). This has important bearing upon the tectonic environment of formation of these rocks. The proportions of peritectic garnet, K-feldspar and ilmenite entrained in the Trivandrum Block are in the approximate molar ratio of 3.6:3:1, consistent with phase equilibrium of the migmatites at 860-900 °C and 6-7 kbar. The age-corrected (550 Ma) heat production of the crustal section now represented by the exposed Trivandrum Block, based on the weighted average of preserved migmatite, in-situ leucosomes and leucogranites of all types, was 1.7 ± 0.5 μWm^{-3}. Correction of the 550 Ma heat production to account for an estimated 30% of migration and loss of well-segregated leucogranites with higher heat productions (2.7 ± 0.8 μWm^{-3}) from this middle crustal migmatite complex yields a syn-orogenic heat production of c. 2.0±0.6 μWm^{-3}. More detailed sampling for petrology, geochemistry and geochronology was carried out in the Nagercoil block and Kambam UHT terrain in Madurai Block with focus on U-Pb dating of accessory minerals such as zircon and monazite.

(ii) Studies in Eastern Ghats Belt (EGB):

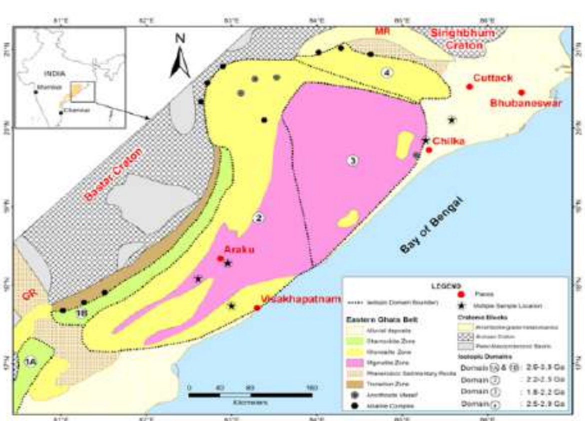


Fig.1.1.3: Generalised geological map of EGB

Representative samples of granulites and adjacent melanosomes and leucosomes were collected for detailed isotopic geochemical studies. On the basis of petrography and whole rock chemistry six samples (corresponding to migmatitic granulite, melanosomes and leucosomes) from Chilika Lake Granulite Complex were selected for detailed petrochemical study along with *in-situ* studies (U-Pb/Hf in zircon and U-Pb in rutile) to provide the best estimate of crystallization age, age of source sediments and the age of metamorphism. Mineral chemistry of different phases and chemical dating of texturally constrained monazites were analysed by EPMA at IIT Kharagpur. Preliminary results point towards two-stage melting of aluminous granulites at 1005-990 Ma associated with UHT metamorphism and later at ~950-940 Ma associated with reworking of cooled UHT crust.

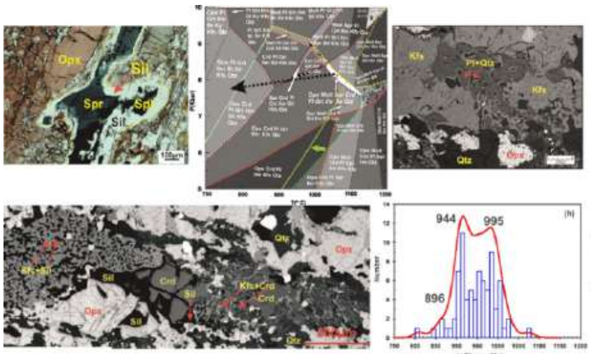


Fig. 1.1.4: a) Evidence M_{1L} melting; b) P-T pseudosection to represent peak- to post-peak conditions of metamorphism; c-d) The assemblage of different types of intergrowths form an overprint on M_1 assemblage and commonly develops within the leucocratic layers.; e) Probability density plot of weighted ages of monazite showing three peaks

(iii) Studies in Himalayas:

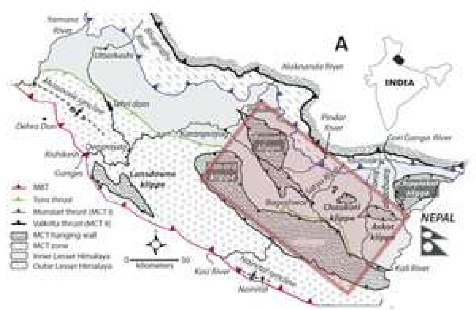


Fig. 1.1.5: Geological map of Kumaun-Garhwal Himalayas

Field work was conducted in Almora (Almora crystallines, AC) and Ramgarh Group in Kumaun Himalayas. Representative samples of phyllites, garnet-mica schist, quartzo-feldspathic/garnet bearing gneiss, basement granite, amphibolites exposed in the region were collected for petrographic studies from Almorah and Champawat section of Kumaun Himalaya.

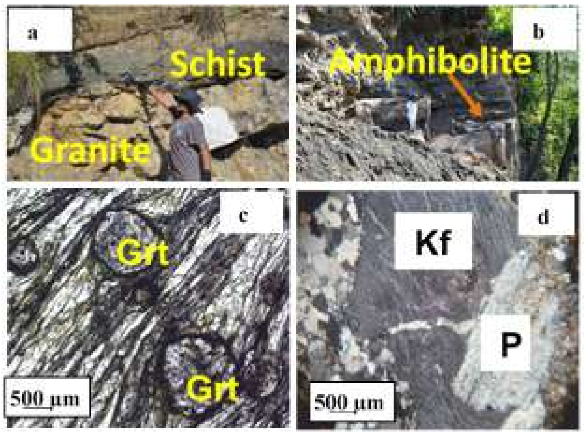


Fig. 1.1.6: a) Granite-schist contact; b) Amphibolite; c) Garnet porphyroblast over wavy schistosity defined by chlorite, muscovite and biotite d) K-feldspar and plagioclase in granite

Petrographic observation of these samples is under progress. Whole rock chemistry of basement granite and phyllites/schist from Almorah and Champawat section of Kumaun Himalayas were generated by XRF for phase equilibria modelling.

1.2 Deep lithospheric structure across shear zones, South India

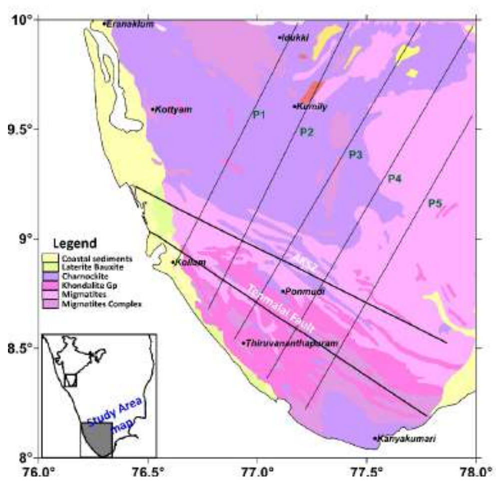


Fig. 1.2.1: Geological map of study area

Achankovil Shear Zone (AKSZ) is a fundamental sub-crustal lithospheric structure located in one of the oldest Archean cratons of world - SGT (Southern Granulite Terrain); (Fig. 1.2.1). It has been shaped by many tectonic events in South India. Nonetheless, the crustal structure and its tectonic evolution toward southern part of SGT is not fully understood. The zone provides an opportunity to understand the tectonic and geodynamic evolution of this high-grade granulite terrain surrounded by major shear and tectonically disturbed areas. We used high resolution ground measurements gravity data published in literature combined with satellite measure gravity data to fill the gap and airborne magnetic data. AKSZ is easily marked by magnetic map but it does not have any signature in Bouguer gravity map. Five different profiles from north to south is taken across the AKSZ, and 2D joint modelling of gravity and magnetic data are performed constrained with available tomography data to assess the extent, kinematics and contribute to the understanding of the tectonic origin of AKSZ (Profile P3 is given for example as shown in figure). The results showed that AKSZ extending 12-21 km wide from west to east direction and ~120 km long oriented towards the NW-SE direction. The vertical extent of AKSZ varies from 17 km in north-west to approximately 13 km in south-east direction confirms the upper crustal structure (Fig. 1.2.2).

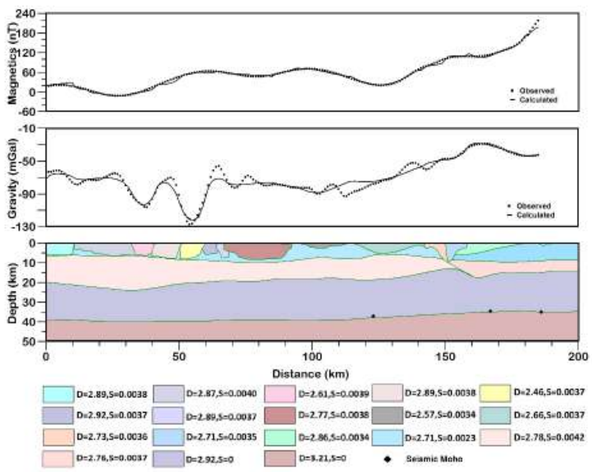


Fig. 1.2.2: Joint modelling along P3 using gravity and magnetic data

1.3 Palaeo fluids in the petroliferous basins of western offshore – India

The study on palaeo fluids in the sediment fill of the petroliferous basins of western offshore had been a micro-scale effort to verify and compare the fluids that interacted with the various strata in the offshore sedimentary formations of especially the Mumbai and the Kerala-Konkan (KK) offshore basins. Fluid inclusions (FIs) have great diversity of applications in exploration geology and are invaluable tools in the reconstruction of fluid flow histories in reservoir rocks. Petrographic studies were carried out for 25 samples from KK-basin, and fluorescing fluid inclusion was observed at some depths under microthermometric study, oil window is noted at some depths in KK-basin. The fluid inclusion studies help determining the hydrocarbon assay in terms of palaeotemperature and API gravity of oils in HCFIs (Fig. 1.3.1). Along with HCFIs some CO_2-H_2O inclusions are also detected at KK-basin with different salinity range.

The applicability of the FI technique developed to determine the unknown API gravity was confirmed with the studies in KK-basin and the API gravity obtained wss between 22 and 31 (Fig. 1.3.2). The fluid inclusion data can be used for the thermal, compositional and migration calibration studies using petroleum modelling systems that is not possible with any other conventional means and we have recently procured a Petromod software for the same. The fluid inclusion data so far obtained in our study is highly significant to the petroleum exploration industry and steps are being initiated to have a long-term collaboration with ONGC, Govt. of India for furtherance of the developed technique.

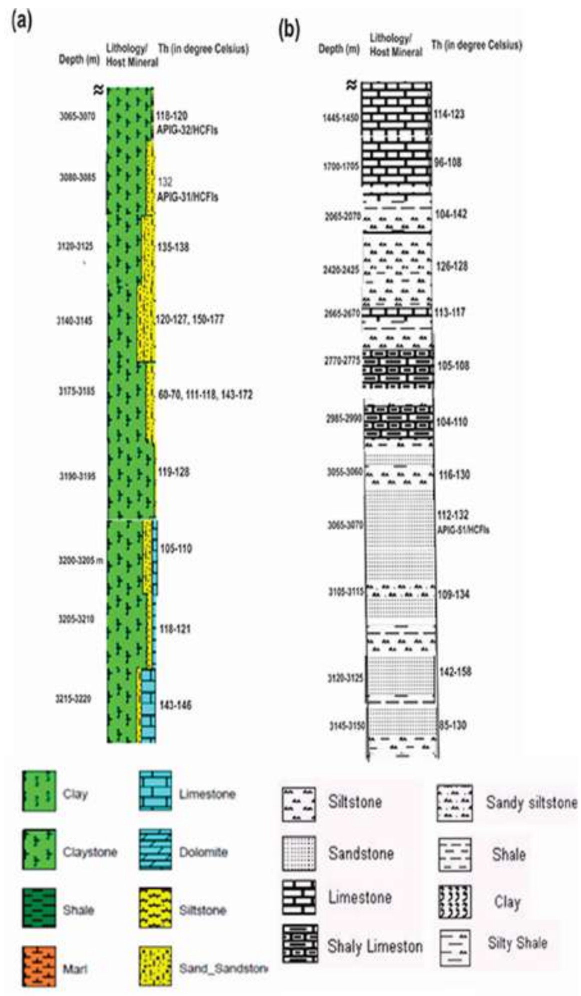


Fig. 1.3.1: Depth-wise comparison of fluid inclusion data from Mumbai and Kerala-Konkan offshore basins. Lithological details, oil window, and API gravity where HCFIs identified are shown (apparent depths are given)

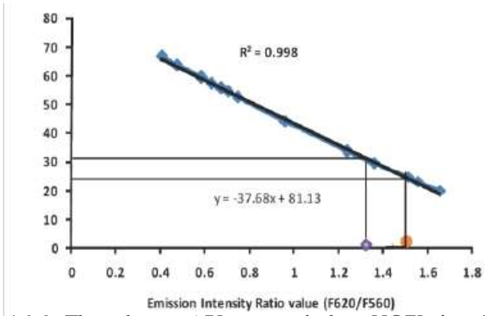


Fig. 1.3.2: The unknown API gravity of oils in HCFIs from Kerala offshore basin was determined with the standard bivariate plot based on empirical equation $y = y_0 (x_0 - x)^{t} \pm 1$

1.4 Crustal and mantle structures and geodynamic model for Western Ghats

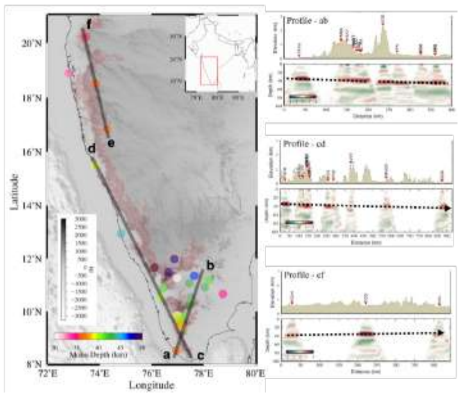


Fig. 1.4.1: The obtained Moho depth plotted at the station locations (left panel). Common Conversion Point (CCP) images along the three profiles ab, cd and ef (right panel).

The Western Ghats (WG) is one of the great escarpments that extends ~1500 km almost parallel to the west coast of India in NNW-SSE direction. It has an average elevation of ~1.2 km. The WG is a mosaic of different geological formations having different structural and physical characteristics. Many studies have been carried out to understand the evolution of WG, however, a conclusive explanation still remains elusive. Thus, in the present study, we investigate the crustal structure along and across the WG using the Ps converted phase technique in order to provide a vital input to understand the evolution of WG. For this, we compiled the 27 Broadband Seismological Stations (BBS) data from different institutes and deciphered the crustal structure along and across the Western Ghats. The results are as follows (Fig. 1.4.1).

1. A clear change in the crustal thickness along the WG is observed. The crustal thickness increases from ~36 km to ~42 km from south to the centre of the WG and then decreases towards the north, from ~42 km to ~35 km.

2. A step like variation of Moho is observed across the WG, with a sudden jump of the Moho from ~39 km to ~44 km.

3. A strongly negative phase is observed along the WG just after the Moho, which could be due to the existence of a sub-Moho LVL.

4. The observed crustal thickness and strong negative phase shed light on the different rifting episodes along the west coast of India, which also gains support from the strong and consistent negative isostatic anomalies over the WG.

1.5 Insights into Indian Ocean Geoid Low: Geodynamic exploration

The Indian Ocean Geoid Low (IOGL) is the most prominent geoid anomaly (-106 m) on the globe. Although several hypotheses are proposed as causes for this spectacular feature, a conclusive explanation remains elusive. The most popular theories are (i) hot/low density anomalies in the depth range of 410 km and 660 km, called the Mantle Transition Zone (MTZ) (ii) cold/high density anomalies in the lower mantle, between 1000 km and 2891 km depth and (iii) combined effect of these two anomalies. In the present study, we investigate the Mantle Transition Zone (MTZ) structure beneath the region using P-Receiver Functions (PRFs), to examine its role in the genesis of this prominent feature. Results reveal a thin MTZ due to a depression of the 410 km and elevation of the 660 km discontinuity (Fig. 1.5.1), suggestive of anomalously hot temperatures in the mid mantle beneath the IOGL region, possibly sourced from

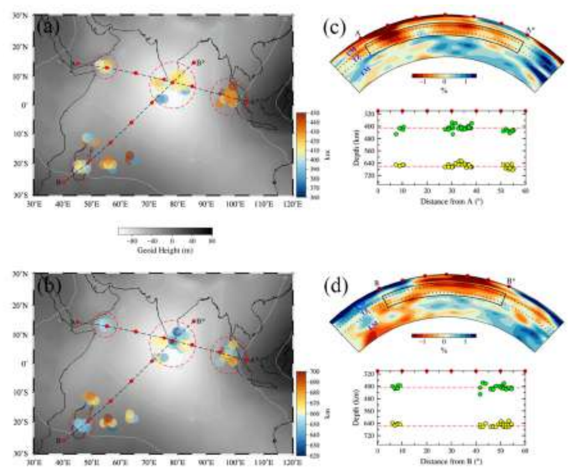


Fig. 1.5.1: Map showing the depths to the, a) 410 km and b) 660 km discontinuities, along with the selected profiles AA and BB*. Depth sections from 0 to 1600 km of the S40RTS tomographic model along with the observed 410 and 660 km depths plotted along the profiles AA* and BB* (c and d respectively). Dashed horizontal red lines indicate the 410 and 660 km depths and green and yellow circles indicate the observed 410 and 660 km discontinuity depths.*

the African LLSVP. The combined effect of the hot (low density) material in the mantle transition zone proposed in this study and the (high density) cold slab graves atop the Core Mantle Boundary inferred from previous studies can possibly explain this geoid low.

1.6 Landslide and its triggering factors in the Western Ghats: An integrated geological, geotechnical and geophysical approach

Landslide is one of the most catastrophic natural hazards in global terms with both economic loss and fatality. The Western Ghats is a highly fragile area and prone to landslides. Every year with the onset of monsoon, a series of landslides are occurring with different magnitudes along the Western Ghats. The land disturbances include debris flow, debris slide and lateral spreads. Studies had been carried out in two phases - pre disaster and post disaster to understand these processes. Extreme rainfall events during the monsoonal months between June to August, 2018 and 2019 caused several devastating landslides in the Southern Western Ghats. These landslides caused extensive damage to houses, roads, bridges, communications networks, and other infrastructure; and washed away crops and livestock. Post disaster landslide studies were carried out in Western Ghats region of Kerala and Karnataka areas.

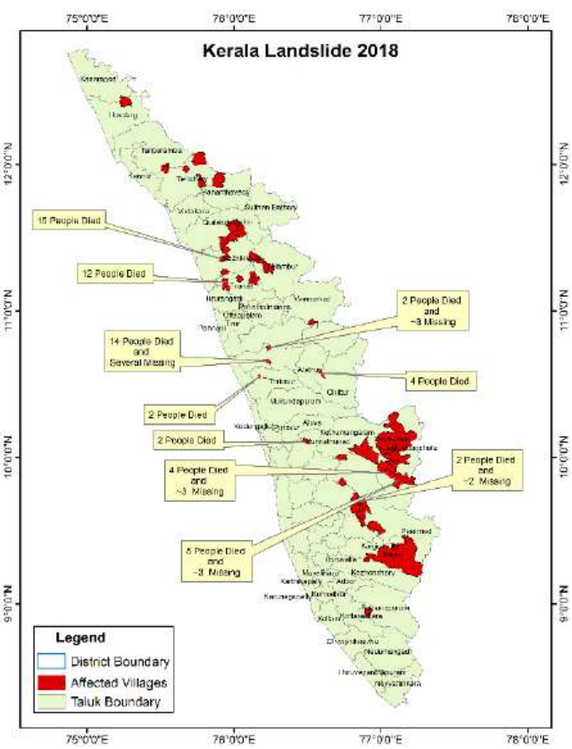


Fig. 1.6.1: Landslide affected locations in the districts of Kerala in 2018-19

The scientists of the Crustal Processes Group were engaged in the following investigations in regards to landslides in Western Ghats (2018-2019).

1. Field work in Idukki, Thrissur, Wayanad and Kannur district of Kerala and Madikkeri Taluk in Coorg, Karnataka during the recent SW monsoon period (2018-2019).
2. Detailed field investigations carried out in 62 landslide worst-affected areas (loss of life & property) in the post flood scenario based on respective District Collectors' appeal to Director, NCESS.
3. Soil samples collected from various locations for geochemical and geotechnical analysis.
4. Resistivity survey has been carried out in selected locations.
5. Stability computation done on soil slopes in Thrissur, Idukki, Kannur and Wayanad areas.

Table 1.6.1. Landslide inventories of different districts (Field work carried out in 2018 - 2019)

Landslide Type	Kannur	Wayanad	Idukki	Thrissur	Coorg, Karnataka
Debris Flow	3	4	5	3	4
Debris Slide	2	3	7	2	12
Rock cum debris slide	-	1	-	-	2
Lateral spreads	2	-	5	6	1
TOTAL	7	8	17	11	19

Fig. 1.6.2: Field view of two landslide areas

Lateral spreading is quite a newly recognized phenomena in the Western Ghats which leads to the development of deep cracks extending several meters to kilometers and creating serious threat to human habitations. Lateral spreads are distinctive because they occur on very gentle slopes or on almost flat terrain. The dominant mode of movement is lateral extension accompanied by shear or tensile fractures. The failure is caused by liquefaction, the process whereby saturated, loose, cohesion less soil (usually sands and silts) are transformed from solid to a liquefied state. Failure is usually triggered by gravity or added weight that destabilize the slopes. When coherent materials or soil, rest on materials that liquefy, the upper units may undergo fracturing and extension and may then subside, translate, rotate, disintegrate, or liquefy and flow. Lateral spreading in fine-grained materials on shallow slopes is usually progressive. The failure starts suddenly in a small area and spreads rapidly. Often the initial failure is a slump, but in some materials movement occurs for no apparent reason. Combination of two or more of the above types turns into a complex landslide. Lateral spread/land subsidence investigations were carried out in Idukki, Thrissur, Kannur and Kasaragod districts of Kerala.

Laboratory studies: Rocks and soils were sampled (more than 150 samples collected from different regions of Western Ghats) for laboratory analysis to determine the extent of weathering.

X-ray diffraction analysis:

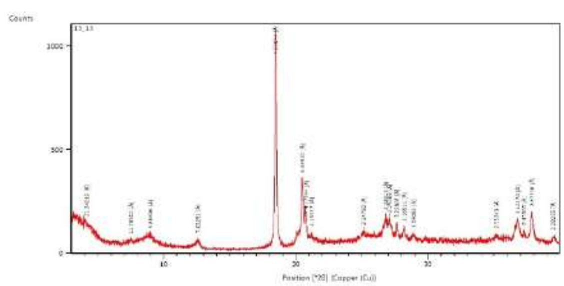


Fig. 1.6.3: XRD result of sample collected from Idukki area

The main mineralogical constituents of the rocks along the landslide zone were determined from thin sections made from fresh and weathered rock samples and confirmed using XRD. The results show that loose, highly oversaturated, lateritic, soil is enriched with Kaolinite, Illite, Chlorite, Gibbsite and to some extent of Montmorillonite. It indicates that the selected locations are failed due to highly weathered stage of rocks. In future also, it may fail because of very loose cohesive strength of the materials.

Geotechnical Investigations: NCESS has been doing this work with extensive field study and soil sample collection for geotechnical investigation with the team from NIT Calicut. A total of 450 soil samples were collected from various locations for slope stability modelling. Lab tests of the samples have been completed.

Slope stability modelling: For better understanding of the process, these slopes are planned to model in the software GEOSLOPE by giving input parameters like slope, soil thickness, soil properties and assuming Mohr coulomb model for behaviour. The analysis will give the Factor of Safety (FOS). By artificially varying effecting parameters the behaviour of predicting landslide can be examined.

Slopes modelled using Geoslope 2019: Slopes were analysed for the Factor of Safety (FOS) and the result is shown in figure 1.6.4. In all slopes, piezometric lines were assumed at the ground level for taking the worst case. If the value of this ratio is equal to one, it indicates imminent failure, and a factor of safety below one implies unstable conditions. Therefore, the slope is theoretically stable if the factor of safety is greater than one.

Geotechnical test results from the field samples collected from various sites of Idukki and Thrissur regions show less cohesion and friction components in the range of 10 to 70 kPa and 23-40° respectively. The calculated FS against sliding for all soils taken from the sites is less than 1 indicating failure.

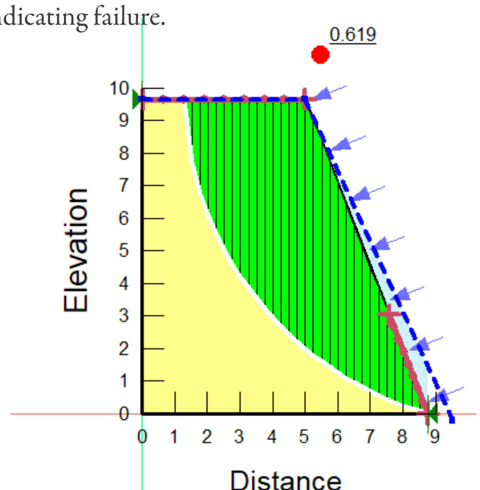


Fig. 1.6.4: Analysed slope with its factor of safety

Geophysical investigations: Field investigations were carried out to measure the thickness of overburden materials using electrical resistivity tomography.

Interpretation of soil piping phenomena found in Kizhakkanodi area of Kinannor village, Kasaragod district:

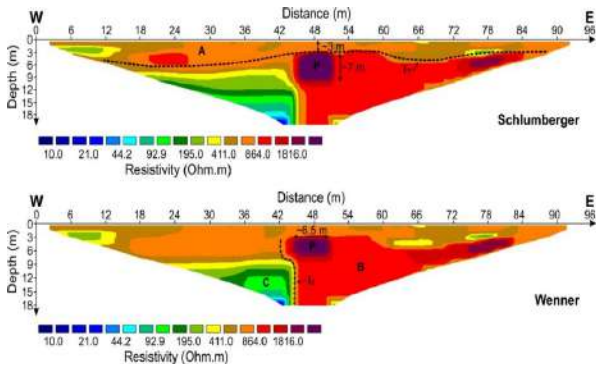


Fig. 1.6.5: 2-dimensional resistivity sections obtained after inversion for Schlumberger and Wenner arrays show detailed electrical signature of subsurface, based on which subsurface is divided into different parts like A, B, C and P. I1 and I2 are the interfaces between two type of formations. The anomalous very high resistive zone (P) at the central part of the sections signifies the hollow part caused due to the soil piping

1.7 Assessment of global environmental changes in Sahyadri

1.7.1 Stable isotope studies on moisture source variations and associated water cycle dynamics in Periyar river basin, Southern Western Ghats

Rainwater samples for the 2017 south-west monsoon (SWM) season were collected from the lowland, midland and highland locations of Periyar river basin; and Trivandrum coastal station (TRV) and evaluated for understanding the amount effect.

Amount Effect: Amount effect, the inverse relationship between rainfall amount and its $\delta^{18}O$ is investigated and found to register varying results along the three stations. The summary of these relationships with slope, intercept, correlation coefficients and number of samples of these stations are given in Table 1.7.1.1. Along Periyar River Basin (PRB), only lowland station shows statistically significant amount effect. The days with rainfall <10 mm recorded an average $\delta^{18}O$ of -1.3‰ and those with >10 mm recorded -2.3‰. The continuous supply of moisture from Arabian Sea (AS) to the lowland region can reduce the isotopic depletion in small spells (less than 20 mm). Also, as per the Rayleigh model, the first condensate (lowland) of any rainy event is expected to be enriched and starts depleting as proceeding over mountains. This observation from lowland station agrees with the explanation by Rozanski et al. (1993), the precipitation isotopic composition during heavy showers decreases with respect to time owing to the continuous isotopic exchange of ambient moisture with falling raindrops. Hence, the weak relationship in the case of amount effect over midland and highland stations are driven by weak rain events with varying (both depleted and enriched) $\delta^{18}O$ values. Although, earlier Lekshmy et al. (2015), had observed a significant positive correlation for monthly amount effect over one of the Kerala station, later they found out a significant negative correlation for daily samples along the same station explaining about 4% of the $\delta^{18}O$ variability. This indicates that amount effect over Kerala state varies for different time scales and different stations. Similar observation as that of the PRB lowland station is observed in the TRV coastal station with statistically significant negative correlation. The TRV station is also located along the lowland terrain of the state, directly receiving the advected moisture from the AS. The linear correlation coefficients explain 7% and 24% of total variance respectively along the lowland and TRV station.

Table 1.7.1.1: Rainfall - $\delta^{18}O$ correlations at different stations of PRB (The bold value indicates statistically significant correlation for ($p<0.05$)

Station	Slope	Intercept	Correlation, R2	p value
Highland	-0.02	-4.21	0.01	0.60
Midland	0.01	-2.15	0.00	0.69
Lowland	-0.03	-1.69	0.07	0.05
TRV	-0.04	-1.34	0.24	0.01

Regional convective activity and $\delta^{18}O$ variation:

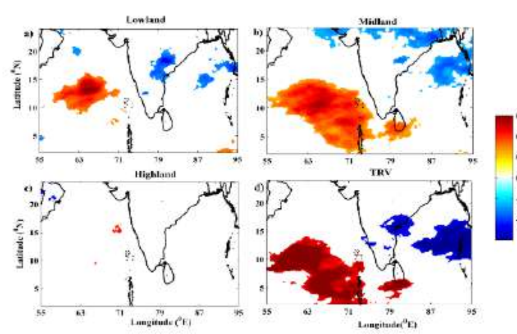


Fig. 1.7.1.1: Spatial plot showing correlation field of average OLR with isotopic composition of rain

The results in the previous section indicate that amount effect is variably manifested along different elevations of the Western Ghats. Hence, we have considered the effect of regional convective activities on the $\delta^{18}O$ variation along these elevations. In PRB, the correlations of $\delta^{18}O$ with Tropical Rainfall Measuring Mission (TRMM) (though not shown here) derived rainfall (in mm) and Outgoing Long-wave Radiation (OLR) show concurrent results with the highest correlations along the midland station followed by the lowland. For highland station, the correlation map shows a difference without any statistically significant correlation with OLR (Fig. 1.7.1.1) and a few patches of negative correlation with TRMM. The correlations were stronger for TRV station which could be due to the spatial location of the sampling station.

As observed elsewhere, the pattern of $\delta^{18}O$ correlation with that of TRMM is stronger compared to OLR indicating the faster dissipation of deep convective clouds and the further role of shallow precipitating clouds. The regions of significant correlations were spatially located in the offshore AS close to the monsoon circulation corridor to the Kerala state. According to the rainout effect, the moisture advected from this region undergoes $\delta^{18}O$ and $\delta^{2}H$ depletion throughout its track to the sampling station. Thus, increasing amount of rainfall over this region increases isotopic depletion over the continental station. Though local amount effect is not significant in the present study (except for midland station), the TRMM spatial correlations reveal significant 'distant amount effect' (lowland and midland stations). The regions with strong TRMM correlations coincide with that of OLR correlations indicating the propagation of convective systems from these regions towards southern India. The studies carried out in other stations of southern India also depict significant correlations with TRMM and OLR values along the same region. This confirms the significance of this region in producing distant amount effect over southern India. However, similar kind of observations were lacking along the highland stations where the OLR and TRMM rain did not produce any significant correlation. The rain events over this region is possibly linked with the cumulative effect of local convective activity, orographic effect or the supply of dry moisture from the Tamil Nadu uplands.

1.7.2 Assessment of land and land resources in Periyar basin, Southern Western Ghats

The impact of climate change on soils is a slow complex process because soils not only be strongly affected by climate change directly but also can act as a source of greenhouse gases and thus contribute to the gases responsible for climate change. The accelerated increase in temperature all around the globe results in loss of soil carbon which indirectly affects other soil characteristics like soil structure, stability, water holding capacity, nutrient availability and erosion. The present study deals with the climate induced changes in the soils of Periyar River Basin (PRB) which is the most prominent and longest river system in Kerala originating from the Western Ghats. The basin lies between North latitudes 9°15'-10°21' and East longitudes 76°08'-77°24'. The watershed area of the river is 5389 km^2 covering 88 villages. The land use pattern of the area can be broadly divided into agriculture land, forest land and waste land. The basin is occupied by a spectrum of rock types which include crystalline rocks of Precambrian age and sedimentaries of Tertiary and Quaternary periods. The major rock types include quartz-feldspar-hypersthene granulite, pyroxene granulite, gabbro, hornblende gneiss, calc-granulite, granite and garnet biotite gneiss.

(a)

(b)

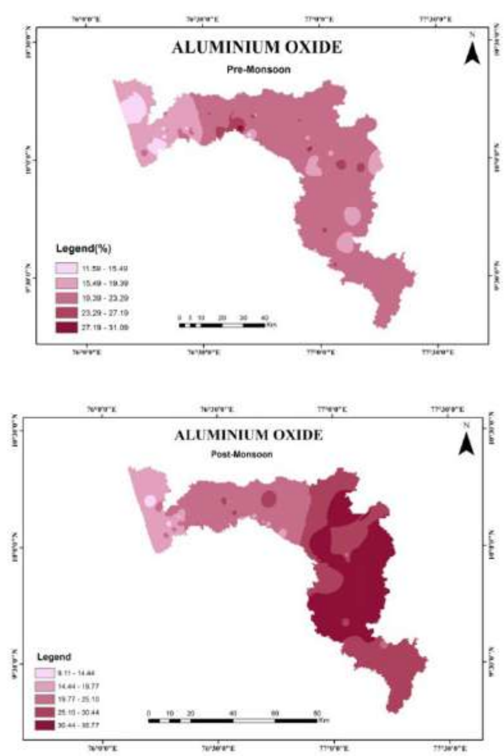


Fig. 1.7.2.1: Spatial variation of Al_2O_3 during a) pre-monsoon/pre-flood and; b) post-monsoon/post-flood seasons

Owing to the direct effect of climate change, the water content in soils decreases while evapo-transpiration increases. As a consequence, higher re-suspension of soil dust particles occurs. Hence, in order to assess the climate induced changes, the elemental concentrations in PB soils were taken into consideration. The pollution status from the low, mid and some regions of high lands during pre-monsoon/pre-flood (May 2017, February 2018 and April 2018) and post-monsoon/post-flood (December 2017, October 2018 and January 2019) seasons employing various geochemical indices viz. Pollution Load Index (PLI), Crustal Enrichment Factor (EFc), Geo-accumulation Index (I_{geo}) and Degree of Contamination(C_{deg}) were analysed to study the impacts of August 2018 flood (extreme weather event). This study deserves utmost importance, as it can give a clear picture of the soils in Periyar Basin in the pre-flood and post-flood scenario. As the intensive rainfall and resultant soil erosion may have eroded all the top soils, the pre flood analysis will give the extent of loss of chemical elements in PRB. Moreover, from the previous literatures, it is learnt that only few works have been conducted on the characteristics of heavy metal ions in the soil of PRB before flood.

Results of the major oxides in the present study were compared with the International Standards for Major Oxides in Soil, composition of Charnockites from Kerala and the previous background values of major oxides from the study area to assess the enrichment or depletion of major metal oxides. The elemental concentrations of Al_2O_3 and Fe_2O_3 major oxides showed a marginal increase during post-flood times. It is observed from the literature, soluble or exchangeable Al levels will increase as a consequence of increasing acidity and from our results it is confirmed that the soils of PRB are acidic in nature. Fig. 1.7.2.1 a & b show the spatial variation of Al_2O_3 in two different seasons.

The EFc and I_{geo} of various elements in the study area were studied. From the results it was observed that the elements V, Cr, Ni and Zr exhibit moderate enrichment while the other elements fall in the category of deficiency to minimal enrichment. In the case of geo-accumulation index, elements such as Cr, Ni, and Zn lie in the moderately polluted category while the other elements like Ce, Ba, Nb, Ga, Cu and V fall in the unpolluted category.

The four potential climate scenarios (Arid, Semi-arid, Sub-humid and Humid) have great impact on important soil processes as the texture differentiation in the soil profile. From the textural results it was observed that the sand, silt and clay percentage during pre-monsoon was 17.30-88.18%, 2.27-58.01%, 7.22- 55.89% while in post monsoon the percentage of sand varied from 8.43-92.94%, silt content was in the range of 3.68-47.53% and clay content in the range 3.37-50.64%. Therefore, from the results it is observed that majority of the samples fall in the broad category of sandy loam and sandy clay loam category (Fig. 1.7.2.2 a & b).

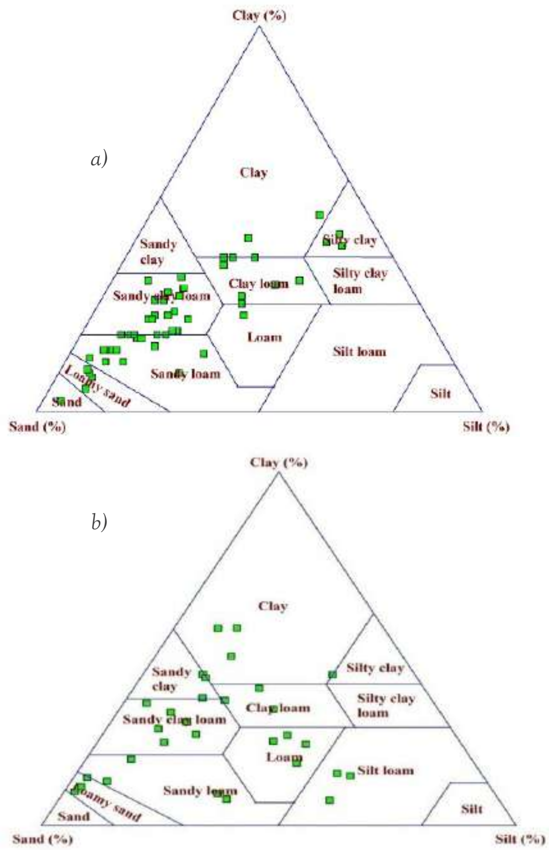


Fig. 1.7.2.2: Ternary diagram showing various textural facies of soils during a) pre-monsoon and; b) post-monsoon seasons (USDA soil survey staff, 1993)

1.7.3 Assessment of water resources and water quality of Periyar basin, Southern Western Ghats

Kerala is characterized by 44 rivers, which originates from Western Ghats, follows a meandering course before debouching into the coastal waters. A distinctive feature of the rivers flowing across Kerala is their short length and the difference in elevation between high and low lands, which causes the rapid flow of water. All these are rain-fed, which means that Kerala is heavily dependent on the monsoon which is determined by alterations in climate. The impact of climate change on water resources is one of the most important issues to address in order to develop adaptation and resiliency strategies. The climate change determinants affecting water quality are mainly the ambient (air) temperature and the increase of extreme hydrological events.

Though Kerala has 44 rivers, numerous freshwater lakes, ponds and a productive ground water regime, expansion of agriculture, damming, diversion, over-use, and pollution are threatening these irreplaceable water resources. Therefore, characterization of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources. In addition, pollutants entering a river system normally result from many transport pathways including storm water runoff, discharge from ditches and creeks, vadose zone leaching, groundwater seepage, and atmospheric deposition. These pathways are seasonal-dependent. Therefore, seasonal changes in surface water must be considered since it can provide a better knowledge about the river hydrochemistry and pollution and this can also ensure effective and efficient water management.

The study focuses on Periyar river which is the most prominent and longest river system in Kerala originating from the Western Ghats., The river lies between North latitudes 9°15'-10°21' and East longitudes 76°08'-77°24'. The watershed area of the river is 5389 km^2 covering 88 villages. The lower reaches are heavily polluted with industries of chemicals- petrochemical products, pesticides, rare-earth elements, rubber processing chemicals, fertilizers, zinc/chrome products and leather products, discharging their waste into the river.

In this study hydrochemical parameters (physical and chemical) were used to assess seasonal (pre-monsoon/pre-flood, monsoon and post monsoon/post-flood) variations. Sampling were carried out in the months of February and April 2018 indicating pre-monsoon, August 2018 during monsoon and October 2018 during post monsoon seasons. Physical parameters like pH, EC, TDS, NaCl and temperature were determined *in-situ*. Samples were subjected to various analyses to elucidate the hydrochemistry. In Fig. 1.7.3.1, the variation of total hardness during the three sampling seasons are illustrated. Major ion chemistry has been validated by using Normalised Inorganic Charge Balance (NICB) representing the extent of deviation between sum of anions charge and sum of cations charge. All parameters were analysed following standard methods.

The results were interpreted with respect to drinking water potential by considering microbiology (WQI), Irrigational water quality (SAR and Wilcox's) and Hydrogeochemistry (Piper diagram, Gibbs diagram and Stiff diagram). The results so obtained were compared among the three seasons and with available literature to evaluate the effect of flood in the basin. Water (SW, GW and precipitation) samples were assessed for stable isotopes of δD and $\delta^{18}O$ by dual-inlet IRMS to determine the seasonal variation of isotopes to changing weather conditions.

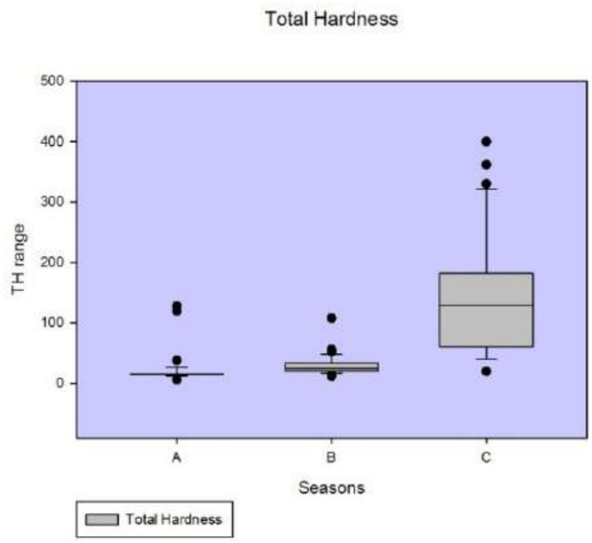


Fig. 1.7.3.1: Variation of hardness in the surface water of Periyar River (A: post-monsoon, B: monsoon and C: pre-monsoon)

Major ions in river originated from a variety of physical and chemical processes occurring in and around the basin which includes chemical weathering, anthropogenic inputs like extensive dissolution of fertilizers from agricultural fields and industrial waste etc. The hill piper diagrams (Fig. 1.7.3.2) showed that during pre-

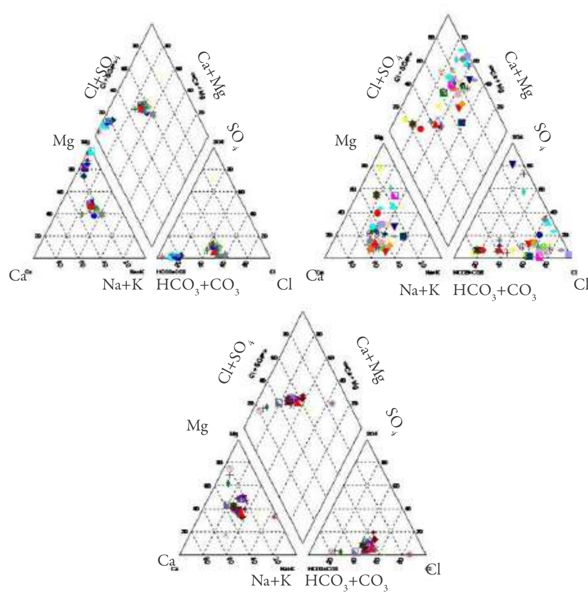


Fig. 1.7.3.2: Piper trilinear diagrams showing the surface characterization for pre- monsoon, monsoon and post-monsoon seasons

monsoon season the hydrochemical facies obtained was Ca-Cl and mixed type. No individual element was seen in the dominant phase whereas for anions Cl was the dominant phase. From the analytical results also, it is justified that Ca and Cl concentrations were higher during pre-monsoon season. During the monsoon and post monsoon season Mg-HCO_3 and mixed type was obtained as the hydrochemical facies. No dominant cations and anions were seen during monsoon whereas during post monsoon Mg was obtained as the dominant cation phase and HCO_3 was obtained as the dominant anion type. There is no significant change in the hydrochemical facies noticed during the study period (monsoon and post-monsoon), which indicates that most of the major ions are natural in origin.

1.7.4 Assessment of groundwater resources in Periyar basin, Southern Western Ghats

Groundwater in shallow aquifers constitutes a major source of freshwater in most parts of the world. It is now widely accepted that the suitability of groundwater not only lies on its widespread occurrence, but also its quality which in turn is determined by different kinds of natural and man-made factors including the quality of the recharged water, atmospheric precipitation, and soil-rock weathering. Climate change and urbanization have led to an increase in the frequency of extreme water related events such as flooding, which has negative impacts on the environment, economy and human health. In the present study, an attempt has been made to evaluate the variation in seasonal groundwater quality in the low lands and midlands of Periyar River Basin (PRB) which witnessed worst flooding in August 2018, after 100 years due to the global climate change phenomenon as confirmed by UN. It is important to focus on impact of flood on groundwater parameters as it can show drastic changes in some of the physico-chemical characters of underlying water. The understanding of groundwater quality of PRB will help in assessing the health risks after the flood event; and in the planning of measures aimed at improving the water quality. A total of 26 groundwater samples each were collected during the pre-monsoon / pre-flood (February, April 2018), monsoon/ flood (August 2018) and post-monsoon / post-flood (October 2018) season. The present investigation indicates that there is a decreasing trend of EC, TDS, chloride, hardness, bicarbonate, nitrite, silicate, phosphate, magnesium in post-flood compared to pre flood due to dilution effect of flood water. Acidic pH during pre and post flood may be due to excessive runoff with chemicals and pollutants from agriculture practices and irrigating lands, anthropogenic and industrial pollutants, organic wastes, and sewage from the adjacent areas. The heavy rainfall caused leaching of metals into the water, which can have an immediate or a long-term effect by influencing the chemical composition and pH fluctuations of the water. There is increase in trend of ammonia, turbidity, sulphate, sodium, potassium in post-flood compared to pre flood. The higher values of ammonia recorded in post-flood were attributed to acidification of water by elevated microbial degradation of organic debris and concentrated dissolved solids. The increase in the turbidity in post flood was due to high infiltration rate into the aquifers which further causes high dissolution rate of substances that made the ground water turbid where as in the pre flood, less infiltration rate caused most of the dissolved substances to settle down leading to a reduction in the turbidity. Sulphates are highly soluble in water so dissolves ammonium sulphate fertilizers, industrial wastes, organic matter and ultimately become part of groundwater. Source of cations is mainly attributed to primary rock weathering, industrial effluents, sewages. *Escherichia Coli* colonies detected were high in pre-flood and post-flood compared to flood event. These pathogens may be washed into the groundwater from human, animal wastes, improperly treated septic and sewage discharges, leaching of animal manure, storm water runoff. Piper trilinear diagram (Fig. 1.7.4.1 a, b, c) reveals that samples belong to the Mg-

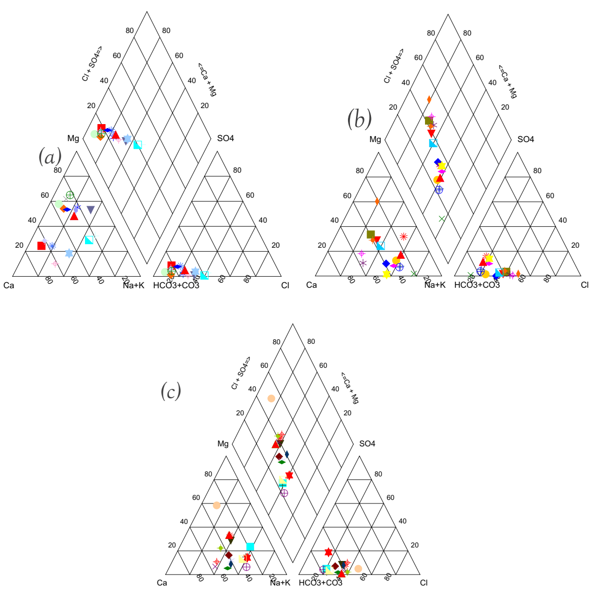


Fig. 1.7.4.1: Piper trilinear diagrams showing the groundwater characterization for, a) Pre-monsoon; b) Monsoon; c) Post-monsoon Seasons

HCO_3 type in the pre-monsoon, Mg-HCO_3 type and mixed type in both monsoon and post-monsoon period. The HCO_3-Cl-SO_4 anion triangle implies water samples have been plotted in bicarbonate and chloride type end members and sulphate is not present in any significant proportion. For pre-flood, alkaline earths (Ca+Mg) exceed alkalies (Na+K) and weak acids (HCO_3+CO_3) exceed strong acids (SO_4+Cl). During pre and post-flood period, no remarkable change is observed in hydro-chemical facies indicating natural origin of major ions (Sadashivaiah, 2008). As PRB comprised of biotite gneiss, hornblende gneiss, charnockites, laterite and alluvium, the minerals like biotite, hornblende, augite, dolomite, serpentine, diopside etc were possible source of Mg.

The Gibbs plotting of chemical data (Fig. 1.7.4.2 a, b, c) was mainly around rock dominance area and partly in precipitation dominance zone. It means the rock-water interactions are playing vital role in determining the groundwater quality in the study area irrespective of seasons. Post flood samples do not show much variation in the dominant mechanism determining the water quality. Hence flood effect on major ion concentration is minimal instead silicate weathering predominates. Periyar river basin is mainly composed of Precambrian crystallines such as biotite gneiss, hornblende gneiss, charnockites, laterite and alluvium. The concentration of alkali metals could be attributed to weathering and dissolution of feldspar, pyroxenes and amphiboles of these rocks. Overall results suggest that the industrial, agricultural, domestic effluent leachate into groundwater pose severe threat to ecology even beyond the flooding effect.

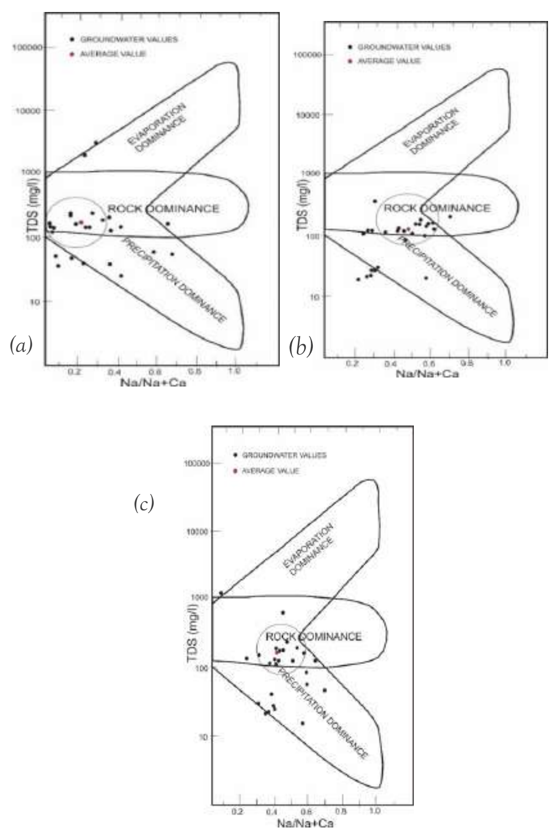


Fig. 1.7.4.2: Gibbs Plot showing the contributing factors of groundwater quality in, a) Pre-monsoon; b) Monsoon; c) Post monsoon Season

1.7.5 Texture and geochemistry of the sediments with special reference to Anthropocene: A study of Periyar river sediments, Southern Western Ghats

Rivers, the life sustaining system, act as the major pathways to the dissolved sediments and transport sediments from terrestrial areas to the coasts. The human evolution and material use affected the environment adversely. The post-industrial period, the Anthropocene, witnessed drastically changed scenario making the subsistence of life forms jeopardised. Sediments play vital role in finding the history of the pollution also. They act as sink and carriers of contaminants in the aquatic environment. The presence of trace elements especially the heavy metals are the chief constituents and the presence of which indicate the source of natural or anthropogenic sources. In addition, it gives the source like weathering of rocks as well as the anthropogenic interference pertaining to dumping of both effluent discharge and sewage to the water body. Sediment transport and the conditions under which sediment is deposited or eroded from the various environments in a river is therefore critical for understanding and managing sediment and sediment related habitat in rivers.

The present study deals with the textural characteristics as well as the chemical composition of sediment collected from different locations of Periyar river, which is known as the life line of Kerala. The river having a length of 300 km which is stretching from Sivagiri hills in the Western Ghats to Lakshadweep sea. The total drainage area is 5389 sq. km and the total annual flow is 11607 cubic meters. The River Periyar has been enriched with water of minor tributaries like Muthayar, Perumthuraiar, Chinnar, Cheruthony, Kattappanayar and Edamalayar at different junctures. Periyar plays lead role in shaping the economic prospects of Kerala, owing to its cardinal contribution to domestic water supply, irrigation, tourism, industrial production, collection of various inorganic resources and fisheries.

Systematic field work was conducted for collecting samples from the river basin. A total of 26 sediment samples collected in the months of April and August in 2018. The sediment samples were pre-treated and analysed using different sophisticated instruments. The obtained results were recorded and tabulated. To understand the elemental composition, XRF technology is used and the textural aspects were obtained using conventional method of pipette analysis.

Grain size distribution is considered as a potentially informative fundamental property of the sediment. Knowledge of grain size is often essential in order to understand temporal and spatial changes of sediment and their bearing on depositional environments. The particle size analysis of the samples showed different percentages in pre monsoon season and post monsoon season. According to Folk and Ward (1957) classification, in most of the sample during pre-monsoon sand is the dominant textural facies. There were five facies of samples observed. Whereas in the samples collected during post monsoon, most of the samples are muddy sand facies and few samples falls in sandy mud facies (Fig. 1.7.5.1).

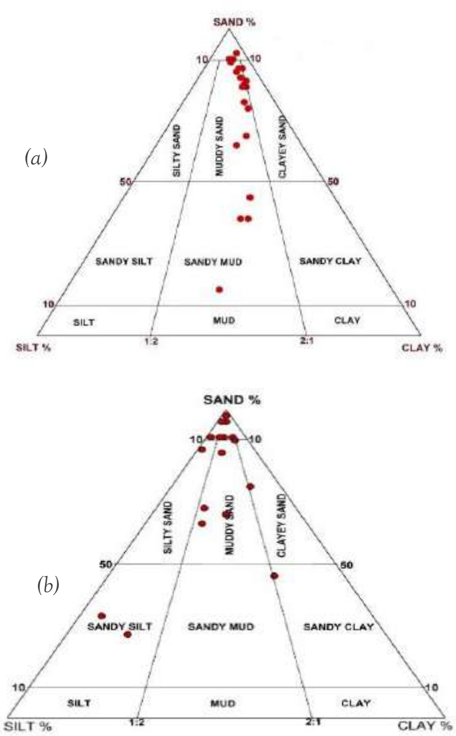


Fig. 1.7.5.1: Textural facies of the samples in, a) pre-monsoon; b) post monsoon seasons

The major elemental concentration identified in the study area are: SiO_2, TiO_2, Al_2O_3, MnO, Fe_2O_3, CaO, MgO, Na_2O, K_2O and P_2O_5. The significant variation in values which are recorded in both the study period indicated below (Table 1.7.5.1).

Table 1.7.5.1: Values showing the variation in elemental concentration in two seasons

Sl. No.	Parameters (%)	Post-monsoon		Pre-monsoon	
		Min	Max	Min	Max
1	SiO_2	0.51	2.15	0.15	2.42
2	TiO_2	0.30	1.63	0.36	1.33
3	Al_2O_3	6.04	12.73	4.34	11.6
4	MnO	0.02	0.15	0.006	0.012
5	Fe_2O_3	2.54	7.96	2.01	5.99
6	CaO	0.78	2.06	0.64	2.058
7	MgO	0.70	2.30	0.18	1.43
8	Na_2O	0.51	2.15	0.15	2.42
9	K_2O	1.69	3.68	0.71	3.91
10	P_2O_5	0.04	0.17	0.05	0.15

Among the values observed in both seasons the Si value found to be within the limit of world average shale value. The maximum limit of Ti was found exceeded to the world average shale value of 0.46 percentage, which indicates dominance of weathering of Ti bearing rocks. Fe concentration was found to be almost similar concentration with average shale value also anthropogenic inputs can contribute too. Phosphorous concentration has been found to be higher when compared to world shale value, indicating the runoff from cultivated lands. The higher concentration of Mn indicates the anthropogenic input as well as silicate weathering.

1.8 Palaeomagnetism and geochemistry of the Proterozoic igneous units to trace Indian shield within the supercontinental reconstructions and to unravel petrogenesis in terms of nature and development of subcontinental mantle lithosphere

Indian shield comprises cratonic elements (Dharwar, Bundelkhand, Bastar, Singbhum and Aravalli) that are among the oldest cratons of the world and are surrounded by high-grade granulite terrains. The region has witnessed multiple igneous activities of diverse compositions during Proterozoic. These igneous units are important manifestations of the breakup and amalgamation of continental blocks. An integrated study of these Proterozoic igneous units combining palaeomagnetism, geochemistry and U-Pb geochronology is generally considered as ideal for understanding the evolution and origin of large igneous provinces and to draw correlations between the mafic igneous rocks distributed over wide areas. Furthermore, the results help to trace the position of India within various Precambrian continental configurations and also to understand the petrogenetic evolution of mantle and subcontinental lithosphere processes under the Indian shield.

Under this, above background studies have been carried out over the years on mafic igneous rocks, particularly on mafic dykes across the cratons; in recent years, studies are mainly focused on Gwalior and Bijawar traps and the progress of work during 2018-19 is summarized below:

Palaeomagnetic and geochemical investigations of mafic igneous units in the Gwalior, Bijawar sedimentary basins were continued during this period. Natural Remnant Magnetisation (NRM) measurements and step-wise alternating field demagnetization experiments were conducted on a recent collection of 23 additional samples from 5 previous sites and 10 samples from one new site of the Gwalior traps. Rock magnetic properties were also carried out; the properties determined include susceptibility measurements, saturation isothermal remanent magnetization, coercivity of remanence and thermomagnetic analysis (susceptibility vs temperature). With these works, detailed palaeomagnetic results are available on 8 sites (70 samples) of the Gwalior traps and 6 sites (40 samples) of the Bijawar igneous units. Characteristic magnetizations were computed using the stereographic and orthogonal projections and principal component analysis. Within-Site and between-site mean direction computations, summarizing the results and detailed analysis of the data will be carried out in near future as the geochronological results are available. Furthermore, Baddeleyite separation from both Gwalior and Bijawar igneous units was carried out and the isotopic dating will be carried out soon.

1.9 Palaeomagnetism and geochemistry of the late Phanerozoic magmatism, mantle plume evolution and the breakup history along the passive continental margins of India

The passive continental margins and elevated escarpments along the coastal tracts of India is formed as a result of the final phase of rifting and breakup of the supercontinent Gondwana. The rifting and breakup of continental fragments are linked with mantle plume activity and formation of large igneous provinces. In India, the Reunion plume activity, manifested as 65-70 Ma Deccan continental flood basalt, had resulted breakup along the western continental margin of India paving way for the development of the escarpment on the coastal front. Several igneous occurrences are known in south Indian shield to the south of the Deccan province in the vicinity of the west coast of India. Many earlier studies regarded them as magmatic responses related to the Reunion plume activity. However, recent studies have shown that not all the magmatic occurrences relate to Reunion plume event, and some relate to the earlier Marion plume event. Thus, there is a need to revisit these igneous occurrences to isolate the magmatic responses related to different mantle plume events in the Indian Ocean region and to understand their role in shaping the passive continental margin. In the above background studies are focused on Koyna drill hole basalt sequence and basement basalt samples from Laxmi basin recovered by the IODP 355 Expedition and the salient outcomes during this year is as follows.

Palaeomagnetism and Geochemistry of Deccan basalt across the Koyna drill core: Palaeointensity, characteristic magnetization inclination determinations and geochemical investigations on the Deccan stratigraphic sequence along 1250 m drill hole from the Koyna Deep Scientific Drilling program, has been continued during this period. Most experimental procedures completed earlier and during this period the data have been analysed and synthesized.

Palaeomagnetic studies are mainly devoted to determine polarity determinations as the drill cores are not azimuthally oriented (except KBH-8). Characteristic magnetization inclinations were computed from alternating field demagnetization results using principal component analysis for three drill hole samples (KBH-7, KBH-5A and KBH-8). The data recorded moderate upward or downward inclinations permitting reliable polarity determinations. Depth-wise inclination profiles of all the three drill holes, with reference to mean sea level, remarkably shows a polarity transition at about 600 m MSL elevation. The flows above ~600 m MSL are of normal polarity and the flow sequence below up to the basement is of reverse polarity (Fig. 1.9.1). The KBH-5, towards coast at lower elevation, recorded only the reverse polarity. These results are from a section without the bias of stratigraphic correlation and confirm the earlier reports of a single polarity transition in the entire 1300 m section of the Deccan lava pile.

The geochemical work includes major and trace element (including REE) analyses using XRF and ICPMS methods. The samples are all iron-rich sub-alkalic tholeiitic basalts in composition. The samples with Mg no. <0.60 are all evolved through fractionation from primary mantle melts. Quantitative modelling of Cr and Ni values indicate picrite/gabbro fractionation defines the spectrum of geochemical variations. Depth wise variations of selected elements show some subtle variations and that may define stratigraphic formations. Variations in incompatible and trace elements and their relation to degrees of melting and source compositions are being worked out.

The palaeomagnetism and geochemistry are combined with existing geological and geophysical results to explain the mechanism, chronological order and relationships between volcanism, uplift and extension/rifting along the volcanic continental margin. Here main interpretations are that (a) igneous underplating was a cause of initial epeirogenic uplift in the WG, (b) extension/rifting followed shortly after volcanism and (c) thermal collapse and subsidence caused slumping down of basalt basement below sea level, while returning to normal temperatures after the Seychelles-India breakup

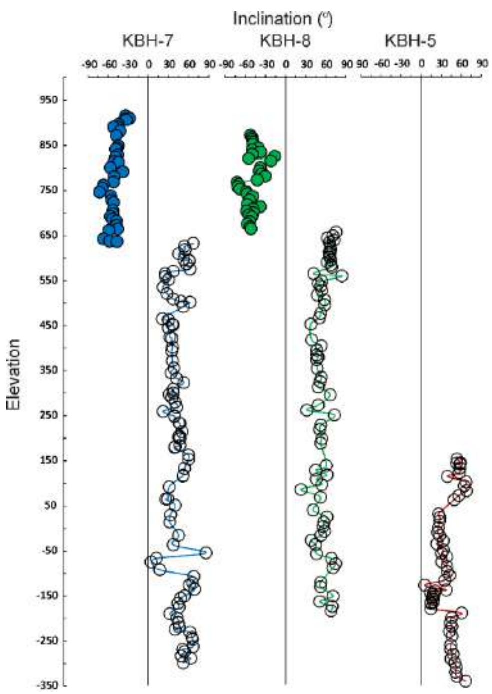


Fig. 1.9.1: Characteristic magnetization inclinations of Deccan basalt down to basement interface along three drill holes (KBH-7, KBH-8 and KBH-5A) against the mean sea level (MSL) elevation and seen that only one geomagnetic polarity transition recorded between normal (closed symbol) and reverse (open symbols) polarity at ~640–650 m above MSL

Rock magnetic experiments were conducted essentially to screen out promising samples for palaeointensity experiments. These includes magnetic susceptibility, Isothermal Remanent Magnetization (IRM), both acquisition and back-field demagnetization, temperature versus susceptibility, Lowrie Fuller test, Anhysteretic Remanence Magnetisation (ARM) and hysteresis loops. The results indicate presence of titanomagnetite / magnetite of stable thermoremanent origin. Palaeointensity experiments were conducted on ~72 carefully chosen samples. Classical Thellier-Thellier method in its modified form employed for the palaeointensity determinations. Experimental and computation methods involve a rigorous approach and used pTRM vs pNRM plots, orthogonal projections, intensity decay curves, pPTRM-pTRM tail checks, cooling rate and anisotropy corrections and well accepted quality check criteria proposed in recent literature. The estimated mean raw PI value is 8.11 ± 2.8 μT. In view of the methods adopted here, this result is the best palaeointensity result from one of the two largest Phanerozoic flood basalt provinces of the world. Now, more detailed palaeointensity data interpretations on Mesozoic era is in progress.

IODP 355 Expedition and basement of Laxmi basin, Arabian Sea: A large set of trace elements including rare earth elements were determined by ICPMS method on basement basalt samples recovered from U1457 hole of the IODP Expedition in Laxmi Basin of the Arabian Sea. Mineral chemistry results were also obtained using EPMA. Petrography and major and a few trace elements were already determined for these samples during the previous year. Alternating field demagnetizations to determine characteristic magnetizations and routine rock magnetic experiments were completed on 14 samples. Analysis and interpretation of these data is in progress.

2. Coastal Processes

The coastal zone is one of the highly dynamic environments in the world as it is constantly undergoing changes under the action of natural drivers like wind, waves, tides, currents etc., and also anthropogenic activities. To have a thorough understanding of the different processes at work in the coastal zone, particularly the nearshore dynamics which has a direct influence on the shoreline dynamics, an interdisciplinary approach is needed. This can be accomplished by conducting a detailed study of the various physical oceanographic parameters responsible for the dynamic nature taking into consideration the environmental, societal and economic aspects which could eventually help in building resilient community/resources and to make better decisions on the management of the coast. Of the various problems/issues associated with the coast, coastal morphodynamics is one of the least explored areas due to the intrinsic complexity of the problem and the difficulties in data collection. With better instrumentation and numerical modelling capabilities it is possible to study these processes in an integrated approach. The studies carried out by the CoP group aims at providing vital information on the link between the morphological and sedimentary features of the coast and the various parameters of the coastal processes. The investigations undertaken are expected to help in building scientific knowledge to support developmental requirements along the coastal area with minimal environmental impact within the threshold of sustainability.

2.1 Beach-surf zone dynamics at locations with diverse environmental settings

Study of the beach-surf zone dynamics along the coastal stretch extending from Kadalundi inlet to Quilandy in SW coast of India, was taken up to understand the coastal dynamics at locations with diverse environmental settings by adopting both field measurements and numerical modelling studies. This study area was chosen mainly because of its inherent complex nature as it comprises of a complex coastal morphological unit consisting of tidal inlets, coastal plains, rocky promontories, seawalls, groins, harbour, breakwaters etc.

Numerical modelling of waves along the SW coast: Numerical simulation of waves in the Indian Ocean has been carried out using the Spectral Wave Model of the MIKE 21 software. Two separate models have been setup for the present study, viz.: the global model which covers the entire Indian Ocean and the regional model which represents the SW coast of India. The bathymetry data from ETOPO1 (1 arc minute resolution) is used for setting up model. The global model domain covers the entire Indian Ocean, extending from Lat: 31.5˚N to 50.5˚S and Long: 25.5˚E to 110˚E. The model domain is meshed in such a way that it is coarser at the offshore (about 500 km) and finer (about 20 km) towards the nearshore region (Fig. 2.1.1 a and b). The global model mesh generated for the entire Indian Ocean region has 11311 nodes and 19000 elements. For running the model, the global wind parameters from the ECMWF ERA-Interim reanalysis data are given as the primary driver. For this study, wind forcing with spatial and temporal resolutions of 0.5×0.5˚ and 6 hr interval respectively are used. The modelling is carried out for the one-year period of 1st January 2014 to 31st December 2014.

For setting up of the regional model, the bathymetry data generated using DHI's C-Map tool box and the fine grid bathymetry data available with NCESS for the nearshore region of selected coastal sectors of the SW coast have been used. To ensure accurate modelling of the shallow water transformation of waves, the mesh size is limited to 100 m in the nearshore region whereas the mesh size gradually increases to 10 km at the offshore boundary. The number of nodes and elements in the regional model mesh are 31535 and 52901 respectively.

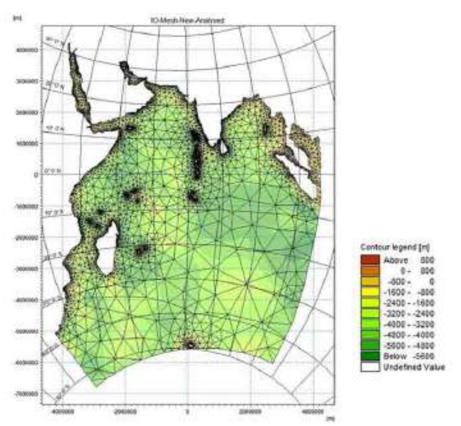


Fig. 2.1.1: Global Model domain bathymetry; Mesh model

The domain selected for the model study covers the entire southwest coast of India. For validation of the model results, one year simulated significant wave height data for the period January - December 2014 was compared with that of the measured data from the Wave Rider Buoy data deployed off Kollam at 22 m water depth. The simulated wave data showed reasonably good corroboration with a correlation coefficient of 0.75. A brief discussion on the numerical model results is given in the following section.

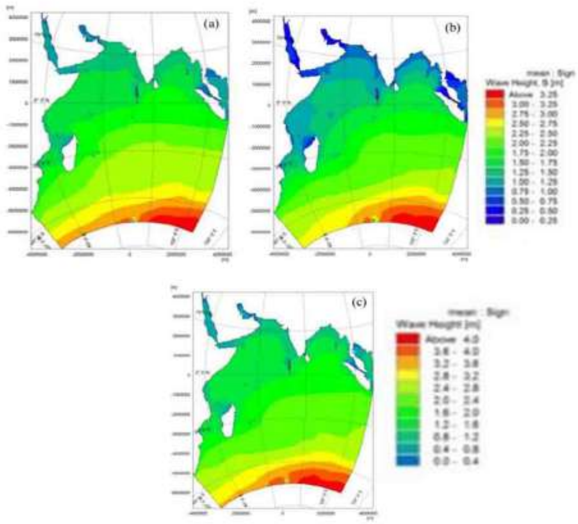


Fig. 2.1.2: Simulated significant wave height for a) pre-monsoon; b) monsoon; c) post-monsoon for the whole Indian Ocean

The simulated average significant wave height in the Indian Ocean region for the three seasons viz. pre-monsoon, monsoon and post-monsoon are presented in Figs. 2.1.2 a, b and c respectively. The simulated monthly average significant wave height, peak period and mean wave direction for the entire Indian Ocean clearly indicates domination of swell waves over the wind waves all along the southwest coast of India during the non-monsoon and vice versa during the monsoon period. The swell and wind separated components of the wave parameters also show a similar trend.

2.2 Investigation of roles of remote forcing along the coast and forecasting of coastal flooding

The occurrence of coastal flooding events along the SW coast of India particularly during the non-monsoon period has always been a matter of concern as this causes an unexpected rise in the water level which usually lasts for a few hours causing lot of hardship to the coastal community (especially in areas where the shore/land elevation is relatively low). As per the earlier studies carried out by CESS/NCESS, remote forcing of waves was identified as one of the key factors for coastal flooding. The project has been taken up to address this issue of coastal flooding along the low-lying regions of the SW coast of India. The major objectives are to study the different types of coastal flooding along the SW coast of India and to build in house capability for prediction of events through modelling studies.

As part of this study, attempts have been made to model the offshore wave dynamics and the related nearshore hydrodynamics for different types of coastal flooding events which occurred along the SW coast of India. For the model study, the coastal flooding events of 2nd September 2012, 6th September 2018 and 18th March 2019 were considered as examples.

In addition to the model studies, field measurements like nearshore waves and data pertaining to local beach morphology were also taken at regular intervals to understand the spatial and temporal variation in the nearshore hydrodynamics and its inter-relation with the local morphology, particularly during the flooding events. Since long-term wave measurements were not envisaged as part of the project, available old set of data from Wave Rider Buoys (WRB) deployed at about 22 m water depth, off the Quilon and Calicut coasts representing the southern and northern region of the SW coast were used. In order to collect the wave data pertaining to a high energy coast in the southern part, a WRB was deployed off the Valiathura coast in Trivandrum at about 20 m water depth and it is operational since June 2018. It also has an acoustic current meter attached to it for measurement of surface current. For analysing the most recent flooding events and also validating the model results, the data from the Valiathura buoy is used.

Discussion on model studies and their results:

The present study aims at analyzing in detail the causative factors for different coastal flooding events reported along the SW coast of India. Results from one of the modelling studies carried out at NCESS to analyse a flooding event in 2018 (during 26-28 September) is presented as a typical case study for flooding due to remote forcing or influence of long period swells. Apart from this, attempts were also made to study other types of coastal flooding events which are directly or indirectly related to the passage of storms. Numerical model results for one such flooding event which caused coastal flooding at low lying locations along the southern coast of Kerala in March 2019 are also presented here and the origin of this high wave activity was traced as the cyclonic storm formation near Madagascar.

For setting up of the model, the bathymetry data from ETOPO1 NGDC has been used for the offshore region whereas the fine grid bathymetry data available with NCESS was used for the nearshore region. Two models were set up for the analyses viz: global model covering the entire Indian Ocean and a fine grid regional model with the Trivandrum coast as model domain (Fig. 2.2.1 a&b).

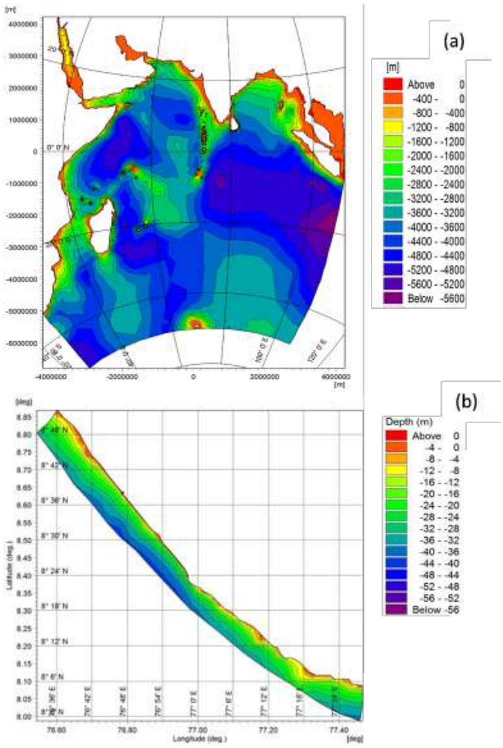


Fig. 2.2.1: Model domain a) global; b) regional

For simulation of the wave parameters, the Spectral Wave module of MIKE 21 is used. The forcing function for the global model is the ECMWF wind data, whereas for the regional model, the output wave parameters from the global model are used. Fine tuning and calibration of the wave model was carried out by comparing the model results with the measured wave data from the Wave Rider Buoy deployed at 20 m water depth off the Valiathura coast (Fig. 2.2.2). The model performance after fine tuning is reasonably good with a correlation coefficient of 0.77 and 0.89 for Hs and Tp respectively.

For validation of the model results of the flooding events, the beach profile data and LEO observations taken at three pre-defined coastal stations viz. Valiathura, Shangumugham and Adimalathura along the Trivandrum coast have been used.

Coastal flooding event during 26 –28th September 2018: The model results for the most recent flooding events of September 2018 and March 2019 are presented in Fig. 2.2.2. The coastal wind data for September 2018 recorded by the AWS installed at Valiathura were also analysed to study the influence of wind during the event.

From the model results it is inferred that during the coastal flooding event of 26-28 September 2018, there was domination of southern ocean swell waves with peak wave periods reaching up to 18 s. The simulated significant wave height during the event is about 1.5 m and this also corroborates well with the WRB observations. The analysis of tidal data during the event showed that the tidal elevations were relatively high during the flooding event. Continuous wind with magnitude up to 6 m/s was also present during the flooding event. Hence it can be concluded that the observed flooding is due to the combined effect of swell waves, wind and high tide conditions that prevailed during the event.

Coastal flooding event during 19 –20th March 2019:

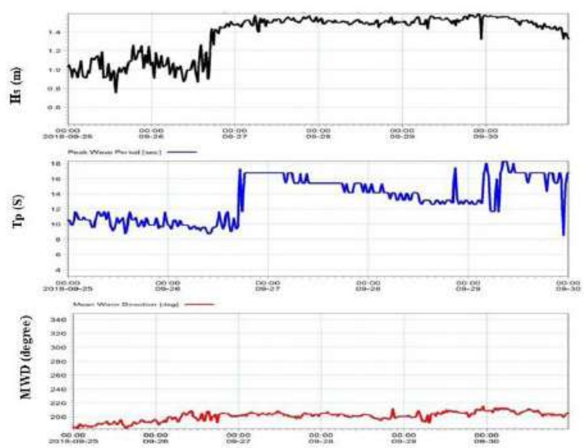


Fig. 2.2.2: Simulated results for the coastal flooding event of September 2018

The simulated wave parameters and tide for the flooding event of 19–20 March 2019 are shown in Figs. 2.2.5 and 2.2.6. Detailed analysis of the wave and wind data prior and subsequent to the event indicated that the flooding can be directly linked to the disturbances that occurred in the southern Indian Ocean before the event. During the middle of March 2019, the Indian Ocean witnessed 3 cyclonic storms viz. IDAI, SAVANNAH, JOANINAH. The first cyclonic storm is the IDAI, which had its origin off the eastern Mozambique coast on 4th March 2019. The cyclone which initially moved to the Mozambique Channel has subsequently changed its course towards east hitting the coast near southern Africa for the second time on 14th March. The second tropical cyclone SAVANNAH with its origin in north-western Australia on 14th March 2019 moved in the west-southwest direction and eventually got dissipated on 21st March after entering into the southern Indian Ocean. The third tropical cyclone JOANINHA, developed east-northeast of Mauritius on 22nd March, subsequently moved in the southwest direction and got dissipated on 31st March. These events in succession, led to the generation of high swell waves in the southern Indian Ocean region. The first and third cyclonic events had generated reasonably high amplitude swell waves (5 to 6 m coming from 18°S) which reached the southern part of the southwest coast of India. The wave height reached up to a maximum value of 2 m with wave periods of 16.5 s and inundated the low-lying areas of the southern part of the southwest coast of India. Based on this study, it can be concluded that the flooding event during 18-19 March 2019 is mainly due to the cyclonic disturbances that had its origin in the Indian Ocean.

2.3 Infra-gravity waves and its implications on the nearshore region of the west coast of India

Ocean surface waves comprises of waves in different frequencies ranging from capillary waves (<0.1 s) to Trans tidal waves (>24 hrs.). Of these, the infra-gravity (IG) waves having frequencies (more than 30 s) less than the wind-generated ocean surface gravity waves, but higher than the semi-diurnal tides can have significant influence on the coastal hydrodynamics of a coast, particularly the beach dynamics and sediment transport. These IG waves are generated by non-linear mechanism and they propagate freely in deep ocean. Even though studies related to the generation, propagation and dissipation of IG waves in other Oceans have been carried out since the middle of 20th Century, similar studies on the Indian Ocean are scanty, probably because of the limitations in getting measured data. The present study is taken up in this context to understand the IG waves generated in the Indian Ocean. The study which is in the preliminary stages, also aims to investigate the spatial variability of the IG waves in the deeper parts of the north Indian Ocean which includes deep waters of both Arabian Sea (to the west) and the Bay of Bengal (towards east) that surround the Indian Peninsula.

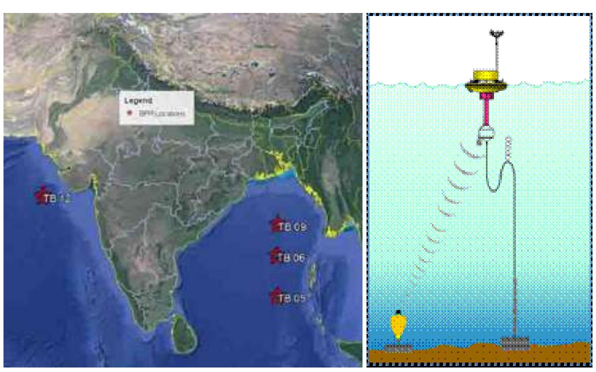


Fig. 2.3.1: Study area a) Bottom Pressure Recorder (BPR) locations; b) Anchored BPR & mooring for surface buoy

To study the infra-gravity waves in the northern Indian ocean, the pressure data obtained from four Bottom Pressure Recorder (BPR) stations (Fig. 2.3.1) established by NIOT, Chennai in the deep seas (at depths more than 2000 m) of the Arabian Sea (1 No., TB 12) and the Bay of Bengal (3 Nos, TB 05, TB 06 & TB 09) are utilized. The BPR stations which are established and maintained by the Ocean Observation Systems (OOS) team of NIOT, essentially forms part of the network of the Deep Ocean Tsunami Buoys which are meant for providing early warning in the event of occurrence of Tsunami. The BPR which is anchored to the seabed (Fig. 2.3.1 b) at predefined locations has potential to record sudden variations in the bottom pressure of the sea at very high frequency (15 s interval). A piezoelectric type pressure transducer is used by the BPR to take average of the pressure exerted by the overlying column of water, every 15 seconds and the recorded data is transmitted to the surface Tsunami buoy via an acoustic link. In order to obtain temporal variations in the sea surface elevations from the recorded BPR, the Fast Fourier Transformation Technique (FFT) is applied.

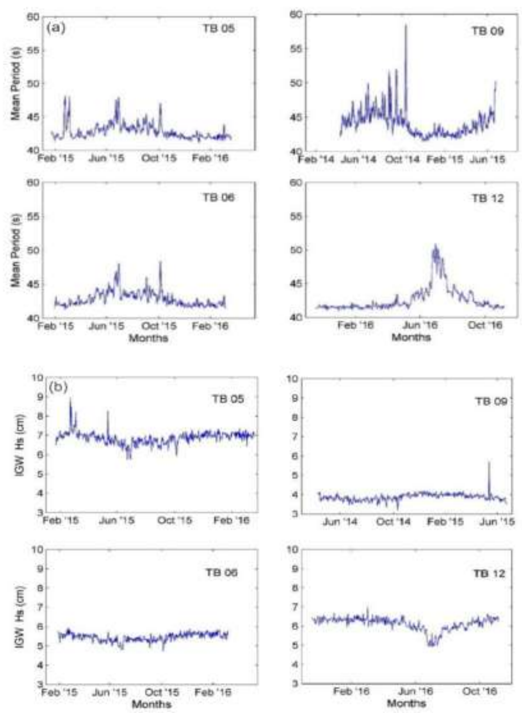


Fig. 2.3.2: Temporal variations in IG wave parameters from the BPR stations in the Northern Indian Ocean a) mean wave period; b) significant wave height

For the present study, the BPR data for the one-year period of Feb. 2015 - Feb. 2016 have been used. A detailed analysis of the data from the 4 BPR stations in the northern Arabian Sea reveals that the two stations namely TB 09 and TB 12 located in the northern Bay of Bengal and the northern Arabian Sea respectively, show a distinct increase in energy level, particularly between 30 sec and 20 minutes interval whereas it is not so evident at the other two locations (TB 06 and TB 09). The results of the analyses are presented briefly in the following sections:

The variation of mean wave period and significant wave height associated with the IG waves at the 4 locations are presented in Figs. 2.3.2 (a) and (b) respectively.

From Fig. 2.3.2 (a) it can be seen that the stations TB 05 and TB 06 show more or less similar trend except during early March. During this period, the TB 05 station shows higher wave period compared to TB 06 with the maximum reaching up to 48 s. In general, all the 4 recording stations showed seasonal variation in the wave period. But the seasonal variation in wave period was more pronounced for stations TB 09 and TB 12. These stations showed the maximum variation during the summer monsoon months of June, July, August and September (JJAS) and minimum during the pre-monsoon months of February, March, April and May (FMAM). However, the mean wave period range for the station in Arabian Sea (TB 12) was higher than that of the Bay of Bengal Stations (TB 05, TB 06 and TB 09).

The significant wave height shows decreasing trend towards the northern location and the seasonal variability is similar to that of the mean wave period. The variation in mean wave heights at the TB 09, TB 06 and TB 05 stations are (approx.) 4 cm, 5.5 cm and 7 cm respectively. The seasonal variability is more pronounced at TB 12, the station in the Arabian Sea, particularly during the summer monsoon months of JJAS. The highest wave height of 7 cm (approx.) is observed during the post monsoon months of FMAM and the lowest (~4.9 cm) during the summer monsoon months of JJAS.

Preliminary study conducted on the characteristics of IG waves in the northern Indian Ocean points out that the wave parameters viz. mean wave period and significant wave height exhibit both temporal and spatial variation. In spite of being seasonal, the significant wave height associated with these IG waves in the Indian Ocean exhibit more or less constant mean heights of 4 cm, 5.5 cm and 7 cm at stations TB 09, TB 06, and TB 05 respectively throughout the year, whereas the mean period varies between 40 and 60 s. In the Arabian Sea, the significant wave height shows seasonal variability with minimum mean value of 4.9 cm during the summer monsoon period of JJAS and an average of around 6.3 cm during rest of the time. But the mean wave period shows an opposite trend with the maximum observed during the summer monsoon months of JJAS and the minimum value during other months. In general, it can be stated that, as the energy level of the IG waves in the Indian Ocean is relatively more compared to that in the other major oceans like the Atlantic and Pacific Oceans, these IG waves can have an influence on the dynamics of the ocean.

In addition to the analyses carried out using the BPR data of NIOT, the measured sea level data obtained from the S4DW and Directional Wave Rider Buoy (WRB) off Ratnagiri, eastern Arabian Sea, located along the west coast of the Indian sub-continent is used to investigate the presence of infra-gravity waves as well as the source of infra-gravity waves that reach the near-shore regions of eastern Arabian Sea. Based on FFT analysis of the wave data, the estimated mean infra-gravity wave height is 0.04 m with a peak value of 0.08 m whereas the mean wave period of the infra-gravity waves is 60 s with a standard deviation of 8.9 s. Detailed analysis of the WRB data (wave period in the range of 0-30 s) provide reliable evidence indicating the presence of infra-gravity waves in the eastern Arabian Sea. The source of infra-gravity waves that propagate into the nearshore region could be either remotely or locally generated waves. However, it is observed that the presence of long-period gravity waves in the region has a direct influence on the infra-gravity waves. The amplitude of the infra-gravity is found to increase with the arrival of long period swell waves and vice versa.

2.4 Influence of northerly low-level jets in the South Asian mid-latitudes on the coastal wave dynamics of the west coast of India

There have been several studies in the past reporting the occurrence of persistent and periodic northerly low-level jets in the South Asian mid-latitudes and subtropics, but their influence on the Indian coast have not gained much attention. It is observed that in the eastern Arabian Sea, the normal propagation path of the northerly low-level jet gets altered as they move towards the Makran mountain ranges, located in the southwestern section of Baluchistan Province in southwestern part of Pakistan. The presence of the Makran mountain ranges with height up to 1500 m in this region literally acts as a barrier and this causes transformation of the prevailing northerly low-level jets, forcing the wind to blow predominantly in the west-northwest to northeast directional sector. The newly developed wind system is named as "Makran winds" as the Makran mountain ranges are mainly responsible for the transformation of the northerly low-level jet. As per observational evidence, sustenance of moderately strong wind conditions in this region (Makran winds) can lead to generation of a new wave system which propagates through the Arabian Sea with wave characteristics similar to that of swells. This newly identified wave system, which prevails mostly during the non-monsoonal months of October to May, is named as Makran swells as the forcing wind system has its origin in the Makran mountain ranges. In the present study, an attempt has been made to investigate the influence of the Makran swells on the wave dynamics of the west coast of India.

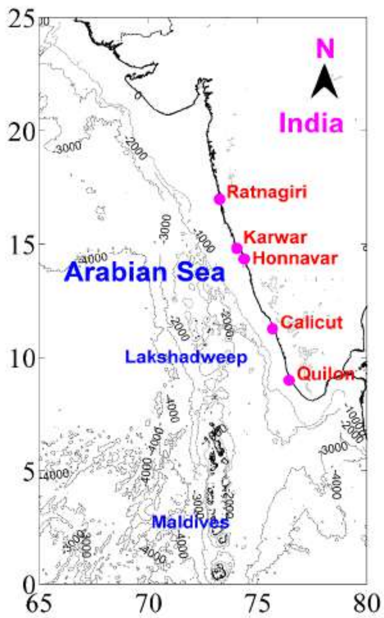


Fig. 2.4.1: Wave measuring locations along the west coast of India

For this study, the measured wave data collected from five nearshore Wave Rider Buoy (WRB) stations viz. Ratnagiri (13 m depth), Karwar (15 m depth), Honnavar (9 m depth), Calicut (22 m depth) and Quilon (22 m depth) spread over a coastal stretch of 1000 km (approx.) along the west coast of India (Fig. 2.4.1), have been used. The WRB measurement periods considered for the study is the one-year period, from February 2014 - January 2015 for the Calicut and Quilon stations and the two-year period, January 2012 - December 2014 for the Honnavar, Karwar and Ratnagiri stations. From the measured WRB data, the spectral and integral wave parameters were derived adopting the method described by Tucker (1989). Some of the salient findings of the study are discussed in the next section.

Detailed analyses of the measured wave spectra at selected locations viz. Ratnagiri, Karwar, Honnavar, Calicut and Quilon along the west coast of India clearly indicates the influence of a newly generated wave system during the non-monsoon Makran events. A case study of a similar condition that prevailed during the typical non-monsoon month of February (i.e. in February 2014) is presented here. Critical examination of the wave spectra during February 2014 at the 5 coastal stations mentioned earlier revealed the presence of two distinct swell systems: (a) long period swells (<0.12 Hz) that propagated from southern Indian Ocean in S-SW direction and (b) moderate swells (0.12–0.25 Hz) that propagated from the northern Arabian Sea in NNW direction (Fig. 2.4.2 a-c). Of the two systems, the southerly/south-westerly swells are common along the west coast of India and they prevail throughout the year, with varying intensity. The second system i.e., the NNW swells are generated by the newly identified Makran wind system that propagates from the Makran mountain ranges. During the Makran events, it is observed that the prevailing south-westerly swell in the northern Arabian Sea weakens and subsequently a strong northerly wave system develops. The growth and propagation of this new wave system are mainly controlled by the intensity and duration of the Makran wind system, which after generation propagates in two dominant directional sectors: (a) WNW to NNW and (b) N to NE. The duration of a typical Makran event can vary between 1 and 6 days. The wave spectral densities during the Makran swell period are higher off the Ratnagiri coast compared to Quilon and the corresponding peak energy frequencies at Ratnagiri and Quilon are 0.22 and 0.18 Hz respectively (Fig. 2.4.2). This clearly indicates that there is a distinct decrease in the intensity and duration of the Makran swells as we move from north to south along the west coast of India. The maximum Hs associated with Makran swells at Ratnagiri, Karwar, Honnavar, Calicut and Quilon stations are 1.47, 1.55, 1.26, 0.90 and 0.86 m respectively. The corresponding Tm02 at Ratnagiri, Karwar, Honnavar, Calicut and Quilon stations are 6.0, 6.5, 6.9, 7.0 and 7.1 s, respectively and these are more or less similar to that of the shamal swell periods. Even though the period of the waves arriving at the 5 coastal stations during the event appears to be relatively low, these waves have all the characteristics of typical swell waves as they have travelled considerable distance out of the generation area without the influence of the source wind system. It is observed that similar short period swells occur along the west coast of India during the SW monsoon as well wherein the potential swell generation area is the southwestern Arabian Sea. The maximum Hs is observed at Karwar (central west coast) even though percentage of occurrence is relatively high at Ratnagiri. This discrepancy is attributed to the spatial variation in bathymetry of the region. The continental shelf off the Ratnagiri coast being wider compared to Karwar causes relatively larger dissipation of wave energy. Another interesting observation during the occurrence of the Makran swells is that the south-westerly swells are generally insignificant. The Makran swells, as they approach the west coast of India propagate in a direction almost normal to the shore, indicating a deviation of 30– 45º from the dominant Makran swell wave direction (transformation from NNW to NW/WNW) and this invariably can be attributed to the shallow water effects as the waves propagate into the shallow sea. The estimated arrival time for the Makran swells to reach the west coast is 2-3 days based on observations. Considering the generation area of Makran swells as the central south coast of Pakistan, the estimated arrival time for waves with a mean period of 6 s at the Ratnagiri and Quilon

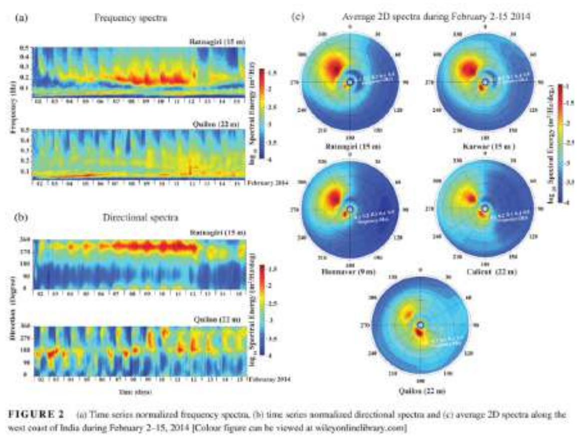


Fig. 2.4.2: a) Time series normalized frequency spectra; b) time series normalized directional spectra; c) average 2D spectra along the west coast of India during 2-15 February 2014

coast are 37 and 63 hrs respectively. This clearly shows that there is a time lag of ~26 hrs for the arrival of Shamal waves between these two stations which are located 1,000 km (approx.) apart.

Although relatively low, the influence of the sea breeze-land breeze system on the wind sea component of the wave energy is quite evident at all the 5 coastal stations and this essentially contributes to the diurnal variability. The present study even though in the preliminary stages gives a clear indication that the Makran swells can have significant influence on the shallow water wave characteristics along the west coast of India. This in turn can cause spatial and temporal variations in the nearshore currents and the related sediment dynamics of the region.

This work has been carried out in collaboration with CSIR-NIO. The wave data used are from the Wave Rider Buoys of NIO and INCOIS.

2.5 Long-term shoreline changes along the southwest coast of India

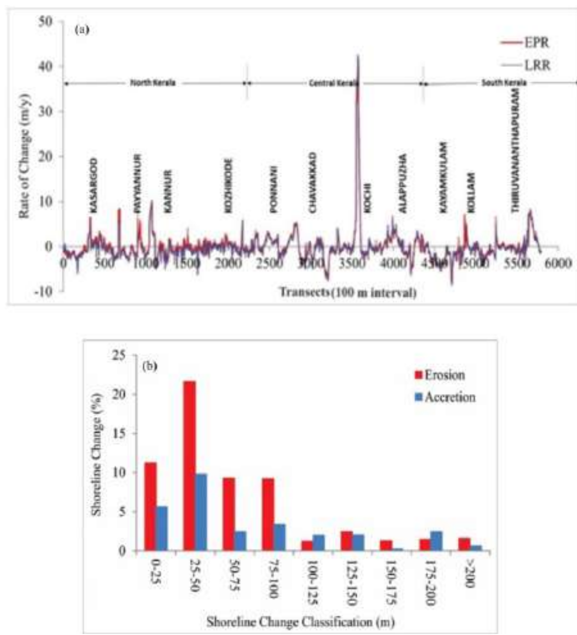


Fig. 2.5.1: a) Computed rate of shoreline change along the Kerala coast during 1968 - 2014 using EPR and LRR methods; b) Shoreline change in percentage along the Kerala coast

Long-term shoreline changes (1968 - 2014) along the south-west coast of India have been studied and their causative factors delineated. The data used for the study are the digitised shorelines from multi-dated satellite imageries and Survey of India (SoI) topographic charts. For this study, rate of shoreline changes along different sectors of the coast has been computed using the DSAS software (USGS). For arriving at the current status of the coast, the entire coastal stretch has been broadly classified into 7 classes based on the computed rate of shoreline change over a pre-defined period of time. As per the defined classification, the present status (stable / dynamically stable / unstable) of different sectors of the coast is assessed. The computed rate of shoreline changes along the Kerala coast during 1968 – 2014 using EPR and LRR methods, and shoreline change in percentage along the Kerala coast are shown in Figure 2.5.1 a and b respectively. The study reveals that almost 60% of the SW coastline has an eroding nature and about 29% shows an accreting trend.

2.6 Development of coastal video monitoring system for India

In India, many of the coastal areas are under enormous stress due to various factors like increase in population, rapid industrialization, other anthropogenic activities like beach sand mining, dredging activities related to port and harbour construction etc. In addition, changes induced due to sea level rise as a result of global warming and other natural factors like occurrence of storms (their frequency, intensity and duration) also play a vital role in maintaining the stability of the shoreline. It is observed that flash flood events occurring during the non-monsoon period are common, particularly along the SW coast of India which is considered as a highly dynamic wave dominated coast. However, details pertaining to these events viz. causative factors - frequency, intensity and duration are not well documented mainly due to lack of direct observations (continuous monitoring). In this context, the need for continuous monitoring of critical coastal regions is essential to have an understanding of the short-term and long-term changes and also for planning appropriate coastal protection measures as well as disaster mitigation measures.

NCESS has taken up a project with the prime objective of developing an indigenous coastal video monitoring system which can provide valuable scientific information to understand and study the complex coastal processes. The first in India camera station was installed at Valiathura, Thiruvananthapuram in 2016 and methods for data acquisition, camera calibration pre-processing have been developed during first phase of development. The progress of work in connection with the development of coastal video monitoring system for India is briefly described in the next section.

Development of algorithm for nearshore wave analysis: Time series datasets have been extracted from rectified video imagery for nearshore wave analysis. These time stacks are severely affected from sunlight variations and the non-linearities of nearshore coastal processes because of varying bathymetry and other local influences. In such noisy environments, non-linear modulated transfer functions are inevitable for processing of video data. A Wave and Tide Recorder (WTR) has been deployed in the nearshore for *in-situ* wave measurements. The data from WTR has been used for estimation of transfer function and also for validation of video-based wave analysis.

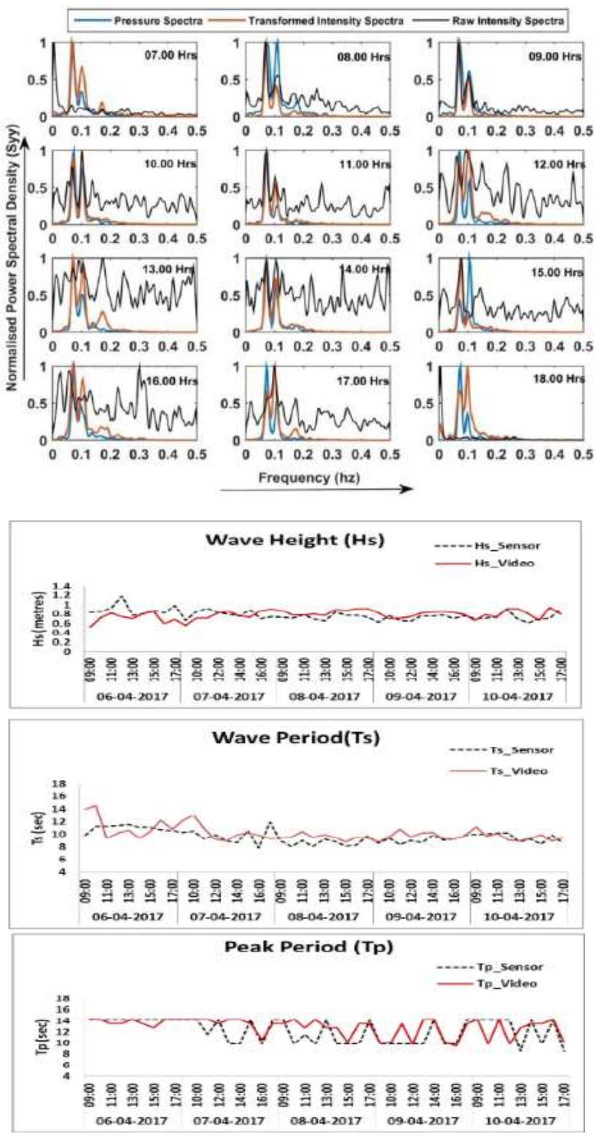


Fig. 2.6.1: Nearshore wave analysis

Here a new transfer function between video time stack and pressure data from WTR has been designed using Thomson's multi taper method to reduce the noise from various sources viz. local weather conditions and contaminants if any. The application of this transfer function has reduced the errors significantly as it is observed that the transformed intensity spectra obtained from video time stack and spectra from *in-situ* pressure data are in good agreement with a correlation above 85 % throughout the day. Then, the wave parameters such as wave height (Hs) and peak wave period (Tp) were estimated with the transformed video time stacks and validated with the *in-situ* measurements from WTR. The measurements are corroborating well and the values of mean bias and RMS error are within acceptable limits. It is also confirmed that adopting multi-taper methods in transfer function estimation will reduce the noise and local influences for video-based wave analysis.

Installation of second camera station at Kozhikode: With the knowledge and field experience gained from Valiathura monitoring station, the NCESS team made further modifications in the design of mounting frames and their installation, in order to improve the overall performance by addressing various issues like long-term use in marine environment, optimum settings that can take care of variations in sunlight, minimizing errors in geo-rectification etc. Thus, a new frame and camera protection outdoor units were designed in-house and a 2nd camera station was installed (about 41 m above MSL) at Kozhikode with two cameras covering 1.6 km alongshore. The initial camera calibration, image colour scheme adjustments, recording schedule to record a video of 10-minute duration with 8 fps for every half-an-hour and data archiving setting were adjusted during the installation. The camera station started collecting video data since 01 August 2018. All the image products like Timex and Variance images have generated. Then ground control points were also collected using DGPS and Total Station survey and rectified Planview images have been produced. A detailed experimental study with simultaneous field measurements like beach profiling, nearshore bathymetry, recording of wave and tide by deploying instruments at pre-defined locations, shoreline survey etc. was conducted in April 2019 to develop and fine tune algorithms for Kozhikode station and validated the performance of the system under varying environmental conditions.

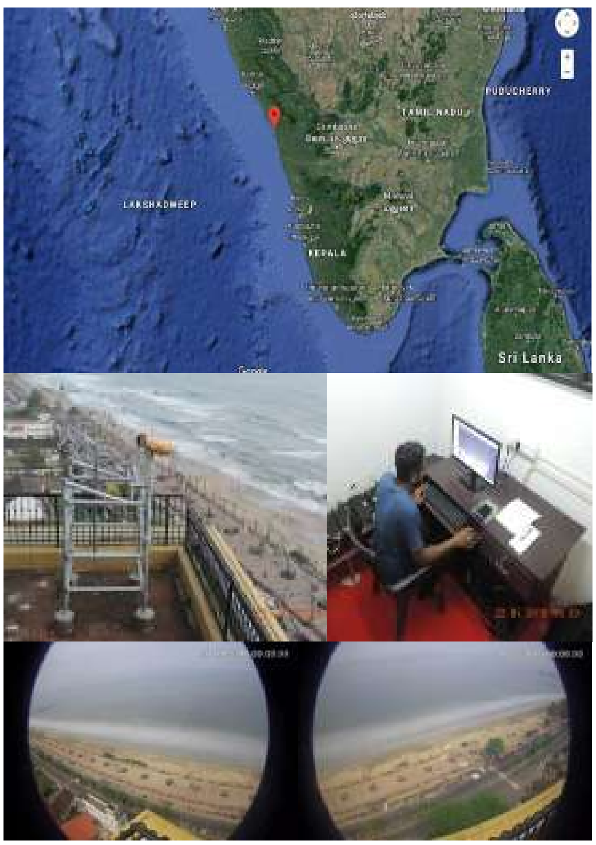


Fig. 2.6.2: Kozhikode camera station

Testing with various cameras for designing simple and robust camera system hardware for future camera stations: Field trials have been conducted using different types of cameras viz. PiCamera and MOBOTIX at Valiathura, Shanghumugham and Adimalathura beaches to explore the possibility of upgradation of the existing camera system with advanced functionalities like night vision, inbuilt NVR, solar power supply, online data transfer/cloud storage facility so that we will be able to configure a system which will satisfy all our technical requirements. The field trials have shown that combination of optical and thermal cameras can provide 24-hr continuous monitoring of the coast.

2.7 Depositional history of sediments along the Calicut coast - southwest coast of India

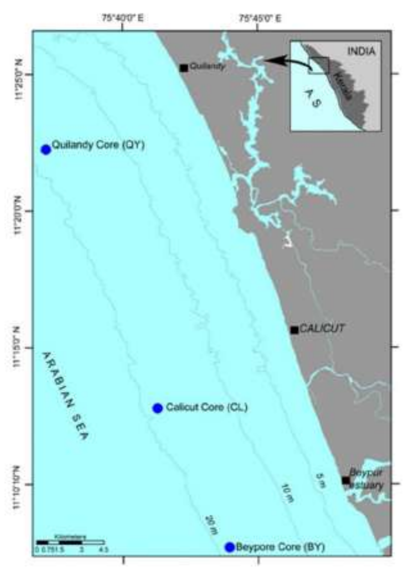


Fig. 2.7.1: Location of sediment cores along the Calicut coast

The main objective of this work is to delineate the source-sink relationship, sedimentation and depositional history of inner-shelf sediments off the Calicut coast. The study area is the inner-shelf region of Calicut coast extending from Beypore in the south to Quilandy in the north located along the SW coast of India. Three sediment cores with retrieval length of 180 to 214 cm were collected from 20 m water depth off Calicut coast (Fig. 2.7.1) using gravity corer. In the present investigation one sediment core (214 cm length) representing the Beypore estuary is taken up for detailed sedimentological and geochemical analyses. Sediment core was sub-sampled at 2 cm interval and based on visual observations, about 48 samples were chosen for grain size analysis using CILAS 1180 Particle Size Analyser. Subsequently, the sand-silt-clay percentages and statistical parameters such as mean, sorting, skewness, and kurtosis are computed using the Gradistat software. The sediment samples are also analysed for Total Carbon (TC) and Total Sulphur (TS) contents using CHNS analyser.

Sediment litholog: The textural analysis reveals that the core comprises of 5 litho units indicating changes in the depositional environment. The first unit (0-40 cm) comprises of light brownish sediment with sand, silt and clay contents ranging from 9.77 to 38.19%, 54.82 to 76.89% and 6.99 to 13.5% respectively with small amount of heavy minerals. The TC and TS content ranges from 1.41 to 2.42% and 0.97 to 1.47% respectively. This is followed by the second unit (40-130 cm) which consists of light greyish sediments enriched with silt content varying between 59.1 and 84.88% and has less percentage of sand content. In this unit, the TC content ranges from 1.66 to 2.62%. TS content varies between 1.09 and 2.01%, which is slightly higher compared to that of the previous unit. In the third unit (130-150 cm), the sand content increases sharply from 0.77 to 49.96% with slight reduction in the silt content (avg. 57. 52%) and also significant amount of bivalve shells which are partially broken or fully preserved are observed indicating drastic change in the depositional environment. Moreover, presence of heavy minerals is also observed in this unit. Here, the TC and TS contents range from 1.32 to 2.77% and 0.52 to 1.3% respectively. This is followed by the fourth unit (150-180 cm) where the sediments are reddish brown to very dark grey in colour, showing enrichment of clay with percentage varying from 28.54 to 62.28%. The TC and TS contents indicate significant enrichment with percentages ranging from 0.94 to 7.9% and 0.88 to 6.66% respectively. The last unit (180-214 cm) comprises of equal proportion of sand, silt and clay contents ranging from 23.67 to 41.26%, 31.07 to 39.45% and 27.67 to 38.74% respectively. The sand content comprises of medium to coarse grained sediment type while the TC and TS contents showed negligible content throughout the unit, with percentages varying between 0.28 to 0.47% and 0.66 to 1.97% respectively.

The radiocarbon dates on selected samples based on AMS dating reveal that the age ranges from 2515 to 2740 Kyr Cal BP at 80 cm depth, whereas it is 7660 to 7901 Kyr Cal BP for 80-100 cm depth. At 150 cm depth, the age ranges from 8132 to 8356 Kyr Cal BP and at the bottom (200 cm) it varies between 11163 and 11533 Kyr Cal BP, indicating the deposition of sediments from early Holocene to recent.

Geochemistry: Major and trace element geochemical analyses of selected samples representing the top, middle and bottom of the core were carried out using XRF analysis. The geochemical elements are normalised based on the values of upper continental crust. It is observed that the MgO, K_2O, CaO and Na_2O contents in the lower section of the core show significant variations compared to that of the upper and middle sections. The analysis results indicate depletion of the metal Zn in the core whereas enrichment of Cr, Ni and Cu is noticed in the upper and middle sections of the core samples, compared to the bottom. The result indicates a change in the detrital source. The ternary diagram for the source rock plotted based on K_2O-Fe_2O_3-Al_2O_3 composition reveals that the major source rock is charnockite. The Nickel (Ni) versus Vanadium (V) graph plotted to understand the depositional environment indicates deposition of sediments under marine-terrestrial-oxic-disoxic conditions. In order to study the sedimentation

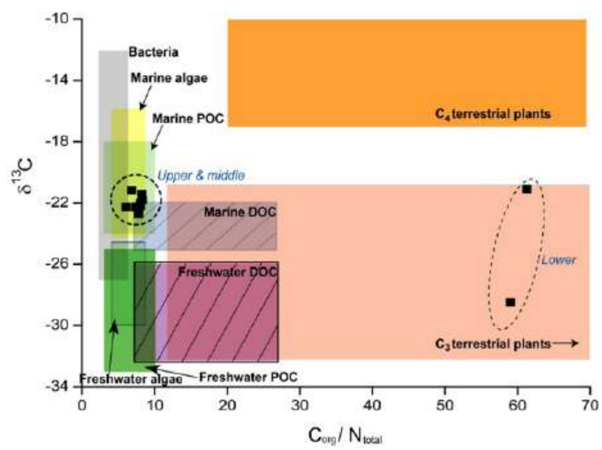


Fig. 2.7.2: TOC/TN versus $\delta^{13}C$ plots demarcating source of organic matter in the Beypore sediment core

rate, off the Beypore and Calicut coast, the ^{210}Pb dating technique was adopted. The sedimentation rate for the Beypore core is 2.05 cm/yr whereas for the Calicut core, the rate is 0.5 cm/yr. The higher sedimentation rate for the Beypore core can be attributed to the sediment inputs from the Chaliyar River through Beypore estuary. In addition, stable isotope composition of organic matter in the core is also studied based on the TOC/TN and δ^{13}C contents. The TOC/TN vs δ^{13}C plot (Fig. 2.7.2) indicates that the source of organic matter in the lower section of the core is C3 and C4 terrestrial plants whereas for the upper and middle sections, it is attributed to a mixture of terrestrial and marine sources.

Based on sedimentological and geochemical studies and age determination using radiocarbon dating it can be inferred that high amount of monsoon rainfall followed by the sea level changes during the early Holocene lead to the incision of large amount of sediment inputs from the Beypore estuary. The results indicate that the early shoreline was at 20 m depth from the present shoreline. The multi-modal grain size distribution and the increase in coarse grain size fractions at the bottom of the core also confirms the change in deposition scenario. The absence of smectite clay minerals at the bottom (11000 years) of the core indicates formation of frontal beach system during the early Holocene period.

2.8 Environmental magnetic and geochemical characteristics of core sediments from the Beypore estuary, southwest coast of India

Environmental magnetic/rock magnetic and geochemical characteristics of estuarine sediments are studied to understand the environmental condition and sedimentary history. The Beypore estuary is a tropical, micro-tidal, diurnal wave-dominated estuary situated in the Kozhikode district of Kerala, southwest coast of India. Biotite-hypersthene gneiss, biotite-hornblende-hypersthene gneiss and charnockite are the hinterland geology of the study area. Occasional presence of pebble beds is seen on the banks of the Beypore and Chaliyar River. During the 19th and 20th century the Chaliyar river was extensively used as a water way for carrying the timbers and other wood material. Because of the Chaliyar agitation, the Gwalior Rayon factory at Mavoor was permanently closed down in 2002. The important industries in the banks of the estuary are textile mills, saw mills, ship breaking units and numbers of tile and brick factories.

The prime objective of this work is to obtain the high-resolution paleo environmental data using magnetic susceptibility as a proxy. Many investigators have successfully used the environmental magnetism as a proxy for identifying various pollution sources from the sediment samples. This is a simple, rapid, inexpensive, sensitive and non-destructive tool to determine the paleo environmental condition. Composition, magnetic mineral concentration and grain size are the controlling factors for magnetic enhancement. For the present study eight short sediment cores and 16 surficial sediments collected from the estuary representing the upstream of the river (Fig. 2.8.1) were used. The cores were sub-sampled into 1 cm and 2 cm interval. Two cores representing C7 and C8 are from the fresh water regime of the Chaliyar River. This work is a preliminary set of environmental magnetic data of sediment samples from a tropical estuary.

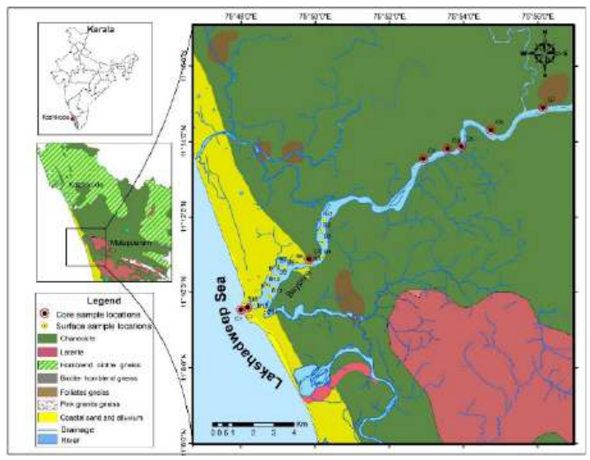


Fig. 2.8.1: Study area showing the short cores and surficial sediment locations along with the geology of the area

The sediment samples from the estuary are dominated by sand (63.31%) followed by clay (7.52%) and silt (28.23%). The sediments of the upstream of estuary are sandy in nature due to the influence of Chaliyar River, while coming into bar mouth where the fresh and saline water is mixing, the sand percentages decreases and clay and silt contents increase. All the sediment cores show high variation of fine to coarse sediments. At the top of the core fine sediments dominates even up to the 20 cm length. Probably the coarse grains of the sediments are removed and transported due to the dredging activity. But in the middle of the cores, there is a sudden increase in the grain size approximately 2 times of grain size corresponding to the period of 1999-2011 (except C5, even though it is from middle of the estuary, it shows fine sediments). The mean grain size ranges from 13.5-

96.48 μm in the lower, 46.71-95.92 μm in the middle and 12.63-207.63 μm in the upper estuaries respectively. Lead - Caesium dating is one of best methods for the dating of short cores from the recent times. Dating of selected 10 samples was done from PRL (^{210}Pb and ^{137}Cs). The sedimentation rate in the Beypore estuary is estimated to be 3.32 cm/yr and 1.5 cm/yr. Magnetic susceptibility was also measured which is indicative of the magnetic mineral concentration present in the samples. The value ranges from 22.72 to 499.13*10^{-8} m^3/kg in core sediments. High values are at the middle portion of the core. The ratio of magnetic parameters like χARM, SIRM/χlf, χARM/χfd %, S ratio, χfd %, SIRM, χARM/χlf, etc. show considerable changes, during the period (Fig. 2.8.2).

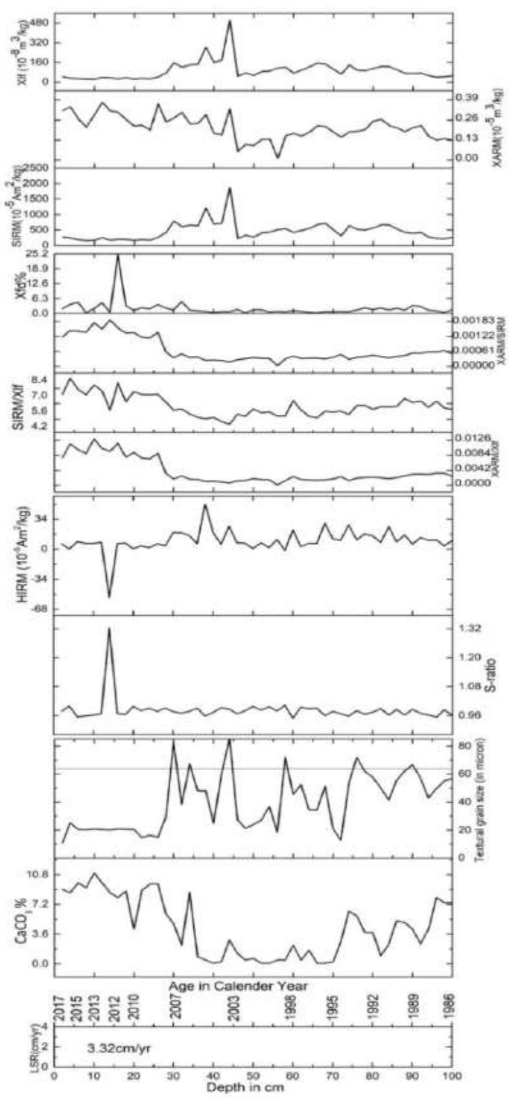


Fig. 2.8.2: Downcore variations of multi proxy approach of the core sediment from the bar mouth of the Beypore (rock magnetic, heavy metal, organic chemistry & grain size)

The susceptibility value is ranging from 15.84 to 112.89*10^{-8} m^3/kg in surficial sediments. The values are anomalous in meandering regions. Activities related to harbour development, dredging operations including various physico-chemical processes could be the triggering mechanism for the enhancement of concentrations of these elements. High rainfall periods are characterized by a high concentration of magnetic minerals as the chemical weathering is intense leading to a high input of magnetic minerals along with terrigenous material and vice versa.

2.9 Landform dynamics and its impact on stability of coastal zone

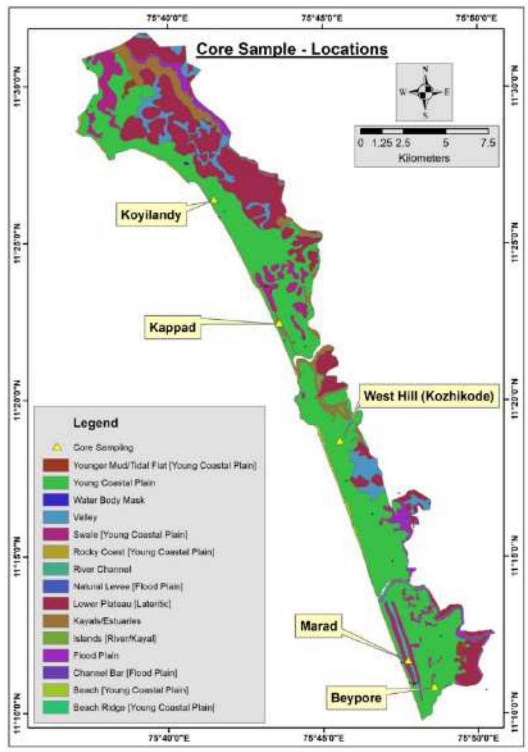


Fig. 2.9.1: Core sample locations along the Beypore-Koyilandi coastal stretch

The different coastal geomorphological units were mapped along the Kozhikode coast, SW India in 1:10000 scale and cadastral scale, and generated high resolution Digital Elevation Model (DEM). The subsurface lithological data were also collected from resistivity surveys. After critically examining the landforms generated from the DEM and lithological data, five locations were identified for retrieval of core samples as shown in Figure 2.9.1. The background information available with CWRDM and CGWB on resistivity and lithological information were also used to precisely identify the sampling locations. The sampling locations viz. Koyilandi, Kappad, Kozhikode, Marad and Beypore are selected in such a way that the primary core data would provide first-hand information to understand landform changes during the Quaternary Period. Based on the data generated, the paleo shoreline was identified at 2 to 5 km landward of the present shoreline. It is reported that the river course of the area has changed during the Pleistocene – Holocene period under tidal influence. Based on the study, different geomorphic maps on drainage, lithology and land use/land cover are prepared.

The collected core samples are prepared for dating and sedimentological analyses. The works are in progress. Analyses of the core samples collected from the first locations is presented here. It is observed that at the first location i.e. Koyilandi, the top portion of core samples is composed of medium sand, and further down, coarse to very coarse sand mixed with shell fragments and silty clay with sand are present. Occurrence of lateritic soil and red clay at 10 m depth and mica with sandy clay is seen further down indicating signatures of regression. The second core sample collected from south of Kappad, with recovery length up to 21.5 m depth indicates presence of clay and blackish silty clay with peat. The third sample collected from the midportion of the study area has a core length of 12.8 m. It is composed mainly of medium to coarse sand. The 4th and 5th core samples which represent the southern portion of the study area were collected representing Marad and Beypore respectively. The subsamples from these cores will be subjected to particle size analysis to obtain the lithological sequence which is in progress. In addition, the representative samples from each location are further processed for dating to have an understanding on the evolution of the coastal plain.

2.10 Benthic foraminifera as potential ecological proxies for environmental monitoring in coastal regions: A study on the Beypore estuary, southwest coast of India

Worldwide, benthic foraminifera is being utilized as bioindicators to demonstrate the impact of environmental changes. The increasing inputs of pollutants affects both species composition and the biodiversity of the environment. In this study, benthic foraminifera were assessed from 16 sediment samples collected from the Beypore estuary, southwest coast of India. Foraminiferal specimens are extremely sparse in the samples; the median number per sample was 12 specimens. The lower estuary has yielded more than 50 specimens from 50 g subsamples of the sediment sand fractions (>1 specimen per g). Even the two samples from near the mouth of the estuary, in which 77 % of all specimens were found, yielded <15 tests per g. The abundance and diversity of *Quinqueloculina lata*, *Textularia agglutinans*, *Haplophagmoides canariensis*, and *Quinqueloculina stelligera* were dominated by stress-tolerant taxa such as *Ammonia tepida*, *A. parkinsoniana*, *Nonion grateloupi*, and *N. scaphum* in the estuary. Overall, 17 species were identified; the median number of species per sample was 3.

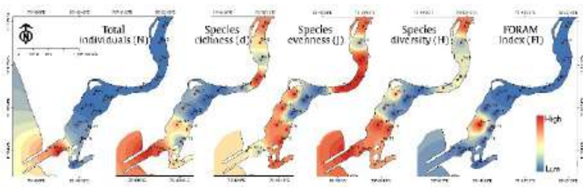


Fig. 2.10.1: A model of the ecology and distribution of benthic foraminifera at Beypore estuary

The small-size foraminifera test probably perished in a juvenile stage because of the high temperature and low salinity that prevailed in the ecosystem. The dominance of stress tolerant benthic foraminifera and absence of *Elphidium* species in the estuary suggest the prevalence of hypoxic (low-oxygen) conditions. The quantitative foraminiferal data were used to calculate several foraminiferal indices including total foraminiferal absolute abundances (A), relative abundances (R%), total individuals (N), species richness (d), species evenness (J), Shannon-Wiener diversity (H) and FORAM Index (FI). The absolute abundance shows its increasing trend from upstream (upper estuary) to estuarine mouth (lower estuary). The foraminiferal diversity indexes show consistently low values and the dominance of stress-tolerant taxa indicates highly stressed conditions (Fig. 2.10.1). The absence of *Elphidium* in the estuary indicated possible hypoxic conditions. The low diversity and low total number of tests in 60% of the estuary are stressed either by anthropogenic activity and natural variability in ecological parameters. The dominance of *Ammonia* spp., a known stress tolerant benthic taxon and absence of *Elphidium* spp., validates prevalence of low-oxygen conditions. The FI < 1.5 indicates environmental conditions that support substantial populations of stress-tolerant species.

Based on the dominance of *Ammonia* in all the locations, the tests of *Ammonia parkinsoniana* and *A. tepida* was analysed using SEM and EDX detectors for the element weight percentages (Wt%) from spectrum generated by irradiation of the EDX detector at one shooting point (aperture) (Fig. 2.10.2). Chemical constituents screening in the benthic foraminiferal shell is a step ahead to identify the capacity of benthic foraminifera in responding to anthropogenic metal contamination in coastal areas. The main building elements of *Ammonia sp.*, shell is oxygen on an average range of 45.36- 51.45 Wt% and calcium on an average range of 23.88- 39.34 Wt%. The Principal Component Analysis (PCA) and Cluster analysis revealed that, when the element Wt% of Al, Si, and Fe increased, Ca Wt% was decreased. The increasing Wt% of anthropogenic elements indicate that the study area is highly stressed with anthropogenic activity. This preliminary research showed that the juvenile form of *Ammonia sp.*, tends to contain lower C and O elements due to anthropogenic activity.

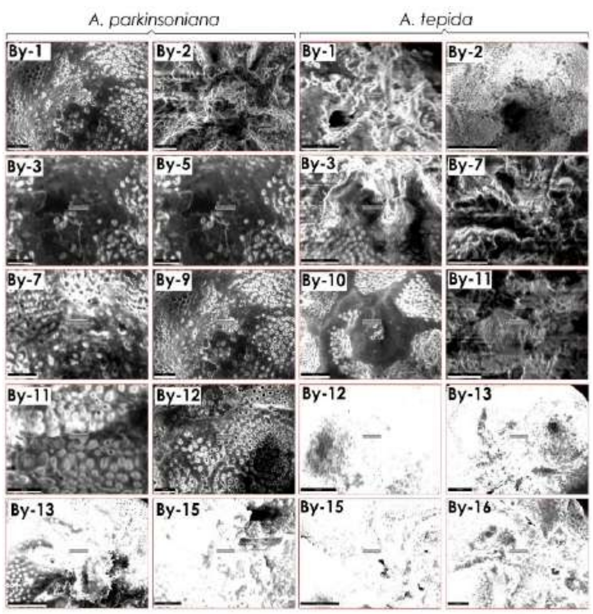


Fig. 2.10.2: SEM photograph of EDX detector shooting point (aperture) of A. parkinsoniana and A. tepida

2.11 Characterization of SW coastal zone exhibiting Submarine Groundwater Discharge

Submarine groundwater discharge (SGD) and sea water intrusion are two facets in coastal aquifers. SGD is a mixture of both fresh groundwater and marine (saline recirculated) groundwater that discharges over spatial scales from meters to kilometres to the sea.

To define SGD's prospective zones, the groundwater dynamics pertaining to India's SW coast (Kanyakumari to Mangalore) was examined using archival information from the Central Ground Water Board (CGWB). Data from the monitoring wells across the Kerala coast were used to create groundwater level map above mean sea level. The undulating nature of the topography is reflected in the water table also. The data in general show that elevated water table positions are seen towards the northern Kerala coast in comparison to the southern side. The high hydraulic gradient towards the shoreline (> 5 m aMSL) provide clues on groundwater discharge to the sea in such segments (Fig. 2.11.1 a). Alternatively, potential zones of seawater ingress are also visible (hydraulic gradient < 0) in this analysis. It is observed that the hydraulic gradient towards the sea is more than 10 m aMSL at southern (Kanyakumari to Kollam) and northern (Kozhikode to Mangalore) segments (Fig. 2.11.1 a), which is related to the physiographic set up of the area.

Further, satellite thermal infrared imaging was used to identify the location and spatial variability of SGD by exploiting the temperature difference between surface water and groundwater at certain times of the year, particularly summer. Sea surface temperature derived from Landsat 8 thermal infrared (TIR) imagery of SW coast in India is shown in Fig. 2.11.1 b. TIR images have allowed mapping several thermal anomalies related to outflows of freshwater plumes with temperatures ranging from 28.2 °C to 30.6 °C which is lower than the minimum sea water temperature (25–33 °C) usually recorded for the area. SST demonstrates the spatial variability in SGD alongside the beach face, which allows to design appropriate field sampling campaign subsequently.

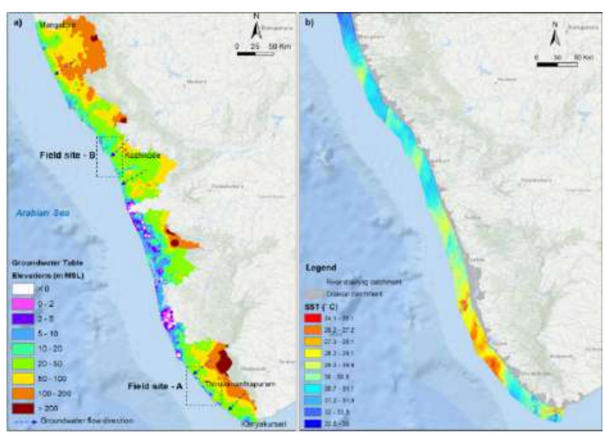


Fig. 2.11.1: a) Map showing the indication of coastal groundwater dynamics by archival data; b) Sea surface temperature composite from Landsat 8 (February-March, 2019)

Field Programs: After delineation of zones of probable groundwater discharge using archival database and satellite thermal data, fieldwork was carried out to collect primary evidence between Kanyakumari and Alappuzha in first stage during 2018-19. The dynamism of SGD was demarcated at locations where presence of freshwater occurs very close to shoreline even in summer. Confirmatory tests were carried out using extensive Radon surveys. The first phase of the coastal range of 257 km was investigated and of which 27 km shoreline was excluded being the presence of back waters and estuaries. Water table level, groundwater conductivity, salinity and groundwater temperature from the beach as well as from adjacent wells were monitored using *in-situ* water quality data loggers. Natural radon is an excellent tracer for identifying areas of significant groundwater discharge because of its conservative nature, short half-life, high abundance in groundwater compared to surface water. Radon activities in groundwater are often 2-4 orders of magnitude higher than those of seawater. Radon values obtained from the pore-water and well water samples are presented.

A total of 108 pore water and groundwater samples were gathered and analysed during early 2019 covering the beach and wells close to the shoreline. The samples were collected during the low tide period to nullify the effect of saline water interferences. The average water table depth is 2.6 m with a range between 0.7 m (Kollam) and 9.05 m (Kanyakumari). While the pore water from intertidal zone was collected with the help of a push point piezometer which enabled sampling from a depth of 1 m. The activity of ^{222}Rn was determined using RAD AQUA and RAD H2O (Durridge Company, Inc.).

Since radon is influenced by the radioactive sediments present in beach placers, it cannot alone be taken as a proxy for SGD. However, radio activity does not affect the EC and therefore, it can be used in conjunction with radon levels and temperature. The average EC measurements for Arabian Sea are 35-35.5 PSU during pre-monsoon (Kumar, 2013). Thus, the salinity was converted to EC (53.7 mS / cm) and those samples with < 53.7 mS/cm were classified as representing the influence of fresh water. The radon concentration in these same samples confirms fresh water interference. The sample temperature falling below the average temperature (30.4 °C) was also associated with measurements of radon and EC. Thus, those sampling locations with low EC and temperature and elevated radon content were demarcated as potential SGD segments for further investigations.

Sixty sampling sites out of 108 locations from Kanyakumari to Alappuzha denote this classification of fresh water impact. Sampling locations that have more than 5 km of continuous spatial extension have been categorized as prospective SGD areas. Figure 2.11.2 shows the potential zones of SGD between Kanyakumari and Alappuzha coast. Four such coastal sectors have been recognized with two zones (zones 1 and 2) in Kanyakumari and two zones (zones 3 and 4) in Thiruvananthapuram and Alappuzha. Zone 1 in Kanyakumari has coastal length of 16.2 km and the zone 2 has 29.6 km of shore line. The SGD zone 3 in Thiruvananthapuram has a coastal stretch of 27.7 km and the largest zone with 31.5 km of shore line falls in Alappuzha (Zone 4).

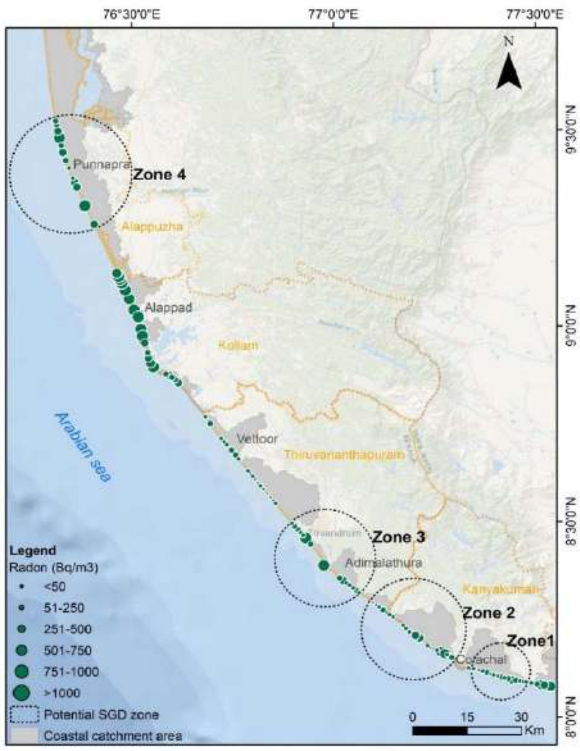


Fig. 2.11.2: Spatial distribution of radon activities. The encircled areas represent the potential zone for the SGD using different parameters

Subsurface characterization of SGD zone: The electrical resistivity tomography (ERT) was conducted further to define the subsurface lithology and to comprehend the groundwater-seawater relationship. ERT images obtained in profiles perpendicular and parallel to the sea disclosed that this intertidal zone consists primarily of loose sand, laterite, limestone, sandstone, sandy clay etc. in general, and are saturated with salt water or brackish water or freshwater. An upper layer consisting of unsaturated alluvium, laterite and clayey sand was found throughout the area with elevated resistivity levels. From Kanyakumari to Kollam, the thickness of this layer varied between 5 and 10 meters. Laterite outcrops are also seen throughout the area at different locations. This layer is underlain by a relatively low resistivity layer of sedimentary rock, consisting of well-saturated sand, clay, clayey sand, sandy clay, limestone and sandstone bearing aquifer system. Total thickness of these sediments is the maximum in the Kollam area (70 m) and the minimum is in the northern portion of Kanyakumari (10-25 m). The elevated resistivity value corresponding to basement rocks is seen in shallow depth (20 to 30 m) between Kanyakumari and Trivandrum and at deeper level (> 100 m) towards northern side of study area.

Almost all the profiles taken close to shoreline are saturated with water and recorded very low values of resistivity owing to saline water-saturated materials. At places, they show relatively high values of resistivity owing to saturation of freshwater (Fig. 2.11.3).

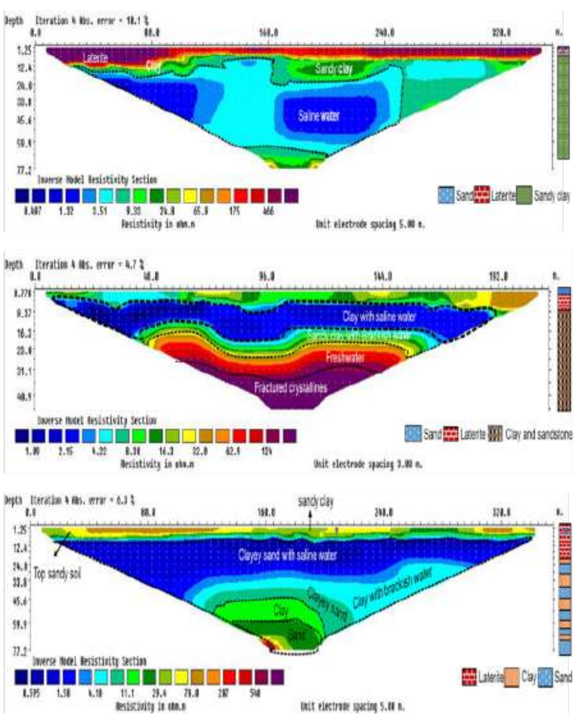


Fig. 2.11.3: ERT images of a) Kanyakumari; b) Thiruvananthapuram; c) Kollam

Radium Survey: Offshore sampling and monitoring were carried out from Thiruvananthapuram to Kozhikode (~400 km) along the SW coast of India to understand the groundwater discharge from the unconfined aquifer system to sea. Different *in-situ* parameters (Temperature, Salinity, Electrical Conductivity (EC), Nutrients) were monitored in the sea at various depths (maximum 30

Fig. 2.11.4: Spatial variation of in-situ a) EC; b) temperature in the sea between Trivandrum and Kozhikode

m) up to 4 km offshore from the shoreline at a distance of average 1 km interval. Total eight such transects were measured in November 2018 at 50 km interval to examine the SGD signatures. Samples were also collected to measure radium isotopes in coastal groundwater and nearshore seawater (up to 4 km). The result suggests that seawater temperature images showed major thermal

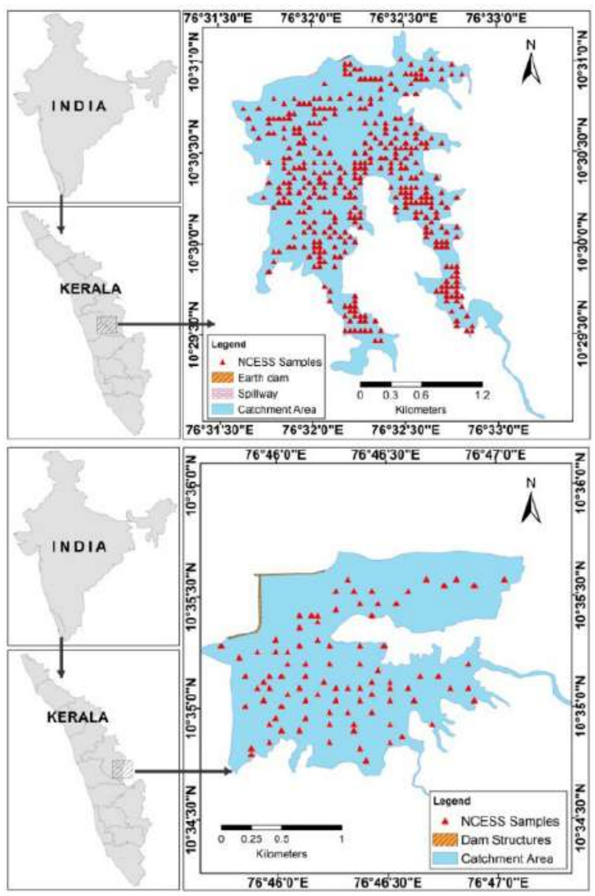


Fig. 2.12.1: Sampling locations of a) Chulliyar Dam; b) Mangalam Dam

plumes (low temperature) concentrated in southern and northern part of the study area (Fig. 2.11.4). Other outflows detected are comparatively smaller, which is confirmed with the seawater monitoring (EC, salinity and nutrients measurements) that the SGD is associated with the coastal springs.

Quantification of SGD: Based on the information gathered, two segments (Varkala and Adimalathura) in Thiruvananthapuram district (Field Site - A) and three segments (Gotheeswaram, Kappad and Koyilandi) in Kozhikkode district (Field Site - B) were chosen for site specific analyses of quantification of SGD in SW coast of India (Fig. 2.11.1 a).

The average fresh SGD rate in Thiruvananthapuram was computed as 700 $m^2/y/m$ compared to 946 $m^2/y/m$ in Kozhikode area based on water balance method. SGD derived Nitrite + Nitrate, Ammonia, Phosphate and Silica fluxes were 21.62 µg m^2/d, 244.29 µg m^2/d, 34.22 µg m^2/d and 609.31 µg m^2/d respectively in Thiruvananthapuram region, and 349.69 µg m^2/d, 206.35 µg m^2/d, 160.72 µg m^2/d and 1085.87 µg m^2/d respectively in Kozhikode region. While tertiary sedimentary formations particularly sandstones form the coastal aquifer in Field Site - A, the electrical resistivity surveys provided information that SGD occurs through the unconfined aquifers of recent coastal alluvium, laterites and fractured crystalline rocks at the Site - B.

2.12 Estimation of sandy sediments for desiltation of Chulliyar and Mangalam reservoirs, Palakkad, Kerala

The Chulliyar (10°6'N and 76°46' E) and Mangalam (10˚31'N and 76˚32' E) reservoirs are constructed across the river Cherukunnapuzha which is a tributary of the Mangalam River situated 48 km south of Palakkad Town, Kerala. The main objective of the study is to estimate the percentage of sand in the Chulliyar and Mangalam reservoirs for the effective increase of the storage capacity of the dams. Further the sand resource available in the reservoirs can be effectively exploited as a source of construction material. Heavy mineral and heavy metal concentrations were also estimated to understand depositional environment. The sediment cores were collected in reservoirs at a depth ranging from 0.5 to 3 m in 50x50 m grid size. Cores were collected using Gravity corer to obtain undisturbed sediments.

The average percentage of sand, silt and clay in the Chulliyar dam is 30.82%, 26.39% and 42.78% whereas in Mangalam dam it is 32.74%, 22.91% and 44.33% respectively. The sediments are dominated by coarse sand to clay. The sediments show moderately poorly sorted to extremely poorly sorted sediments, very coarse skewed to very fine skewed, very platy kurtic to extremely leptokurtic nature. The sand is dominant in the areas of NE and SW of Chulliyar and SW of Mangalam dam, where the river input is seen. The finer sediments deposited towards the deeper part of both the dams is mainly due to the low-velocity turbidity currents that are capable of carrying large amounts of fine sediment into the deeper parts of the reservoir. The CM plots indicate that the sediments might have been deposited under the pelagic suspension mode under tractive current. The hydrodynamic condition illustrates that the sediments from the reservoirs are deposited under the calm to the violent environment but few falls in the quietest environment.

The heavy mineral percentage of core samples from Chulliyar reservoir ranges from 3.45 to 23.14 (Av. 11.47%) at the surface and 5.17 to 20.37 (Av. 12.11%) at the depth of 100 cm. In the case of Mangalam reservoir it ranges from 7.54 to 23.04% (Av. 14.14%) at the surface and 5.98 to 14.96% at the 100 cm depth. The fluctuations in the concentration of heavy minerals within the study area are mainly due to the inability of the low energy current to entrain the heavier after its deposition and the shielding action of coarser light minerals which prevent further movement of heavies.

Table 2.12.1: Sediment quantification in reservoirs

Dam	Total Catchment Area (km2)	Estimated average quantity of sediments (%)		
		Sand	Silt	Clay
Chulliyar	29.75	30.80	26.39	42.78
Mangalam	48.85	32.74	22.91	44.33

Generally, the heavy metal concentrations in sediments will indicate the quality of the aquatic ecosystem. However, the risk of pollution by heavy metals under sediment disturbance or changes in the sediment chemistry was assessed by using pollution indices such as CF, PLI, I_{geo}, and EF. The pollution study demonstrated the heterogeneous pattern of geochemical anomalies in the study area resulting from the temporal changes in natural and anthropogenic forces. The pollution indices conformed that the sediments are low to moderately polluted, where moderately polluted nature was seen near the riverine input regions of the dam. Apart from natural contribution, the heavy metals may be incorporated into the aquatic system through anthropogenic sources such as agricultural activities in the catchment area. The chemical index of alteration of Chulliyar dam showing a range (50-81%) of incipient to intense weathering of the source materials. The relatively low contents of K_2O (K-feldspar) and Na_2O (Na-feldspar) suggest that the source rocks may have been exposed to weathering. The aluminous minerals are secondarily formed while Na, Ca bearing silicate minerals is significantly removed during intense chemical weathering. The Mangalam dam sediments showing extreme weathering (80-93%), because the alkali and alkaline earth elements are totally removed from the weathered sediments.

2.13 Submarine groundwater discharge and nutrient flux along the coastal region of Kozhikode district, northern Kerala

Geometry of coastal recharge zones and hydraulic gradient influenced by topography has a greater role in groundwater discharge in the tropics. Three site specific analyses (Gotheeswaram, Kappad and Puthyappa) showed occurrence of submarine groundwater discharge through the recent coastal alluvium, laterite and fractured crystalline aquifers in Kozhikode. Kozhikode has almost a uniform coastal geomorphology which results in saltwater intrusion through the tidal inlets and in locations where groundwater pumping is more. Electrical resistivity tomography in the above identified locations show clear demarcation of fresh groundwater very close to shore and shows the path for discharge through the coastal alluvium in the top 20-50 m depth.

The radon mass balance method was used to calculate the groundwater discharge in the identified SGD zones of Kozhikode coast. The concentration of Radon in the water column will depend on several factors like (1) *in-situ* production from ^{226}Ra, radon's radioactive parent dissolved in water/biogeochemical reactions; (2) inputs by diffusion, sediment resuspension, bioturbation, or gas ebullition from sediments; (3) input by groundwater discharge; (4) removal by exchange with open ocean water (i.e., dilution with low radon/methane offshore water); (5) removal by evasion from water to the atmosphere; (6) losses by radioactive decay/biogeochemical reaction. Being a gas, ^{222}Rn does not build up in the surface water but escapes directly to the atmosphere. Thus, a mass balance between the above-named input and output fluxes of radon into the coastal water column, allows to calculate an SGD flux. This can be expressed as:

$$F_{SGD} = F_t + F_{sed} - F_i + F_{atm} + F_o + F_{mix}$$

where F_{SGD} is the ^{222}Rn flux attributed to SGD, F_t is the difference in concentrations of excess ^{222}Rn between two successive hours, F_{sed} is the ^{222}Rn flux diffused from sediments, F_o is the ^{222}Rn flux leaving with the outgoing tide, F_i is the ^{222}Rn flux entering with the incoming tide, F_{atm} is the ^{222}Rn flux into the atmosphere, F_{mix} is the ^{222}Rn flux out of the system via mixing with offshore waters.

Based on the above-mentioned radon mass balance method, groundwater discharge was calculated and it varied in the ranges of 0.91-56.3 cm/day, 3.2-43 cm/day and 2.5-208 cm/day at Gotheeswaram, Puthyappa and Kappad respectively. Integrating over the complete coast of Kozhikode, SGD flux was calculated to be (4.94-33.58)*10^5 m^3/day and the respective nutrient flux is (2.10-11.644)*10^4 mol/day for DIN, (1.23-56.31)*10^2 mol/day for DIP and (7.28-24.44)*10^4 mol/day for DSi. Wet seasons and high rainfall (~3000 mm annually) especially due to the influence of two rainy seasons (SW and NE monsoon) saturate the aquifers, resulting in high SGD rates through the conducting layers. The hydraulic gradient of the study area catalyses this process. Different marine processes such as tides and waves, seasonal declines in hydrologic head in coastal aquifers, and also dispersion drive the seawater into the coastal aquifer system. This water eventually discharges back to the surface creating a second saline component of submarine groundwater discharge that enhances nutrient transport from the land to the coastal zone (recirculated SGD). As SGD transports terrestrial DIN, it is important to have a control on the inland nitrogen use to protect the water quality of coastal groundwater and near shore water. In the case of recirculated SGD, tourism and nutrient sources from different marine based activities also affect coastal water quality.

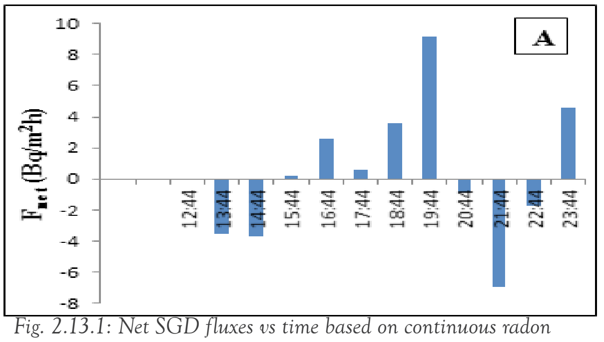


Fig. 2.13.1: Net SGD fluxes vs time based on continuous radon measurements at Gotheeswaram

The assessment of Submarine Groundwater Discharge in three zones of unconfined aquifer of a very dynamic coastal zone of Kozhikode coast reveals that sandy horizons, laterite and weathered/fractured rock are found to act as aquifer zones. Based on different field investigation techniques, Gotheeswaram (1500 m), Kappad (2300 m) and Koyilandi (1500m) were identified as potential zones of groundwater discharge in the Kozhikode coastal aquifer (32 km). The aquifer has a thickness of maximum 10-20 m and apparently the crystalline contact zone is allowing the highest discharge.

Future studies include deciphering three-dimensional geometry of potential zones for SGD and estimating the quantity of freshwater that can be tapped sustainably from coastal aquifers with barest minimum environmental impacts to the coastal/near shore aquatic ecosystems. Depending on the SGD associated nutrient fluxes, this study will play a major role in the nutrient and water resource management practices in similar coastal hydrological systems.

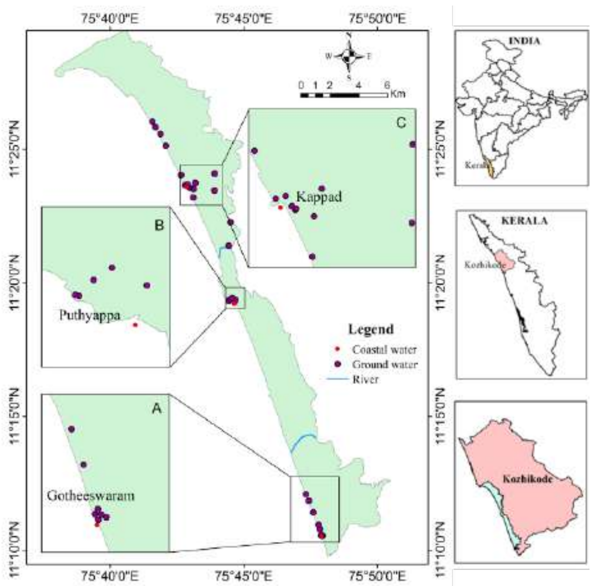


Fig. 2.13.2: Study area showing sampling locations for groundwater (nutrients) and time series measurements of radon in coastal water in Kozhikode coast, SW India

2.14 Impact of Sea Level Rise on coastal aquifers of Thiruvananthapuram district, Kerala

In a steady state condition, freshwater-saltwater interface (transition zone) in the coastal aquifer is stationary which indicates a dynamic equilibrium between the fluids due to their density difference. The shape and position of transition zone depends on geology, topography and groundwater discharge from land towards sea. Under normal conditions, aquifers are recharged by rainfall events and in general, groundwater flows from the regions of higher groundwater levels to the regions of lower groundwater levels. This natural movement of freshwater towards sea prevents saltwater from entering into freshwater coastal aquifers. Due to increased sea level rise, tidal fluctuation, over exploitation of groundwater and modification of hydrological cycle, the shape, size and position of the transition zone will migrate towards inland. This disturbs the equilibrium between fresh groundwater and saline seawater, modifying the shape of interface or the subterranean estuary. The two main processes that control the coastal groundwater dynamism are Submarine Groundwater Discharge (SGD) and Seawater Intrusion (SWI), which in turn determines freshwater-seawater geometry in the coastal aquifer. In addition to the characterization of this interface, the present study addresses understanding of hydrogeochemical status of groundwater in the coastal aquifer under consideration.

This study focuses on the coastal zone of Thiruvananthapuram district in Kerala which has 76 km shoreline from Pozhiyur in the south to Kappil in the north, located in the southwest coast of India. Northern and southern parts of the area is partially cliffed with pocket beaches whereas central part from Kovalam to Kaikkara is a combination of strand plains and barrier beaches. South of the Kaikkara, Anjuthengu-Kadinamkulam estuary lies parallel to the shoreline. Towards Veli and Kovalam, Precambrian rock exposures are well noted. Further south up to Poovar, there is a small estuary where Neyyar River joins to the Arabian Sea. Geologically, the area consists of Precambrian crystalline rocks as basement, overlain with Tertiary sedimentary formations as well as recent coastal alluvium and sands.

In all, 90 water samples were collected during pre-monsoon in 2018, to determine its quality and geochemical characteristics. *In-situ* parameters of water were measured in the field itself, because of their transient characteristics and detailed hydrochemical studies were carried out in the laboratory after the fieldwork using standard water quality analysis procedures. Radon concentrations of both groundwater and pore water from selected locations were measured using a modified Rad 7 radon-in-air-monitor and it was correlated with salinity data for SGD study. Statistical analysis was carried out to understand the interrelationship amongst the measured parameters and to make inferences on their impact on the groundwater chemistry of the study area. Spatial analysis provided a visual dimension of the complex behaviour of groundwater parameters.

Spatial distribution of hydrochemistry and delineation of freshwater/saline-water interface: Groundwater levels of the northern and southern parts of the study area are deeper and the aquifers in these areas are laterite and Tertiary sedimentary formations, whereas the wells located in the coastal alluvium in the middle part of the area possess shallow groundwater level. Groundwater in the area shows slight acidic trend, especially the water samples belonging to the lateritic aquifers in Varkala and Pulluvila areas. The higher pH values were seen near shoreline wells where seawater interaction to the coastal aquifer is predominant. Assimilated TDS data from wells were used to delineate the extent of shift of freshwater/saltwater interface towards the coastal aquifer (Fig. 2.14.1). The coastal stretch of Anjengo to Kadinamkulam, Vizhinjam and Poovar areas are the most sensitive due to the encroachment of seawater intrusion. Salinity variation is also reported in the inland wells of Poovar, due to the ingress of saltwater from nearby riverine estuary to the aquifer. On the other hand, wells from Varkala to Kapil and in and around Adimalathura areas, there are no signatures of seawater ingress.

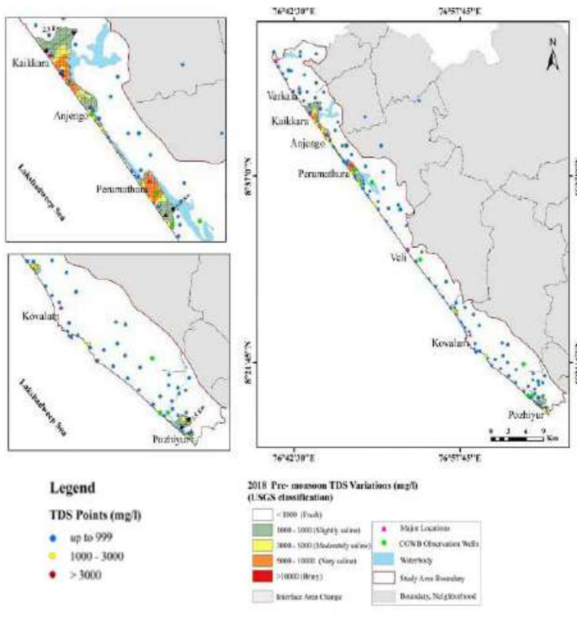


Fig. 2.14.1: Freshwater/saltwater interface along the coast of Thiruvananthapuram District

Hydrogeochemical Facies: Piper diagram clearly shows that out of 90 samples, above 75% groundwater samples are in zone-6 in the diagram, which belongs to secondary salinity category and exhibited calcium chloride type water wherein non-carbonate hardness exceeds 50%. While those falling under zone-5 belong to temporary hardness category where groundwater is magnesium bicarbonate type and carbonate hardness (secondary alkalinity) exceeds 50%. i.e., chemical properties are dominated by alkaline earths and weak acids. Remaining few percentage samples are in zone-9, the mixed zone, where type of groundwater cannot be identified as neither anion nor cation dominant. This area indicates no one cation-anion pair exceeds 50%. Irrigation suitability analysis shows that all groundwater samples in the area fall in the category of low sodium hazard. However, few samples fall in very high salinity hazard category due to the seawater intrusion to the coastal aquifer.

Radon as groundwater tracer: Radon is a noble gas that is chemically stable and does not react with the surrounding environment. Several authors have used radon as a tracer to study groundwater flow to streams, lakes and oceans. Based on the salinity and water level data, two known locations (Adimalathura and Varkala) were selected for further studies on submarine groundwater discharge. Radon (^{222}Rn) values of both pore-water and groundwater were obtained and concluded that groundwater samples represent single aquifer system in Varkala unlike in Adimalathura, where multi aquifer system apparently contribute groundwater to local aquifer system. Further, there is also a similarity between inland wells and shoreline wells in terms of radon concentrations and apparently exists rapid flow with limited residence time.

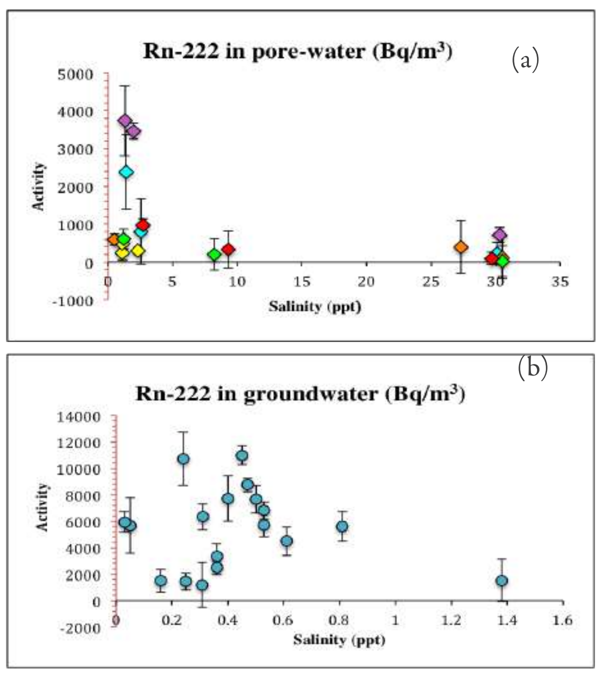


Fig. 2.14.2: Radon concentration of a) pore-water; b) groundwater of Adimalathura

It was evident that decrease in freshwater discharge in pre-monsoon was the most sensitive parameter causing saltwater intrusion. However, influence of coastal rivers must be considered in the vulnerability of inland aquifer. Study on ground water level, *in-situ* parameters and radon measurements have pointed out locations for submarine groundwater discharge and saltwater intrusion. More than 70% groundwater samples are calcium chloride types. However, a slight variation was observed in the second highest water type which was magnesium bicarbonate in the piper plot and it was followed by mixed type where no cation- anion exceeds 50%. The Wilcox diagram shows that most of the groundwater samples in the study area falls in the low sodium hazard and medium to high salinity hazard category. ^{222}Rn concentration in all transects represent a gradient radon flow towards the open sea; which, in turn substantiate the presence of Subterranean Estuary

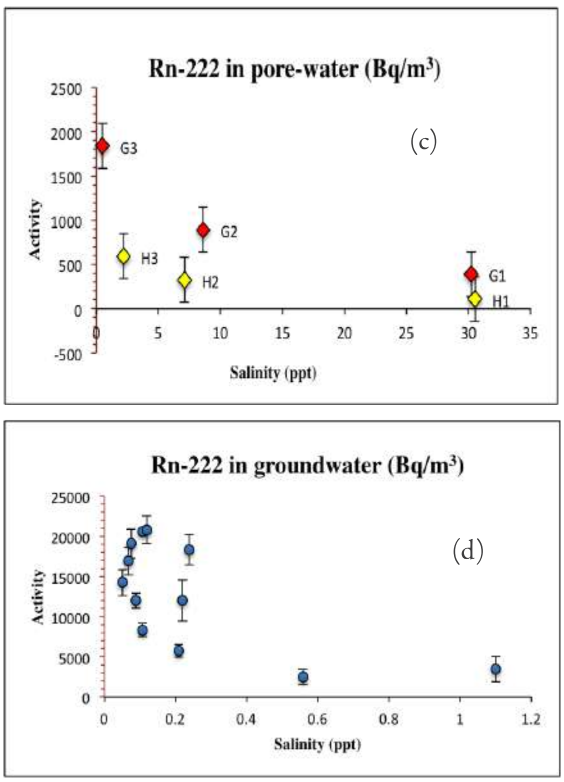


Fig. 2.14.3: Radon concentration of c) pore-water; d) groundwater of Varkala

through which nutrient exchange is taking place along the coast. Based on the studies, two hotspots of SGD and extent of seawater intrusion along the coastal stretch of Thiruvananthapuram district were identified.

2.15 Development of Vembanad management action plan through a geological perspective

Vembanad Lake, Kerala is a notified wetland under Ramsar Convention. The research study addresses the physico-chemical parameters in the shallow aquifer zone around the Vembanad Lake. In order to define the spatial variability and the quality of groundwater around the lake, 78 shallow open well samples were collected during the pre-monsoon period of 2018. The physico-chemical parameters were measured *in-situ* with a multi parameter water quality meter and major ion chemistry was analysed based on the APHA analytical procedures. The groundwater of this season shows a slightly alkaline and fresh to brackish in nature.

The groundwater quality varies in space and time with respect to various controlling factors. However, monitoring of groundwater quality provide complex and interrelated data, which are difficult to interpret into meaningful conclusions. In such situations, we identify the factors controlling groundwater quality using various analytical techniques of graphical diagrams and statistical analyses. Here we resorted to geostatistical and geospatial techniques to decipher hydrochemical characteristics. A brief statistical summary of the physico-chemical parameters of the groundwater of study area is shown in the Table 2.15.1.

These parameters were compared with the drinking water quality standards prescribed by Bureau of Indian Standards (BIS, 2004). Several water quality index methods are available to classify the groundwater for drinking purpose. The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) is a useful and efficient method for assessing the quality of water. Based on this CCME classification, 3.4% of samples fall under excellent category, 29.4% fall under good category, 35.3% fall under fair category, 25.2% under marginal category and 6.7% fall under poor water quality category. The spatial distribution of CCME water quality index is shown in Fig. 2.15.1. From the figure, it is noted that water quality is deteriorated in the eastern part of the study area. This may be because of agricultural run-off, coir retting and also from the interaction of groundwater with the brackish lake water.

Table 2.15.1: Statistical summary of physico chemical parameters pertaining to pre-monsoon of 2018

Parameter	Min	Max	Mean	SD
Temperature (°C)	27	30.4	28.74	0.72
pH	6.1	8.1	7.02	0.38
EC (μS/cm)	212	10125	1700.18	1696.16
TDS (mg/l)	62	6145	798.69	988.06
Salinity (PSU)	0.02	6.8	1.07	1.16
Na (mmol/l)	0.41	12.55	2.68	2.6
K (mmol/l)	0.01	1.35	0.22	3.19
Ca (mmol/l)	1.05	14.07	4.29	2.94
Mg (mmol/l)	0.1	4.57	1.41	0.89
Cl (mmol/l)	0.6	17.66	5.14	4.41
HCO_3 (mmol/l)	1.08	11.52	3.79	2.15
SO_4 (mmol/l)	0.012	1.76	0.28	0.31

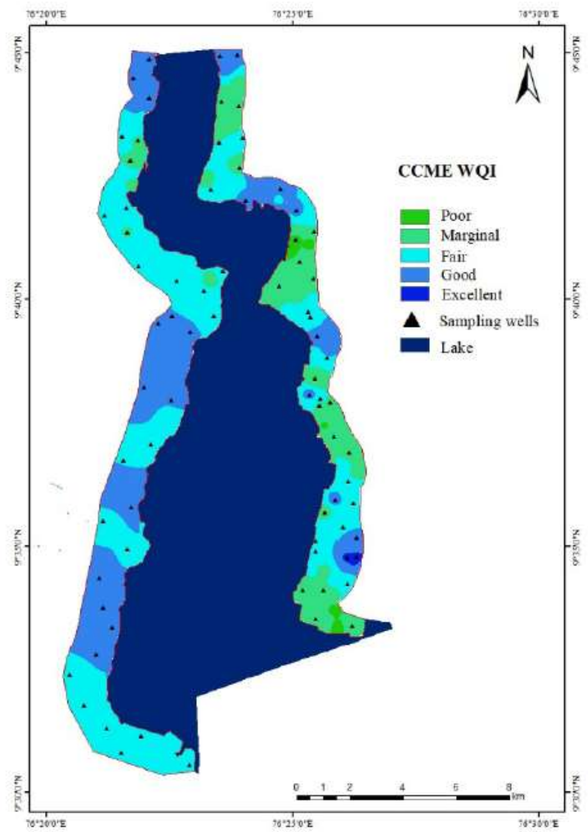


Fig. 2.15.1: Spatial distribution of CCME WQI in the study area

2.16 Hydro-Geochemical, stable isotopic studies and modelling of groundwater reserves of Greater Kochi, India

The main objective of the study is to addresses the impact of urbanization on the landuse change and shallow aquifer system in Greater Kochi region. The

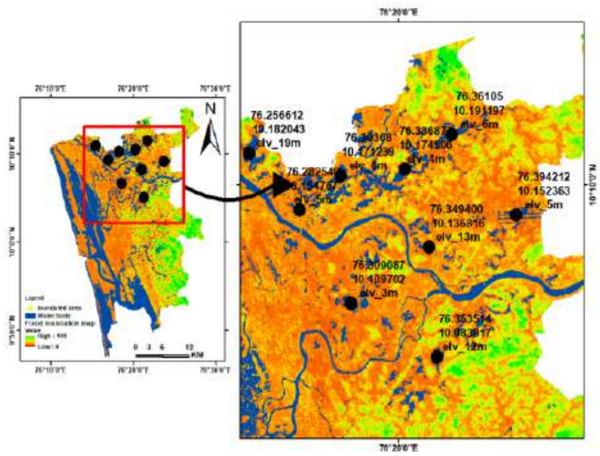


Fig. 2.16.1: Flood inundation during 21st August 2019

study also emphasises the amount of alteration due to urbanization in hydrologic system. The data on hydro-geochemistry, landuse (LU) change from remote sensing, hydrometeorological parameters, and stable isotope chemistry aided with geophysical studies were

Synthetic Aperture Radar (SAR) data collected for a period of one year (April 2018 to March 2019) were used to detect the seasonal variation in water body with respect to the flood event. Only limited data of the 2018 flood event is available. The spatial extent of inundation before the flood (9th August), during the flood (21st August) and after the flood (27th August) as observed are 129.39 km^2, 140.67 km^2 and 121.63 km^2 respectively (Table 2.16.1). Area of water body shows drastic variation on inundation during 9th to 21st of August 2018 (Fig. 2.16.1).

Table 2.16.1: Inundated area during flood 2018

Date	Area of water body (km2)	Inundation (%)
09.08.2018	129.39	9.31
21.08.2018	140.67	18.84
27.08.2018	121.63	2.77

2.17 Studies on selected rivers in different climatic regime, Southern India

The differential rainfall and temperature play an important role in the weathering processes and associated changes. The present study aims to understand the textural, geochemical and mineralogical variations under different climatic regime, of two distinct river basins viz. the Periyar and Vaigai.

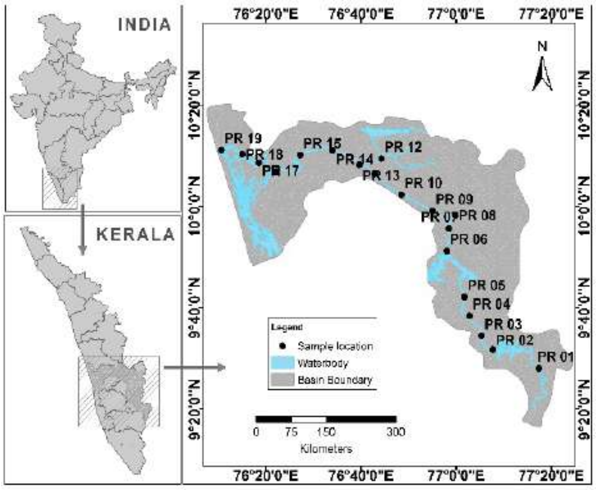


Fig. 2.17.1: Periyar Basin with sampling locations

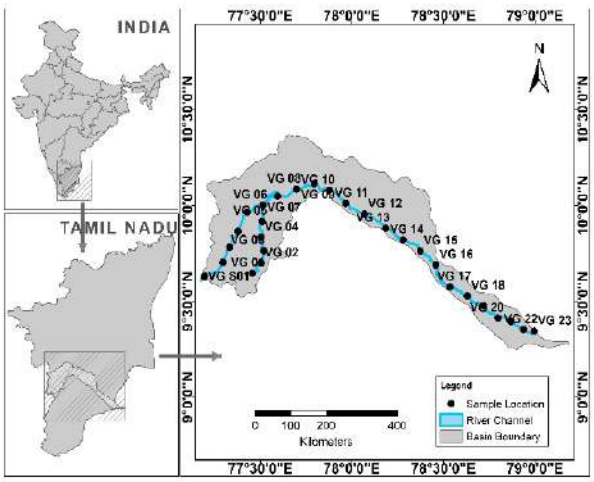


Fig. 2.17.2: Vaigai Basin with sampling locations

The sediment samples (Figs. 2.17.1 and 2.17.2) collected during the pre- and post-monsoon seasons from the Periyar and Vaigai Rivers are composed of gravel, sand and mud. Sand and gravel dominate in both seasons. On an average, more than 70% of the sediment are composed of sand in both the rivers. However, the average mud percentage is higher in the pre and post monsoon in the Periyar River as compared to the Vaigai River. The Periyar River exhibits a wide range in texture i.e. gravelly sand, gravelly muddy sand, sandy gravel, slightly gravelly sand, muddy sandy gravel, slightly gravelly muddy sand and slightly gravelly sandy mud. In contrast, the Vaigai River have mostly sandy gravel, gravelly sand, slightly gravelly sand, muddy sandy gravel and slightly gravelly muddy sand. The variations in the granulometric composition of the samples from Periyar and Vaigai Rivers is related to the local geology and the slope characteristics. In addition to this, the construction of check dams and bunds leads to trap the coarser sediments and disperse the finer sediments of silt and clay into the water column.

After reaching Alwaye, the Periyar River bifurcates into the Managalapuzha branch and the Marthanda Varma branch. The Marthanda Varma branch flows through the industrial belt in the basin, which drains into the Vembanad Lake at Varapuzha. Hence the analyses were carried out to assess and quantify each of the geochemical signatures, in order to estimate how much the sediment is impacted naturally (rock weathering rates) and anthropogenically (anthropogenic fluxes) with heavy metal in sediments. The analytical results indicate that the sediments are largely made of mud, sandy mud and silty sand. The riverine sediments are generally clayey sand to sand type whereas the estuarine and inner shelf sediments are of sandy mud to mud in nature. The progression of textural facies from the sand dominant to the mud dominant sediments indicates sediment input from the rivers which join the study area. The enrichment of finer particles (silt and clay) with patches of sand rich zone is due to the peculiar pattern of water movement in the approach channel with funnelling action dominating during flood tides and jetting in ebb tides. In addition, the textural association is enhanced severely by waste disposals from urban sewages and dredging activities. The Cr, Ni, Pb, and Zn concentrations reported in this study shows higher than those in the average shale value. Pearson's correlation matrix was performed on metal concentrations, texture of sediments and total organic carbon content to evaluate the possible sources and the controlling factors of heavy metal enrichment in the region. It is observed that Al and Fe are having good correlation with TOC, clay and trace elements. Cr and Ni are having strong correlation with mud and TOC whereas Cu and Zn shows good correlation with TOC. The good correlation of Cu and Ni with TOC than clay is mainly due to their tendency in solution with organic matter by chelation process. Pb shows negative or no correlation. The cluster analysis was carried out to study the similarity between the sampling locations comprising of metals. Based on the dendrogram obtained, twenty-one sampling locations are clustered in the three associations.

Factor analysis was carried out on the data set (nineteen variables) to compare the compositional patterns between analysed heavy metal samples and to identify the probable sources. The factor analysis identified three principal components accounting to 77.8% of the total variance of the parameters. The geochemical compositions of the study area are plotted on a ternary

(A-CN-K) diagram to understand the weathering trends and mineralogical compositions. The CIA ratios are intermediate (65-85), indicating intermediate to strong weathering. The (A-CN-K) diagram distinctly indicates substantial removal of Ca and Na bearing silicate minerals from the rock. The CF values of metals are more than 1 at certain locations indicating moderate pollution. I_{geo} values for some trace metals show moderately polluted sediment quality. The PLI study affirms that the sediments are contaminated by metals to a certain extent. Higher metal concentrations are mostly observed in the region of major industrial area. The main sources of pollutants are metal-smelting and chemical industries. Further, the low-lying nature of the area makes the periodic flushing out of pollutants leading to become a large heavy-metal sink.

2.18 Wetland studies of Akathumuri – Anchuthengu - Kadinamkulam (AAK) estuarine system, southwest coast of India

The Akathumuri - Anchuthengu - Kadinamkulam backwater system is facing lot of environmental crises/ degradation (Fig. 2.18.1). This back-water system receives freshwater input from the Vamanapuram River. The brackish water body has a maximum depth of 4 m and has a permanent connection to the Arabian Sea through the Muthalapozhi inlet. The Vamanapuram River which originates from Chemmunji Mottai at about 1717 m above MSL in the southern part of Western Ghats, debouches into this estuary at Anchuthengu after draining about 81 km.

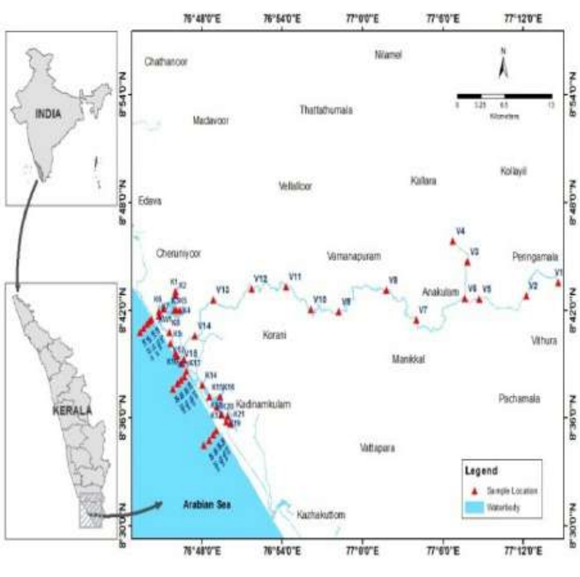


Fig. 2.18.1: Study area with sampling locations

As part of the present study, the spatio-temporal changes of the wetland ecosystem with respect to Land Use - Land Cover changes were examined adopting remote sensing and GIS techniques. The LU/LC maps were prepared for the year 1967, 2000 and 2019 (Fig. 2.18.2) using the Survey of India toposheet Nos. 58D/9, 58D/10, 58D/11, 58D/14, 58H/1 and 58H/2, and the Landsat satellite images (Landsat 7 and Landsat 8) for different years (2000, 2019) downloaded from the website https://glovis.usgs.gov

During the period 1967-2019, significant increase in the built-up area, from 47 km^2 in the year 1967 to 149.4 km^2 in 2019 is noticed. The area under vegetation for the period 1967, 2000 and 2019 are 543.4 km^2, 499.5 km^2 and 518.7 km^2 respectively. During the period 1967-2019, it is found that the estuarine area has declined by 8 km^2. The area of the Akathumuri - Achuthengu estuary reduced from 5.45 km^2 to 3.47 km^2 while the Kadinamkulam estuary which had an initial area of 5.01 km^2 was decreased to 3.83 km^2. Presently, only 97.43 km^2 (12%) of the area is under forest, while the forest cover in the year 1967 was approximately 137.04 km^2. The beach along the study area showed a gradual increase from 0.63 km^2 in the year 1967 to 2.25km^2 at present. The study

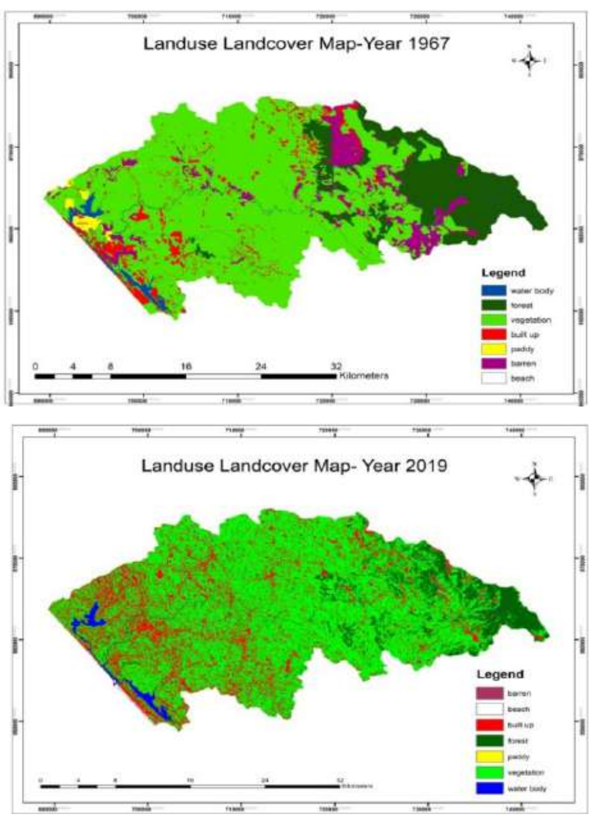


Fig. 2.18.2: Land use/land cover map of the study area for 1967 and 2019

indicates that the area under built-up land, vegetation and beach shows an increasing trend while the area covered by barren land, water body and forest is reduced. The rapid increase in the built-up area has significant impact on the wetland ecology of the area. This 8.8% increase in infrastructure and built up area (71.8 km^2) is mainly due to the absence of an infrastructure policy, conversion of agricultural lands particularly paddy and barren land, increase in population and rapid urbanization.

2.19 Investigation on fog dynamics as a component of hydrological cycle in a changing climate in the tropics using stable isotope geochemistry

Monsoon system in India is mainly controlled by the summer monsoon moisture from the Arabian Sea and the winter monsoon moisture from the Bay of Bengal carried respectively by the seasonal southwesterly and northeasterly winds. The availability of fresh water in India is largely dependent on inter-annual variability of summer monsoon rainfall. Although the oceanic source moisture plays a major role in Indian monsoon dynamics, it is interesting to note the significant contribution of monsoon vapour from terrestrial based moisture flux with the enhanced climate change effect. There has been no observational study on the characteristics, transport and rain out history of the terrestrial source moisture though few large-scale modelling work approach via the factor derived from the world (mostly temperate zones) or remotely sensed data. There is a need to determine the role of terrestrial source moisture flux in controlling the hydrological system, soil, vegetation and climate in humid tropical mountainous ecosystem. This is addressed through the study of moisture flux by geochemical and isotopic investigations of fog/mist/dew, vapour, rain, river, ground water, soil and plant dynamics in the Western Ghats and its adjacent coasts over temporal and spatial scales. The region acts as an ideal zone for monitoring these critical responses (inter-dependent for mutual sustenance) with growing local, regional and global anthropogenic stress on land use/land cover, fresh water accessibility and changing climate in the tropics. The temporal sampling of fog/mist and rain in Mangalore station has been initiated under this program. Further procurement and designing of instruments is under process and will be installed for sample collection at different stations like Mangalore, Trivandrum, Agumbe, Kudremukh, Madikeri, Ooty, Wayanad, Munnar, Braemore, etc along the coastal plains and highlands of the Western Ghats.

3. Atmospheric Processes

The objective of the Atmospheric Process Group is to understand the physics and dynamics of atmospheric processes on large and mesoscale levels, and orographic influence using the surface-based remote sensing observations, satellite and through model simulations. Key areas of investigation include cloud and precipitation systems. Interaction of environments from the scale of individual clouds embedded in the monsoon systems and thunderstorms through mesoscale convective systems and cyclonic storms. It also includes to scale out the impact of these systems on regional and global climate and to understand them from the natural hazard point of view. The processes of the interaction of the atmosphere with the land and ocean surface beneath it are also of high priority.

3.1 Doppler weather radar reflectivity prior to thunderstorm and lightning

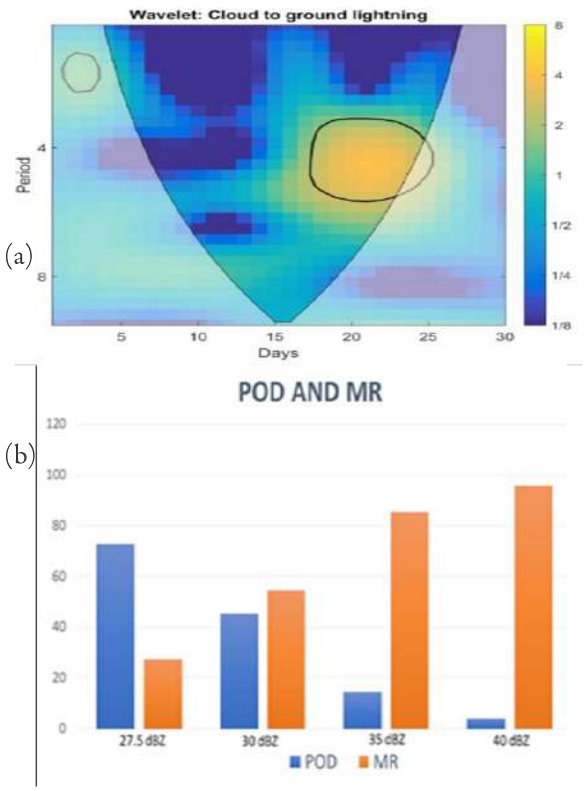


Fig. 3.1.1: a) Wavelet analysis of daily CG activity; b) POD and MR (%) for radar reflectivity considered for nowcasting

The lightning detection network and S-band DWR in Kochi are used to examine the radar reflectivity characteristics in southwest India prior to thunderstorm and lightning in the region during the 2018 post-monsoon season. Lightning activity has been observed extensively in Kottayam and its vicinity. Wavelet analysis indicates that synoptic systems have a significant influence on lightning activity in the region (Fig. 3.1.1 a). Radiosonde data has been analyzed to identify the -10°C isotherm altitude for this study. Radar reflectivity prior to lightning (up to 15 minutes) in this altitude was analyzed and skill scores like probability of detection (POD) and MR were computed. Four reflectivity thresholds (27.5, 30, 35 and 40 dBZ) at -10°C isothermal level has been analyzed (Fig. 3.1.1 b). It has been observed that 27.5 dBZ reflectivity at -10°C isothermal level found to be a good predictor for lightning in the region. The analysis has resulted in a POD of 72.67% and MR of 27.32%. However, high MR for high reflectivity can be improved with the use of a hydrometeor identification algorithm.

3.2 Classification and seasonal distribution of rain types based on surface and radar observations over a tropical coastal station

An attempt has been made to classify stratiform and convective rain based on precipitation recorded using an impact type disdrometer at a tropical coastal site. All rain-events during the study period of eight years were analyzed and accumulated water (rainfall in mm) were considered in respective rain-type. On further analysis of precipitations for different seasons, apart from stratiform and convective rain-types, transition and mixed rain-types have also been identified. Stratiform and convective rain-types are confirmed with bright band & non-bright band observations from Micro Rain Radar, N_0^* (scaling parameter for the concentration of raindrops) and D_m (mass-weighted mean volume diameter) variations from disdrometer and atmospheric electric field, E from Atmospheric Electric Field Mill (EFM). Seasonal variations in rain-duration and associated accumulated water were investigated for four seasons (winter, pre-monsoon, summer monsoon and post-monsoon). General rain-events (with stratiform and/or convective) and mixed rain-events (without stratiform or convective) were also identified.

Summer monsoon received the second maximum rainfall followed by post-monsoon. A bimodal variation in rainfall with a primary peak in June and secondary peak in October is observed in the annual cycle. Rainfall is more intense during pre- and post-monsoon and less intense during summer monsoon. Shorter interval rain-events are repeated in summer monsoon and fewer rain-events of longer intervals have resulted during pre- and post-monsoon. During this duration, mixed rain accounts the second higher in all seasons. In rainfall, contribution from convective rain is dominant except in winter. In summer monsoon, mixed and transition phases contributed much water. Mixed phase contributes more in duration and transition phase contributes more to water. From day and night variation analysis, day-high and night-low is observed in pre-monsoon and it is reversed in post-monsoon, with almost the uniform occurrence during the summer monsoon. From analyses with respect to the number of rain-events, it is clear that general events are less and mixed events are more during summer monsoon. From statistical analyses, an increase is observed in duration of rain-event from winter to post-monsoon. About 20% of duration is aggregated by longer duration events in all seasons except during winter.

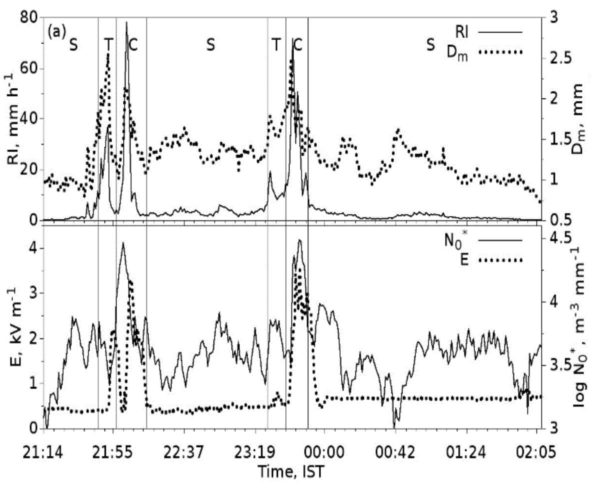


Fig. 3.2.1: Temporal evolution of RI, D_m, log N_0 and E in an event, where C, T, and S indicate convective, transition, and stratiform phases, respectively, and they are marked with solid vertical lines*

The classification scheme is applied to a rain-event, one from 21:14 hrs on 31st October, 2012 to 02:08 hrs on next day (295 minutes) represented in Fig. 3.2.1. Based on the present classification scheme, there are three stratiform, two transition and two convective phases in the event. Disdrometer and EFM observations are also plotted in Fig. 3.2.1. Fig. 3.2.2 shows the vertical profile of Z and RI from MRR.

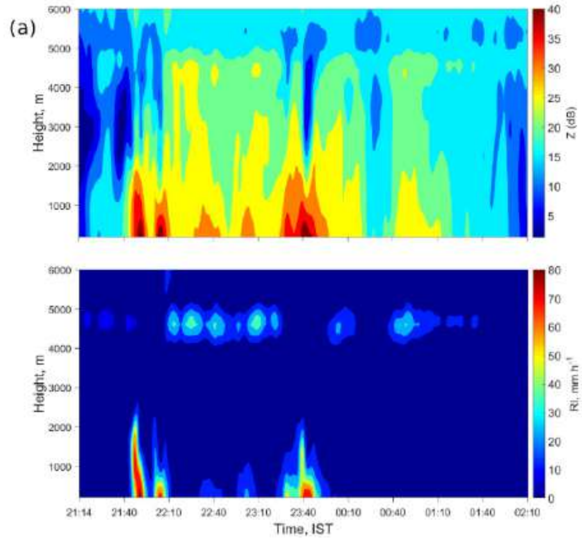


Fig. 3.2.2: Vertical profile of Radar reflectivity, Z and Rain intensity, RI of an events on 31st October 2012

In percentage of rain duration, stratiform is above 65% in all seasons. Summer monsoon received least duration as stratiform rain and though the winter got the most (666 minutes only), post-monsoon obtained 79% stratiform minutes (24787 minutes) of total rain duration. The Mixed rain accounts the second higher duration in all seasons.

Contribution from convective rain is abundant in three seasons barring winter. Though the contribution of water in convective rain is most in summer monsoon, the percentage appears to be low, on account of percentage computation based on the number of events in each season. In the same season, mixed and transition have contributed considerable water. Duration and water reduced from stratiform is not accounted in convective, but it is reflected in mixed rain (both in duration and rain). In the post-monsoon, events under mixed and transition have contributed least water quantity. Also, a major part (~50%) of rainfall is from transition and mixed category in summer monsoon. In post-monsoon, contribution from the same category is only 25% of the total. Apart from winter, post-monsoon received high water contribution from stratiform. In all seasons, mixed rain contributes more in duration, and transition phase contributes more to accumulated water. The percentage of duration and accumulated water is more or less matching in mixed rain category in all four seasons.

Amount of water available from the transition and mixed rain types in tropical coastal site like Thiruvananthapuram is substantial in all seasons. The mechanism of rain in transition and mixed rain are similar. Summer monsoon registers the maximum duration in percentage (~30%) and accumulated water (~50%). The least duration (~16%) and water amount (~25%) are received in post-monsoon. An increasing trend is seen in duration percentage from winter to summer monsoon and a decrease thereafter.

IST 06:00-18:00 hrs is taken as day hours and 18:00-06:00 hrs as night hours. Rain event durations and their contributions in day and night hours show a monotonic behavior in three seasons. A distinct night high is found only during winter. Day-high and night-low observed in pre-monsoon gets reversed in post-monsoon, with near even duration in summer monsoon. The water contribution is dominant in night hours during pre and summer monsoon and in day hours during post-monsoon. This indicates that RI in night hours are high in pre and summer monsoons while day time RI is high during post monsoon. The general events are less and mixed events are more during summer monsoon and reversed in post-monsoon. These support the rapid fluctuation of RI in summer monsoon and its stability in post-monsoon.

Monthly mean RI is calculated from monthly accumulated water and total rain duration. Primary observations are (a) rainfall is more intense during the pre-monsoon and post-monsoon, (b) less intense rainfall is encountered during successive monsoons at this tropical coastal site for the entire data period and (c) more events of shorter interval repeated in summer monsoon and fewer events of longer interval resulted during pre- and post-monsoon. In summer monsoon the percentage of number of rain-events are exceeding the percentage of duration.

3.3 Microphysical processes of precipitation during Bright Band events at mid and high-altitude regions over Southern Western Ghats, India

The physical characteristics of precipitation are diverse in tropical regions during different seasons and it has both societal and economic impacts. The amount, periodicities of precipitation and types of cloud systems that accords the precipitation over a particular region, are strongly controlled by the topography and dynamic conditions of atmosphere prevailing over the region. Therefore, rain microphysical observations at different terrain conditions are essential to make a holistic understanding of the physical processes during precipitation and to formulate the parameterization of precipitation in weather and climate models. The present study examines inherent microphysical processes associated with stratiform precipitation in different terrains over southern regions of Western Ghats (WG) during the Indian summer monsoon.

In this study, the features of stratiform precipitation are identified from the observations made with micro rain radar at two different altitudes over windward side of WG one at Braemore, mid-altitude location in Thiruvananthapuram (8°46'3.24" N, 77°5'39.2" E, 400 meters above MSL) and a high-altitude location at Rajamallay in Munnar (10°9'19.94" N, 77°1'6.6" E, 1820 meters above MSL). The stratiform precipitations were identified by a distinctive pattern of enhanced radar reflectivity factor known as Bright Band (BB). In a well matured stratiform cloud, falling ice particles from cloud top grow by deposition of vapor to a moderately large size, then within about 2.5 km of 0°C isotherm level (freezing level), aggregation and rimming process occur to form irregularly shaped large snowflakes which then melt and produce BB signatures. The mid and high-altitude regions of Western Ghats are consistently influenced by the formation of BB events during monsoon season. It is observed that onset and withdrawal days of monsoon are also characterized by BB formation. About 15.54% (mid-altitude) and 31% (high-altitude) of surface rain are associated with rainfall having BB conditions. The surface rain intensities at both locations depend on the variations in BB formation height which varies with atmospheric conditions and orographic features.

The stratiform precipitation in the monsoon season at high-altitude is evolved from shallow layers of clouds and its interaction with large scale monsoon circulation. The shallow cloud layers formed between 2–3.5 km levels signify that warm rain processes initiate precipitation and melting layer cloud decks are embedded with clouds that have relatively shallow depth. Time series of DSD evolution observed by MRR, during the formation of bright band event at high-altitude (18:00 IST on 1st September to 03:00 IST on 2nd September 2017) region are illustrated in Fig. 3.3.1. The collision-coalescence process of raindrop growth can be seen in the time series of drop size distribution at 4km (Fig. 3.3.1 a) and at 2 km (Fig. 3.3.1 b). The higher concentration of small size drops at 2 km are due to collision induced break up process. On reaching the surface, these small and mid-size drops will further increase by accretion of cloud droplets, since cloud bases are very near to the surface (Fig. 3.3.1 c). Surface rain drop distributions (Fig. 3.3.1 d) reveal relatively higher concentration of small drops and a considerable increase in rain rate (25 $mmhr^{-1}$) in high-altitude region. This shows that, the rain drop size distribution spectra at high-altitude region are influenced by upper layer clouds/melting layer and considerable growth of raindrops occurred as they pass through low-level feeder cloud generated by the forced uplifting of moist low-level air ascend over elevated topography. These internal dynamics between cloud layers create a seeder-feeder mechanism that plays a major role in determining the DSD spectra and precipitation at higher elevations in WG.

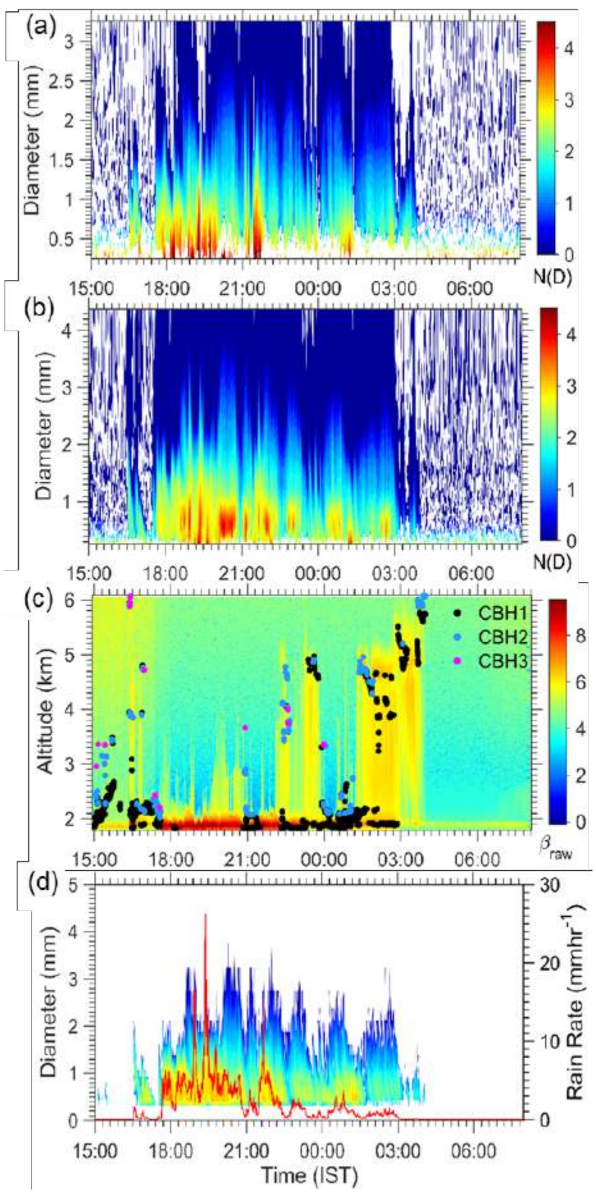


Fig. 3.3.1: Time series of raindrop concentration at, a) 4000 m; b) 2000 m level; c) back scatter profile over laid with cloud base height (km); d) surface drop size distribution and rain intensity (disdrometer) at high-altitude region of WG

3.4 Monsoon low level jet variability in wet and dry rainfall episodes over southwest India

The rainfall and low-level circulation features over the southern part of India are distinctly different from the rest of Indian subcontinent during summer monsoon season. When the south-westerly low-level jet (LLJ) contributes significantly to the monsoon rainfall over India, the north-westerly winds act as a main source of moisture at the southern tip of India. A comprehensive investigation is therefore performed in this study to understand the monsoon LLJ variability in relation with wet and dry spells of rainfall over a coastal station Thiruvananthapuram (8.48°N, 76.95°E), Kerala. The analysis also comprises dynamic and thermo-dynamic changes in the lower and mid layers of the troposphere in both the epochs. Several observational datasets from instruments like Radiosonde, Ceilometer, Micro rain radar and Automatic weather stations are incorporated for the in-depth analysis over a location for the five-year monsoon period (2010-2015 except 2012).

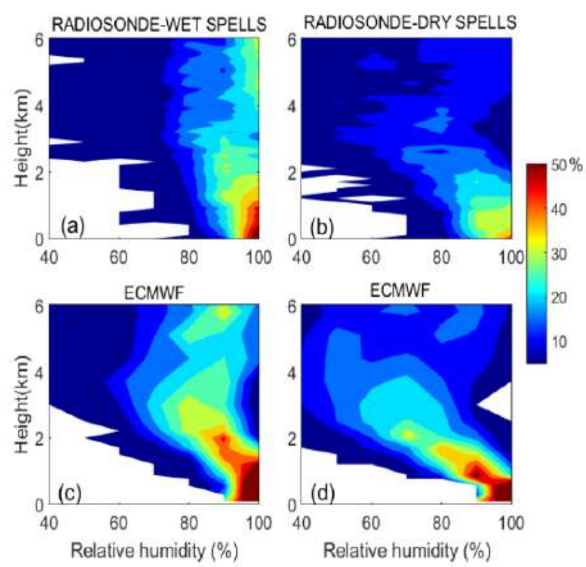


Fig. 3.4.1: Vertical profile of the composite percentage of relative humidity in wet and dry spells using radiosonde (upper panel) and ECMWF (lower panel) analysis

On an average a monsoon season comprises of approximately 5 (7) wet (dry) spells, each spell with an average duration of 5 (6) days, indicating frequent occurrence of dry spells with long duration of dry days. The analysis revealed the dominance of north-westerly winds over the southern tip of India. The wet (dry) spells are characterized with strong (weak) LLJ and advection from north-westerly direction is predominant in dry spells. The lower levels and zero-degree isotherm layer (at 5 km) are found to exhibit coherent peaks in temperatures, with frequent occurrence of warm temperatures at lower levels (5 km level) during dry (wet) spells. Whereas, distinctly different temperature peaks are observed from 2 to 4 km levels, with dry spells associated with warmer temperatures (1°C to 1.5°C) than wet spells. Both the wet and dry spells experience humid (>80%) boundary layer condition. However, considerable differences are noticed in the mid-levels (between 2 to 5 km), with anomalous moistening (drying) during wet (dry) spells. The study suggests a strong association of the variations in mid-level humidity and thermo-dynamical features with rainfall characteristics over the southern tip of India.

Vertical variation of the percentage of relative humidity over Thiruvananthapuram has been examined using radiosonde (upper) and ECMWF (lower) analysis (Fig. 3.4.1) in wet and dry spells. Since the time series of wet and dry spells is not continuous, the percentage of the vertical variations has been computed. Within the boundary layer (less than 1 km) higher percentage of humidity in wet spells has been observed than the dry conditions. The vertical profile clearly shows that wet spells mark with more than 80% relative humidity up to 6 km. The dry spells also coincide with higher percentage in the lower levels, but the demarcation clearly noted above 2 km. The analysis using ECMWF shows that boundary layer humidity conditions were more than 50% in both the spells with discrete differences in the mid-levels (Fig. 3.4.1 c and 3.4.1 d).

Distinct changes in vertical thermal structure of atmosphere are observed between active and weak phases of convection during July-August 1999, evident from the observations carried out as part of the Bay of Bengal Monsoon Experiment (BOBMEX). Warmer layer between 6-13 km and cooler layer below 6 km are also identified with largest fluctuations in humidity at middle troposphere, during the experiment. The analysis also explains that boundary layer fluctuations are not well simulated during the active and break spells. Our analysis suggests that the uninterrupted supply of moisture from the ocean keeps the boundary layers in a moist condition during both the spells. However, humidity variations are mainly noted above the layer of peak LLJ, with wet spells associated with more moisture than during dry spells. Wet spells are found moist up to middle troposphere and dry spells with moisture trapped in the boundary layer is also observed over the Indian inland station of Gadanki. Our analysis of LCL over Thiruvananthapuram also indicate cloud base to be located at lower levels within the boundary layer, during the monsoon season. Atmospheric drying is evident during the transition period from wet to dry spells above boundary layer.

3.5 An inter-comparison in the diurnal variation of cloud base height during 2017 and 2018 over Trivandrum region

A laser-based cloud height meter Lufft 15K Nimbus (CHM 15K NIMBUS) Ceilometer installed at NCESS campus has been used for obtaining the two-year data (2017 and 2018). The data has been processed for studying the hourly variation of different layers of Cloud Base Height CBH (m) for three different seasons over the region. The data have been computed and the averages of three different cloud base heights, CBH1, CBH2 and CBH3 for the three seasons, pre-monsoon, monsoon, post monsoon has been analyzed to understand its characteristics.

In 2017, the pre-monsoon has shown an increase in height at 6:00 LST and a sharp decrease at around 10:00 LST nearly for all the three layers and then a sudden increase at 15:00 LST and 23:00 LST (Fig. 3.5.1). During Monsoon, oscillations are observed in height with the maximum at early hours around 0:00 LST, dropping at 9:00 LST and again picking up around 20:00 LST at night hours. Also, it has been observed to be applicable for all the three layers. Now on considering the post monsoon event, an increase in height is observed at 5:00 LST followed by a decrease in height at 10:00 LST (CBH1 only) and again increasing observed between 19:00 LST and 20:00 LST for all the three layers. On considering all the three events (Pre-monsoon, Monsoon and Post Monsoon) there is an increase in height during the early morning and night hours with the same pattern being followed by all the three layers.

In the year 2018, Pre-monsoon depicts the maximum heights at 5:00 LST with a sudden fall in height around 9:00 LST further increasing the height gradually with minor fluctuations for all the three layers. During Monsoon, the height gain is maximum during early hours around 0:00 LST, getting reduced at 10:00 LST and further increasing to reach maximum at 23:00 LST. The condition appears much similar to the 2017 monsoon event. During Post monsoon, for all the three layers, height is found to be the maximum at early morning around 6:00 LST followed by minor variations from 15:00 LST - 20:00 LST further decreasing at 10:00

LST in between. While considering both the years, height of all the three layers has been maximum during early morning and late-night hours.

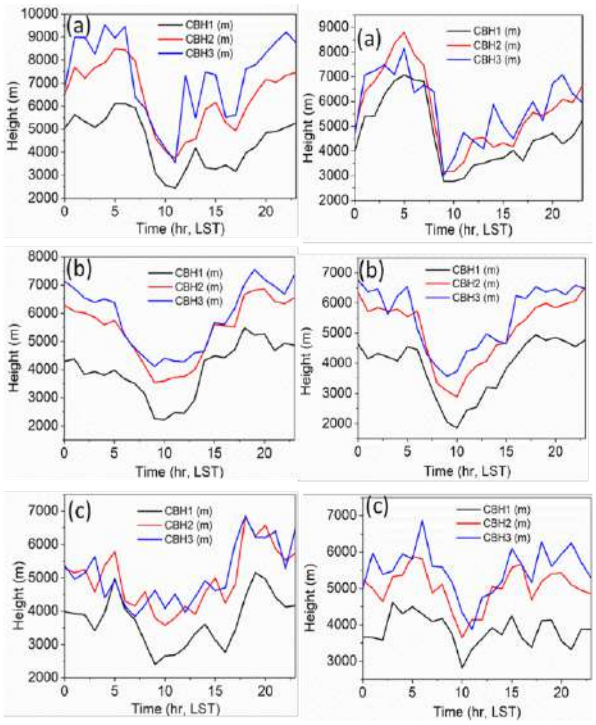


Fig. 3.5.1: Average of different layers of cloud base height, a) Pre-monsoon; b) Monsoon; c) Post Monsoon on 2017 and 2018

3.6 Precipitation characteristics in terms of DSD and Z-R relations for different types of rain

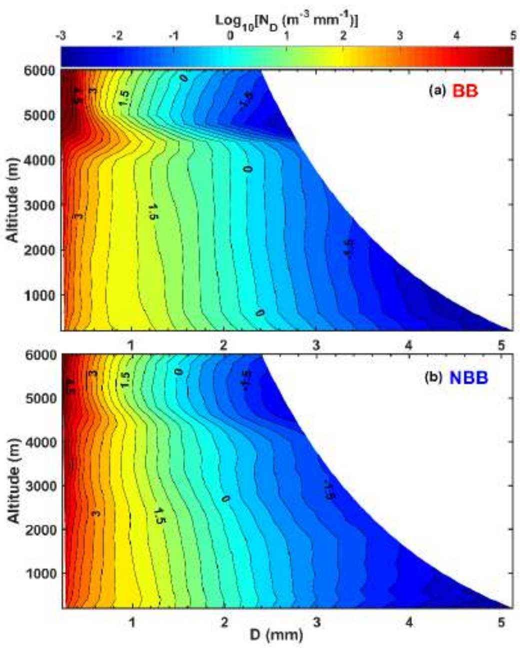


Fig. 3.6.1: Vertical profile of DSD for BB and NBB cases

The processes associated with rainfall are very complex, particularly in tropics. Exploring the microstructure of precipitation is essential to understand the related atmospheric processes. In particular, profiles of DSD obtained from a Micro Rain Radar (MRR) observation for different types of rain events will help us understand the processes that raindrops go through while falling from its origin at cloud level to surface level. Another significant aspect is the well-known approach of remote sensing of rainfall using radars, which uses an empirical relation between rain rate and radar reflectivity, which turns out to be of power law type (i.e. $Z=aR^b$). The parameters of this relationship vary significantly for different regions over the globe as well as for different types of rain (i.e. stratiform, convective or mixed convective-stratiform type). The variability in rain DSD and Z-R relation is a topic of utmost importance in the tropical region.

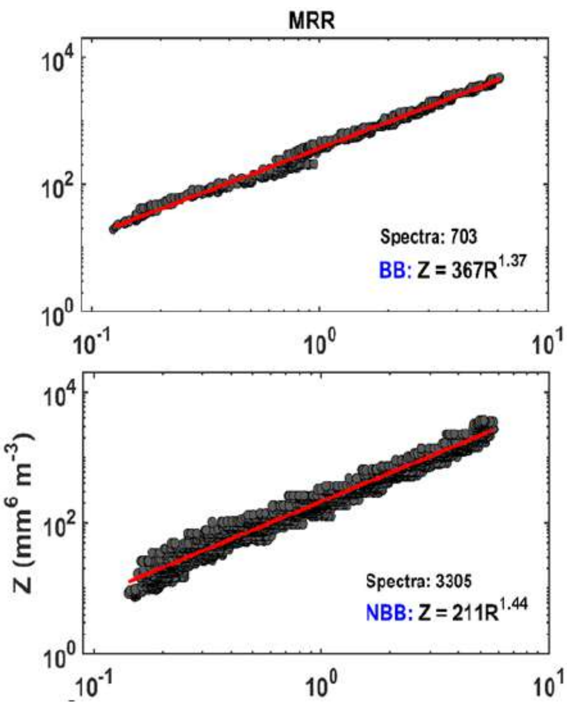


Fig. 3.6.2: Z-R relations obtained from MRR (200 m) (right panel) for BB (top) and NBB (bottom) conditions

To investigate the variability in DSD and Z-R relations, comparisons for two different types of rain – 1) BB (i.e. in presence of Bright Band) 2) NBB (i.e. No Bright Band) has been attempted. Both the cases have rain intensity in the range $0.1 \leq R \leq 7$ mm h-1. Fig. 3.6.1 shows the vertical profile of DSD for BB(a) and NBB(b) cases. DSD profile for BB case visibly shows the melting layer signature between 4 to 5 km altitudes. Such clear signature is not present in the NBB case. In the BB case, starting from the melting layer till the lowest level, the DSD remains almost uniform, however, in NBB case a clear variation in DSD shape with altitude has been observed. One can observe a clear shift between the two DSD profiles for BB and NBB, which illustrates that the number concentration of smaller drops is much higher for NBB compared to BB. On the other hand, the number concentration of larger drops is higher for BB compared to NBB.

Fig. 3.6.2 shows the Z-R relations for BB and NBB cases from MRR and the Z-R relations have been obtained using the Sequential Intensity Filtering Technique (SIFT), which reduces the scatter in the Z-R scatter diagram significantly, leading to more reliable Z-R relations. The agreement between the relations (for both BB and NBB) obtained from MRR and Disdrometer is remarkable. The values of parameters 'a' and 'b' agree well with the other studies done over tropical regions.

3.7 Characteristics of surface ozone and its precursors over a tropical station Trivandrum

The present study has examined the variations of tropospheric ozone (O_3), a secondary air pollutant, and the influence of precursor gases along with meteorological variables on seasonal as well as temporal trends during the 5-year period of April 2014 - May 2018 in a tropical station at Trivandrum. Data from real-time air quality monitoring station are considered. Average concentration of ozone is 19.34±8.91 ppb during the period. Diurnal variation of O_3 shows that the concentration increases gradually after sunrise attaining the maxima around noon, further decreasing towards the evening. Seasonal variation of O_3 has been found maximum during winter (24.4±13.1) the lowest recorded during monsoon (13.7±4.7 ppb). Variations in meteorological variables and planetary boundary layer height were responsible for seasonal variations in O_3 concentrations. Night-time values of O_3 are lower than that of the daytime. The daytime increase in ozone mixing ratio is basically due to photooxidation of precursor gases, like CO, CH_4, and other hydrocarbons in the presence of sufficient amount of NO/ NO_x. The rate of change observed has been higher during winter and post monsoon season. During winter, its magnitude was of the order of 12.3 ppb/hr at 09:00 hrs, whereas in the post monsoon season the value was 7.0 ppb/hr at 09:00 hrs. Moreover, the rate of decrease of O_3 was high (-7.5 ppb/hr) at 19.00 hrs in winter, probably due to the diminished photochemistry and shallow mixing layer height. The rate of change of production of O_3 at Trivandrum is 4.3 ppb/hr. The rate of change of O_3 during evening at Trivandrum is -4.0 ppb/hr. The study area resembles an urban location with a comparable rate of change of O_3 in the morning and evening.

The annual mean concentrations of NO_x, CO, CH_4 and TNMHC are 6.29±2.03 ppb, 0.56±0.21 ppm 1721.8±196.9 ppb and 60.06±19.66 ppb respectively. NO_x, CO, CH_4 and TNMHC concentrations were the highest during the winter season. Reduction of concentration during monsoon could be due to rainy wash out. The diurnal patterns of all the gases also showed similar seasonal variation. NO_x, CO, CH_4 and TNMHC showing peaks during morning and late evening hours and trough in the afternoon during all the seasons. Both CO_2 and CO depict similar pattern of variation.

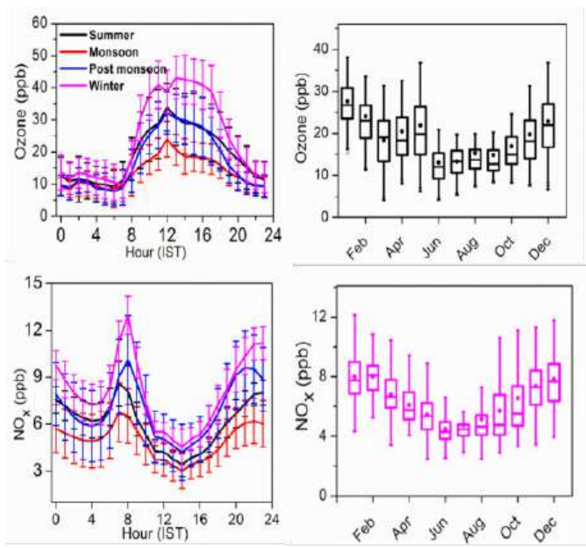


Fig. 3.7.1: Seasonal variation and box whisker plot of ozone, NO_x 2014-2019

3.8 An integrated geospatial landslide susceptibility mapping over Kodagu, Karnataka

Numerous landslides have occurred in Kodagu area (Karnataka) and caused damage to agriculture and pasturelands. An attempt has been made for an integrated landslide mapping and management system for the Kodagu region incorporating field investigations, satellite data products and rainfall datasets onto a geospatial platform to understand the susceptibility of the region for landslides.

Conventionally, landslides were mapped using aerial photographs and field investigations being the only source of landslide inventory till the recent past. Hitherto, satellite images proved to be more potential due to their capability of providing synoptic view and repeated data acquisition which is more economical and practically viable as opposed to that of aerial mapping. In the current study, the level 2A product of the Sentinel 2A Multispectral Imager (MSI) data at 10 m spatial resolution has been used for the generation of satellite based geospatial inventory. The Level-2A processing includes a scene classification and an atmospheric correction applied to Top-Of-Atmosphere (TOA) Level-1C orthoimage products. The final product is the Bottom-Of-Atmosphere (BOA) corrected reflectance product. A geospatial landslide inventory map with a total count of 273 landslides that occurred during the August 2018 floods could be mapped applying various digital image-processing techniques validated by visual interpretation.

Field investigations were carried out for mapping the geomorphometric characteristics of the landslides using a mobile-based Android Application GeoMAPP. The Geoscience Mapping APP (GeoMAPP) Android Application developed by NCESS is a multi-function data collection application catering to the different domains of the Geoscience field investigation. The landslide portal of the APP makes use of the inbuilt mobile GPS to extract the geographic coordinates of the location and geotagged photographs also can be captured by enabling the mobile camera through the APP. The information about the landslides collected during the field campaign using the GeoMAPP is directly uploaded into the server in NCESS to be consumed into a web GIS portal. The web mapping portal makes use of the

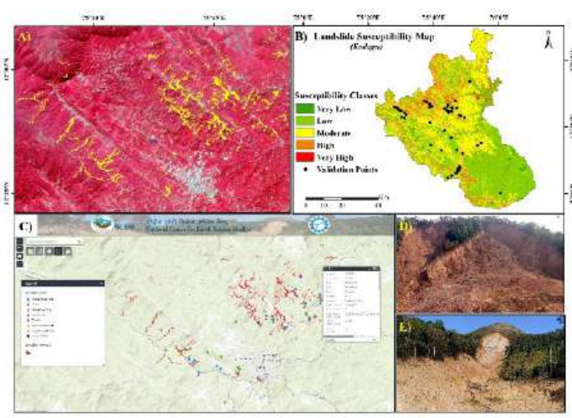


Fig. 3.8.1: Landslide susceptibility mapping in Kodagu: A) Satellite based geospatial landslide inventory; B) Frequency ratio-based landslide susceptibility map of Kodagu; C) Web App for landslide information dissemination; D) Slope failure in Devagiri, Kodagu; E) Debris flow in Madenad, Kodagu

ARC GIS Enterprise version to create a portal for data management followed by a hosted layer. The hosted feature service is published as a map service wherein the user will have the privilege of obtaining details on a specific landslide location collected using the mobile APP including the geo-tagged photographs of the landslide. Similarly, different types of landslides can be queried based on the classification defined as per their failure mechanism.

Mitigation and management of any natural hazard, especially landslides, starts with the preparation of a landslide susceptibility map. In Kodagu, the landslide susceptibility mapping is carried out using the satellite derived geospatial inventory and the field information as the basic inputs. Frequency ratio - a statistical approach to simulate the environmental conditions considering multiple landslide causative factors is used to generate the landslide susceptibility map for the Kodagu region. Eight landslide occurrence related factors - slope angle, slope aspect, curvature, distance to roads, distance to lineament, geology, land use/land cover, and drainage density were used to establish the relationship to the occurred landslides with respect to the various landslide causative factors. The final susceptibility map is validated using 90 independent landslide events of the same region. The final landslide susceptibility map is classified into five classes based on the classification by GSI, 2005 ranging from very high to high, medium, low and very low susceptibility. The computed susceptibility maps showed sufficient agreement with the validation points with 3.45% landslides falling in the very high susceptible region followed by 45.98% falling in the high hazard region, 39.08% falling in the moderate hazard zone and 11.49% falling in the low hazard zone.

3.9 Satellite rainfall thresholds for initiation of landslides in Wayanad, Kerala: A conceptual framework

Landslides are one of the major natural hazards in Kerala, where 13 out of the 14 districts are prone for landslides. Majority of the landslides in the Western Ghats are Debris flows triggered by intense rainfall events. Devastation caused during the recent floods of August 2018 reiterates the need for elaborate investigation on landslide mapping, monitoring and forecast. The present study is an earnest attempt to establish cumulated rainfall–duration relationship vis-à-vis landslide occurrences leading to identification of rainfall thresholds that can stimulate debris flow. The multi-satellite precipitation product – Global Satellite Mapping of Precipitation (GSMAP) reanalysis of rainfall data for Wayanad region of Kerala is used to establish the relationship between intensity/cumulated rainfall and debris flows. The power law-based model determines the cumulated event rainfall–rainfall duration (ED) thresholds adopting frequentist and bootstrapping techniques on the rainfall conditions that triggered the landslides via the Calculation of Thresholds for Rainfall-induced Landslides-Tool (CTRL). The landslide inventory of Geological Survey of India (GSI) as well as data collected by NCESS has been used in this study. The rainfall records indicate that majority of events occurred on the 7th – 8th and 16th -17th of August 2018 reiterating the prevalence of intense rainfall prior to and on the days of the failure. The results highlight that short duration spells as well as long duration spells with an overall cumulated rainfall of 250 mm contribute to the slope failures. Eventually, high intense short duration spells lasting up to 40 hours and low intense long duration spells (>200 hours) accorded for most of the slope failures. Probably, the antecedent nature of *in-situ* soil moisture condition also has to be collated from microwave satellite information to arrive at a precision threshold functioning.

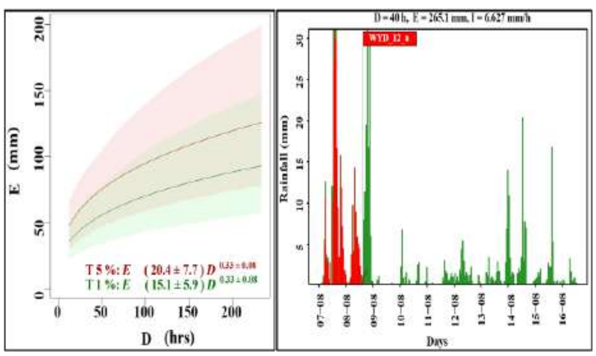


Fig. 3.9.1: Rainfall thresholding for Wayanad region

This is an initial attempt towards building rainfall thresholds for triggering landslides along Western Ghats using the satellite derived reanalysis data. Non-availability of a structured landslide inventory mainly without the exact date and time of occurrence is a major impediment towards rainfall threshold modelling. Hence the study proposes for a paradigm conceptual framework for landslide inventory mapping using satellite-based information integrated with field inventorying in addition to strengthening field measurements of rainfall to validate and augment satellite derived rainfall products. Rainfall threshold studies need to be done with improved datasets which can further enable better understanding of process which can lead to forecasting of the hazard thus reducing the risk and ensuring safety of life in future.

3.10 GeoMAPP: An android mobile field data collection app for geoscience applications

Currently, telecommunication, mobile communication devices have become indispensable in daily life. The multitude of sensors and applications within a single hand device makes mobile devices useful in many ways. Application of these devices for various purposes including data collection in various geoscience domains and geohazard assessments can revolutionize their utility. In the case of landslides and floods, reporting of the incidents can be augmented considerably through the development of the mobile technology especially in the remote hilly regions and regions with no or poor connectivity where researchers cannot reach when the hazard takes place. Further, developments of the geospatial techniques for a web-based data management and data mining using machine learning techniques can further improve the knowledge and spatial analysis of landslides or any geoscience application of that kind. The concept of using smartphone-based methods for various field investigations in the geoscience domains and assessing geohazards has been emerging at a faster pace. Smartphones can be used to collect data in the field which can by large reduce manual data entry in the field and updating in the laboratory as well which makes up considerable time after each field visit. The added capability to transmit data online into a structured geospatial database enhances ease of data delivery permitting decision support through web-enabled applications. Apart from geoscience data and geohazard mapping, smartphones also can be used for early-warning to help researchers to better identify the hazard triggering mechanism.

The Geoscience Mapping APP (GeoMAPP) Android Application developed by NCESS initially focused mainly on landslide mapping whereas currently, the APP is developed as a multi-function geoscience data collection application for various field related geoscience mapping applications. The Applications consists of five major sub categories namely - landslides, geology, hydrology, floods, beach and shore. The landslide module allows detailed mapping of landslides whereas the geology module enables field-mapping of different terrains sub-divided into metamorphic, igneous, sedimentary and alluvium. The geology portal also incorporates a section for core – logging to log the basic information during core drilling like run length, depth and type of material. The hydrology portal would enable any geoscience related mapping in the lakes, river and wells (open/tube) ranging from river bank mapping to water quality parameters. The beach and shore module would have portals for beach survey parameters like width of the beach, beach slope, wave breaker height, surface currents etc. while the water quality module is also added in order to enable nearshore water quality measurement.

Developed in the MIT App Inventor platform based on JavaScript, the app inventor enables developing android apps in a web browser. The application can be installed in any mobile device running on android platform. Traditional layered architecture is followed for the development of this application. The three layers that constitute architecture are the Presentation layer, the Application layer and the Database layer. Through the presentation layer, user gives inputs to the device. Application layer is responsible for accepting those input values and processing them. The database layer helps to store the processed data and share it.

The salient features of the mobile applications are listed below:

1) Enables structured data collection to be used in a Geodatabase for further analysis.

2) Geolocationing through direct extraction from the inbuilt Global Positioning System (GPS) of the device.

3) Capable of uploading data directly to the server of NCESS data centre.

4) Ability to store in the internal memory of the device in case the location of field investigation is having poor internet coverage and later the same can be transmitted to the server once the device receives network coverage.

5) The data stored in the local device is encrypted for necessary data security.

6) Field photographs can be taken directly using the mobile camera in the device, which would link to the location making the archiving of data easy for documentation.

7) The data flow and application usage are completely monitored by a layered administrator privilege to have a tract on the machines using the application and how data is being collected (to maintain security aspects).

Fig. 3.10.1: Screenshots of the mobile app

The landslide module of the mobile APP was successfully validated in the Kodagu region and currently being validated in the Western Ghats regions of Kerala. Similarly, the validation of the geology module is ongoing and the APP is expected to be officially released for researchers once all the modules are validated for their integrity and geodatabase structure in the server side of NCESS Data Center.

A huge quantum of legacy scientific dataset collection during various scientific investigations are still hidden from researchers. The archival and maintenance of such legacy datasets especially collected during the geoscientific research can provide valuable insights beyond the perceived level. The collection of geoscience datasets in a well-maintained archive and well-documented structure will be a storehouse of information capable of enhancing knowledge for better assessment and sustainable management of the natural system and provide better understanding of the geological hazards.

The development of the GeoMAPP is a first step of the ladder under the initiative of "Sophisticated Centralized Geomatics Lab and Geoscience data Infrastructure" which aims at addressing appropriate documentation for data archival and sharing in a more systematic manner.

3.11 Land degradation assessment and mapping in Tirunelveli district of Tamilnadu, South India using GIS – AHP technique

National Centre for Earth Science Studies (NCESS) signed an MOU with Space Application Centre (SAC) - ISRO, Ahmedabad as a participating agency to carry out the external funded project titled *Desertification and Land Degradation: Monitoring, Vulnerability Assessment and Combating Plans*. The major components of the project includes (i) Research and development - to develop the digital image classification techniques for land degradation status mapping using satellite images; (ii) Semi-operational - to develop the methodology / tools for desertification & land degradation vulnerability assessment at 1:50K scale; (iii) Development of methodology for action plan for combating desertification & land degradation for watershed at 1:10K scale. As part of this project, the work plan namely *GIS - AHP modeling of land degradation vulnerability in Tirunelveli district of Tamil Nadu, South India* has been executed during the period of April 2018 – March 2019. The digital mapping of land degradation vulnerability (LDV) for Tirunelveli district of Tamil Nadu has been prepared using integrated remote sensing and GIS technology. Land degradation (LD) is one of the most pressing factors and current global challenge for sustainable development. United Nations goal of LD neutrality calls for improvement of the degrading lands. Towards this, it is imperative to measure and monitor LD and its significance worldwide. Assessment of LD can be executed using GIS based Analytical Hierarchy Process (AHP) technique that considers comprehensively multifaceted indices from the analysis of various geo-environmental parameters such as geological features, soil properties (depth, texture and permeability), land use and land cover, slope, rainfall, temperature, soil erosivity, and population density. Multiple datasets like Landsat (ETM+ and OLI), ASTER DEM (30 m), IMD rainfall, and SOI topographical maps are sourced for deriving outputs such as, LULC, NDVI, SAVI, VSI, and LST digesting different indices.

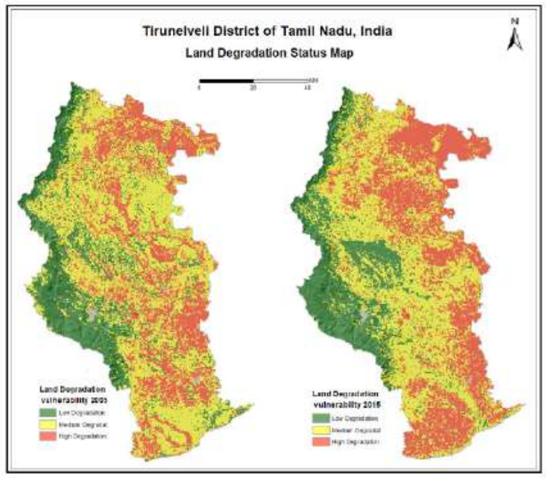


Fig. 3.11.1: Land degradation status of Tirunelveli district of Tamil Nadu, India based on multiple geo-environmental parametric analysis using GIS-AHP model

The AHP technique uses empirical equation, which operates pair wise comparative analysis of weighted parameters and their feature classes for multi-criteria decision-making measurement using index overlay model in GIS environment. The technique uses the derived parameters assigned with weights and ratings based on their susceptibility and potentiality to LD process. Measuring the vulnerability index values to site-specific LD in raster format (at pixel scale of 10*10 m) is processed by computing the weighted parameters. The result reveals that 14.11% of the area in the Tirunelveli district of Southern Tamil Nadu spatially falls under higher vulnerability to LD, whereas 50.01 % of the area has lower vulnerability leaving rest vulnerable at moderate levels. Land use dynamics transforming cultivable lands to fallow and then to barren explicitly triggers LD process. During past decades, increasing land surface temperature combined with deficit rainfall has affected soil moisture and fertility causing potential vulnerability to LD throughout the district. The study expound that GIS based AHP approach is a robust technique to rely on for meaningful assessment and mapping of the LD vulnerable zones at user-required scale.

4. Hydrological Processes

Like many other parts of the world, the demand of potable water is outstripping its supply in India as well. Fertilizer intensive agricultural activities and other skewed developments are polluting the freshwater sources year by year. The adversities of climate change is another major threat which is being surfaced in the form of extreme flood and drought events. Degraded ecosystems - and the species that live in them- are less resilient to these climate impacts, and communities that depend on the services provided by healthy freshwater ecosystems become increasingly vulnerable. The Hydrological Processes Group has taken up a wide range of studies covering Critical Zone hydrology, bio-geochemistry river ecosystems, hot and cold-water springs, paleo-hydrology/paleoenvironment etc., of Southern Western Ghats as a case study site to understand the hydro-environmental changes in the region and suggest strategies for sustainable utilization/management of the natural resources in general and the freshwater resources in particular.

4.1 Critical Zone Observatories: NCESS initiatives

The need for adequate number of fully functional Critical Zone Observatories (CZOs) is increasing in India, as the country is undergoing rapid economic developments over the past few decades. Critical Zone (CZ) is the upper most part of the earth extending from top of vegetation canopy down to the subsurface depths of the fresh groundwater aquifers. The critical zone sustains terrestrial life including man. Critical Zone studies have been initiated worldwide in the beginning of the 20th century mainly to address the adversities of unscientific developments and evolve mitigation strategies to bringdown the negative impacts of developments within the natural resilience of ecosystems. Critical Zone studies are conducted by establishing the CZOs an environmental laboratory and a platform for research, that functions at the catchment / watershed scale focusing on the interconnected chemical, physical and biological processes shaping Earth's surface. During the last two decades, more than 70 CZOs have been established worldwide, majority of them are located in developed countries like United States and the European Union. At the same time, very limited attempts have been made to study the Critical Zone characteristics of the tropics, even though tropics are known for their heterogeneous climatic and geo-environmental setting, and rapidly growing economic activity. Considering the importance of environment-inclusive development for sustainable growth, Ministry of Earth Sciences, Govt. of India, planned to establish CZOs in selected agro-climatic zones of India (MoES Vision Document - 2030). Accordingly, NCESS has initiated establishment of a few CZOs in the southern Peninsular India, in line with the Kabini CZO – the only fully functional and adequately instrumented CZO in India, maintained by IISc, Bangalore. Setting up of CZOs is now progressing in Munnar (Periyar river basin), Attappadi (Bhavani river basin) and Thanjavur (Cauvery river basin). These CZOs will be instrumented adequately in the coming years to monitor the Critical Zone variables and processes at different spatial and temporal scales.

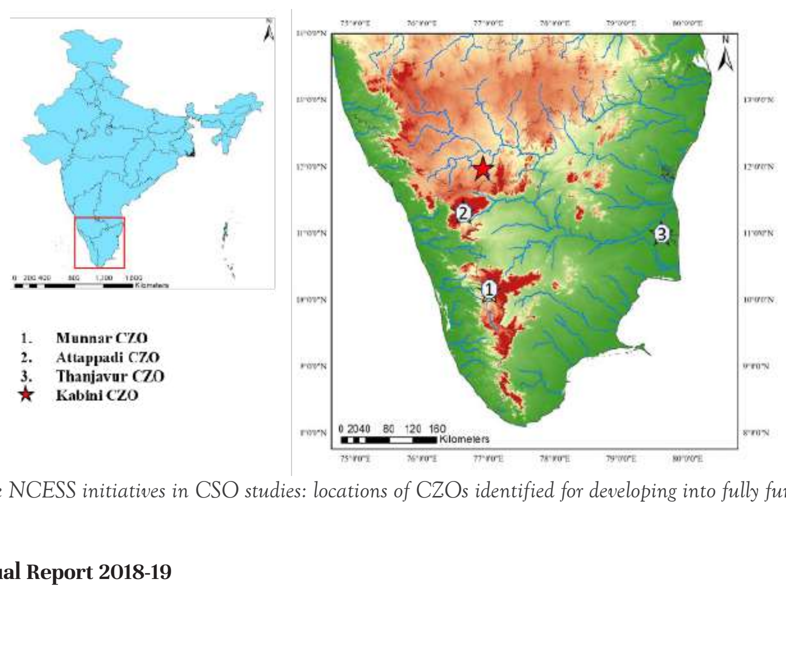


Fig. 4.1.1: The NCESS initiatives in CSO studies: locations of CZOs identified for developing into fully functional CZOs

Figure 4.1.1 shows the locations of the three CZO sites identified by NCESS for further developing into fully functional CZOs. Among the three sites, instrumentation has been initiated in the Munnar and Attappadi sites. The instrumentation in the Thanjavur CZO is yet to be initiated. The key objectives of these CZOs are to study the Critical Zone processes as a whole using a multidisciplinary approach. The CZOs are instrumented to monitor instantaneous and continuous soil moisture (surface and profile), groundwater level, streamflow, canopy characteristics (Leaf Area Index, Vegetation Water Content, Biomass), porewater geochemistry, hydrochemistry of surface and groundwater, soil properties (physical and hydraulic properties), meteorological variables, evaporation, soil water balance (Lysimeter) etc. These variables are monitored at different spatial locations and at different temporal scales. The data generated from these observatories will enable to understand the Critical Zone dynamics, its resilience in the context of natural and forced changes. These CZOs are being developed as calibration-validation (cal-val) sites for several satellite products with an aim to work on a larger concept of 'Monitoring Critical Zone from Space'.

Munnar CZO: Munnar CZO is a tropical high-altitude mountainous observatory, characterized by a highly heterogeneous terrain features and located in the Idukki district of Kerala state. Geologically the area forms a part of the Madurai granulite block (MGB) of the southern granulite terrain (SGT) and comprised essentially of charnockites, hornblende gneiss, granite etc. Geomorphologically the area forms a part of Munnar plateau whose elevation varies between 1460 m and 1620 m above MSL. The slope is generally steep (>30°) and the soil is mainly of lateritic type with appreciably high content of clay. The hills of Munnar are home to different cash crops. Tea gardens and settlement with mixed cultivation are the major land use of this area. Eucalyptus and acacia, planted under the government's social forestry scheme, occupy a major part of the forest plantation, whereas the upslope portions are occupied by degraded forests, shola forests and grasslands.

Attappadi CZO: Attappadi CZO lies in the transition zone between the humid to sub-humid areas in the Nilgiri plateau and extends to semi-arid region. River Bhavani, which is the tributary of the Cauvery river drains through the area. Attappadi's climate is classified as tropical with an average annual temperature of 24.8°C and precipitation of 1731 mm. The predominant rock types present in area are, charnockite group of rocks, high grade metasedimentary rocks, khondalites and peninsular gneissic complex. Black cotton soil and virgin forest soils forms a major part of the soil type in the region. Attappadi region is inhabited by a sizeable number of tribal population and is predominantly an agricultural watershed.

Fig. 4.1.2: Snapshots of the continuous profile soil moisture sensors installed in the Attappadi CZO

Instrumentation and Monitoring: Instrumentation and monitoring of key Critical Zone variables have been initiated in the Munnar and Attappadi CZOs. As a first step, Munnar and Attappadi CZOs are instrumented with soil moisture sensors and rain gauges. The continuous soil moisture sensors installed in Attappadi CZO is shown in Fig. 4.1.2. A total of 10 continuous profile soil moisture sensors has been installed in the Munnar and Attappadi CZO. Monitoring of surface and groundwater of the CZOs have already been initiated.

4.2 Coupled vadose zone - Groundwater modelling of Bhavani CZO

Traditional groundwater model considers recharge as a percentage of rainfall, without taking into consideration the complex vadose zone processes. In order to understand the influence of vadose zone on groundwater recharge, a modelling scheme was developed by coupling vadose zone model (HYDRUS) with groundwater model (AMBHAS) at plot scale. The model was run with rainfall data recorded in the rain gauge and a synthetic rainfall generated based on the evidences of increase in number of high intensity rainfall events and decrease in moderate rainfall events. Fig. 4.2.1 shows the normal rainfall data and synthetic rainfall data generated for modelling the groundwater recharge. Even though the total of the annual normal rainfall and annual skewed rainfall remains the same (1464 mm), precipitation data generated for the synthetic rainfall has less number of rainy days as compared to the gauge recorded rainfall. The synthetic rainfall has been generated taking into account the observed trends in the number of high intensity rainfall events across the Western Ghats and also by considering the rainfall pattern of 2018.

The synthetic rainfall data thus generated helps to understand the importance of vadose zone in computing the recharge to groundwater. The recharge flux thus computed from synthetic rainfall was compared with the recharge flux computed from normal rainfall. Fig. 4.2.2 shows the recharge flux computed by HYDRUS during normal rainfall and synthetic rainfall. The results showed that the annual recharge flux computed from normal rainfall is 114.75 mm which is 7.8% of annual rainfall and the annual recharge flux computed from skewed rainfall is 75.97 mm which is 5.1% of annual rainfall. It is thus clear that, as the intensity of rainfall increases, the recharge to groundwater decreases. Hence the assumption of a constant recharge factor (recharge coefficient as a percentage of rainfall) does not accurately provide the best estimates of groundwater recharge.

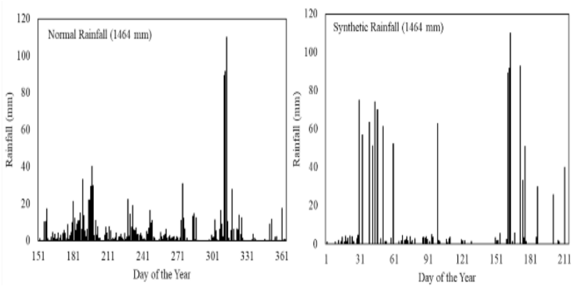


Fig. 4.2.1: Daily distribution of rainfall (mm) used in the study

Vadose zone models (soil moisture models) simulate the soil water flow based on the soil hydraulic properties and hence represent a realistic information about the potential recharge into the groundwater. The annual surface runoff produced in normal rainfall is 899 mm which is 61% of annual rainfall and the annual surface runoff produced in skewed rainfall is 1001 mm which is 68% of annual rainfall. It revealed that high intensity rainfall was expected to contribute more towards streamflow rather than groundwater. Thus, it is clear that from the above results that the recharge coefficient obtained from normal rainfall and skewed rainfall was 0.051 and 0.078 respectively and hence it can be understood that an assumption of constant recharge factor is not valid for high intensity rainfall events which is characteristic of the forthcoming climate change era. Field level studies on these observations drawn from the simulation exercise in the test beds selected for NCESS CZOs is in progress.

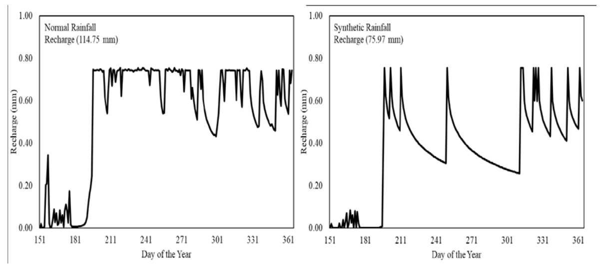


Fig. 4.2.2: Recharge flux computed from HYDRUS

Simulation was carried out for five wells situated in different landuse classes using AMBHAS. Calibration was done for the year 1981-2004 and validation for the year 2005-2013. The daily recharge flux produced from HYDRUS was converted into monthly recharge flux and annual recharge flux using MATLAB and then it is read in AMBHAS for simulation of groundwater flow. Wells which falls in the landuse category forest and agriculture plantation mixed, showed a better annual recharge coefficient of 0.09-0.004 than wells which falls under the double crop type, with an annual recharge coefficient of 0.08-0.004. The performance of the model for all the five wells was satisfactory as shown in their computed root mean square error (RMSE) and normalized root mean square error (NRMSE) values. The R^2 value obtained in the calibration for all the five wells when simulated for annual results was found to be 0.91, whereas R^2 value during validation period was found to be 0.94. The results of the study revealed that the rainfall pattern plays a major role in the groundwater recharge process in semiarid and arid regions. The areas, where there is an increase in moderate rainfall events, showed increase in the groundwater recharge, thus highlighting the importance of moderate rainfall events in the groundwater recharge process. Further studies are progressing to understand the changes in the rainfall characteristics and the groundwater recharge through field level experiments at the CZOs and modelling studies.

4.3 Changes in the hydrological characteristics of rivers draining the eastern side of Southern Western Ghats, India

Cauvery river basin receives much of the rainfall during the two monsoon seasons and the rainfall across the Cauvery river basin is highly heterogeneous. The regions close to the Western Ghats receive higher rainfalls as compared to the middle and lower reaches of the

Cauvery river basin. Temporal distribution of rainfall varies across the Cauvery river basin, with the western side of the basin receiving majority of rainfall during the SW monsoon season and the eastern part receiving much of the rainfall during the NE monsoon season. The SW monsoon rain starts in June and continues till the end of September. The NE monsoon contributes to the rainfall in Cauvery river basin in the months of October to December. Precipitation varies considerably across the basin. While, the western side of the catchment experiences the SW monsoon from June to September; NE monsoon from October to December falls on the eastern side. The rainfall during the rest of the period is generally insignificant. Major parts of the middle Cauvery region showed a decline in the annual rainfall, whereas the upper Cauvery and the lower Cauvery showed an increasing trend in the annual rainfall. Figure 4.3.1 shows the Sen's slope of the annual rainfall in the Cauvery river basin. The northeastern side and southwestern side of the middle Cauvery, particularly the areas in the higher altitudes showed an increasing trend in the annual rainfall. The increasing trend in the annual rainfall in the upper Cauvery basin is found to be statistically significant in most of the regions, while the decreasing trend in the middle Cauvery was not found to be statistically significant at $\alpha = 0.05$ or 0.10.

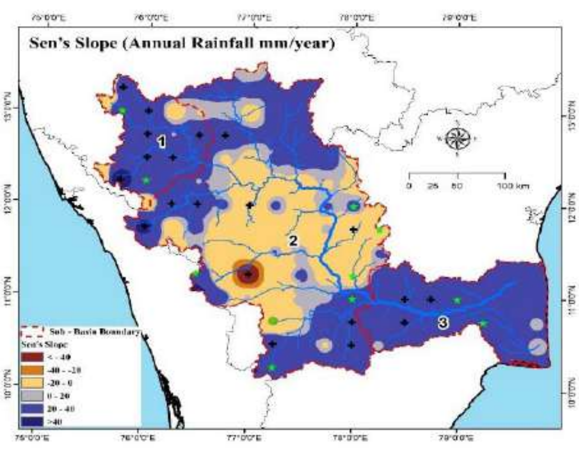


Fig. 4.3.1: Sen's slope of annual rainfall in the Cauvery river basin (period of study: 1984 - 2013

In the middle Cauvery region, which is relatively a flat terrain and semi-arid, the decreasing trend in annual rainfall is found predominantly along the Palghat gap, a climate corridor linking the humid regions in the west of Western Ghats to the semiarid and arid regions to the east of the Western Ghats. The increasing trend in the annual rainfall in the lower Cauvery delta regions can be mainly attributed to the cyclonic events in the Bay of Bengal. The decreasing trend in the middle Cauvery region was also observed in the rainfall during the summer season and SW monsoon rainfall, whereas no major changes in the rainfall was observed during the NE monsoon rainfall.

The rainfall in the summer season did not show significant changes in the upper and lower Cauvery basins. The northeastern part of the middle Cauvery basin showed a statistically significant increasing trend in the summer rainfall, whereas the other regions in the middle Cauvery basin did not show any significant trend. Major parts of the upper Cauvery basin showed an increasing trend during the SW monsoon season which is consistent with the trend in the annual rainfall, whereas during the summer and NE monsoon season no significant trend was observed in this region. The Cauvery delta region (lower Cauvery) showed increasing trend in the SW rainfall season, though not statistically significant at $\alpha = 0.05$ or 0.10, whereas the decreasing trend in the rainfall in the middle Cauvery region was found to be statistically significant, particularly in the Palghat gap corridor. High altitude regions in the northeastern and southwestern part of the middle Cauvery basin showed an increasing trend in the SW monsoon rainfall, though not statistically significant. NE monsoon rainfall did not show any dominant trend in all three regions of the Cauvery river basin, though a relatively smaller declining trend was observed in the Cauvery delta region. This can be attributed to the seasonality of the rainfall in the Cauvery river basin, with majority of the rainfall being contributed by the SW monsoon rainfalls and the NE monsoon rainfall is relatively a lesser contributor of the rainfall.

The number of rainy days (rainfall > 2.5 mm) showed marked changes in major parts of the upper and middle Cauvery region (Fig. 4.3.2). The upper Cauvery region showed an increasing trend in the number of rainy days, which are found to be statistically significant at $\alpha = 0.05$. Such a phenomenon is not observed in the lower Cauvery region. In the middle Cauvery region, the areas adjoining the Western Ghats, except the Palghat Gap and the northeastern uplands, showed an increasing trend in the number of rainfall days. These trends are found to be statistically significant at $\alpha = 0.05$. The regions in the Palghat Gap corridor showed a decreasing trend in the number of rainfall events. The decreasing trend in this region was not found to be statistically significant in majority of the areas. The delta region of the Cauvery river basin exhibited an increase in the number of rainfall events, though they are not found to be statistically significant.

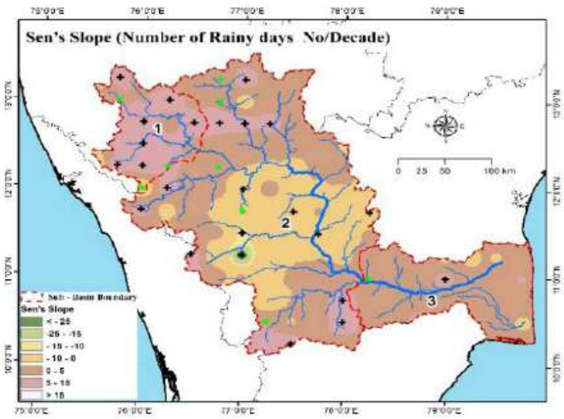


Fig. 4.3.2: Sen's slope of number of significant rainfall events (period of study: 1984 - 2013) in the Cauvery river basin

The annual discharge recorded at majority of the stations showed a decline in streamflow. All the gauge stations located along the main channel of the Cauvery River showed a decline in the streamflow. When the seasonal analysis of the discharge recorded at the different gauge stations along the main Cauvery river was performed, it was observed that the streamflow characterized a declining trend during summer season and SW monsoon season for all the gauge stations, whereas during the NE monsoon season, the decline in discharge was limited to the gauge stations located in the mid and lower reaches of the Cauvery river. In the SW monsoon season, the streamflow in general showed a decreasing trend in the upstream side of the Cauvery river basin, while the tributaries in the downstream sides mostly exhibited an increasing trend though not statistically significant. During the NE monsoon season a reverse trend is observed. The tributaries in the upstream side showed an increasing trend in general, while the tributaries in the downstream side showed a decreasing trend. Though the decreasing trend in the streamflow and groundwater can primarily be attributed to the decreasing trend in the rainfall, a part of the decrease in the streamflow and the decline in the groundwater levels of Cauvery basin can also be attributed to the increase in water use for irrigation and other purposes. The total irrigated area of Cauvery river basin increased from ~21% to ~33% between 1985 and 2005, thereby increasing the agricultural water demand. Similarly, with the increase in per capita water demand the area witnessed a population growth from 4.7 million to 8.5 million from 2001 to 2011. The water pumped from the Cauvery river is the major source of drinking water for the dependent population. Tributaries and landscapes within the watersheds of Cauvery river, have undergone tremendous alteration due to the land use changes and these have altered the hydrological characteristics of the river.

4.4 Assessment of groundwater potential zones (GWPZ) of Vamanapuram river basin

The delineation of the groundwater potential zones of the Vamanapuram river basin is carried out using GIS and Analytical Hierarchical Processes (AHP). A total of 12 thematic layers were used for this study and the weighted overlay analysis was performed for preparation of the groundwater potential zone map. Identification of GWPZ was performed through an information-based factor analysis using a set of thematic layers comprising geology, geomorphology, land use land cover (LULC), drainage density, lineaments, rainfall, soil, roughness, slope, curvature, topographic position index (TPI) and topographic wetness index (TWI) layers. ERDAS Imagine 9.2 and Geomatica Demo Version 13 were used for image processing analysis of satellite data and extracting lineaments. ArcGIS 10.3 software was used for GIS analysis.

The hydrological settings of the Vamanapuram river basin reveals that groundwater occurs in the basin in unconfined aquifer, especially in the alluvium, laterite, weathered and fractured crystalline rocks, and also in semi-confined to confined aquifer in the deep-seated fractured aquifers in the crystalline rocks. Generally, the alluvium is composed of sand, silt and clay which generally occur in the coastal plains and valleys of the basin. Laterite forms another potential aquifer in the basin, which is blanketed over both crystallines in the highlands and midlands and, the Tertiary and Quaternary sediments in the lowlands. The groundwater availability is not uniform in space and time and therefore, detailed and accurate assessment of the groundwater resource is required. The weighted overlay method has been applied to generate the groundwater potential zones in the Vamanapuram river basin. The resultant map is divided into very high, high, moderate, low and very low groundwater potential zones and the aerial spread of these categories are 1.5 km^2, 78 km^2, 412 km^2, 200 km^2 and 2.9 km^2 respectively (Fig. 4.4.1). As seen from the figure, very high and high groundwater potential zones occur predominantly in midland and lowland regions. Very high and high groundwater potential zones generally confined to the high rainfall regions that in turn have high infiltration potential. The moderate groundwater potential zones occur generally in the valley fills, areas of high drainage density and agriculture land. The low and very low groundwater potential zones spread mainly in highlands and lowlands but comparatively less in the midlands. The low and very low groundwater potential zones occur in the migmatite complex, steep slope, high drainage density and reserved forests.

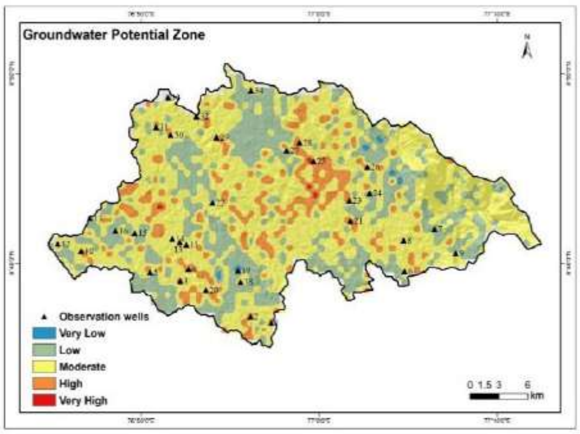


Fig. 4.4.1: Groundwater potential zone of Vamanapuram river basin

Cross validation: The GWPZ map prepared in the study was cross-validated with the groundwater prospects map of National Remote Sensing Centre. It is found that, the wells located in the very low and low groundwater potential zones have water yielding capacity in the range of 10-50 liter per minute (LPM). However, the wells located in moderate groundwater potential zones have water yielding capacity in the range of 50-100 LPM and the wells located in high and very high groundwater potential zones have water yielding capacity of 100-200 LPM. The accuracy of the GWPZ delineation was found to be about 85% based on the results with cross-validation. From the study, it can be concluded that the GIS and AHP - based techniques of delineation of groundwater potential zones adopted herein is a useful method that can be applied while going for river basin - based planning and developments of tropical and sub-tropical regions having varied geo-environmental setting.

4.5 Sub-watershed prioritization of Cauvery River Basin for sustainable development and management of water resources

Prioritization of sub-watersheds in a river basin using morphometric parameters is one of the simplest approaches for development of watersheds for its wise use and management. In this perspective, a study has been undertaken in the Cauvery river basin in South India, using morphometric analysis of the entire river basin in relation to its 17 sixth order sub-watersheds. The Cauvery river basin has a unique geo-environmental setting. The river basin shows three broad geomorphic units - the Mysore plateau in the upstream, the Biligirirangan - Mahadeswaramalai (BR-MM hill ranges) in the midstream and the Tamilnadu plains in the downstream. In the Mysore plateau, the river exhibits fairly high degree of meandering and low amount of headward erosion. The slope of the longitudinal profile up to the Krishnaraja Sagar dam is at the rate of 0.7 m/km, whereas slope increases thereafter (1.27 m/km) till the Sivasamudram falls. In the Tamilnadu plains, the slope is at the rate of 0.56 m/km. Unlike the Mysore plateau and Tamilnadu plains, BR-MM hill ranges in the middle part of the basin exhibits high degree of erosion and channel incision. The river channel at many places are carved out into deep canyon like features especially in areas like Mekedatu, Hogenakal etc.

The slope between the Sivasamudram falls and the Mettur dam is at the rate of 2.67 m/km. Considering the above highly varied geomorphic characteristics and the imminent need for water resource-based developments and managements for improving the quality of life in the area, a detailed investigation has been carried out to understand the nature of drainage pattern and landform characteristics of the river basin. Using the morphometric characteristics, prioritization of the 17 sub-watersheds has been carried out for the better understanding of the hydrological and denudational process taking place in the study area (Fig. 4.5.1).

The linear parameters such as drainage density, bifurcation ratio, stream frequency, drainage texture and length of overland flow have a direct bearing on the erodibility - the higher the values, the more the erodibility. The shape parameters like elongation ratio, compactness coefficient, basin shape, circularity ratio and form factor have an inverse relationship with the erodibility. Compound value (Cp) was calculated by adding the values of linear and shape parameters of each watershed (Table 4.5.1). High rank is assigned for least Cp values while low rank was assigned for high Cp values. Sub-watersheds considered for the present study were grouped into three categories on the basis of priority and ranks - high, medium and low.

Among the high priority watersheds, about 25 % of the watersheds fall in the Mysore Plateau and BR-MM hill ranges and 50% in the Tamilnadu plains. In the case of medium priority watersheds, 43 % fall in the Mysore Plateau, 14 % in the BR-MM hill ranges and 43 % in the Tamilnadu plains. Of the two low priority watersheds, one fall in the Mysore Plateau and the other in the Tamilnadu plains. All the high and medium priority watersheds in the Cauvery river basin need considerable attention and well-designed action plans, including construction of appropriate recharge structures for improving the water resource potential of the river basin.

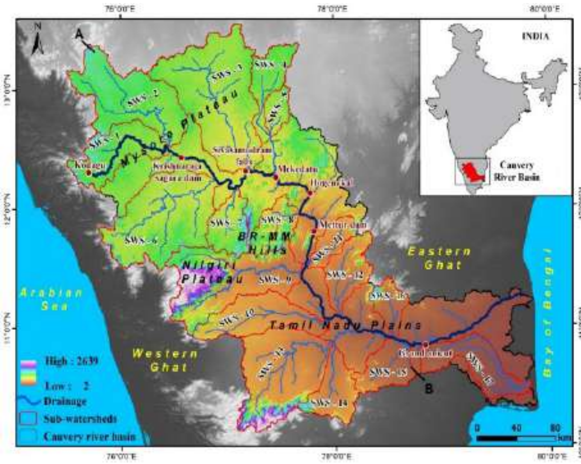


Fig. 4.5.1: The Cauvery river basin showing the seventeen sixth-order sub-watersheds selected for watershed prioritization studies

Table 4.5.1: Values of morphometric parameters used, estimated compound values (Cp) and prioritization of sub-watersheds of the Cauvery river basin

SWS	Rbm	Dd	Fs	Rt	Lg	Rf	Re	Cc	Rc	Cp	Rank	Final Priority
1	4.534	0.88	0.489	4.022	2.273	0.19	1.02	1.95	0.26	1.73	13	Medium
2	4.656	0.89	0.49	5.23	2.247	0.18	0.48	1.99	0.25	1.82	15	Medium
3	5.388	0.95	0.53	7.75	2.105	0.16	0.46	1.80	0.31	2.16	17	Low
4	4.188	0.88	0.5	3	2.273	0.21	0.49	2.09	0.23	1.54	7	High
5	3.492	0.99	0.51	2.89	2.020	0.23	0.54	1.46	0.47	1.40	2	High
6	4.896	0.9	0.48	4.0	2.222	0.17	0.47	1.69	0.35	1.68	11	Medium
7	3.746	0.91	0.45	3.27	2.198	0.21	0.19	1.69	0.35	1.44	4	High
8	3.678	0.79	0.43	3.1	2.532	0.212	0.52	1.62	0.38	1.47	5	High
9	4.7	0.9	0.45	4.88	2.222	0.18	0.47	2.05	0.24	1.78	14	Medium
10	4.338	0.96	0.514	4.44	2.083	0.19	0.49	1.94	0.26	1.69	12	Medium
11	3.898	0.94	0.39	2.3	2.217	0.23	0.19	1.24	0.36	1.30	1	High
12	4.02	0.95	0.47	3.69	2.105	0.2	0.51	2.26	0.35	1.61	10	Medium
13	4.794	0.95	0.5	7.32	2.105	0.18	0.47	1.54	0.42	2.03	16	Low
14	3.968	1.07	0.46	3.52	1.869	0.2	0.51	1.74	0.33	1.51	6	High
15	3.852	0.99	0.51	4.09	2.020	0.2	0.51	1.57	0.4	1.57	8	High
16	3.546	0.95	0.48	2.95	2.105	0.22	0.53	1.60	0.39	1.41	3	High
17	4.202	1.04	0.52	3.86	1.923	0.19	0.499	2.08	0.23	1.61	9	Medium

Note: SWS- Sub-watershed, Rbm-Mean bifurcation ratio, Dd-Drainage density, Fs-Stream frequency, Rt- Drainage texture, Lg-Length of overland flow, Rf-Form factor, Re-Elongation ratio, Cc-Compactness co-efficient, Rc-Circulatory ratio, Cp-Compound value.

4.6 Mapping flood inundated areas - Kerala flood, 2018

The extreme rainfall and associated flooding of August 2018 in Kerala had a remarkable impact on the socio-economic and environmental fabric of the state. This extreme climate event that hit most of the districts of Kerala not only claimed the life of many people but also made hundreds of thousands homeless. The state experienced an abnormally heavy rainfall from 1st June 2018 to 19th August 2018 with peak downpour during 15 - 17 August 2018. As per India Meteorological Department (IMD), Kerala received 2346.6 mm of rainfall during this period as against the expected rainfall of 1649.5 mm. This 42% rise in the downpour caused many rivers to overflow and made the people in the riparian areas, valleys and coastal lowlands homeless.

Fatalities were occurred in the highlands and hilly areas as a result of landslides. The fall in economy and damages in the geo-environmental setting will persist for long as most of the adversities are irreparable in the human life scale. From the district-wise rainfall received during 1st June 2018 to 22nd August 2018 (CWC, 2018), it is evident that with the exception of Kasaragod, Kannur and Thrissur, all the other districts of Kerala received extremely high (either 'Excess' or 'Large Excess') rainfall.

Vembanad lake catchment is one of the most flood prone areas in Kerala state. The severity and occurrence of flooding in the area is increasing year after year as the area is undergoing rapid development and urbanization. The August 2018 flood has made severe havoc in the area. Flood inundation map of the study area was prepared by Sentinel 1A data acquired on 21st August 2018. The preprocessing techniques were worked out using SNAP software program. After processing the data, the flood foot prints were extracted. A total of 83 flood marks were recorded from the field with respect to current lake bed level.

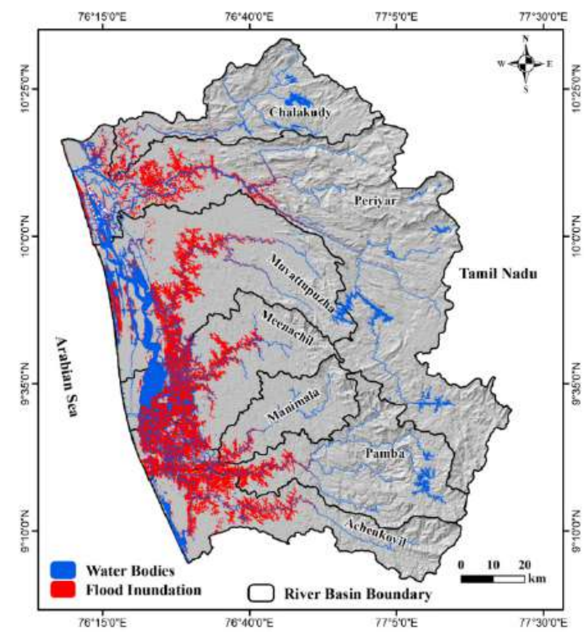


Fig. 4.6.1: Flood inundation map of Central Kerala during August 2018

Fig. 4.6.1 shows the flood inundation map of the Vembanad lake and its inflowing rivers. As seen from the map, the Vembanad lake catchment is highly inundated with water during August 2018. The lake catchment comprises of seven major rivers; Periyar, Chalakudy, Muvattupuzha, Manimala, Meenachil, Pamba and Achenkovil. The areal extend of flood inundation is 13 km^2 in Chalakudy, 129 km^2 in Periyar, 192 km^2 in Muvattupuzha, 228 km^2 in Meenachil, 14 km^2 in Manimala, 220 km^2 in Pamba and 150 km^2 in Achenkovil.

4.7 Mechanisms controlling the dissolved solute fluxes and CO_2 consumption of a tropical river - Cauvery, South India: Role of natural and anthropogenic processes and secondary minerals in soils

Solute acquitisation in river waters is controlled by various physical, chemical and biological process within the river basin. Chemical weathering of country rock and soil minerals in presence of CO_2 (atmosphere/soil) is the major source for solute accumulation. The natural and anthropogenic impacts need to be assessed while understanding the profound effects of climate change and rapid socio-economic development on water resources. Among the natural sources, rock weathering is dominant one for the tropical rivers, as high temperature and heavy rainfall accelerate the process. Silicate weathering consumes atmospheric/soil CO_2 and hence estimation of silicate weathering rates (SWR) and CO_2 consumption rates (CCR) are essential for global carbon cycle budget modelling. Cauvery river basin (CRB) located in south India and lies between 75°27' - 79°54' east longitudes and 10°9' - 13°30' north latitudes. Geologically, CRB form part of two geological terrains - Dharwar craton in north and southern granulite terrain in south. Soil types vary across the basin and mostly possess red soil followed by black soil, mixed soil, alluvial soil and lateritic soils. In the land use of CRB, agricultural land is dominant (66.2%) followed by forest area (20.5%), built up area (4.1%) and waste land (3.9%). Present study uses the surface water hydrochemical data of Cauvery river, including Na, K, Ca, Mg, SiO_2, Cl, SO_4 and HCO_3, pH, EC, TDS and streamflow. These data were obtained from hydrological observation (HO) stations maintained by Central Water Commission (CWC) for the years 2011-15 on monthly basis. Among the cations, the pattern of dominance is Ca> Na > Mg > K in (mg/lit) and the anionic pattern of dominance is HCO_3 > Cl > SO_4 in (mg/lit).

Processes controlling the solute chemistry in CRB: Dissolved solutes in river waters are controlled by various mechanisms including, atmospheric precipitation, evaporation-crystallization, weathering and dissolution of drainage minerals (primary and secondary), dissolution of soil salts and anthropogenic activities. Gibbs diagram for the CRB waters (Fig. 4.7.1.a) shows overall dominance of water-rock interaction, suggesting solutes are accumulated through chemical weathering mechanism. In the Mg/Na vs Mg/Ca plot (Fig. 4.7.1.b) of CRB water samples, it is observed that, there are no soil-salt leaching effects from both axes (Na-leaching and Ca-leaching) and shows considerable differences between upstream and downstream regions. The Na-normalized mixing diagrams (Fig. 4.7.1c) for CRB shows that the samples fall parallel to the trend line between the silicate and carbonate end members. This imply that hydrochemistry of CRB waters is primarily controlled by mix of silicate weathering as well as the carbonates, though the extent of mixing is closer to the silicate end member. Even though, the mean composition of CRB lithology is underlined by silicate rocks, the availability of carbonates in soil systems and saprolite (pedogenic carbonates) play a crucial role to determine the solute chemistry.

Quantification of sources input to the dissolved load: To decipher the contribution of each solute source, chemical mass balance forward model based on the major ion concentrations of the dissolved load have been used. The chemical mass budget equation for any solute 'X' in the dissolved load of CRB is given by: $[X]_{rw} = [X]_{atm} + [X]_{anthro} + [X]_{sil} + [X]_{carb}$ where rw = river water, atm = atmospheric input, anthro = anthropogenic input, sil = silicate weathering and carb = carbonate weathering. The proportional contribution of solutes from the different sources are; 1) Atmospheric input: The atmospheric contribution to the river waters can be estimated by using the following eq. $X_{atm} = (X/Cl)_{rain} \times Cl_{ref}$ and the estimated values of atmospheric input to the total dissolved load (TDS) varies but the weighted average contribution is 10% for the whole basin; 2) Anthropogenic input: Anthropogenic input to the river waters can be quantified by using the values of Cl_{ref} and the residual chloride (Cl_{res}) in the river waters. The estimated values for anthropogenic input to the total dissolved load (TDS) varies but the discharge weighted average contribution is 21% for the whole basin; 3) Silicate weathering input: Solutes released into the water through silicate weathering can be quantified using the suitable proxies, for instance, by using the atmospheric and anthropogenic input corrected Na (Na_{sil}) concentrations in river waters. Silicate weathering contributions of Ca and Mg were estimated by using the silicate component of Na (Na_{sil}) as the reference based on the assumption that, Ca_{sil} and Mg_{sil} are released in to the river waters in a fixed proportion relative to Na from the silicate minerals. The calculated silicate weathering input to the total dissolve load (TDS) values varies but the discharge weighted average contribution is 30% for the whole basin, indicates that the contribution of silicate weathering input is more significant; 4) Carbonate weathering input: The residual excess of Ca and Mg in rivers waters after the correction of silicate weathering is then allocated to carbonate weathering. The additional sources of Ca and Mg (other than the silicate weathering) might be due to occurrence of pedogenic carbonates in black soil (vertisols) systems and in saprolites. The quantified carbonate weathering input to the total dissolve load (TDS) values varies but the discharge weighted average contribution is 39% for the whole basin, indicating that the contribution of carbonate weathering input is highest and predominates the dissolved solute chemistry of the Cauvery river

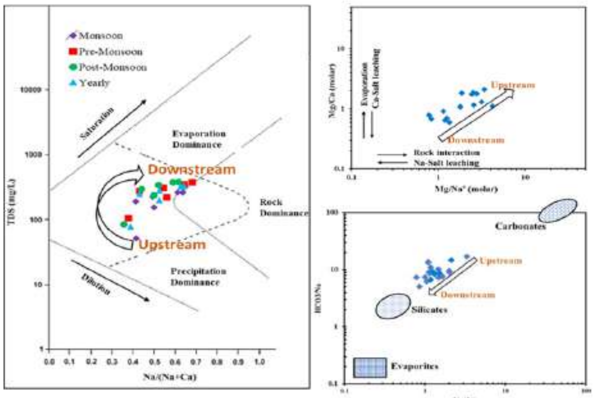


Fig. 4.7.1: a) Gibbs model for CRB waters, indicates water-rock interaction domination; b) Bi-variate plot for CRB waters, suggests no leaching of solutes from soil salts; c) Na-normalized molar mixing diagrams for CRB waters indicates mixing of chemical weathering from silicate endmember to carbonate endmember

4.8 Evolution, hydro-geochemistry and drinking water potential of spring water resources of Western Ghats

The Western Ghats and its adjoining areas host many natural springs of highly varied hydrological and hydrochemical characteristics. Although many of the surface-groundwater systems are subjected to detailed studies, much attention has not been given to the spring water sources, which fall within the interface between surface and groundwater sources. The uplifted west coast of India hosts many high yielding springs. Although majority of these springs are of cold-water types, a few of them in Karnataka and Maharashtra States are thermal springs. Among the springs, a few are protected and others are unprotected. Field level investigations show that many unprotected springs are at the verge of degradation because of human interventions and lack of adequate protection structures. Under these circumstances, a systematic study has been carried out in the SW coast of India. In the first phase, thirteen spring (cold water) from Varkala - Kollam areas and fifteen springs from Dakshina Karnataka (13 cold water spring and two thermal spring) are selected for detailed study. The springs in the Varkala region are classified into four distinct groups - Ashtamudi group of springs, Paravur group of springs, Nadayara group of springs and Varkala group of springs. The seasonal analysis reveals that monsoon season records the maximum water discharge (796.43 mlpy) than non-monsoon (406.93 mlpy) season. The water chemistry shows that all the physico-chemical parameters, except pH (acidic), are well within permissible limit of drinking water quality standards as suggested by WHO and BIS. The hydro chemical facies identified using the Piper Hill diagram shows that the free-falling type cold water springs in Southern Kerala Coast are Na-Cl type. According to Wilcox diagram, the cold-water springs of Southern Kerala fall in the C1S1 region which means very low sodium and salinity hazard. Hence the water is fit for irrigation.

Although many studies have been carried out on the cold-water springs, investigations on thermal springs are scarce. Therefore, NCESS started a systematic monitoring of the two thermal springs in Dakshina Kannada (Karnataka State) located in Belthangadi (Bandarutheertha) and Puttur (Irde Puttur), along with the cold-water springs and well/ borewell waters to understand the state of the water environment in the area. In the case of cold-water springs of Karnataka also, all the physico-chemical parameters, except pH (majority are alkaline) are within the permissible limit of drinking water quality as per WHO and BIS standards.

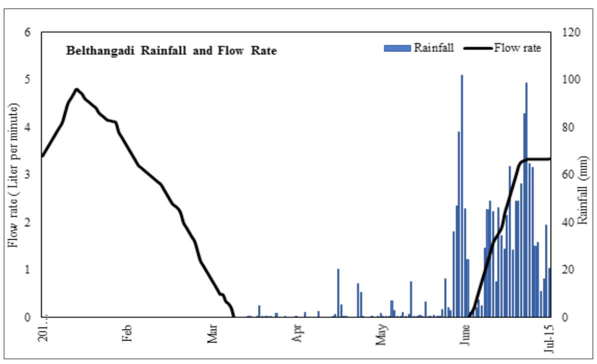


Fig. 4.8.1: Bandarutheertha, Belthangadi thermal spring flowrate and rainfall

As per Sodium Absorption Ratio (SAR), the cold springs in the Dakshina Kannada fall mostly under C1S1, indicating that the spring water samples are suitable for irrigation. Discharge rate of Bandarutheertha thermal spring at Belthangadi is 5.04 Lpm (2.65 mlpy) in post monsoon season and for the first time the spring is dried out in the month of May (pre-monsoon). Thermal springs of Karnataka are alkaline in nature. The classification (Giggenbach) based on cationic concentration with Na/1000, K/100 and √Mg at the apices was used to classify waters as fully equilibrated with rock at given temperatures, partially equilibrated, and immature. It indicates that the thermal water from Bandaru has undergone partial equilibrium with the aquifer material while water from Irde has not attained equilibrium caused by the mixing of shallow groundwater. This inference is supported by the presence of high NO_3^- concentration in this water which suggests mixing between thermal waters with NO_3^- rich shallow groundwater influenced by the nearby agricultural lands.

Comparing the total solute loads in cold water and thermal springs of Karnataka, the thermal spring shows higher concentration (TDS of thermal spring approx. 3 times higher than the cold-water spring) than the cold-water spring. The reservoir temperature estimated based on chemical geo-thermometer is about 60°C, the value is substantially lower than the Na-K based geo-thermometer of 110-130°C. The thermal water recorded a consistent silica concentration and the mineral saturation index suggested that silica is in equilibrium with the aquifer matrix hence the reservoir temperature of about 60°C estimated using quartz based geo-thermometer can be considered as the minimum reservoir temperature.

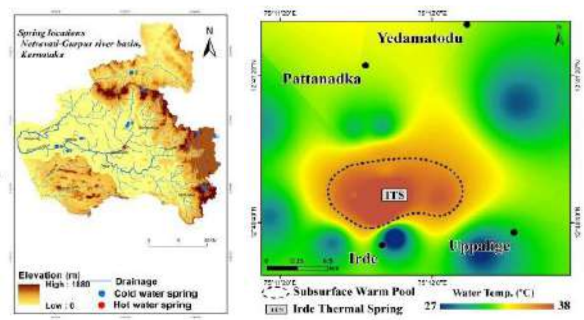


Fig. 4.8.2: a) Location of the Irde Puttur thermal spring: b) the extend of the Subsurface Warm Water Zone surrounding the Irde Puttur thermal spring

To understand the relation between water discharge from springs and rainfall events, weekly water discharge of Varkala springs (Thoduway and Papanasam) are collected. Continuous weekly monitoring of flow rate of springs reveals high values during rainy season. The values remained at higher levels till the beginning of the pre-monsoon season indicating their rainfed nature.

To understand the influence of rainfall events on the discharge characteristics of the thermal springs, weekly monitoring of the Bandarutheertha hot water spring is carried out. Figure 4.8.1 shows the discharge of the Bandarutheertha spring recorded during January to July, 2019. The flow rate is reduced drastically after 15^{th} January 2019 and on March, the discharge of this thermal spring ceased for the first time. From, June onwards, just after the first spells of monsoon, the spring started discharging in warm waters. This kind of phenomena is also noticed in the Irde, Puttur thermal springs. Although, the springs dried out fully several times, the borewell in the area yield warm water. Detailed study is progressing to understand the influence of rainwater on the warm groundwater underneath.

Detailed surveys and borewell sampling carried out in Irde Puttur recently, have unfolded the occurrence of a 'Subsurface Warm Water Zone' covering an area of about 40 hectares around the thermal spring (Fig. 4.8.2). Although the thermal spring dried up in summer season, the bore wells in the area continue to yield warm water with a temperature range of 31°C - 37.4°C, suggesting the fact that the water table of the Warm Water Zone oscillates seasonally, charging the Irde Puttur spring in wet season. Study of heating sources/heating mechanisms of this seasonal thermal spring is in progress.

4.9 Quantification and modelling of selected contaminants in groundwater - a case study from peninsular India

Ground water is an important source of potable water all over the world. Approximately 80% of domestic and 50% of urban and industrial water being supplied from groundwater. Over usage causing degradation of both quality and quantity. Among the contaminants in groundwater, heavy metals are a serious threat as these pollutants are extremely toxic. Numerical modelling of groundwater flow and contaminant transport has been found to be a convenient and cost-effective technique to evaluate the spread of heavy metal pollution in groundwater. The objective of the present study is to estimate the concentration of various pollutants present in groundwater around industrial area along with the assessment of groundwater level fluctuation in different seasons. Simulation of groundwater flow and movement of solutes through the aquifer. The study is being carried out in Chromepet area, Chennai, which is a hub of tanneries releasing significant quantities of heavy metals, especially chromium. The area hosts lots of large scale and small-scale tanning industries. Chrome tanning is the popular method practiced in this area and hence the place got its name as 'Chrome' pet.

Fieldwork was conducted and hydrochemical analysis performed during post-monsoon (2018) and pre-monsoon (2019) seasons. Groundwater levels at 30 dug wells was measured from the ground surface. The location and water table elevation WRT mean sea level (MSL) at wells were determined with the help of GPS and DEM data. A significant fall in groundwater level (~4 m) is observed during pre-monsoon season compared to monsoon season, around the industrial area. This could be attributed to the lack of rainfall during January to May 2019. Results of chemical analysis suggest that the pH of ground water is slightly alkaline in nature (Pr 6.3 to 8.0, av 7.1; m 6.4 to 8.2, av 7.4) in the study area. The average values of electrical conductivity are 2.23 mS/Cm (Pr) and 1.84 mS/ Cm (m), indicating moderate to high mineralization in the area.

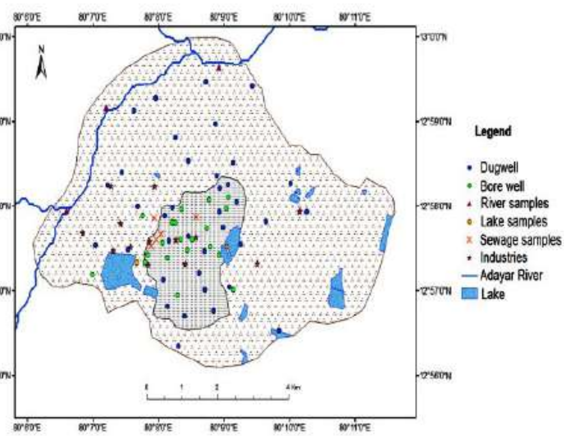


Fig. 4.9.1: Location of the study area

With respect to TDS (avg. Pr 1339 mg/L, m 1089 mg/L), the groundwater is hydrochemically brackish and not suitable for drinking. The major ion chemistry reveals that Na^+ is the most leading cation, and Cl^- is the most dominant anion in both the seasons. The overall concentration pattern of the major cations and anions are in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $Cl^- > HCO_3^- > SO_4^{2-}$ respectively in both seasons.

Estimation of the heavy metals present in water samples are in the process. To get a comprehensive picture of overall quality of groundwater, the Water Quality Index (WQI) was computed for 10 parameters (viz., pH, TDS, HCO_3^-, Cl^-, SO_4^{2-}, F^-, Ca^{2+}, Mg^{2+}, Na^+, K^+) analyzed so far. Results observed for both dug wells and bore wells are summarized in the following table.

Table 4.9.1: Different water types based on Water Quality Index (WQI) in the study area.

WQI Range	Water type	Monsoon		Pre-monsoon	
		DW (%)	BW (%)	DW (%)	BW (%)
<50	Excellent	10	-	3.8	-
50-100	Good	50	15	23.1	12.5
100-200	Poor	40	85	65.4	87.5
200-300	Very poor	-	-	7.7	-
>300	Unsuitable	-	-	-	-

**DW – Dug Wells; BW – Bore Wells*

4.10 Natural resources and environmental management of Periyar-Chalakudy and Netravati-Gurpur river basins, India

Mining and quarrying for hard rock, laterite and river sand are widespread in the highland, midlands and lowlands of the Periyar-Chalakudi and Netravati river basins. Fig. 4.10.1 shows the location of mining/quarrying activities in the study area.

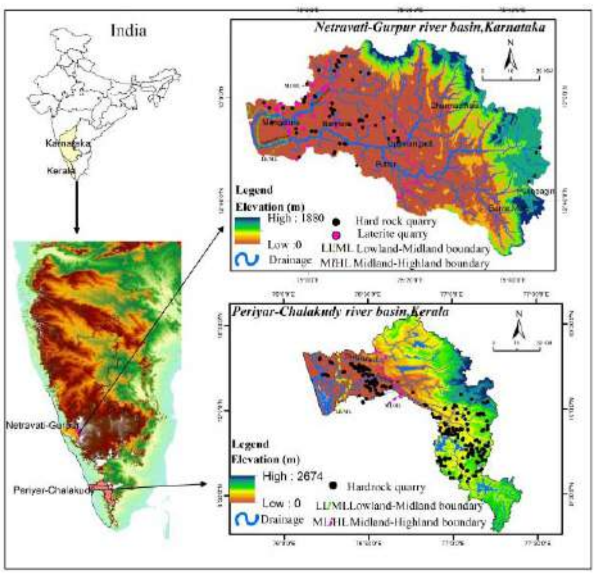


Fig. 4.10.1: Location map-Netravati-Gurpur and Periyar-Chalakudy river basins showing locations of mining and quarrying

Hard rock quarrying: Hard crystalline rocks are quarried as solid block/slabs, or in crushed forms for building constructions. Among different taluks in the Netravati-Gurpur river basin, hard rock quarrying is rampant in Mangalore taluk. A total of 64 hard rock quarries are located within the basin (Fig. 4.10.1). The labour force engaged in the hard rock quarrying sector comes to about 1158 persons. Mangalore, the port city of Karnataka state, shows exponential rise in the rate of urbanization with a marked boom in population and number of households. Demographic components like population and household density correlates positively with the quantity of hard rocks extraction (Fig. 4.10.2). Mangalore taluk is directly catering to the rapid developmental needs of the port city. The production of building aggregates in the different taluks of Dhakshina Kannada district shows that Mangalore taluk produces large quantities of building aggregates when compared to other taluks.

The exceptional increase of population and number of households in the Mangalore taluk is a clear indication of urban sprawl in the region, which in turn has a direct bearing on natural resource consumption and infrastructure development in the area. It is estimated that 6.70 million metric tons/year of hard rock are being quarried from the Netravati-Gurpur river basins. At present, 19 hard rock quarries are left as abandoned in the basin. Among the three physiographic provinces of the basin, hard rock quarrying is rampant in the midland and highland regions. In the case of Periyar-Chalakudy basin, the total number of quarries comes to about 525. Out of these 137 are active quarries, while 388 are abandoned ones. Physiography-wise analysis reveals that, out of the total hard rock quarries 27 are located in lowlands, 288 in midlands and 210 in highlands.

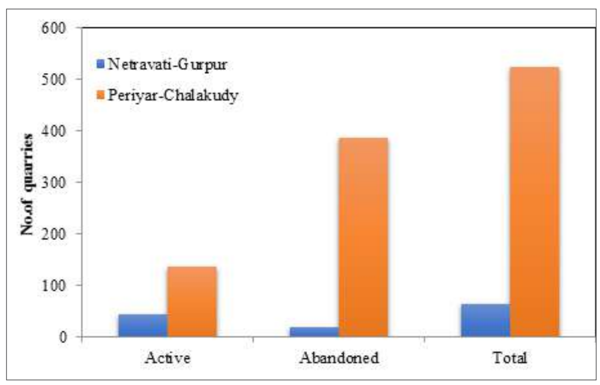


Fig. 4.10.2: Hard rock quarrying in Netravati-Gurpur and Periyar-Chalakudy river basins-a comparative evaluation

The total labour force engaged in mining and quarrying in the basins is 1640 persons. The estimated total quantity of hard rock extraction from these basins is 10.47 million metric tons/year. Number of quarries and the volume of minor mineral extraction in the basin indicate the level of urbanization and growth of cities and townships. Total number of hard rock quarrying shows wide variations among the two river basins. However, higher number of active quarries in the

Netravati-Gurpur river basin indicates the indiscriminate quarrying activity taking place in the basin. Compared to the number of abandoned quarries, active quarries are less in Periyar-Chalakudy river basin. It is a fact that in both the basins, mining activities are noticed even in Ecologically Sensitive Zones. However, such activities are comparatively less in Netravati-Gurpur river basin.

Laterite quarrying: Laterite is a secondary rock, formed due to chemical weathering of ferro magnesian rocks. Humid tropical climates with heavy rainfall and high temperature are conducive for laterization process. Widespread occurrences of laterite are noticed in the midlands and lowlands of Netravati-Gurpur river basin. A total of 21 laterite quarries are identified in the river basin. Most of the laterite mines are mechanized and on an average 25 labours are working in each quarry. The intensity of quarries is high in Mangalore and Bantwal taluks. Total productions of laterite blocks from basins are 42 lakh bricks/year. The hard-lateritic blocks are largely used in building industry. Large scale extraction of laterite has resulted changes in the natural topography and ground water conditions of the area. Both mechanical and manual cutting of laterite is taking place in the Netravati-Gurpur river basin. In Periyar-Chalakudy basins, laterite extraction is not taking place at present, but we could locate 6 abandoned quarries in the area.

River sand mining: Sand mining and related environmental issues are very extensive in Netravati-Gurpur river basin. The amount of extraction is the maximum in lower reaches of the basins. The river sand mining is widespread in Mangalore and Batwal Taluk, a total of 16 locations were identified in the basins. Adayar, a major location for river sand mining in the basin, extracts approximately 45 tons of sand per day. Indiscriminate river sand mining imposed immense stress on the river ecosystem. A systematic analysis was conducted to assess the temporal changes in the cross profiles of Bantwal gauging station due to river sand mining during the period of 2006, 2009 and 2012 respectively. The record of river lowering data from the gauging station provides evidence of channel incision at the rate of 13 cm per year due to imposed sand mining. These can aggravate the incidences like structural collapse near river bank, river bank slumping, valley widening etc. The recent collapse of the Moolar- Patna bridge (5th June 2018) have to be examined in detail in the light of the indiscriminate sand mining activity in the river system. The area of the deposit has reduced approximately 4.4 ha to 1.9 ha due to rampant sand mining in the last 6 years. Comparison of the channel incision of the Netravati-Gurpur river with that of the published accounts revealed that the rate of channel incision of Netravati-Gurpur river is almost as high as the other small rivers of India. A substantial part of sand and gravel deposits in the channel environment have completely been scooped out for construction activities in the basin area.

4.11 Mid-late Holocene evolutionary and climatic history of freshwater lake from SW India

Fairly good attempts were made to comprehend the sea-level and climate records for the glacial-interglacial transition period. But opinion varies regarding the Holocene Period leading to a great diversity in apparent Holocene sea-level records from sites around the world. Nevertheless, some synchronicity has been found in case of climate variations of Holocene period. Thus, it is urged to establish site specific Holocene sea-level variability with simultaneous comparison of local climate with global climate variables. The limited attempts in addressing both climate and sea level variabilities for the mid-late Holocene period is the major lacuna that need to be investigated to pave a better understanding of present sea-level and climate perturbations. In view of this, a sediment core of ~ 10 m was raised from the freshwater lake Vellayani of Southern Kerala, SW India for investigating climate and sea level variability for the mid-late Holocene. During the core retrieval, several marine mega fossils (*Terebra sp.*, *Nassarius sp.* and *Villoritta cyprinoid*) were found thereby indicating marine influence. A multiproxy approach supported by AMS radiocarbon ages were conducted on the sediment core in order to reconstruct the mid-late Holocene climate and sea-level variations. The present study demonstrated a three-fold sea regression phases responsible for the present-day transformation of coastal lagoon to freshwater lake.

Evolutionary History:

Phase-I (6430-4390 cal yr BP): The presence of *Terebra sp.* and *Nassarius sp.* at 780 (5430 cal yr BP) and 645 cm (4810 cal yr BP) depths suggested marine environment during 6430-4390 cal yr BP that supported enhanced calcareous *in-situ* productivity. The high sea stands between 6430 and 4390 cal yr BP submerged the incised river channels of west flowing rivers of Kerala, like the Karamana River in the study area. When the sea-level retreated, a lagoon might have formed along the coast while the coastal longshore currents must have played a significant role in the formation of barrier beaches that restricted the continuous swashing of the sea water thereby a persistent occurrence of lagoonal conditions prevailed that supported the calcareous productivity (*Terebrae sp.* and CaO/Al_2O_3).

Phase-II (4390-2600 cal yr BP): The occurrence of *Villoritta cyprinoid* at 3160 cal yr BP (389 cm) demonstrated a brackish water/estuarine environment as *Villoritta cyprinoid* cannot sustain high salinity environment. The estuarine or a brackish water environment persisted till 2600 cal yr BP as indicated by the presence of *Ammonia sp.* (~295 cm bgl). The occurrence of estuarine conditions after 4000 cal yr BP indicated marginal regression which led to reduced salinity.

Phase-III (2600-440 cal yr BP): The olive colour sediment with absence of any shells of marine/estuarine origin after 2600 cal yr BP delineates the onset of freshwater environment and the present-day configuration of Vellayani lake. The alluvial material brought by the Karamana river must have deposited near the core site thereby hindering the marine inlet at the core location causing the cut off of the Vellayani and transforming it into a fresh water lake. While the spread of the lake reduced after 440 cal yr BP with the continuous deposition of alluvial sediments brought by the Karamana River leaving behind the region as a part of land which was later reclaimed for agricultural purpose.

Climate Reconstruction: The downcore variation of the detrital proxies (TiO_2 and SiO_2) demonstrated improved hydrological conditions as a result of summer monsoon intensification with a gradual decline from 6400 to 3000 cal yr BP. The declining detrital flux during ~4.2 ka corroborating well with the 4.2 ka of Mulwah cave speleothem and is in agreement with the global aridity which led to demolition of several civilizations. Further, the prevalence of monsoon intensification observed during Medieval Warm Period (MWP) is further supported by increased Sea Surface Temperatures in the Arabian Sea. The detrital proxy of the present study is in agreement with marine records (off Srilanka and Arabian Sea) and Greenland Ice core temperature records. The comparison of the detrital proxy with the global records suggested that gradual decline in the solar insolation resulted in reduced effective moisture leading to southward migration of Intertropical Convergence Zone (ITCZ) and increased El Nino events. The comparison of detrital proxies of the present study with the other global records from continents, northern Indian Ocean and Greenland ice core signifies the crucial role of solar insolation in controlling the summer monsoon intensity during the Holocene period.

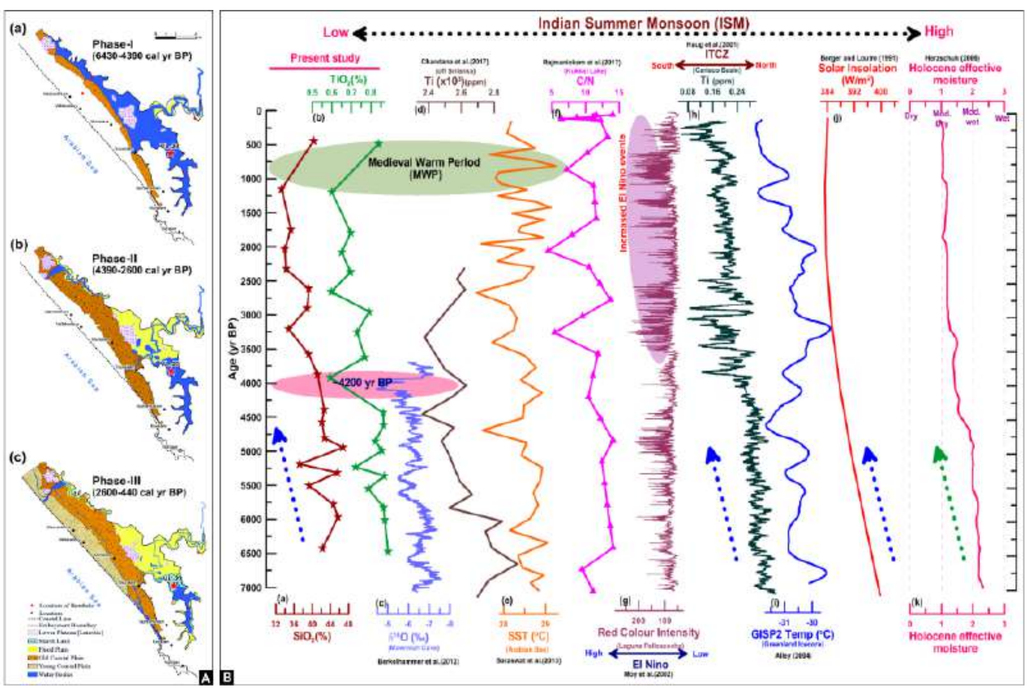


Fig. 4.11.1: [A] The schematic diagram shows the gradual sea regression since mid-Holocene period. Red star (*) depicts the core location at Vellayani Lake; [B] Comparison of detrital proxies (a and b) with other paleoclimatic records

4.12 A pilot level approach to remove anionic species from industrial effluents using a novel carbonate-steam pyrolysed activated charcoal system

The major anionic chemical constituents such as ammonia, nitrite and nitrate, which are highly mobile in liquid phase, are widely reported in wetlands near the industrial belts. It is obvious that, in many cases these nutrients were found to be higher than the short-term exposure limit of >65 µmol/L, set by WHO. Among the nitrogen based chemical entities, nitrite is found to be more toxic and may cause blue baby syndrome in young infants. Moreover, nitrite ions can produce a carcinogenic and mutagenic compound N-nitrosamines, which may lead to gastric cancer. The increased level of these nutrients can lead to eutrophication stage, sometimes trigger out toxic algal blooms and in later stage, it may lead to hypoxia. These observations point towards the importance of reducing the nutrient levels, especially nitrite in water and wastewaters. Under these circumstances, in order to control the amount of nitrite within the permissible levels, we adopted adsorption technique as a mitigation strategy. The effective removal of nitrite ions using various adsorbents such as sugarcane bagasse and wheat straw, calcined (Mg–Al) hydrotalcite, sepiolite and hydrogels were already reported. The application of activated carbon in removing nitrite from aqueous solution is rarely reported as compared with other adsorbent materials.

In this context, a tailor-made adsorbent material, SCIAC, was synthesized using an integrated chemical activation-steam pyrolysis technique, which can scavenge the anionic species from industrial effluents. The surface morphology, pore and functional group distribution in SCIAC is determined using sophisticated analytical tools. The experimental conditions were optimized for maximum nitrite removal efficiency. The equilibrium and kinetic models were evaluated to find the nature of adsorption process during the removal of nitrite from water and wastewater. The study showed the significance of activation-pyrolysis technique in developing a feasible material, which is highly efficient in removing nitrite from industrial effluents. The developed adsorptive removal system is possible to scale up and which may be highly useful in wastewater treatment strategies, especially for the removal of nutrients from fertilizer industrial effluents.

Activated charcoal, obtained locally was used as a precursor for the preparation of SCIAC without any prior treatment. For the impregnation process, 0.1 M 100 mL Na_2CO_3 solution (flow rate: 0.5 mL/min) is dripped to about 5 g of activated charcoal in a specially made round bottom flask. The mixture was continuously stirred for 6 h at 300 rpm speed and successively maintained at 30±2 °C under normal atmospheric conditions. After completing the stirring process, the whole solution kept overnight for completing the soaking process. The dark coloured soaked dispersion with white sprinklings carefully filtered and dried in a hot air oven at 60±2 °Cto remove the volatile impurities. The steam activation of the powder was carried out in a muffle furnace (Make: Labtherm, India) at 400±2 °C. The sample is then heated (20 °C/min to 400±2 °C) for 4 h in a purpose-made graphite tube. The whole set was made in such a way that the steam produced by the generator at the fixed rate (5 mL/min) enters the graphite tube without any hindrance and loss. The repeatedly washed product was dried in a hot air oven at 100±2 °C. The final product was cooled; grounded and sieved in a 230 mesh to get the sodium carbonate impregnated activated charcoal (SCIAC). The SCIAC is stored in clean and closed polypropylene bottles for further studies.

Industrial effluent was collected from a local fertilizer industry in Cochin urban area, Kerala, India for pilot scale nutrient removal studies. The surface water samples were collected from predetermined stations at the industrial area using samplers. The samples were stored in HDPE bottles at 4.0 °C until the analysis. The water quality analysis was carried out according to APHA. Initially the effluent was tested with the newly developed adsorbent material at optimized conditions for the removal of nitrite from wastewater. The physico-chemical composition of the effluent was determined with following results: pH: 7.3, EC: 6.6 mS/cm, TDS: 1246.0 mg/L, DO: 2.1 mg/L; BOD: 19.0 mg/L, COD: 84 mg/L, P as PO_4^{3-}: 7.0 mg/L, Nitrite ($N\text{-}NO_2^-$): 1.9 mg/L, Nitrate ($N\text{-}NO_3^-$): 2.1 mg/L, Free ammonia: 2.0 mg/L, Cl: 2143.1 mg/L, Na: 1967.1 mg/L, K: 87.2 mg/L, Ca: 5.9 mg/L and Mg: 5.0 mg/L. The above effluent was spiked with 3.1 and 8.1 mg/L of nitrite solution to get final initial concentration of 5.0 and 10.0 mg/L, respectively. The effect of SCIAC dosage on the adsorption of nitrite from fertilizer industrial effluent was carried out by agitating predetermined amount of SCIAC (2-12 g/L) with 50 mL of the spiked effluent. After attaining the optimum equilibrium condition, the amount of nitrite adhered on the surface of SCIAC was determined using UV-Visible spectrophotometer. From the Fig. 4.12.1, it is observed that as the adsorbent dosage increases the amount of nitrite removed from aqueous phase also increases. This may be due to the increased availability of active adsorption sites for the uptake of nitrite ions as the adsorbent dosage increases. The adsorption experiments showed that a minimum SCIAC dosage of 2.0 g/L (50 mg in 50 mL of fertilizer industrial effluent) is sufficient for the removal of 57.2 and 47.2% of nitrite from the effluents of initial nitrite concentrations of 5 and 10 mg/L, respectively (Fig. 4.1). Under these conditions in the lab, a maximum of 63.8 and 55.7% of nitrite was adsorbed onto SCIAC. Adsorbent dosages of 8 and 10 g/L are required for the complete removal of nitrite from spiked industrial effluents of initial concentrations of 5 and 10 mg/L, respectively (Fig. 4.12.1). This clearly demonstrates that SCIAC can be effectively used in removing nitrite from fertilizer industrial effluents.

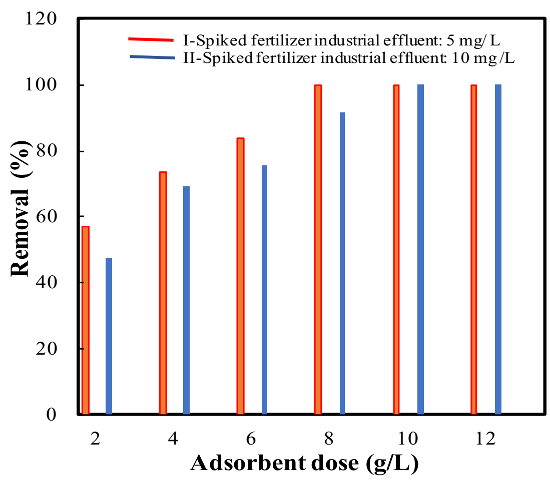


Fig. 4.12.1: Effect of adsorbent dose for the adsorption of nitrite onto SCIAC from fertilizer industrial effluent (Experimental conditions: pH: 3.8, Equilibrium time: 120 min, Temperature: 303 K)

Table 4.12.1: Regeneration studies for nitrite onto SCIAC[a]. Experimental conditions: Adsorbent dose: 4.0 g/L, Equilibrium time: 120 min, Temperature: 303 K, Initial nitrite concentration: 5 mg/L (Adsorption), Equilibrium time: 120 min, Temperature: 303 K (Desorption)

Cycle	Adsorption for each cycle	Total adsorbed amount (mg/g)	Desorption at 0.01M NaOH (mg/g)	Remaining amount of nitrite after desorption (mg/g)
1	2.10 (83.8)	2.10	1.95	0.15
2	2.01 (80.2)	2.16	1.98	0.18
3	1.96 (78.3)	2.14	1.94	0.20
4	1.87 (74.8)	2.07	1.83	0.24
5	1.78 (71.1)	2.02	1.75	0.27

** Values shown in the parenthesis are in percent*

Regeneration studies were performed to confirm the reusability of the spent adsorbent material in removing nitrite from water and wastewater and the results are shown in Table 4.12.1.

The investigated material, SCIAC is excellent in removing aqueous nitrite ions at lower pH values (3.0-5.0). The results showed that, about 83.8% of nitrite adsorbed on to 4 g/L of SCIAC from an initial nitrite concentration of 5 mg/L at an optimum pH of 3.0. The kinetic and equilibrium studies performed to find out the rate and isotherm characteristics of nitrite adsorption process. The adsorption capacity of SCIAC (27.03 mg/g) for nitrite removal is higher than that of the reported values. The investigated SCIAC was successfully tested with fertilizer industrial effluent for the removal of nitrite ions. The studies revealed that an adsorbent dosage of 10 g/L is sufficient for the complete removal of 10 mg/L of nitrite from the industrial effluents. In future, it is possible to integrate the investigated adsorbent material, SCIAC in permeable reactive barriers (PRB) in real system applications for nutrient removal scenario.

4.13 Speciation and transport characteristics of nutrients in the paddy fields of river basin: Focus on biogeochemical processes and adsorptive removal studies

The present work deals with the synthesis and applications of an integrated Fe-montmorillonite-chitosan composite for the removal of phosphate from aqueous solutions. In the last three decades, rapid population growth, industrial proliferations, vast urbanization and increasing living standards caused serious threat to the quality of water bodies. Recently the problem of environmental pollution by anthropogenic activities becomes uncontrollable. Most of the countries of the world are trying to develop feasible technologies for wastewater treatment strategies. Even though the pollution problem is most severe, less attempts for its remediation, which require huge investments, has been taken because of the non-productive nature of treatment processes. The governments as well as private sectors repeatedly neglect this problem. Thus, economically viable treatment strategies for the removal of pollutants from aqueous solutions attain great concern.

Water bodies are mainly polluted either by natural and anthropogenic processes. Nutrient pollution is a major source of water pollution posing threat to both human health and aquatic environment. The agriculture run-off, wastewater from fertilizer industry and sewage contains substantial concentration of nutrients like nitrogen and phosphorous. The transfer of specific nutrient species from sediments to the overlying water (or from water to the sediments) is called as nutrient flux and it is a crucial factor affecting nutrient balance and primary productivity in the water. In this point of view, our aim is to develop feasible and economically viable treatment strategies for the removal of one of the important micronutrients from water, namely phosphate.

The adsorbent used is a chitosan–montmorillonite-iron composite, where, montmorillonite is a 2:1 clay mineral with two tetrahedral sheets of silica sandwiching a central octahedral sheet of alumina. It carries a net negative charge due to the broken bonds around the edges of the silica-alumina units. The cation exchange capacity of montmorillonite clay is due to isomorphous substitution of Mg for Al in the central alumina plane.

Batch adsorption experiments like effect of pH on phosphate solution, Influence of contact time, kinetics of adsorption and adsorption isotherm were conducted to understand the optimized condition of the developed adsorbent. For different initial concentrations of 5, 10, 15, 25, 50 mg/L, maximum adsorption of 2.161, 4.563, 6.72, 10.75, 21.26 mg g^{-1} respectively was noticed at pH 3 for 40 min (Fig. 4.13.1).

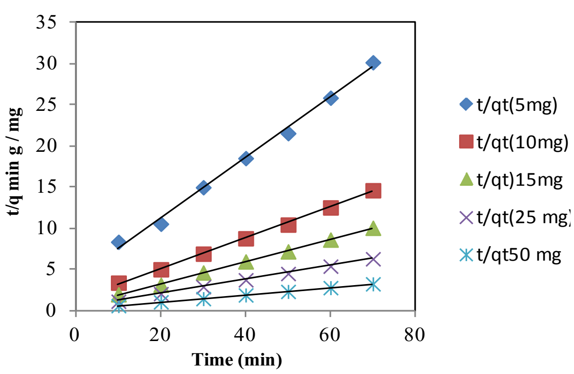


Fig. 4.13.1: Influence of contact time and initial concentration on the removal of phosphate by cht-mmt-Fe

The kinetics of phosphate adsorption onto cht-mmt-Fe composite were evaluated using different kinetic expressions such as pseudo-first-order, pseudo-second-order, Elovich model and intraparticle diffusion model. From the experiments it has been proved that pseudo second order kinetics are in good agreement, so this model is best fitted with the kinetic data (Fig. 4.13.2).

In this study, Freundlich isotherm is best fitted equilibrium model than Langmuir model which is confirmed by the higher values of regression coefficients obtained for Freundlich isotherm and the values are 0.998, 0.983, 0.979 and 0.903. The influence of temperature on phosphate adsorption onto chitosan-mmt-Fe composite was carried out at temperatures ranging from 283K to 313K. The negative values of ΔG° indicated that the adsorption was spontaneous and feasible. The magnitude of ΔH° is found to be -1.49J/mol and negative value of ΔH° confirmed the exothermic nature of the adsorption.

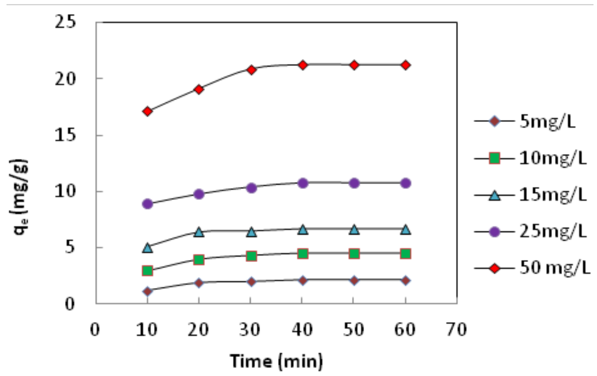


Fig. 4.13.2: Kinetic plots for the adsorption of phosphate onto cht-mmt-Fe

A few characterisation studies have been undertaken for the newly developed adsorbent. The XRD patterns of cht-mmt-Fe composite shows a characteristic peak at 27.8° due to metal entrapment of polymeric matrix. In the FTIR spectrum of pure montmorillonite, the broad band near 3678.88 cm^{-1} is shifted to 2873.8 cm^{-1} in iron pillared chitosan montmorillonite composite (cht-mmt-Fe). The peak at 1028.75cm^{-1} of chitosan which arises from the -C-O stretching vibration of alcohol is shifted to 976.563 cm^{-1} in cht-mmt-Fe composite. All these shifts in IR frequencies are due to the new linkages arising from the influence of chitosan-mmt and Fe-cht-mmt interactions respectively. SEM and EDX of pure chitosan, mmt and Fe-cht- mmt has been taken to understand surface morphological changes of the pure clay and the newly developed adsorbent. Hence the present study concludes that the cht-mmt-Fe composite can be employed as a low cost, eco-friendly and efficient adsorbent for the removal of phosphate from aqueous solution.

4.14 Carboxylate functionalized cyclodextrin derivative for the adsorptive removal of Pb(II), Cu(II), Cd(II) and Zn(II) from aqueous systems

Adequate supply of drinking water is a primary requirement for improving public health in developing world. The importance of water has acquired a new dimension in view of alarming population growth. Urban and industrialization growth creates complex problems of water pollution which seriously undermine the quality of life. Concern for the quality and management of water resources is receiving increasing attention throughout the world. The aim of the study includes developing a cost effective and reactive surface functionalized adsorbent (structurally modified natural polymer) for the effective removal of heavy metal ions from water and wastewaters. The removal of heavy metals from aqueous media is the main topic of this research. There are several methods, generally used for this purpose, like, evaporation, chemical precipitation, electrochemical reduction, membrane filtration, reverse osmosis, co-precipitation, electro dialysis, adsorption, biosorption etc. These methods have distinct limitations and disadvantages while heavy metals are removed from industrial wastewater. Recently, the adsorption techniques are proved to be more efficient, user friendly and economical method for the removal of metal ions. [Activated carbons, inorganic oxides, natural adsorbents (clays, clay minerals, cellulose minerals, chitin and chitosan)]. The present study is to develop an adsorbent derived from β-cyclodextrin to remove Cu(II), Cd(II), Pb(II) and Zn(II) from aqueous media.

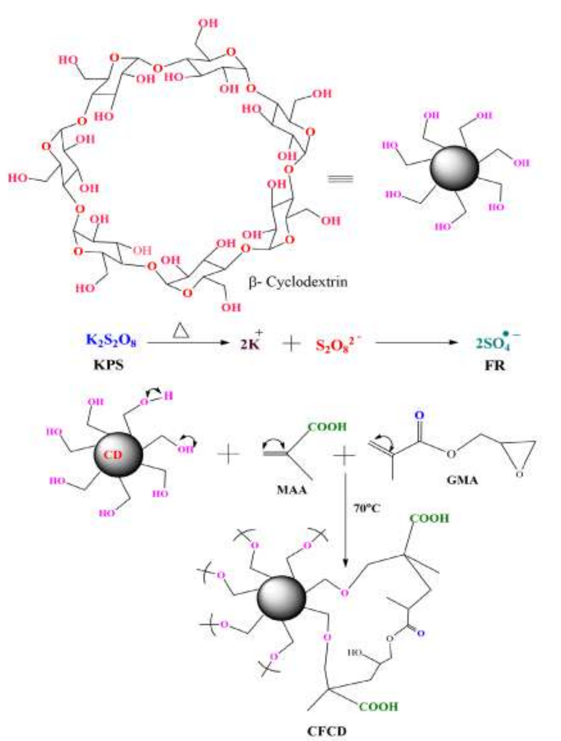
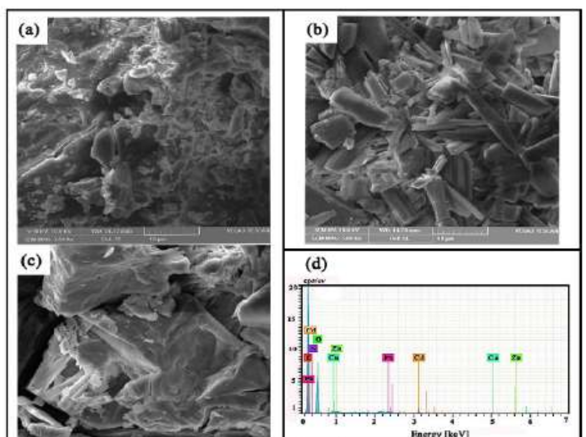


Fig. 4.14.1: Grafting mechanism in the preparation of CFCD

Carboxylate functionalized β-cyclodextrin (CFCD) was synthesized using a novel method and applied for water treatment strategies, especially for the removal of heavy metals from water and wastewaters. The preparative process was triggered using potassium per sulphate as the initiator. In the aqueous media, it dissociates to give sulphate ion and potassium cation. The monomer methacrylic acid undergoes homolytic cleavage to generate two radical sites and the 7 secondary hydroxyl groups of β-cyclodextrin also undergoes homolytic cleavage and generates radical sites at oxygen along with hydrogen radicals. One end of the methacrylic acid radical attaches with the β-cyclodextrin through an ether linkage. Glycidal methacrylate which is the cross- linker in the reaction also generates free radical sites through homolytic cleavage and bond formation takes place in between two methracrylic acid radical sites. Thus, the free radical reaction takes place and the linkages are further conformed by characterisation studies. Finally, we obtained the carboxylate functionalised β-cyclodextrin (CFCD) as our adsorbent for the effective removal of heavy metals.



Element	C	O	Zn	Cd	Pb	Cu
Mass %	40.72	53.09	1.19	1.36	1.85	1.79

Fig. 4.14.2: SEM images of a) β-Cyclodextrin; b) CFCD polymer; c) CFCD loaded with Pb(II), Cu(II), Cd(II) and Zn(II); d) EDS spectrum of CFCD loaded with Pb(II), Cu(II), Cd(II) and Zn(II)

β-cyclodextrin shows a broad peak at 3235 cm^{-1} which corresponds to -OH stretching frequency. The peaks at 2873 cm^{-1} and 1323 cm^{-1} corresponds to stretching and bending vibration of C-H bond in $-CH_2$ group respectively. Two peaks at 1154 cm^{-1} and 1021 cm^{-1} represents the asymmetric stretching vibrations of the glycosidic C-O-C and coupled ν(C-C/C-O) bonds respectively. The peaks shifted to 3268 cm^{-1} and 2914 cm^{-1}; peak area and peak intensity increased due to overlapped stretching frequencies of -OH, -CH in

-CH_2 groups. Carboxylic acid peak (-COOH) were introduced at 1632 cm^{-1} and the peak position was shifted after adsorption. The SEM images are analysed to study the morphology of the synthesized adsorbent CFCD. In fig. 4.14.2 a, the less ordered structure of the β-cyclodextrin can be visualized. On the further modification of β-cyclodextrin the adsorbent CFCD shows a more ordered arrangement in fig. 4.14.2 b. After adsorption of CFCD the crystalline nature is further enhanced fig. 4.14.2 c. From the EDS data, the amount of heavy metal adsorbed is obtained. The mass percentage of Zinc, Cadmium, Lead, and Copper is 1.19%, 1.36%, 1.85%, and 1.79% respectively. From the results obtained we could understand that the grafting is successful and the adsorbent CFCD is effective in the removal of the heavy metals. The percentage of carbon in β-cyclodextrin is 38.87% and percentage of hydrogen is 7.57%. The percentage of carbon in the adsorbent before adsorption is 38.30% and the percentage of hydrogen is 7.14%. The percentage of carbon in the adsorbent after adsorption decreased to 36.92% and the percentage of hydrogen decreased to 6.920% which indicate that some heavy metals have replaced the positions of carbon and hydrogen and adsorption phenomenon has taken place.

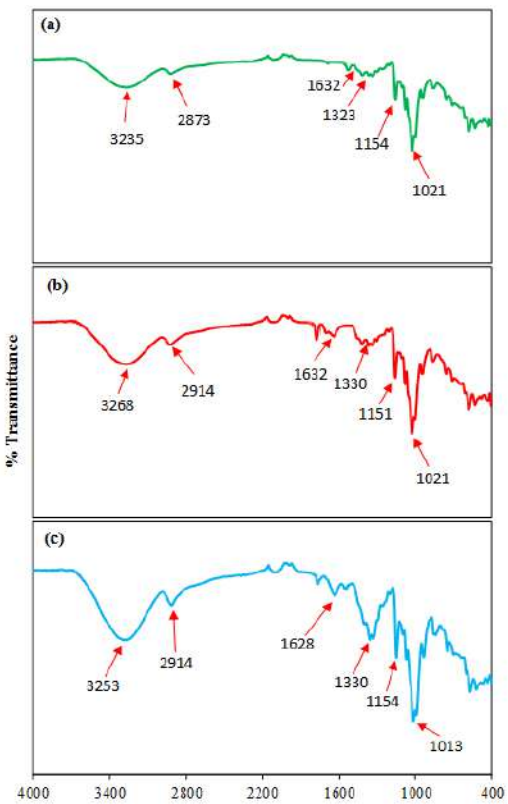


Fig. 4.14.3: IR Spectrum of a) β-cyclodextrin; b) CFCD before adsorption; c) CFCD after adsorption

The pH adsorption is very important as pH is a measure of acidity (pH<7) or basicity (pH>7) of an aqueous solution. The pH factor is very important in the adsorption process as the adsorption of metal ions onto solid was markedly affected by the pH of solution because it influences the metal chemistry. The maximum adsorption occurs at pH 7. Adsorption is an equilibrium process and their action time is one of the important factors influencing the adsorption of metal at the solid-liquid interface. Removal of Zn(II), Cd(II), Pb (II) and Cu(II) by CFCD is carried out at pH 7 for initial concentrations of 20, 40, 60, 80 and 100 mg/L. In order to estimate the adsorption behaviour of adsorbent accurately, it is important to allow significant time for the experimental solution to reach equilibrium. The figure shows the uptake of metal ions onto CFCD, as a function of time and the result clearly indicates that the adsorption of metal ions reached equilibrium at 30 minutes beyond which there may not further increase in the adsorption process, and thus it was fixed as the optimum contact time. The adsorption rapidly increased in the first minute after which adsorption slowly approaches equilibrium. Cu(II) shows maximum adsorption in the optimum contact time. With a bare surface initially, the available surface area is very large compared to the density of Pb(II) ions and consequently, the rate of adsorption was very high. However, with the increase in coverage, the fraction of bare surface area rapidly diminished and Pb(II) ions and Zn(II) compete for adsorption sites and showed comparable results. This results in slowing down of the interaction and the rate now becomes predominantly dependent on the rate at which Pb(II) ions are transported from the bulk to the adsorbent-adsorbate interface. Temperature has a direct influence on the adsorption of Pb(II) on

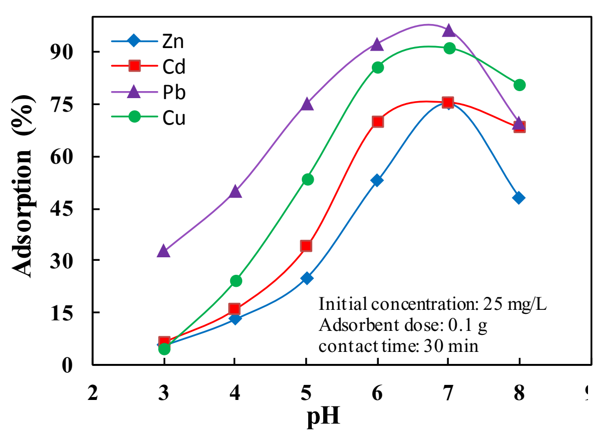


Fig. 4.14.4: Effect of initial ion concentration of Zn(II), Cd(II), Pb(II) and Cu(II) onto CFCD

chitosan. The adsorption experiments were performed in the temperature range 20-50°C for different initial concentrations of 10, 25, 50, 75, 100 and 125 mg/L at a constant adsorbent dose of 0.1 g/50 mL and at a pH of 6. The result shows that the equilibrium adsorption capacity increased with the rise in temperature and the maximum adsorption of Zn(II), Cd(II), Pb(II) and Cu(II) on 30°C.

The present study was successful in developing CFCD for binding the heavy metal ions like Pb(II), Cu(II), Cd(II) and Zn(II), especially to apply in a natural water system. The maximum adsorption capacity was observed for CFCD at pH: 7, Temperature: 30°C, and Time: 30 min. The maximum adsorption efficiency of CFCD for the removal of Pb(II): 37.12 mg/g, Cu(II): 32.34 mg/g, Cd: 28.95 mg/g and Zn: 24.74 mg/g in a simulated multi-metal aqueous system with an initial concentration of 50 mg/L. Langmuir isotherm is best fit with the model and the D-R isotherm also reveals the chemical nature of the adsorption process. The efficiency of adsorptive removal of these metal ions follows Pb(II) > Cu(II) > Cd(II) > Zn(II) and shows the greater affinity of Pb(II) and Cu(II) species for CFCD.

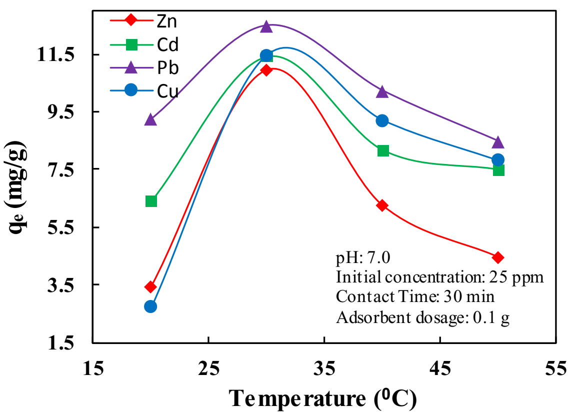


Fig. 4.14.5: Effect of temperature on the adsorption of Zn(II), Cd(II), Pb(II) and Cu(II) onto GMA grafted chitosan

4.15 Seasonal investigation and evaluation of water quality parameters of Mangalore coast, Karnataka, India

Mangalore officially known as Mangaluru (12.87°N, 74.88°E) is a coastal port city of Dakshina Kannada district, Karnataka, Southern India. Average elevation is 22 m above sea level. Mangalore region in Karnataka exhibits all the major characteristics of a three-tier tropical hydrological system comprising fresh, estuarine and marine components. Netravati and Gurupur are the major rivers flowing through Mangalore and they together forms an estuary called Mangalore estuary. Both the rivers meet at Mangalore estuary and finally debouches into Arabian Sea. Netravati and Gurupur rivers are the fresh water components of Mangalore estuarine system. Netravati River originates at Bangrabalige valley, Kudremukh in Chikmagalur district, Karnataka. The river rises at an elevation of 1000 m and flows in north-south direction up to 40 km near Gohattu. It flows over a length of 104 km and drains about an area of 3504 sq.km. Netravati gets polluted due to discharge of waste water and untreated sewage. It is reported that, the entire sewage from Bantwal town is let in to Netravati. Untreated discharge of domestic and industrial sewage not only pollutes Netravati-Gurupur river system, but also deteriorates groundwater quality in the Mangalore city.

The Gurupur River, otherwise called the Phalguni River, originates in the Western Ghats at an attitude of 1880 m above sea level and flows towards west and joins Netravati River at Bengre. This has a length of 80 km. It takes a right angle turn near coast and flows nearly 6 km south wards parallel to coast and debouches into estuary. Gurupur is a perennial river which receives the maximum amount of water during south west monsoon. Gurupur River has a catchment area of 824 sq.km. Beyond the month of February, Gurupur River receives less significant flow. However, Gurupur waters are less utilized for multipurpose project. Gurupur forms northern boundary of Mangalore while, Netravati skirts the southern boundary.

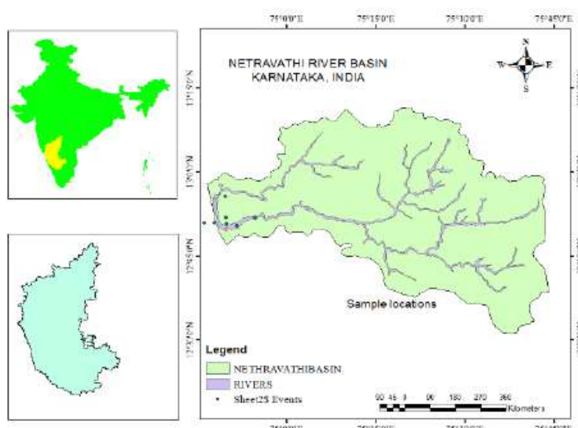


Fig. 4.15.1: Study area and sampling locations in Netravati River basin

The details of sampling stations are presented in Fig. 4.15.1. Monsoon season accounts for the highest species diversity in all the fresh zones. In addition to diatoms, green algae and blue green algae have enriched species composition in fresh zone, while in estuary diatoms contributes greater portion of phytoplankton species. However, in non-monsoon season, species diversity was comparatively higher in estuarine area and species density was low. This scenario was more pronounced in estuarine area. It is reported that salinity is a major influential factor in controlling phytoplankton equilibrium and diversity in estuarine system. Salinity fluctuation from fresh zone to estuarine zone is obvious from the values. The comparative reduction in species diversity in nutrient loadings have significant impact in governing species composition of an area. Alteration in nutrient loadings influence species composition of phytoplankton. Mangalore coast is one of the major upwelling systems of south west coast of India. Oceanographic features of the region is a true representation of Malabar upwelling system. Phytoplankton composition in estuary and coast may affect the fish biomass produced in the specific area. Diatom dominated estuary supports fifty times more fish biomass as compared to cyanobacteria, or green algae dominated fresh waters. Our study predicts the Mangalore estuary as a positive niche for fisheries resource, as the estuary is dominated by diatoms all over the seasons. Silicate concentrations were found to be decreasing from fresh zone to estuarine zone. The transition can be finely visualized from fresh water to estuarine systems. Proliferation of centric diatoms like *Skeletonema coastatum* in non-monsoon season got replaced by *Coscinodiscus radiatus* in monsoon season. Thus, there occurs a shift in phytoplankton composition. The proliferation of *Coscinodiscus radiatus* was more pronounced in estuarine waters. Both the species were reported to be non-toxic in nature. However, if the proliferation of major diatoms like *Skeletonema coastatum* and *Coscinodiscus radiatus* exceeds 100000 Cells L^{-1}, then it would result into a bloom which may deplete DO levels further, if the bloom persists over long time. Large nutrient loadings in estuaries stimulate algal blooms, which in turn results into hypoxia.

Study classifies estuarine zone as the most sensitive zone in terms of species composition, nutrient loadings and other physico-chemical parameters including salinity and dissolved oxygen (DO). Estuary receives adequate amounts of fresh water, nutrients, suspended solids, organic matters from land and transfers energy and material to open ocean. Estuaries are biogeochemical hotspots as they receive large amount of nutrients and other organic matters from land and ocean, thus supporting higher rates of phytoplankton production. Pearson correlation values and PCA biplot signifies important correlation and affinity between certain physico-chemical parameters (DO, TN:TP, SiO_4, Salinity) and phytoplankton. Inverse relationship of silicate loadings and phytoplankton could be obviously visible in all the three zones. TN:TP values are positively correlated with phytoplankton density. Depletion of dissolved oxygen levels in estuarine zone describes seasonal proliferation of diatom species like *Skeletonema coastatum* (non-monsoon) and *Coscinodiscus radiatus* (monsoon), which is rather limited by silicate loadings. Optimum salinity is a major driving factor for this process. Salinity is a major determinant factor for phytoplankton composition and distribution in a river ocean continuum. Optimum salinity favours phytoplankton biomass accumulation in estuary. Large flux of nitrogenous and phosphorous forms of nutrients from rivers delivered into estuaries. Phytoplankton are the first component of ecosystem to respond to these loadings by increased production. Gurupur and Netravati rivers carries these nutrients into Mangalore estuary. The positive correlation between TN:TP ratio and phytoplankton biomass conveys the idea of nutrient proportion required for certain species like *Coscinodiscus radiatus* and *Skeletonema coastatum* to proliferate in estuarine waters. Higher N:P ratios favours diatom production. Relative ratio of major nutrients like N and P governs phytoplankton production in estuarine and marine zone. The depletion in silicate values reflects the diatom proliferating stage of estuary by consuming SiO_4, the major dissolved nutrient for building diatom skeleton. Thus, the estuary is said to be silicate saturated. Higher photosynthetic ability owing to higher chlorophyll content in diatom promotes higher rate of diatom growth. Seasonality also influenced the rate of diatom proliferation and species shift in estuary. Thus, among the three zones, estuarine area is considered as most sensitive zone with respect to environmental perturbations. Owing to anthropogenic activities and fresh water input from Gurupur and Netravati rivers, species composition, and biological activity, Mangalore estuarine zone forms a unique zone, as supported from our AHC analysis study. Regular monitoring and proper treatment of anthropogenic and solid waste could improve the health of the estuary.

4.16 Appraisal of marine ecosystem of Kavaratti Island in southwest coast of India with special reference to lagoon system

Kavaratti is the capital of Lakshadweep Islands and is famous for the tourism activities due to the presence of pristine white sand beaches and shallow lagoon. Kavaratti occupies an area of 3.6 km^2 and lies between 10°32' and 10°35' N latitude and 72°35' and 72°40' E longitude and also 360 km from the Kerala coast. Kavaratti is the most populated island of Lakshadweep Archipelago which occupies 5.6 km length, 1.6 km width and 8.6 km^2 of lagoon area. The copepods are the major zooplankton groups dominated in the Lakshadweep group of islands. The higher biodiversity and biomass occur in the open sea around the atoll, and the zooplanktons crossing the reef and washed out to the lagoon may serving as the food to reef community. The present project aims to study the seasonal variability and abundance of zooplankton and phytoplankton and their relationship with environmental variables in the aspect of the pollution indication.

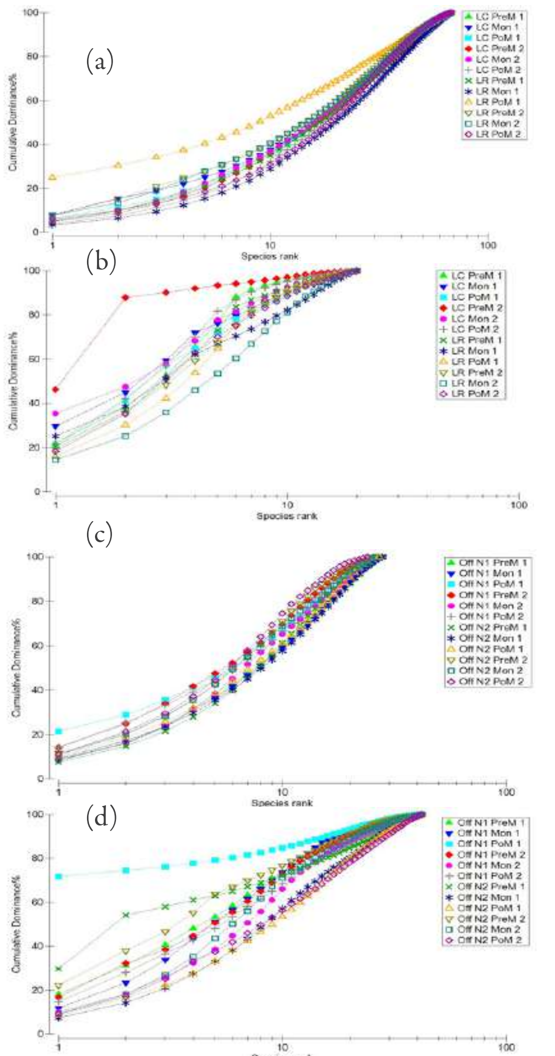


Fig. 4.16.1: K- dominance curve showing the abundance and distribution pattern of planktons: a) K-dominance curve for zooplankton in lagoon; b) K-dominance curve for zooplankton in offshore; c) K-dominance curve for phytoplankton in lagoon; d) K-dominance curve for phytoplankton in offshore

The fig. 4.16.1 shows the distribution and abundance of planktons in lagoon and offshore waters. The maximum abundance was observed in both lagoon and offshore area. The distribution pattern of phytoplankton are useful bio indicators of changing environmental conditions and the advantage of using biological indicators over chemical or physical ones. On the other hand, newly introduced species have ecologically negative effects on ecosystems. Therefore, the identification and qualitative studies of phytoplankton populations not only have an important role in the collection of historical data but are also necessary to understand the polluted and under stress environment of the Kavaratti atoll. Phytoplankton distribution in this ecosystem is not uniform during different seasons of the year. At present, there are several problems in this sensitive and vulnerable ecosystem which are considered as major environmental concerns.

This study reveals the influence of physico-chemical parameters on zooplankton and phytoplankton diversity in coral lagoon and offshore region of the Kavaratti atoll. The canonical correspondence analysis shows the relation between plankton assemblages and environmental parameters (Fig. 4.16.2). The water quality parameters such as nitrite, nitrate, inorganic phosphate, pH, and silicate were significantly influencing the assemblages and distribution pattern of plankton taxa. Spatial and temporal differences of plankton assemblages have been observed during the study period. The dominance curve shows the even distribution pattern over the locations. The lagoon area shows disturbances in the community structure and abundance during the pre-monsoon season of the study period. Chlorophyll-a concentration also seems to be high in lagoon, which indicates that the nutrient enrichment was higher in the lagoon and may lead to eutrophication. Zooplankton abundance in the lagoon showed the environmental stress of the aquatic ecosystem in responses to natural/anthropogenic disturbances.

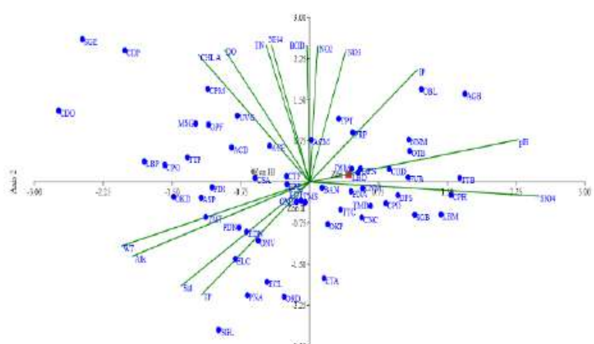


Fig. 4.16.2: Canonical correspondence analysis plot for relation between plankton species with water quality parameters

4.17 Environment monitoring of water and sediment quality parameters in the backwaters of Cochin Port Trust

Kochi is the industrial capital of Kerala, and a lion's share of chemical industries are situated on the banks of the Periyar River. There are over 200 medium and large-scale industries and about 2000 small scale industries, handling diverse organic and inorganic formulations, discharging their effluents either directly or indirectly into the water bodies besides municipal wastes. Apart from this, indiscriminate use of fertilizers, insecticides/fungicide and other consumables causes considerable damage to the water quality of riverine, estuarine and marine systems posing serious threat to biotic community including man. The route of entry of metals to man be direct, by way of drinking water, or indirect often involving food chain. Two major rivers discharge fresh water into the Cochin estuarine system; the Periyar River flows into the Northern parts and the Moovattupuzha River into the Southern parts. The Kochi backwaters is one of the largest estuaries on the West coast of India and is permanently connected with the Arabian Sea by an opening which forms the main entrance to the Kochi harbour. To the north and south, the harbour is continuous with extensive, shallow, brackish water areas, which receive the waters of several rivers. In this context, Cochin Port Trust entrusted us to carry out a detailed study on the water and sediment quality aspects of backwaters of Cochin Port Trust for over a period of five years starting from August 2017 onwards.

The work involves collection and analysis of water and sediment samples for various marine/estuarine pollution parameters at seven locations in the Cochin harbour as shown in Fig. 4.17.1 with details of sampling stations.

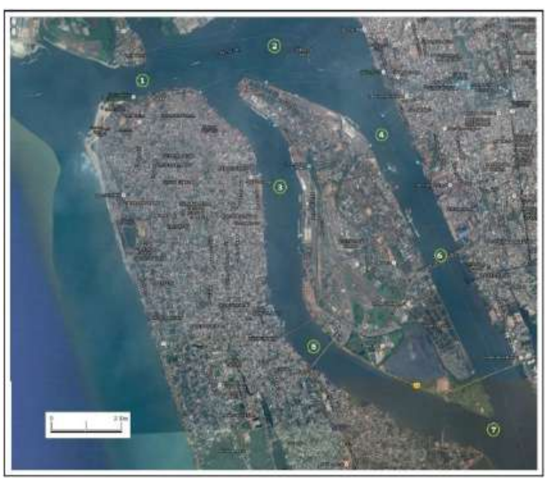


Fig. 4.17.1: Details of sampling locations at Cochin harbour

The work was carried out during last week of every month (April 2018-March 2019).

Water and sediment quality in terms of physico-chemical parameters in the backwaters around Cochin port was monitored. The water temperature varied from 27.0°C to 32.2°C. The pH of water showed fluctuations from surface and bottom due to the influence of saline water and rainwater inflow. Dissolved Oxygen varied from 4.68 mg/l to 6.45 mg/l in surface water and 4.54 mg/l to 5.35 mg/l in bottom water. The salinity of surface water varied from 21.90 ppt to 27.54 ppt and for the bottom water it was 24.12 ppt to 33.58 ppt. Inorganic phosphate showed highest values, varying from 1.15 µmol/l to 3.45 µmol/l and recorded an average maximum during the month of November. The nitrite nitrogen values are ranging from 0.68 µmol/l to 2.42 µmol/l. The average nitrite nitrogen values are high during November and are low during January. The ammonia nitrogen concentration is ranging

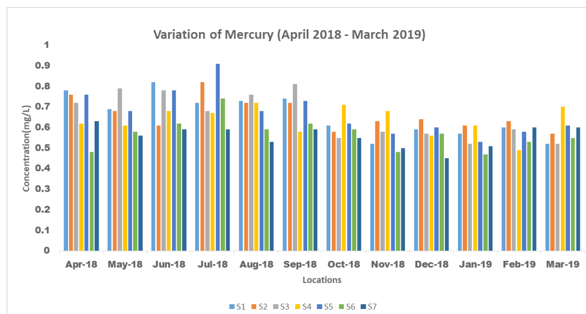


Fig. 4.17.2: Variation of mercury level in sediments of the study area

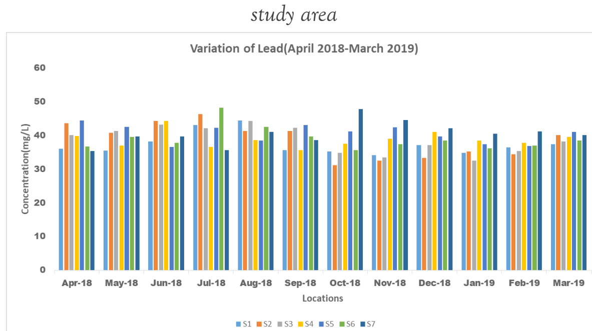


Fig. 4.17.3: Variation of lead level in sediments of the study area

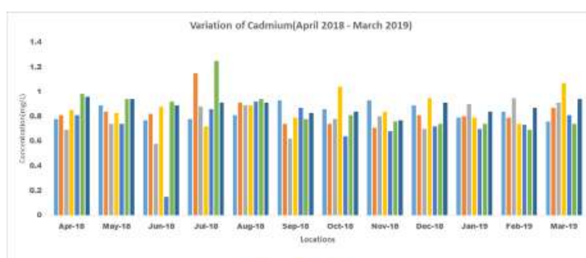


Fig. 4.17.4: Variation of cadmium level in sediments of the study area

from 0.32 µmol/l to 0.66 µmol/l. The average values are maximum during November and minimum during the month of September. In surface water, petroleum hydrocarbon (oil and grease) varied from 14.32 mg/l to 36.04 mg/l during the study period. Petroleum hydrocarbon in bottom water varied from 0.14 mg/l to 0.62 mg/l. Surface water showed higher values for petroleum hydrocarbon (PHC) because of its low density. Stations 2 and 6 showed the highest values of PHC during the entire study period. Gross production showed values ranging from 21.08 to 30.25 mg C/m^3/hr for surface water and 17.48 to 27.64 mg C/m^3/hr for bottom water. A general trend in the concentration of nutrient availability is more for bottom water than surface water indicating the inoculation of nutrients from bottom sediments to the surface water.

As regards sediment quality parameters, the pH showed variation from 7.43 to 7.91 during the study period. The concentration of Cd, Pb and Hg in the sediments around Cochin Port Trust is ranging from 0.69 to 1.25 ppm, 35.39 to 48.24 ppm, and 0.48 to 0.91 ppm respectively. A considerable increase in the concentration of Lead and Mercury were observed during the study period than previous years. Cochin region contains higher levels of Pb and Hg in sediment. This can be due to the intensive industrialization along with sewage disposal input of these metals into the estuary. The sediment quality parameters are indicative of industrial effluent discharge in the study area.

4.18 Hydrogeochemistry and nutrient fluxes of the rivers of Western Ghats

River basins representing main source of freshwater and river pollution has become a hot environmental issue, since rivers carry various types of dissolved chemical components. The fate and dynamics of the solute load depends on natural and anthropogenic factors. Water quality deterioration has become a serious issue worldwide due to natural processes (e.g., weathering, precipitation, soil erosion, etc.), anthropogenic activities (e.g., agricultural, urban and industrial activities) and the increased utilization of water resources. The monitoring studies in the river basin of Netravati has been carried out seasonally during 2018-19. The sampling locations of River and Paddy fields in the basin are given in Fig. 4.18.1.

Extensive field works conducted to collect water and sediment samples from Netravati river basin seasonally (monsoon, post-monsoon and pre-monsoon). The study was carried out to assess the seasonal variation of hydrochemistry of 24 river water samples and 12 paddy water samples. From the seasonal data and region wise water flow variations are evaluated. The samples collected were submitted for chemical and bacteriological examination in view of chemical composition and quality aspects. The following physico-chemical parameters were estimated: temperature, pH, conductivity, dissolved oxygen, BOD, alkalinity, chloride, sulphate, hardness, nitrite, nitrate, ammonia, inorganic nitrogen, total nitrogen, organic nitrogen, inorganic phosphorus, total phosphorus, organic phosphorus and silica.

The physico chemical parameters of river water were as follows. The average pH values in 2018-2019, MON (6.57), PoM (8.07), PrM (6.61), which is within the permissible limit prescribed by WHO which is 6.5 to 8.5. Post monsoon samples shows relatively higher pH values. The salinity of the river water increases as it is getting closer to the coastal region of Mangalore. There is a dam erected about 6 km inland from the sea. It prevents salt water intrusion upstream river. Conductivity is considered as an important parameter to categorize drinking water quality. The value ranges from, MON [1.06 -159.6 µS/cm (mean 42.99 µS/cm)], PoM [11.2-23090 µS/cm (mean 1087.75 µS/cm)] and PrM [32.29-163 µs/cm (mean 74.29 µS/cm)], and the mean values lie within the permissible limit. The increase in electrical conductivity may be attributed to decrease in the water level due to evaporation and increase in organic matter contents. Alkalinity is known as the ability of water to neutralize acids. From the results, carbonate alkalinity was not observed in any of the water samples. The concentration of bicarbonate in the study area varied as PrM > PoM > MON. Most of the physico-chemical parameters stands within the standard limit prescribed by WHO (2011) and do not pose any threat to aquatic biota.

The status of nutrients brought out that the concentrations had increased in 2018-2019 compared to previous year data. It might be due to the torrential rain received in the monsoon of 2018. It might increase the levels of leaching and weathering process in nature. Nitrite is an essential anion required in the nitrogen cycle, but its over-enrichment or low concentration leads to hazardous results. The average values are: MON (12.67 µg/l), PoM (17.33 µg/l), PrM (5.20 µg/l). In case of Nitrate, values decreased over the seasons from MON (131.74 µg/l), PoM (79.55 µg/l), PrM (22.39 µg/l). Presence of nitrate is an indicator of anthropogenic pollution. Nitrate is derived from industrial and agricultural areas, due to leaching from plant nutrients, nitrate fertilizers and domestic and industrial waste. In the present study the increasing order of nitrate and nitrite concentrations varies as MON > PoM > PrM and PoM > MON > PrM respectively. The variations of nitrate and nitrite are plotted in the Fig. 4.18.2 c and d.

In case of concentrations of Phosphate (fig. 4.18.2 a) value varied from MON (19.89 µg/l) to PoM (23.69 µg/l) and to PrM (27.50 µg/l). The normal value of phosphate in surface water is 5 mg/l and the excess level can cause eutrophication. Phosphate concentrations were observed highest during PrM followed by PoM and MON. The concentration of silicates (fig. 4.18.2 b) can be considered as a measure of weathering. Besides, it can occur anthropogenically from industrial effluents, sewage waste etc. Enrichment of silicate reduced the nutrient concentration. The concentrations are as follows: MON (5.08-8.74 mg/l), PoM (3.86-9.16 mg/l) and PrM (0.95-9.18 mg/l). The concentrations of silicate during the three different seasons were the exact reversal of that obtained for phosphate nutrients. The nutrient values in the study area do not pose a threat to the aquatic system. To better address societal needs, future advances will require a holistic approach to interpret hydro-geochemical data.

The studies conducted in paddy fields of Netravati basin gives the following information: the pH of water sample varies from 7.07- 9.14 during PoM and in PrM, the range is found to be 5.29-7.24. The pH range in MON is found to be 5.37-6.60. Usually for rice cultivation the effective pH range is found to be between 5.5 and 6.5. One of the most important parameters which affects rice cultivation is the electrical conductivity. The EC of rice strongly depends on temperature and moisture content and it should be in the range of 0.01-0.06 S/m, EC during PrM is found to be high in certain sites. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. In our study, the TDS ranges between 47.86-316.60 mg/L (PrM), 10.2-636.3 mg/L (MON) and 21-170 mg/L (PoM). Dissolved oxygen is of great importance in all aquatic ecosystems as it regulates most of metabolic processes of organism. DO concentration is found to be less than 5 mg/L during PrM. The values of nutrients such as phosphate, nitrite, nitrate, silicate and ammonia in all the three seasons in the year are found to be within the limits prescribed by World Health Organization (WHO), 2011. The above results highlight the effective water management system in and around our study area.

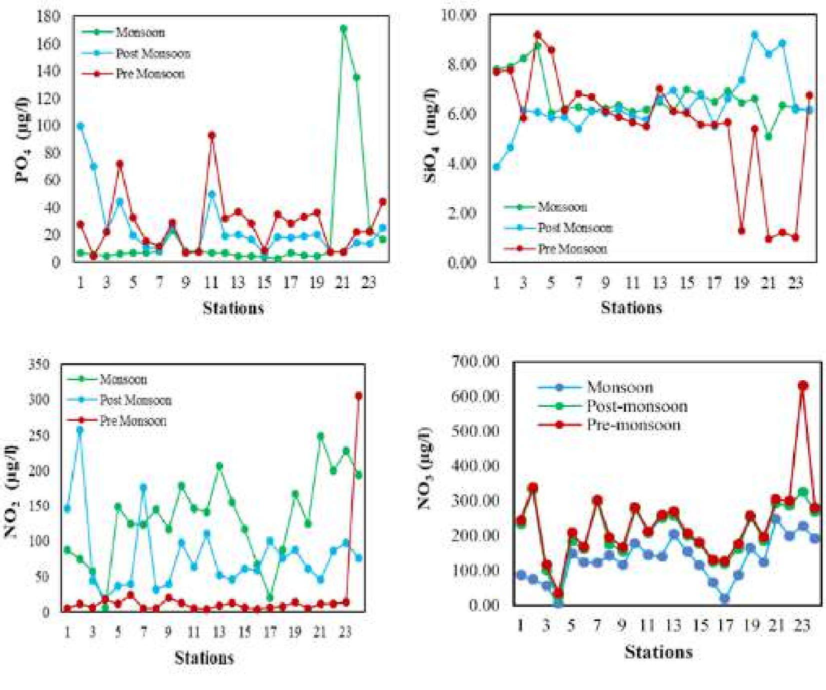


Fig. 4.18.2: Variation of a) phosphate; b) silicate; c) nitrite; d) nitrate

5. External and Consultancy Projects

NCESS carried out few external grant-in-aid projects and a number of consultancy projects during the year 2018-19. The externally funded projects were sponsored by Govt. of Kerala and Govt. of India agencies (Table 5.1).

The consultancy projects were undertaken mainly for the demarcation of HTL and LTL for Coastal Regulation Zone. Rapidly changing land use has adversely affected the coastal ecosystems, coastal morphology and livelihood resources of the coastal areas of our country. A significant percentage of the population live in the coastal area; the demographic pressure and higher economic and other subsistence activities deteriorate the quality of coastal environment. In order to conserve the coastal ecosystems of the country, the Government of India issued Coastal Regulation Zone (CRZ) Notification under the Environment Protection Act (1986) for regulating various activities in the coastal zone. The CZM Lab at NCESS has been equipped fully to carry out demarcation of High Tide Level (HTL) and Low Tide Level (LTL) and related coastal morphologies and also to prepare Coastal Zone Management Plans (CZMPs) and CRZ maps at state and local levels. Currently, NCESS is the dominant player in the country in undertaking CRZ projects related to the demarcation of HTL and LTL for coastal zone management.

During 2018-19, CZMP for the state of Kerala and three districts of Maharashtra were accomplished. In Kerala, there are 10 coastal districts where CRZ is applicable. The project mainly engages the preparation of CZM Plan Maps in 1:25K and local level CZM Plan Maps in 1:4K scale, for application at the local level with cadastral base and survey plot information. The generated geo-database to these states has been verified and approved by the National Centre for Sustainable Coastal Management (NCSCM) and later approved by the Ministry of Environment, Forest and Climate Change, Government of India. 18 consultancy projects were completed during the year (Table 5.2) and works of 14 consultancy projects are in progress (Table 5.3)

Table 5.1: List of external grand-in-aid projects

Sl. No.	Project Title	Funding Agency	Group	Project Period	Total Outlay (Rs. in lakh)
1	Environmental monitoring of water and sediment quality parameters in the back waters of Cochin Port Trust (CPT 4)	Cochin Port Trust, GoI	HyP	2017-22	30.00
2	Junior Research Fellowship – Ms. Sajna S. (CSIR 25)	Council of Scientific and Industrial Research, GoI	CrP	2017-19	2.70
3	Junior Research Fellowship – Mrs. Sandhya Sudhakaran (CSIR 26)	Council of Scientific and Industrial Research, GoI	HyP	2017-19	0.20
4	Proposal on impact of sea level rise in Kerala coast (DECC 2)	Department of Environment and Climate Change, GoK	CoP	2013-18	67.80
5	Drought mitigation through enhanced water retention in Ponds – a field experiment in Vadakarapathy Panchayath, Palakkad (DECC 3)	Department of Environment and Climate Change, GoK	CoP	2017-19	34.50
6	Natural hazard mitigation and management drought risk reduction and soil piping projects of NCESS (DMD 2)	Kerala State Disaster Management Authority	CoP	2017-19	55.14
7	De-siltation of reservoirs – Investigation works for estimating and sediments for de-siltation of reservoirs of Mangalam and Chulliyar dams in Palakkad (IDRB 1)	Irrigation Design and Research Board, GoK	CoP	2018-19	96.20
8	Coastal Zone Management Plan of Kerala with respect to Coastal Regulation Zone - 2011 (KSCS 29)	Kerala State Council for Science, Technology & Environment	CoP	2014-18	299.75
9	KSCSTE Fellowship – Mrs. Parvathy K. Nair (KSCS 30)	Kerala State Council for Science, Technology & Environment	CoP	2014-18	8.34

10	'Back to Lab' programme – Wetland studies of Akathumuri – Anchuthengu - Kadinamkulam estuarine system, south west coast of India by Mrs. Krishna R. Prasad (KSCS 31)	Kerala State Council for Science, Technology & Environment	CoP	2015-18	23.10
11	KSCSTE Fellowship – Ms. Praseetha B. S. (KSCS 32)	Kerala State Council for Science, Technology & Environment	CoP	2015-18	5.29
12	KSCSTE Fellowship – Ms. Saranya P. (KSCS 34)	Kerala State Council for Science, Technology & Environment	CrP	2015-18	4.20
13	KSCSTE Fellowship – Ms. Mintu Elezebath George (KSCS 35)	Kerala State Council for Science, Technology & Environment	CoP	2016-19	5.68
14	KSCSTE Fellowship – Ms. Remya R. (KSCS 36)	Kerala State Council for Science, Technology & Environment	CoP	2016-19	2.84
15	KSCSTE Fellowship – Mr. Sribin C. (KSCS 37)	Kerala State Council for Science, Technology & Environment	CrP	2018-21	2.84
16	KSCSTE Fellowship – Ms. Gayathri J. A. (KSCS 38)	Kerala State Council for Science, Technology & Environment	HyP	2018-21	2.84
17	KSCSTE Fellowship – Mr. Amal Dev J. (KSCS 39)	Kerala State Council for Science, Technology & Environment	CrP	2018-21	2.84
18	KSCSTE-Best Paper Award-Project titled "Hydrological response of river basins to climate change- A case study from Kerala, India" (KSCS 40)	Kerala State Council for Science, Technology & Environment	HyP	2018-21	1.00
19	Land disturbance due to soil piping in Western Ghats (LDSP)	Kerala State Disaster Management Authority	CoP	2017-20	7.90
20	National Post-Doctoral Fellowship (N-PDF) to Dr. Glejin Johnson (DST 84)	Department of Science and Technology, GoI	CoP	2017-19	19.20
21	"Characterization of mid-to-deep crustal metamorphism and melting under varying P-T-X-t conditions and its applications to the Proterozoic Eastern Ghats Belt, India" - DST Inspire Faculty Award (DST 85)	Department of Science and Technology, GoI	CrP	2017-19	8.17
22	Inspire Fellowship under Inspire programme for pursuing full-time doctoral (PhD) programme- Mr. Vipin T. Raj (DST 86)	Department of Science and Technology, GoI	HyP	2018-21	3.69
23	Inspire Fellowship under Inspire programme for pursuing full-time doctoral (PhD) program - Mr. Amal Dev J. (DST 87)	Department of Science and Technology, GoI	CrP	2018-21	3.68
24	Women Scientist Scheme A (WOS-A) entitled "Assessing the trace gas amounts and analysis of their pathways over Indian region using various remote & in-situ data sources for delivering climate action plans" - Dr. Anila Alex (DST 88)	Department of Science and Technology, GoI	CrP	2018-21	31.11
25	DST Inspire Faculty Award - Innovation in science pursuit for inspired research - Dr. Tripti Muguli (DST 89)	Department of Science and Technology, GoI	CoP	2018-21	19.00
26	Teachers Associateship for Research Excellence (TARE) to Dr. Rajaveni S.P. (DST 90)	Department of Science and Technology, GoI	CoP	2019-22	3.35
27	Inspire Fellowship under Inspire programme - Ms. Silpa Thankan (DST 91)	Department of Science and Technology, GoI	CrP	2018-21	3.68
28	Desertification and land degradation: Monitoring, vulnerability assessment and combating plans (SAC 15)	Space Applications Centre, ISRO, GoI	AtP	2017-21	42.48

Table 5.2: List of CRZ reports prepared during the period 2018-19

Sl. No.	Report No.	File No.	Project Name	Monitoring Committee	Investigators	Project Staff
1	NCESS-CRZ-04-2018	CRZ/36/2017	Delineation of HTL, LTL and preparation of CRZ Status report for the proposed renovation and development of District Hospital, Kannur	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Ms. S. Shamna, Ms. Jyoti Joseph, Ms. Parvathy K. Nair, Mr. C.K. Muhammed Haneefa
2	NCESS-CRZ-05-2018	CRZ/10/2017	Delineation of HTL, LTL and preparation of CRZ Status report for the Chethy Beach beautification	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar	Dr. M. Rameshan, Mr. S.L. Sajith, Ms. S. Shamna, Ms. Jyoti Joseph, Ms. Parvathy K. Nair
3	NCESS-CRZ-06-2018	CRZ/43/2017	Delineation of HTL, LTL and preparation of CRZ Status report for Mira Bhayandar	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Ms. S. Shamna, Ms. Jyoti Joseph, Ms. Parvathy K. Nair
4	NCESS-CRZ-07-2018	CRZ/39/2017	Delineation of HTL, LTL and preparation of CRZ Status report for KITCO	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Dr. M. Rameshan, Mrs. S. Shamna, Ms. Jyoti Joseph, Ms. Parvathy K. Nair
5	NCESS-CRZ-08-2018	CRZ/01/2017	Delineation of HTL, LTL and preparation of CRZ Status report for Pearls Garden, Kozhikode	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Dr. M. Rameshan, Mrs. S. Shamna, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Sabarilal
6	NCESS-CRZ-09-2018	CRZ/04/2018	Delineation of HTL, LTL and preparation of CRZ Status report for the construction of commercial building at Kozhikode Corporation	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Dr. M. Rameshan, Mrs. S. Shamna, Mrs. Reshmi Krishnan V.B., Mr. James Varghese, Mr. Sabarilal
7	NCESS-CRZ-10-2018	CRZ/22/2018	Delineation of HTL, LTL and preparation of CRZ Status report for the proposed construction of a commercial building at Kalluthan Kadavu in Kozhikode Municipal Corporation	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Sabarilal
8	NCESS-CRZ-11-2018	CRZ/26/2018	Delineation of HTL, LTL and preparation of CRZ Status report for Adani Vizhinjam Ports Private Limited	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A., Mr. Sabarilal

9	NCESS-CRZ-12-2018	CRZ/30/2017	CRZ Status report for the proposed construction of the Boat Jetty and Landscaping at Sand Banks, Vadakara, Kozhikode District	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A., Mr. Sabarilal
10	NCESS-CRZ-13-2018	CRZ/15/2018	Delineation of HTL, LTL and preparation of CRZ Status report for the construction of a 3-star category Hotel Project at Muzhappilangadu for KTDC	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Sabarilal
11	NCESS-CRZ-14-2018	CRZ/35/2017	Delineation of HTL, LTL and preparation of CRZ Status report for Padne Island development	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A., Mr. Sabarilal
12	NCESS-CRZ-15-2018	CRZ/31/2018	Delineation of HTL, LTL and preparation of CRZ Status report for alteration and addition of existing school building of St. Joseph's Anglo-Indian Girls Higher Secondary School, Kozhikode	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Sabarilal
13	NCESS-CRZ-17-2018	CRZ/20/2017	Delineation of HTL, LTL and preparation of CRZ Status report for River View Hospital, Kasaragod	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Dr. K.K. Ramachandran, Dr. M. Rameshan	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Sabarilal
14	NCESS-CRZ-18-2018	CRZ/40/2017	Delineation of HTL, LTL and preparation of CRZ Status report for Bulk Cement and Logistics Hub Project at Cochin Port Premises at Willington Island, Cochin, Ernakulam	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Dr. M. Rameshan, Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A., Mr. Sabarilal
15	NCESS-CRZ-19-2018	CRZ/13/2017	Delineation of HTL, LTL and preparation of CRZ Status report for Guruvayur, Periambalam Beach Resorts	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Dr. M. Rameshan
16	NCESS-CRZ-20-2018	CRZ/42/2018	Delineation of HTL, LTL and preparation of CRZ Status report for Parappanangadi Fishing Harbour, Malappuram district, Kerala	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith Dr. M. Rameshan, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A.
17	NCESS-CRZ-21-2018	CRZ/41/2018	Delineation of HTL, LTL and preparation of CRZ Status report for CIESCO Girls' Home, Kozhikode, Kerala	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Dr. M. Rameshan, Mr. James Varghese, Mrs. Reshmi Krishnan V.B., Mr. Lakshmanan A.
18	NCESS-CRZ-01-2019	CRZ/57/2018	Delineation of HTL, LTL and preparation of CRZ Status report for development of proposed Sports facilities at Ponnani, Malappuram District, Kerala	Dr. K.K. Ramachandran, Mr. M. Ramesh Kumar, Dr. D.S Suresh Babu	Mr. M. Ramesh Kumar, Dr. K.K. Ramachandran	Mr. S.L. Sajith, Mr. James Varghese, Mrs. Reshmi Krishnan V.B.,

Table 5.3: Ongoing Consultancy Projects

Sl. No.	Project Title	Funding Agency	Total Outlay (Rs. in lakh)	Fund Received during the year (Rs. in lakh)
1	Delineation of HTL/ LTL and preparation of CRZ status report	Vasai Virar City Municipal Corporation, Palghar, Maharashtra	--	77.37
2	-do-	Maharashtra Coastal Zone Management Authority	--	214.47
3	-do-	Lotus Destination Private Ltd.	3.15	3.15
4	-do-	Hindustan Petroleum Corporation Ltd.	2.00	2.00
5	-do-	National Highway Authority of India (Construction of NH-66 project highway)	20.00	20.00
6	-do-	Kitco Ltd. (Extension of inland waterways- C/o Kerala Waterways & Infrastructure Ltd.)	8.00	8.00
7	-do-	Kerala Tourism Infrastructure Ltd.	1.50	1.50
8	-do-	Vizhinjam International Seaport Ltd.	3.15	3.15
9	-do-	Kitco Ltd. (Development of sports facilities at Ponnani, Malappuram)	3.15	3.15
10	-do-	Aashrami Consultancy & Technology Pvt. Ltd.	3.15	3.15
11	-do-	Hindustan Aegis LPG Ltd., Mumbai	6.15	6.15
12	-do-	National Highway Authority of India (4-laning of NH-66 under NHDP Phase-III in Kerala)	15.00	15.00
13	-do-	Thiruvambady Guest House	3.15	3.15
14	-do-	Mr. Jayasimhan K. (Construction of tourist resort at Varkala, Thiruvananthapuram)	3.15	3.15

6. New Facilities

6.1 Inauguration of Central Chemical Laboratory

The Central Chemical Laboratory (CCL) attached to Hydrological Processes (HyP), NCESS has been completely renovated and upgraded with State-of-the-art facilities. The upgraded facility was inaugurated by Dr. M. Rajeevan, Secretary, MoES on 24th October 2018. Dr. N. Purnachandra Rao, Director, NCESS and Dr. D. Padmalal, Group Head, Hydrological Processes were also present.

6.2 Inauguration of Virtual Class room

The Virtual Class room of NCESS was inaugurated by Dr. M. Rajeevan, Secretary, MoES on 05th July 2018 at NCESS in the presence of Dr. B. K. Bansal, Programme Head (NCESS), MoES, Dr. N. Purnachandra Rao, Director, NCESS and other staff of NCESS.

6.3 Microwave Plasma-Atomic Emission Spectrometer (MP-AES) at Central Chemical Laboratory (CCL), NCESS

The basic aim of any analytical atomic spectroscopy (emission/absorption) technique is to identify the elements present in the given sample and to quantify their concentrations either absolutely or by using the reference standards. Microwave Plasma-Atomic Emission Spectrometer (MP-AES) is working based on the technology of microwave energy source generator combined with small amount of argon (Ar) gas to initiate the plasma and using of pure nitrogen (N_2) gas for sustaining the initiated plasma for longer times. The Agilent MP-AES 4210 is a compact, bench-top microwave plasma-atomic emission spectrometer based on a robust nitrogen plasma. It is suitable for elemental determinations using a solid-state CCD detector. The main advantage of these Agilent MP-AES 4210 is that it runs unattended without flammable or expensive gas supply which dramatically reduces the operation cost as well as the time, in addition to eliminating flammable and oxidizing gases (such as acetylene), these MP-AES eliminates the need to plumb multiple gases into the laboratory. Apart from easy handling, Agilent MP-AES 4210 offers high-performance microwave plasma source which enable superior detection limits along with continuous analysis of samples for longer times. One of these highly state-of-the-art technology for elemental analysis is established in the Central Chemical Laboratory (CCL), NCESS during January 2019 with complete infrastructure development and internal calibration, and standardization procedures followed for obtaining accurate elemental estimations. Around 2570 samples of water/soil/sediments have been analyzed till date for major (Na, K, Ca, Mg and Fe), transitional and rare earth elements.

Instrumentation: Includes a standard one-piece quartz torch optimized for high precision and sensitivity with the recommended power and gas flow settings. The torch features a unique polymer base that automatically makes gas connections and aligns the torch when inserted using the torch loader. Includes a multi-purpose sample introduction system that consists of a One Neb nebulizer, a glass cyclonic double pass spray chamber, humidifier for the nebulizer gas line and multi-purpose pump tubing. Configurations for other applications (organics and high sensitivity) are available. Fully PC-controlled peristaltic pump with variable speed of 0–80 rpm, and three channels for sample, drain and internal standard/ionization buffer. A five-channel pump option is also available. Computer-controlled solenoid valves are used to automatically enable and regulate the flow. The plasma gas is fixed at 20 L/min and the auxiliary gas is fixed at 1.5 L/min for ease of operation. Nebulizer gas flow is computer controlled using mass flow control to provide accurate flow control in the range 0.3–1.0 L/min.

Plasma generator: The microwave excitation assembly features a solid-state HV power supply and an industrial-grade, air-cooled magnetron operating at 2450 MHz. Fixed plasma power of 1 kW is there for ease of operation. The unit requires no cooling water supply, as the plasma generator is air-cooled. Computer-controlled plasma ignition using a momentary flow of auxiliary argon is another feature. Once the plasma is operational, it automatically switches to nitrogen for routine operation. Vertically-oriented plasma is set up for improved matrix handling with end-on or axial viewing for optimum sensitivity and best detection limits. Computer-controlled plasma viewing position is another advantage, which is optimized for each wavelength. A pre-optics protection gas flow of compressed air (25 L/min) is used to divert heat from the plasma away from the pre-optics. An operator replaceable pre-optics window has loaded in the equipment to ensure excellent performance.

Optical system: The optical system is equipped with the following features: i) Fast-scanning, high-resolution optical system for fast measurement using a compact design. ii) Czerny-Turner design monochromator with 600 mm focal length and fixed entrance slit for ease of operation. iii) Holographic diffraction grating with 2400 lines/mm is blazed at 250 nm for optimum UV performance. iv) Wavelength range 178-780 nm. v) The optical system can be purged with air for protection in dusty or corrosive environments, or nitrogen at 10 L/min for sulfur determinations. vi) Detector used is Hermetically-sealed, UV-sensitive, back-thinned solid-state CCD detector (532 x 128 pixels) designed especially for low-light level detection with > 90% quantum efficiency at peak sensitivity. It is directly cooled to 0 °C using a thermoelectric Peltier device for low dark current and reduced baseline noise. vii) High dynamic range and blooming resistance allow flexible measurement conditions. viii) The CCD array detector collects the analyte spectra and neighboring background spectra, allowing simultaneous background correction for enhanced stability and precision.

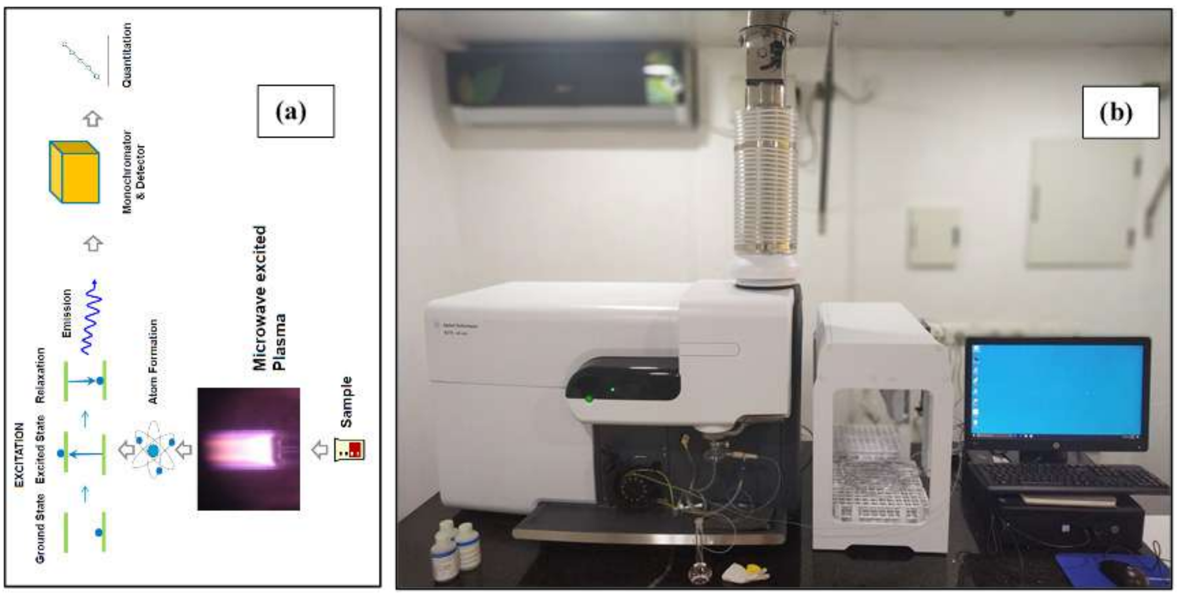


Fig. 6.3.1. (a) Basic working principle of MP-AES (b) Agilent MP-AES 4210 established at Central chemical laboratory (CCL), NCESS

6.4 Lightning observation network in Kerala / southern west coast for real time monitoring and research

Lightning sensors have been installed at eight locations as part of the detection network which will help for severe weather forecasting. The sensor frequency range is 1 kHz to 12 MHz. It can detect cloud to ground (CG) and cloud to cloud (CC) lighting strikes. The spatial density of lightning over Kerala region would be mapped. The locations of the sensors are Kasaragod, Kozhikode, Coimbatore, Palai, Madhurai, Alappuzha, Pathanamthitta and Thiruvananthapuram. The networking has been done in collaboration with IITM Pune and IMD. Fig. 6.4.1 (d) shows the real time lighting strikes observed on 2 Nov 2018, 12 Z in the southwest coast of India.

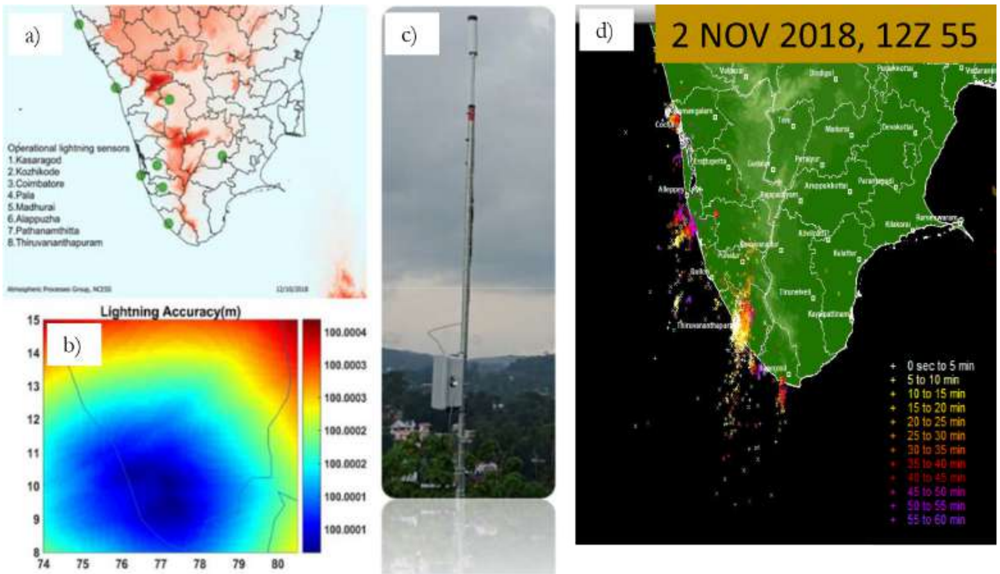


Fig. 6.4.1: a) Locations of the lightning sensors installed in southern India; b) Accuracy map; c) Lightning sensor installed at Pathanamthitta; d) Real time lighting strikes observed on 2nd Nov 2018, 12 Z in the southwest coas

Table 6.4.1: Specifications of the lightning sensor

Coverage	Global
Detection Frequency Range	1 kHz to 12 MHz
Detection Type	CG with significant IC overlay
Feed Type	Binary, ASCII, KML
Data Elements	Lat/Long, Time, Amplitude, Multiplicity

7. Honours, Awards & Academic Activities

7.1 Honours & Awards

Dr. Tomson J. Kallukalam, Scientist-D, Crustal Processes Group has been awarded 'Certificate of Merit Award-2018' by the Ministry of Earth Sciences, Govt. of India.

Dr. Padma Rao Bommoju, Scientist B, Crustal Processes Group received the 'Best paper award' (Subject Area: Earth and Planetary Sciences) for the paper titled "Crustal structure across and along the Western Ghats: Insights from Ps converted phases" in the 31st Kerala Science Congress held at Kollam on February 2019

Smt. Soumya. G. S, has been awarded Ph. D degree under the Faculty of Science, University of Kerala for her thesis "Neoproterozoic anorthosites in South India, a comparative study to delineate petrogenesis and India's position in Rodinia assembly" on April, 2018. Dr. T Radhakrishna, Scientist-G (Retd.) & Senior Consultant, Crustal Processes Group was her supervising guide.

Shri. R. Haridas, Deputy Manager, Personnel & General Administration has been awarded 'Best Employee Award-2018' by the Ministry of Earth Sciences, Govt. of India.

Smt. Femi R. Srinivasan, Executive, Purchase & Stores has been awarded 'Best Employee Award-2018' by the Ministry of Earth Sciences, Govt. of India.

Smt. T. Remani, MTS has been awarded 'Best Employee Award-2018' by the Ministry of Earth Sciences, Govt. of India.

Ms. Mintu Elezebath George has been selected for Senior Research Fellowship (SRF) for the year 2018-19 by Council of Scientific and Industrial Research (CSIR) in the category of Earth Sciences

Ms. P. Saranya, has been selected for Senior Research Fellowship (SRF) for the year 2018-19 by Council of Scientific and Industrial Research (CSIR) in the category of Environmental Sciences.

7.2 Membership in Committees outside NCESS

Dr. D. Padmalal

Member of Board of Studies, Kerala University for Fisheries and Ocean Sciences.

Member of Board of Studies, Department of Geology, University of Kerala.

Member of Board of Studies, Department of Geology and Geophysics, Cochin University of Science and Technology.

Member of the Faculty of Environmental Studies, Cochin University of Science and Technology.

Member of the Editorial Board, Journal of Coastal Sciences.

Member of the Editorial Board, Journal of Geo-science Research, Gondwana Geological Society, India.

Dr. K. K. Ramachandran

Member, Kerala Dam Safety Authority.

Member, Executive Committee of Kerala State Remote Sensing and Environment Centre.

Invitee for the discussion with Chief Secretary, Government of Kerala on 'Finalization of Coastal Zone Management Plan of Kerala'.

Member, Shoreline monitoring cell of Vizhinjam International Sea Port Ltd.

Expert Member, State Wetland Authority of Kerala (SWAK).

Invited Member, Expert committee on 'Administrative Reforms Commission – Sustainable development governance issues' constituted by the Gvernment of Kerala.

Member, Internal review committee on Coastal Zone Management Plan of Kerala & Sindhudurg, Maharashtra.

Invitee, Two-days brainstorming session on Coastal Hazard and Risk Assessment (CHRA) at IIRS, Chennai on 25-26 May 2018.

Invited Expert, Meeting of Department of Survey and Land Records at Survey Directorate, Vazhuthacadu on 03rd August 2018.

Member, Board of Studies, Kerala University for Fisheries and Ocean Sciences.

Member, Technical Sub-Committee constituted by the Government of Kerala to look into the Supreme Court directions in a SLP related to Marad CRZ issue.

Invitee, Meeting on preparation of CRZ Notification 2019 at Chamber of Additional Chief Secretary (Environment), Government Secretariat, Thiruvananthapuram on 03rd January 2019.

Dr. D. S. Suresh Babu

Member, Geo-Host Support Program Sub-committee, 36th International Geological Congress (IGC) 2020.

Reviewer of Journal of Geological Society of India and Current Science.

External Expert, Doctoral Advisory Committee (DAC) Meeting for the Ph.D. program, Manipal Academy of Higher Education (MAHE).

External Examiner to evaluate Doctoral thesis, Anna University, Chennai.

External Examiner to conduct Ph.D. viva-voce examination, Anna University, Chennai.

7.3 Visits Abroad

Dr. T.N. Prakash, Scientist-G & Group Head, Coastal Processes Group attended and presented a paper entitled "Placer mineral deposits of south west coast of India: their sustainable exploitation and environment management" in the International Conference of Geology and Earth Science held at Rome, Italy during 02-04 May 2018.

Dr. D.S. Suresh Babu, Scientist-F, Coastal Processes Group participated in the Bilateral Consultative Meeting cum Joint ZMT - MoES Workshop on Marine sciences and coastal sustainability held at the Leibniz Centre for Tropical Marine Research (ZMT), Bremen, Germany during 20-21 August 2018, as a team member of Indian delegation.

Dr. E.A. Resmi, Scientist-C, Atmospheric Processes Group presented a paper entitled "Monsoon low level jet and the variation in thermal structure in wet and dry rainfall episodes over southwest India" in the European Geosciences Union- General Assembly held at Vienna, Austria during 08-13 April 2018.

Dr. Chandra Prakash Dubey, Scientist-B, Crustal Processes Group attended the Seminar and training on Geo-Hazards monitoring and prevention technology for the countries along Bangladesh- China- India- Myanmar Economic Zone (BCIM-EC) held at Chengdu, China during 14-29 November 2018.

Shri. Ramesh Madipally, Scientist-B, Coastal Processes Group attended and presented a paper entitled "Monitoring of nearshore dynamics in southwest coast of India- A video imagery approach" in 3rd International Conference of Coastal Zones and Oceanography held at Singapore during 18-19 May 2018.

Dr. Padma Rao Bommoju, Scientist-B, Crustal Processes Group attended and presented a paper entitled "Anisotropy in the lowermost mantle beneath the Indian Ocean Geoid Low: insights from ScS splitting measurements" in the American Geophysical Union (AGU) Fall meeting held at Washington DC, USA during 10-14 December 2018.

Dr. Glejin Johnson, Post-Doctoral Fellow, Coastal Processes Group attended a training program on Observing and Modeling Ocean Waves held at Institut Universitaire Européen de la Mer (IUEM), Brest, France in July 2018.

Ms. Mintu Elezebath George, Research Scholar, Coastal Processes Group presented a paper entitled "Multi proxy approach in understanding Submarine Groundwater Discharge in the tropical unconfined aquifers of south west coast of India" in the American Geophysical Union (AGU) Fall meeting held at Washington DC, USA during 10-14 December 2018.

Dr. Tripti Muguli, DST-Inspire Faculty, Coastal Processes Group has been a visiting researcher to Geosciences Environnement Toulouse (GET), Université Toulouse III - Paul Sabatier, Toulouse, France during October-December 2018.

Ms. P. Saranya, Research Scholar, Crustal Processes Group presented a paper in the European Geosciences Union- General Assembly held at Vienna, Austria during 08-13 April 2018.

Dr. Kumar Batuk Joshi, Scientist-B, Crustal Processes Group attended the pre-dispatch inspection of Nu-Plasma 3 MC-ICP-MS held at Nu instruments factory, Wrexham, UK in November 2018.

Shri. N. Nishanth, Scientific Assistant Gr. B, Crustal Processes Group attended the pre-dispatch inspection of Nu-Plasma 3 MC-ICP-MS held at Nu instruments factory, Wrexham, UK in November 2018.

7.4 M. Sc. / B. Tech. / M. Tech. / M. Phil. Dissertation Programmes / Summer Training

During 2018-19, a total of 36 students from different universities across the country have successfully completed their dissertation / internship under the scientists of NCESS.

Sl. No.	Name	College / Affiliation	Supervising Guide
1	Parvathy. M. S.	Department of Geology, University of Kerala, Thiruvananthapuram	Dr. V. Nandakumar
2	Anjana. C.	Kerala Technological University	Dr. A. Krishnakumar
3	Gayathri Devi. S.	University of Kerala	Dr. A. Krishnakumar
4	Julia Joseph	Kannur University	Dr. A. Krishnakumar
5	Shania James	Pondicherry University	Dr. A. Krishnakumar
6	Timia James	Mahatma Gandhi University	Dr. A. Krishnakumar
7	Vishnumaya. T.M.	Kannur University	Dr. A. Krishnakumar
8	Sradha. A.V.	Department of Earth Science, University of Mysore	Dr. Tomson J. Kallukalam
9	Ashutosh Mishra	Central University, Jharkhand	Dr. K. K. Ramachandran, Shri. Vincent A. Ferrer
10	Harshita Mahanta	Central University, Jharkhand	Dr. K. K. Ramachandran, Shri. Vincent A. Ferrer

11	Anju. J.B.	IIITMK, Technopark, Trivandrum	Dr. E. A. Resmi
12	Abbad Lutfi. A.	Cochin University of Science and Technology, Kochi	Dr. E. A. Resmi
13	Jeena Marian Jacob	Catholicate College, Pathanamthitta	Dr. E. A. Resmi
14	Theertha Sunil	Sree Krishna College, Guruvayur	Dr. E. A. Resmi
15	Arathi. S.	St. Alberts College, Ernakulam	Shri. Dharmadas Jash
16	Athira	Bharathidasan University, Tiruchirappalli	Dr. S. Kaliraj
17	Maha Madhu	IIIMK, Thiruvananthapuram	Dr. S. Kaliraj
18	Anaswara. M.A.	Sree Krishna College, Guruvayur	Dr. C. K. Unnikrishnan
19	Arya Mohan	Catholicate College, Pathanamthitta	Dr. C. K. Unnikrishnan
20	Ashish Shaji	Central University, Rajasthan	Dr. C. K. Unnikrishnan
21	Faheem. K.	Cochin University of Science and Technology, Kochi	Dr. C. K. Unnikrishnan
22	Seba Nazim. K.A.	Calicut University, Kerala	Dr. C. K. Unnikrishnan
23	Shilu Jahan	Periyar University, Salem	Dr. K. Maya
24	Amrutha. P.R.	Department of Chemistry, Government Women's College, Thiruvananthapuram	Dr. K. Anoop Krishnan
25	Anjana. P.S.	Department of Chemistry, Mar Ivanios College, Thiruvananthapuram	Dr. K. Anoop Krishnan
26	Chaithanya Sunil	Department of Geology, University College, Thiruvananthapuram	Dr. K. Anoop Krishnan
27	Gayatri M. Vastrad	Department of Geology, School of Earth Science, Central University of Karnataka	Dr. K. Anoop Krishnan
28	Helan Priya Pious	Department of Chemistry, St. Berchmans College, Changanassery, Kottayam	Dr. K. Anoop Krishnan
29	Lekshmi. M. G.	Department of Chemistry, Mar Ivanios College, Thiruvananthapuram	Dr. K. Anoop Krishnan
30	Midhu P. Alex	Department of Chemistry, Mar Ivanios College, University of Kerala, Trivandrum, Kerala, India	Dr. K. Anoop Krishnan
31	Anju. M.	S. N College, Punalur	Shri. Badimela Upendra
32	Resmi. R.	S. N College, Punalur	Shri. Badimela Upendra
33	Anu S. Patil	National Institute of Technology, Suratkal	Dr. K. Sreelash
34	Shabna Sherin	M.E.S Ponnani College, Ponnani, Kerala	Dr. P. Arulbalaji
35	Athira. S.	Department of Geology, University College, Thiruvananthapuram	Dr. Upasana S. Banerji
36	Sona Salim. A.	Department of Chemistry, Government Arts College, Thiruvananthapuram	Dr. Upasana S. Banerji

7.5 Ph.D. Students

NCESS provides opportunities to researchers to carry out Ph.D. under recognized research guides of the institute. A total of 33 researchers are pursuing research in different universities of India.

Sl. No.	Research Scholar / Sponsorship	Title of Research	Guide	University / Registration Date
1	Revathy Das	Integrated geo-environmental studies of the lacustrine wetlands of Kerala in climate change paradigms for conservation and management.	Dr. A. Krishnakumar	Kerala / 25.11.2013
2	Aneesh T. D.	Hydrological Studies of an Urban agglomerate, Ernakulam district, Kerala	Dr. Reji Srinivas	CUSAT / 13.12.2013
3	Arun T. J. / MACIS	Studies on selected rivers of different climatic regimes, southern India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
4	Krishna R. Prasad / KSCSTE	Wetland Studies of Akathumuri-Anchuthengu-Kadinamkulam estuarine System, southwest coast of India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
5	Viswadas V. (Part time)	Studies on hydrogeological & biological aspects of various streams of Karamana river near Sree Parasuramaswamy Temple, Thiruvallam, Thiruvananthapuram district, Southern India.	Dr. K. Anoop Krishnan	Kerala / 15.01.2014
6	Salaj S. S. (Part time)	Coastal aquifer Vulnerability assessment and mapping along the Kozhikode coast – A geospatial approach	Dr. D. S. Suresh Babu (Co-Guide)	Bharathidasan / 18.03.2014
7	Parvathy K. Nair / KSCSTE	Development of Vembanad Management action plan through a geological perspective	Dr. D. S. Suresh Babu	Kerala / 30.04.2014
8	Sibin Antony / COMAPS 4	Appraisal of marine ecosystem of Kavaratti island in southwest coast of Kerala with special reference to lagoon system	Dr. K. Anoop Krishnan	Kerala / 23.05.2014
9	Vinu V. Dev / CPT-3	Surface functionalized natural polymers for the adsorptive removal of metal ions at the solid-liquid interface: Kinetic and thermodynamic profile	Dr. K. Anoop Krishnan	Kerala / 09.06.2014
10	Praseetha B. S. / KSCSTE	Geochemistry of estuarine and inner shelf sediments	Dr. T. N. Prakash	CUSAT / 18.12.2014
11	Kunhambu V. / CGWB (Part time)	Characterization and evaluation of the aquifer system of Kuttanad area, Kerala for Sustainable Groundwater Development	Dr. D. S. Suresh Babu	Kerala / 05.01.2015

12	Harsha Mahadevan	Assessment of nutrient flux in urban drainage systems: Identification of sources, pathways and treatment strategies	Dr. K. Anoop Krishnan	Kerala / 01.05.2015
13	Saranya P.	Critical zone characteristics and climate change impacts: A case study from Periyar river basin, southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 01.06.2015
14	Mintu Elezebath George	Investigation on Submarine Groundwater Discharge (SGD), over a segment of northern Kerala, SW India	Dr. D. S. Suresh Babu	CUSAT / 27.11.2015
15	Remya R.	Impact of Sea Level Rise (SLR) on central aquifer in Thiruvananthapuram district, Kerala, India	Dr. D. S. Suresh Babu	Kerala / 16.11.2015
16	Rafeeque M. K. (Part time)	Landform dynamics and its impact of stability of coastal zone of Kozhikode, West coast of India	Dr. D. S. Suresh Babu	Kerala / 30.12.2015
17	Sajna S.	Tectonic and metamorphic evolution of Nagercoil block, South India	Dr. Tomson J. Kallukalam	CUSAT / 16.06.2016
18	Ratheesh Kumar M. (Part time)	Seasonal investigation and evaluation of water quality parameters of Mangalore coast, Karnataka, India: Hydro-chemical, marine biological and speciation approach	Dr. K. Anoop Krishnan	Kerala / 05.09.2016
19	Vipin T. Raj / DST-INSPIRE	Solute dynamics and modelling in the river catchments of Southern Western Ghats, India	Dr. D. Padmalal	CUSAT / 07.03.2017
20	Sribin C. / KSCSTE	Seismic structure of crust and upper mantle along the Western Ghats: Constrain on passive continental margin evolution	Dr. Tomson J. Kallukalam	CUSAT / 24.03.2017
21	Amal Dev J.	UHT metamorphism and fabric analysis in the rocks of western Madurai block: Is continental amalgamation true in the SGT?	Dr. Tomson J. Kallukalam	CUSAT / 03.04.2017
22	Shiny Raj R. / UGC-JRF	Pesticide dynamics and associated biogeochemical processes in the cardamom plantations of Periyar river basin: Focus on speciation studies and mitigation strategies	Dr. K. Anoop Krishnan	CUSAT / 30.06.2017
23	Sandhya Sudhakaran / CSIR-JRF	Speciation and transport characteristics of nutrients in the paddy fields of Netravati River basin: Focus on biogeochemical processes and adsorptive removal studies.	Dr. K. Anoop Krishnan	Kerala / 03.10.2017
24	Gayathri J. A. / KSCSTE	Groundwater resource assessment in selected watersheds of Cauvery river basin, India	Dr. D. Padmalal Dr. K. Maya (Co-guide)	Kerala / 23.10.2017

25	Silpa S./ KSCSTE	Seismic structure of mid-to-upper mantle beneath the Indian Ocean Geoid Low using ambient noise tomography	Dr. N. Purnachandra Rao	CUSAT / 03.04.2018
26	Silpa Thankan/ DST-INSPIRE	A comparative study of palaeofluids in the petroliferous basins of western offshore, India	Dr. V. Nandakumar	Kerala / 28.05.2018
27	Jithu Shaji	Reconstruction of Late Quaternary climate of southern Western Ghats: A multi-proxy approach using sedimentary archives	Dr. D. Padmalal	CUSAT / 04.06.2018
28	Ronia Andrews	Characterization of active tectonic deformation processes in the Indian Ocean lithosphere	Dr. N. Purnachandra Rao	CUSAT / 25.10.2018
29	Micky Mathew	Hydro climatological alterations of Western Ghats: Causes and consequences	Dr. D. Padmalal	CUSAT / 26.10.2018
30	Aditya S. K.	Assessment of global environmental change impacts in Sahyadri: A study of Periyar basin, southern Western Ghats, India	Dr. A. Krishnakumar	Kerala / 03.12.2018
31	Prasenjit Das	Quantification and modelling of selected contaminants in groundwater - A case study from peninsular India	Dr. K. Maya	CUSAT / 29.12.2018
32	Sreeraj M. K. / (Part time)	Sedimentary evolution and depositional history of Aleppey terrace Indian continental margin	Dr. Reji Srinivas	CUSAT / 29.12.2018
33	Swathy Krishna P. S.	Coastal Flooding and related process along the south west coast of India	Dr. L. Sheela Nair	CUSAT / 29.12.2018

8. Library and Publications

8.1 NCESS Library

The library has a collection of around 19000 publications including books, reference books, periodicals, conference proceedings, technical reports, standards specifications, maps, CD-ROM databases, video cassettes etc. The NCESS Library has been using the Koha, an integrated Library Management software package with all the modules for the library housekeeping operations. Using Koha OPAC, users can search the Library online catalogue by Author, Title, Subject and Keywords. This year NCESS library has procured 44 books encompassing the subjects' areas of 'Hydrology, Geology, Atmosphere, Biogeochemistry and Geophysics'. Eight international online journals were also additionally subscribed. To promote Hindi language, we purchased seventeen Hindi books. Implemented Dspace, digital library software and customization of the same. Newspaper clipping and CAS started to up-to-date the library members on the latest development of Earth Science field and whenever NCESS is in news. New additions and arrivals are informed through e mail. Conducted Library Management committee for getting experts comments and recommendations for improving the activities of the library. We conducted physical verification of books and weeding out of obsolete resources through a designated committee during the reporting period.

8.2 Research Papers

8.2.1 In Journals

Amrita Yadav, Kalpna Gahalaut, **Purnachandra Rao, N.** (2018). Role of reservoirs in sustained seismicity of Koyna-Warna region - a statistical analysis. Journal of Seismology, Vol. 22 (4), pp. 909-920. https://doi.org/10.1007/s10950-018-9741-1

Anand Singh, Pankaj K. Mishra, Sharma, S.P. (2019). 2D cooperative inversion of direct current resistivity and gravity data – A case study of uranium bearing target rock. Geophysical Prospecting, Vol. 67 (3), pp. 696-708. https://doi.org/10.1111/1365-2478.12763

Aneesh, T.D., **Reji Srinivas**, Archana M. Nair, **Krishna R. Prasad**, **Arun, T.J.**, Bhuvaneswari Ande (2018). Estimation of runoff with respect to temporal and spatial land use changes in Cochin urban agglomerate, India: A case study of 2018 flood. International Journal of Scientific and Engineering Research, Vol. 9 (11), pp. 498-502. https://doi.org/10.14299/ijser.2018.10.10

Antony Ravindran, A., Mondal, N.C., Ramanujam, N., Sudarsan, R., **Suresh Babu, D.S.** (2018). Geo-diversity and geo-heritage site selection in beach ridge and islands in the eastern coast of southern India. Archaeology and Anthropology: Open Access, Vol. 1 (5). http://dx.doi.org/10.31031/AAOA.2018.01.000522

Arulbalaji, P., **Maya, K.** (2019). Effects of land use dynamics on hydrological response of watershed: A case study of Chittar watershed, Vamanapuram river basin, Thiruvananthapuram district, Kerala, India. Journal of Water Conservation Science and Engineering, Vol. 4 (1), pp. 33-41. https://doi.org/10.1007/s41101-019-00066-5

Arulbalaji, P., **Padmalal, D.**, **Sreelash, K.** (2019). GIS and AHP techniques-based delineation of groundwater potential zones: A case study from southern Western Ghats, India. Scientific Reports, Vol. 9 (1), No. 2082. https://doi.org/10.1038/s41598-019-38567-x

Babu Nallusamy, Syed Hamim Jeelani, Mohammed Aslam, M.A., Akash, K., **Reji Srinivas**, **Suresh Babu, D.S.**, Aleem Pasha, M. (2018). Tholeiitic basalt geochemistry and detailed petrography with emphasis on weathering pattern occurring around Kadaganchi, Aland Taluk, Kalaburagi, Karnataka. Environmental Geochemistry, Vol. 21, No. 1&2, pp. 1-11.

Chandana, K.R., **Upasana S. Banerji**, Ravi Bhushan (2018). Review on Indian Summer Monsoon (ISM) reconstruction since LGM from northern Indian Ocean. Earth Science India, Vol. 11 (1), pp. 71–84.

Dharmadas Jash, **Resmi, E.A.**, **Unnikrishnan, C.K.**, **Sumesh, R.K.**, **Sreekanth, T.S.**, **Nita Sukumar**, **Ramachandran, K.K.** (2019). Variation in rain drop size distribution and rain integral parameters during southwest monsoon over a tropical station: An inter-comparison of disdrometer and Micro Rain Radar. Atmospheric Research, Vol. 217, pp. 24-36. https://doi.org/10.1016/j.atmosres.2018.10.014

Dubey, C.P., Tiwari, V.M. (2018). Gravity anomalies and crustal thickness variations over the Western Ghats. Journal of the Geological Society of India, Vol. 92 (5), pp. 517-522. https://doi.org/10.1007/s12594-018-1059-7

Harsha Mahadevan, **Nayana, A.R.**, **Viswadas, V.**, **Sibin Antony**, **Vinu V. Dev**, **Sandhya Sudhakaran**, **Helan Priya Pious**, **Anoop Krishnan, K.** (2019). A pilot level approach to remove anionic species from industrial effluents using a novel carbonate-steam pyrolysed activated charcoal system. Advanced Powder Technology, Vol. 30 (1), pp. 98-110. https://doi.org/10.1016/j.apt.2018.10.011

Hema C. Nair, **Padmalal, D.**, Ammini Joseph, Vinod, P.G. (2018). Hydrogeochemistry and water quality assessment of shallow aquifers in the western flanks of southern Western Ghats, SW India. Arabian Journal of Geosciences, Vol. 11 (4), Art. 73. https://doi.org/10.1007/s12517-018-3401-1

Joshi, K.B., Slabunov, A.I. (2019). Neoarchean sanukitoids from the Karelian and Bundelkhand cratons: comparison of composition, regional distribution and geodynamic setting. Transactions of Karelian Research Centre of Russian Academy of Science, No. 2, Precambrian Geology Series, pp. 5-25. http://dx.doi.org/10.17076/geo841

Kaliraj, S., Chandrasekar, N., **Ramachandran, K.K.**, Selvakumar, S. (2019). Seawater intrusion vulnerability in the coastal aquifers of southern India – An appraisal of the GALDIT model, parameters' sensitivity, and hydrochemical indicators. Environmental Science and Pollution Research, Vol. 26 (10), pp. 9755-9784. https://doi.org/10.1007/s11356-019-04401-0

Kumaran, K.P.N., **Padmalal, D.**, Ruta B. Limaye, Vishnu Mohan, S. (2018). Signatures of Holocene hydrological processes from sedimentary archives in south western India: Case studies from wetlands of Kerala coast. Journal of the Geological Society of India, Vol. 92 (5), pp. 596-606. https://doi.org/10.1007/s12594-018-1073-9

Lakshmanna, B., Jayaraju, N., Lakshmi Prasad, T., **Sreenivasulu, G.**, Nagalakshmi, K., Pramod Kumar, M., Madakka, M. (2018). Data on Molluscan shells in parts of Nellore coast, southeast coast of India. Data in Brief, Vol. 16, pp. 705-712. https://doi.org/10.1016/j.dib.2017.11.081

Mahesh Prasad Parija, Sushil Kumar, Tiwari, V.M., **Purnachandra Rao, N.**, Narendra Kumar, Shubhasmita Biswal, Ishwar Singh (2018). Microseismicity, tectonics and seismic potential in the Western Himalayan segment, NW Himalaya, India. Journal of Asian Earth Sciences, Vol. 159, pp. 1-16. https://doi.org/10.1016/j.jseaes.2018.03.016

Maya, K., **Prasenjit Das**, **Sreelash, K.**, Narendra Babu, K. (2018). The coastal springs of southern Kerala, SW India - Hydrology and water quality assessment. Journal of the Geological Society of India, Vol. 92 (5), pp. 616-625. https://doi.org/10.1007/s12594-018-1075-7

Mayank Joshi, **Rajappan, S.**, **Prasobh Rajan, P.**, **Mathai, J.**, **Sankar, G.**, **Nandakumar, V.**, Anil Kumar, V. (2018). Weathering controlled landslide in Deccan traps: Insight from Mahabaleshwar, Maharashtra. Journal of the Geological Society of India, Vol. 92 (5), pp. 555-561. https://doi.org/10.1007/s12594-018-1067-7

Mercy Varghese, Thara V. Prabha, Murugavel, P., Anu, A.S., **Resmi, E.A.**, Dinesh, G., Jaya Rao, Y., Baban Nagare, Safai, P.D., Sathy Nair, Nandakumar, K., Vishnu, R., Bhavani Kumar, Y. (2019). Aerosol and cloud droplet characteristics over Ganges Valley during break phase of monsoon: A case study. Atmospheric Research, Vol. 220, pp. 125-140. https://doi.org/10.1016/j.atmosres.2019.01.013

Mintu Elezebath George, **Suresh Babu, D.S.**, **Akhil, T.**, **Rafeeque, M.K.** (2018). Investigation on submarine groundwater discharge at Kozhikode coastal aquifer, SW Western Ghats. Journal of the Geological Society of India, Vol. 92 (5), pp. 626-633. https://doi.org/10.1007/s12594-018-1077-5

Nagalakshmi, K., Madri Pramod Kumar, Lakshmi Prasad, T., Jayaraju, N., Lakshmanna, M., **Sreenivasulu, G.** (2018). A study on textural parameters of beach sands along some parts of the Nellore coast, east coast of India: Implications to depositional environment. Journal of Indian Geophysical Union, Vol. 22 (5), pp. 558-567.

Nandakumar, V., Simon L. Harley (2019). Geochemical signatures of mid-crustal melting processes and heat production in a hot orogen: The Kerala khondalite belt, southern India. Lithos, Vol. 324-325, pp. 479-500. https://doi.org/10.1016/j.lithos.2018.11.016

Padmalal, D., **Sreelash, K.**, **Vipin T. Raj**, Sajan, K. (2018). River discharge, major ion chemistry and sediment transport of the Bharathapuzha river, southwest India: Implications on catchment erosion. Journal of the Geological Society of India, Vol. 92 (5), pp. 568-578. https://doi.org/10.1007/s12594-018-1069-5

Prakash Pithani, Sachin D. Ghude, Thara Prabhakaran, Anand Karipot, Anupam Hazra, Rachana Kulkarni, Subharthi Chowdhuri, **Resmi, E.A.**, Mahen Konwar, Murugavel, P., Safai, P.D., Chate, D.M., Tiwari, Y., Jenamani, R.K., Rajeevan, M. (2018). WRF model sensitivity to choice of PBL and microphysics parameterization for an advection fog event at Barkachha, rural site in the Indo-Gangetic basin, India. Theoretical and Applied Climatology. https://doi.org/10.1007/s00704-018-2530-5

Purnachandra Rao, N., Kusumita Arora, Alexander Ponomarev, Aderson Farias do Nascimento (2018). Introduction to the special issue "Fifty years after the 1967 Koyna earthquake - Lessons learned about Reservoir Seismicity (RTS). Bulletin of the Seismological Society of America. https://doi.org/10.1785/0120180240

Qiong-Yan Yang, Sohini Ganguly, Shaji, E., Yunpeng Dong, **Nandakumar, V.** (2019). Extensional collapse of the Gondwana orogen: Evidence from Cambrian mafic magmatism in the Trivandrum block, southern India. Geoscience Frontiers, Vol. 10 (1), pp. 263-284. https://doi.org/10.1016/j.gsf.2017.12.002

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9. Distinguished Visitors

9.1 Visit of Researchers from Abroad

Dr. Eric Wolanski, Professor; Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University, Australia delivered a talk on "Field and model studies of the nepheloid layer in coastal waters of the Great Barrier Reef, Australia" at National Centre for Earth Science Studies as part of Earth Science Forum on 18th March 2019.

Prof. Neil Dixon, Professor, Geo-technical Engineering, Loughborough University, United Kingdom was the Chief Guest of the Mastermind Session on "Landslide Hazards in India" held at National Centre for Earth Science Studies on 10th January 2019.

Dr. Till Oehler, Post-Doctoral Fellow in Working Group on Submarine Groundwater Discharge, Leibniz Centre for Tropical Marine Research (ZMT), Germany delivered a talk on "The work carried out in Kerala coast and investigations at Varkala Subterranean Estuary" at National Centre for Earth Science Studies as part of Earth Science Forum on 16th November 2018.

Dr. Niel Hamilton Williams, Teledyne Cetac Technologies, USA delivered a talk on "LA-ICP-MS technique and its applications" at National Centre for Earth Science Studies as part of Earth Science Forum on 11th October 2018.

Ms. Mithra-Christin Hajati, Ph.D. Scholar, Working Group on Submarine Groundwater Discharge at Leibniz Centre for Tropical Marine Research (ZMT), Germany presented her work on "A new approach to model fresh Submarine Groundwater Discharge (FSGD)" at National Centre for Earth Science Studies on 10th May 2018.

10. Conference, Seminar & Workshop

10.1 Brain Storming Session on Coastal Flooding

A one-day brain storming session on coastal flooding was organized by Coastal Processes at NCESS on 7th September 2018. In the morning session, senior scientists from NCCR, Chennai; NIO, Goa; NIOT, Chennai and NCESS presented on various aspects of coastal flooding and shared their experience on studies/ researches related to coastal flooding events observed along the Indian coast. This was followed by a Panel Discussion in the afternoon in which Dr. M. Baba, Dr. N. P. Kurian, engineers / senior officers / scientists from various government departments of Kerala viz. CPDAC, Irrigation dept., Harbour engineering dept., Fisheries dept., IMD Trivandrum, KERI, etc. participated. Dr. T. N. Prakash and Dr. M. V. Ramana Murthy were the moderators for the panel discussion.

10.2 Mission SGD: National Network Project - First Interaction Meeting of Project Participants

MoES has approved implementation of first phase of the national network project "Unravelling Submarine Groundwater Discharge (SGD) zones along the Indian subcontinent and its islands (Mission-SGD)" - Pilot Study. In order to formulate the roadmap of project activities for the period 2018-19, a one-day meeting of project participants and special invitees was arranged by NCESS at Central Residency Hotel on 12th October 2018. Officials from MoES, CGWB, SGWD; and participants from BARC, PRL, NIH, NGRI, NIO, IIT, JNU, Anna University, Manipal Academy of Higher Education, NITK, CUSAT, KU, PU, VOC College and NCESS attended the meeting.

10.3 Mastermind Session on Landslide Hazards

A Mastermind Session on "Landslide Hazards in India" was organized on 10th January 2019 by Crustal Processes Group at National Centre for Earth Science Studies. Prof. Neil Dixon (Professor of Geo-technical Engineering, Loughborough University, United Kingdom) delivered the keynote address. Prof. S. K. Tandon (Professor Emeritus, University of Delhi) chaired the sessions. A total of 20 research outputs on the recent scenario of landslides in India were presented and discussed by the experts and about 10 research papers were chosen for a special volume on landslide investigations in India.

10.4 Training Programme for International Seabed Authority

A training programme was conducted for representatives from International Seabed Authority (ISA) countries at National Centre for Earth Science Studies during 14-20 January 2019. The delegates interacted with Group Heads, scientists and visited the laboratories. They also visited Indian Rare Earths Limited, Kollam; High Altitude Cloud Physics Observatory, Munnar; and landslide-hit locations in Idukki district.

10.5 Training Programme on Regional Ocean Modelling System

Coastal Processes Group, NCESS organized a 3-day training programme on Regional Ocean Modelling System (ROMS) for oceanographic data processing during 22-24 January 2019. The classes were handled by Prof. Arun Chakraborty (Professor; Centre for Oceans, Rivers, Atmosphere and Land Science; IIT Kharagpur).

10.6 Hindi Workshop at National Centre for Earth Science Studies

With an aim of creating awareness on the importance of Hindi in Central Government Offices for Official purpose, a Hindi Workshop was organized on 04th June 2018 at NCESS. Shri. M. G. Som Shekharan Nair, Senior Hindi Officer, Vikram Sarabhai Space Centre (VSSC) was the guest faculty. Dr. N. Purnachandra Rao, Director, NCESS inaugurated the workshop. Dr. D. S. Suresh Babu, Chief Manager (i/c), NCESS welcomed the gathering and Smt. G. Lavanya, Hindi Implementation Officer, NCESS proposed vote of thanks. During this workshop, NCESS Hindi website was launched by the Director and Hindi Magazine 'Prithvi' was released by the chief guest.

A quarterly Hindi workshop was held on 26th December 2018 at NCESS. The topic of discussion was "The effective implementation of official language in NCESS". Smt. V.S. Rajasree, Hindi translator, conducted the class.

10.7 Workshop on Prevention of Sexual Harassment of women at workplace (POSH)

A workshop on "Prevention of Sexual Harassment of women at workplace (POSH)" was organized by NCESS - Internal Complaints Committee on 15th February

2019 at National Centre for Earth Science Studies. Dr. S. Anitha, Assistant Professor, Loyola College of Social Sciences, Thiruvananthapuram and External member, NCESS - Internal Complaints Committee delivered the talk.

10.8 Workshop on Official Language Rules

A workshop on "Information about Official Language Rules" was held on 6th March 2019 at National Centre for Earth Science Studies. Shri. Pramod Kumar Sharma, Senior Translation Officer, Ministry of Earth Sciences delivered the talk.

10.9 Invited Lectures / Chairing of Technical Sessions

Dr. N. Purnachandra Rao

Delivered an invited talk on "Earthquakes and Tsunamis" in Banaras Hindu University, Varanasi on 20th April 2018.

Attended as the Chief Guest and delivered the keynote address in the Symposium on Landslides: Analysis, Mitigation and Case studies held at Cochin University of Science and Technology (CUSAT) on 1st December 2018.

Attended the panel discussion on "Our Environment – Our Future: Science and technology for rebuilding Kerala" organized as a part of 31st Kerala Science Congress held at Fatima Mata National College, Kollam on 2nd February 2019.

Attended as the Chief Guest and delivered the keynote lecture in the 2nd International Conference on Geology: Emerging Methods and Applications (GEM-2019) held at Christ College, Thrissur on 17th January 2019.

Dr. D. Padmalal

Delivered a key note address on "River Manimala and its Eco System" at Dept. of Botany, Bishop Abraham Memorial College, Pathanamthitta on 19th February 2019.

Delivered a key note address in the seminar on the subject "Pralayananthara Pambayum Maramannum" (in local language) in connection with 124th Maramon Convention at Maramon Retreat Centre, Pathanamthitta on 5th February 2019.

Delivered a talk on "Freshwater sources of Kerala: Environmental threats and management strategies" in the National Seminar on Surface water and ground water resources of Kerala: Management issues, policies, future strategies, jointly organized by Dept. of Geology, University of Kerala & Geological Society of India on 15th March 2019.

Attended a meeting in the Board Room, IDRB, Vikas Bhavan, Thiruvananthapuram, for preparation of road map for implementation of National Water Policy (NWP) on 12th March 2019.

Delivered a key note address on "Wetlands for sustainable future" in the Department of Environmental Sciences, University of Kerala on 28th February 2019.

Attended a meeting with Chief Conservator of Forest & HoFF, Govt. of Kerala and made a presentation on 'Assessment of sand & gravel deposit in Pamba – Triveni' on 23rd March 2019.

Delivered a talk in Govt. L.P.S Kokkothamangalam, Mundela, Thiruvananthapuram on 17th April 2018.

Dr. K. K. Ramachandran

Delivered a lecture on the event of Public Awareness Programme at Atomic Minerals Division, Thiruvananthapuram on 3rd April 2018.

Delivered a talk in connection with World Ocean Day Celebrations organized by Centre for Marine Biodiversity and Department of Aquatic Biology & Fisheries of University of Kerala at Kerala University, Kariavattom campus on 8th June 2018.

Delivered presentations on Coastal Zone Management Plan and attended the discussions and public hearing at Kasaragod, Kannur, Kozhikode, Ernakulam Districts during July - August 2018.

Delivered an invited lecture on "Glimpses of modern geoinformatics" at Department of Geography, Kannur University on 10th August 2018.

Delivered a talk on "Climate change scenario and natural disaster management" engulfing the focal theme "Keep cool and carry on the Montreal Protocol" in connection with Ozone Day Celebration on 25th September 2018.

Inaugurated the Geology Association and delivered a talk on "Remote Sensing - Basic principles and applications" at Department of Geology, Kristu Jyoti College of Management and Technology, Changanacherry on 16th November 2018.

Delivered a lecture on "Application of geospatial techniques on marine sector" in Winter School at Central Marine Fisheries Research Institute, Kochi on 27th November 2018.

Chaired a session in the 'World Conference on Brackish-water Aquaculture (BRAQCON 2019)' at Chennai on 24th January 2019.

Dr. D. S. Suresh Babu

Delivered a talk on "Management options of coastal aquifers having Submarine Ground Discharge" in the National Seminar on Surface water and ground water resources of Kerala: Management issues, policies, future strategies, jointly organized by Dept. of Geology, University of Kerala & Geological Society of India on 15th March 2019

Delivered a talk on "Submarine Groundwater Discharge: Impacts on coastal ecosystems" in the seminar conducted by Water Resources Department, Govt. of Kerala on the occasion of World Water Day at Thiruvananthapuram on 22nd March 2019.

Dr. L. Sheela Nair

Delivered an invited lecture on "Data requirement, availability and data gaps for coastal design" in connection with AICTE sponsored short-term course 'Research avenues in coastal engineering' at Dept. of Civil Engineering, TKM College of Engineering, Kollam on 14th January 2019.

Dr. K. Anoop Krishnan

Delivered an invited lecture on "Significance of water-air pollution in river basin concept" on the occasion of World Environment Day Celebration-2019 at Dept. of Chemistry, Mahatma Gandhi College, Thiruvananthapuram on 28th June 2019.

Delivered an invited lecture on "Hydrochemistry of River Basins: Monitoring and Mitigation Studies" in the National Seminar on Advanced Functional Materials for Analytical. Energy, Environmental and Biomedical Applications (NSAFM 2019) held at Dept. of Chemistry, University of Kerala, Thiruvananthapuram on 26th March 2019.

Delivered an invited lecture on "Hydrochemistry: Significance of the study in river basin point of view" in the National Seminar on Modern Trends in Chemical Sciences held at Dept. of Chemistry, Scott Christian College, Nagercoil, Tamil Nadu on 19th March 2019.

Delivered a talk on "Environmental Protection and Waste Management" in the Residential 'Sahavasa' Camp at St. Mary's Public School, Neyyattinkara, Thiruvananthapuram on 22nd February 2019.

Attended as the Chief Guest of the Seminar on Wetlands: Threatened Land Scape held at Dept. of Zoology, St. Thomas College, Kozhencheri, Pathanamthitta and delivered keynote address on "River basins of Western Ghats: Hydro biogeochemical aspects of wetlands" on 04th February 2019.

Attended as the Chief Guest of the World Wetland Day Celebrations 2019: Wetlands and Climate Change held at Dept. of Chemistry, Sree Narayana College, Chengannur and delivered a talk on "River basins of Western Ghats: Hydrochemistry of Groundwater Resources" on 1st February 2019.

Delivered an invited lecture on "Importance of Chemistry in view of mega flood in Kerala-2018" in the National Seminar on Recent Research and Developments in Chemistry (RRDC-2018) held at Dept. of Chemistry, B.J.M. Govt. College, Chavara, Kollam on 30th October 2018.

Delivered an invited lecture on the Awareness Programme on Environmental Protection and Management of Achankovil River held at Dept. of Zoology, NSS College, Pandalam on 12th March 2018.

Delivered an invited lecture on "Water Resources and Pesticide Pollution" in connection with National Science Day Celebration-2018 with focal theme on Science and Technology for Sustainable Future held at Dept. of Zoology, St. Gregorios College, Kottarakkara, Kerala, India on 28th February 2018.

Delivered an invited lecture on "Water Chemistry and Monitoring Studies" in connection with National Science Day Celebration-2018 with focal theme on Science and Technology for Sustainable Future held at Dept. of Zoology, SN College, Kollam on 27th February 2018.

Dr. S. Kaliraj

Delivered a talk on "Seawater intrusion, vulnerability, assessment and modelling" at Centre for Geotechnology, Manonmaniam Sundaranar University, Tirunelveli.

Invited as 'Resource Person' to NRDMS - DST sponsored "Winter School Training Programme on Geospatial Technologies" organized by Geo-informatics & Building Technology Research Centre, Chitkara University, Himachal Pradesh.

10.10 Papers presented in Conference / Seminar / Symposium

Name	Conference/Seminar/Symposium	Title of the paper / poster
Resmi E. A.	European Geosciences Union General Assembly 2018 at Vienna, Austria during 08-13 April 2018.	Monsoon low level jet and the variation in thermal structure in wet and dry rainfall episodes over southwest India.
Prakash T. N.	International Conference of Geology and Earth Science at Rome, Italy during 02-04 May 2018.	Placer mineral deposits of south west coast of India: their sustainable exploitation and environment management.
Ramesh Madipally, Sheela Nair L., Anoop T. R., Ramachandran K. K., Prakash T. N.	3rd International Conference of Coastal Zones and Oceanography at Singapore during 18-19 May 2018.	Monitoring of near-shore dynamics in southwest coast of India- A video imagery approach.
Kaliraj S., Chandrasekar N., Ramachandran K. K.	International Conference on Impact of Climate Change on Water Resources at Periyar University, Tamil Nadu during 11-13 July 2018.	Groundwater management modelling for watershed development agencies: An evaluation of multiple geo, environment and climatic factors for site-specific runoff harvesting structures – Palakkad District, Kerala.
Salaj S. S.	International Conference on Impact of Climate Change on Water Resources at Periyar University, Tamil Nadu during 11-13 July 2018.	Seawater intrusion: GIS based GALDIT model.
Rajeevan K., Resmi E. A., Nita Sukumar, Ramachandran K. K., Sumesh R. K.	International Symposium on Atmospheric Pollution: Science, Technology, Innovation and Compliance at NIT Calicut during 07-11 August 2018.	Observational study of greenhouse gases (CO_2 and CH_4), CO and total NMHC at Trivandrum: A tropical inland site in South India.
Arulbalaji P., Upasana S. Banerji, Maya. K., Padmalal D.	National Seminar on Effects of Paleo and Anthropogenic Events on Earth System and Annual General Meeting of Geological Society of India at Periyar University during 19-21 September 2018.	Signatures of Late Quaternary land-sea interactions and landform dynamics along southern Kerala coast, SW India.
Upasana S. Banerji, Padmalal D.	National Seminar on Effects of Paleo and Anthropogenic Events on Earth System and Annual General Meeting of Geological Society of India at Periyar University during 19-21 September 2018.	Imprints of Holocene climate instability on Indian Summer Monsoon – An overview.
Sreekanth T. S., Nita Sukumar, Resmi E. A.	National Symposium on Understanding Weather and Climate Variability: Research for Society (TROPMET – 2018) during 24-27 October 2018	Seasonal variations of raindrop size distribution in different rain types at a tropical coastal site.
Gayathri J. A., Maya K., Sreelash K., Padmalal D.	28th Swadeshi Science Congress during 07-09 November 2018.	Hydrochemical assessment of groundwater in Bhavani river basin.

Vipin T. Raj, Sreelash K., Sajan K., Padmalal D.	28th Swadeshi Science Congress during 07-09 November 2018.	Major ion chemistry and sediment transport of Bhavani river, Kerala, SW India.
Mintu Elezebath George	American Geophysical Union (AGU) Fall Meeting 2018 at Washington DC, USA during 10-14 December 2018.	Multi proxy approach in understanding Submarine Groundwater Discharge in the tropical unconfined aquifers of south west coast of India.
Padma Rao B.	American Geophysical Union (AGU) Fall Meeting 2018 at Washington DC, USA during 10-14 December 2018.	Anisotropy in the lowermost mantle beneath the Indian Ocean Geoid Low: insights from ScS splitting measurements.
Parvathy K. Nair, Suresh Babu D. S.	2nd International Seminar on Geology: Emerging Methods and Applications (GEM 2019) at Christ College, Thrissur during 17-19 January 2019.	Evaluation of trace element concentration in the shallow aquifers around Vembanad Lake and its suitability for drinking purpose.
Padma Rao B.	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Crustal structure across and along the Western Ghats: Insights from Ps converted phases.
Vincent A. Ferrer, Senpakapriya, Reji Srinivas, Ramachandran K. K.	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Submergence of Munroe island: Quantifiable insights from satellite based DInSAR time series.
Vandana M., Maya K., Arulbalaji P., Jithu Shaji	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Environmental impact of mining and quarrying in Netravati-Gurpur river basins: A geo-environmental appraisal.
Gayathri J. A., Maya K., Sreelash K., Padmalal D.	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Major ion concentration in the groundwater sources of Bhavani river basin (Kerala) - its implications on silicate weathering.
Vipin T. Raj, Gayathri J. A., Sreelash K., Sajan K., Padmalal D.	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Solute transport through the rivers draining Silent Valley and adjoining regions of southern Western Ghats.
Aditya S. K.	International Conference on Climate Change Impacts, Vulnerabilities and Adaptations at IIT Kharagpur during 26th February – 02nd March 2019.	Assessment of global environmental change impacts in Sahyadri: A comparative evaluation of nutrient levels during the pre and post flood times in Periyar river basin, southern Western Ghats, India.
Rajeevan K., Resmi E. A., Nita Sukumar, Ramachandran K. K., Sumesh R. K.	International Conference on Air pollution and Monitoring 2019 at MG University, Kottayam during 08-11 March 2019.	Characteristics of surface ozone and its precursors over a tropical station Trivandrum.

Vipin T. Raj, Gayathri J. A., Maya K., Sreelash K., Padmalal D.	Brainstorming session on Surface Water and Groundwater Resources of Kerala: Management Issues, Policies, and Future Strategies at University of Kerala on 15th March 2019.	Geochemical evolution of major ions and role of silicate weathering in groundwater of upper Bhavani River basin Kerala India.
Vipin T. Raj, Gayathri J. A., Vandana M., Sreelash K., Sajan K., Padmalal D.	Brainstorming session on Surface Water and Groundwater Resources of Kerala: Management Issues, Policies, and Future Strategies at University of Kerala on 15th March 2019.	Major element chemistry of the Bhavani river, Kerala, SW India - Weathering processes and solute transport.
Merin Mariam Mathew, Micky Mathew, Sreelash K.	Brainstorming session on Surface Water and Groundwater Resources of Kerala: Management Issues, Policies, and Future Strategies at University of Kerala on 15th March 2019.	Acceleration of hydrological cycle: Evidences from the river basins of Kerala
Prasenjit Das, Maya K., Vivek Vijayan, Silpa Mathew, Arya S.	National Seminar on Aquatic Chemistry (Aquasem'19) at Cochin University of Science and Technology (CUSAT) during 21-23 March 2019.	Hydrochemistry of the thermal springs of the southern Karnataka, India.
Upendra B., Maya K., Anoop Krishnan K., Padmalal D.	National Seminar on Aquatic Chemistry (Aquasem'19) at Cochin University of Science and Technology (CUSAT) during 21-23 March 2019.	Hydrochemical assessment of Cauvery river basin (southern India) with special reference to CO_2 consumption rates and silicate weathering
Rajeevan K., Resmi E. A., Nita Sukumar, Ramachandran K. K., Sumesh R. K.	International Conference on Atmospheric Chemistry and Physics in Highly Polluted Environments organized by CIASS at IIT Delhi during 22-24 March 2019.	5-year measurement of surface ozone, carbon monoxide and methane over a tropical station Trivandrum.
Tinku C. D. S., Unnikrishnan C. K., Rajeevan K., Sumesh R. K., Resmi E. A.	International Conference on Atmospheric Chemistry and Physics in Highly Polluted Environments organized by CIASS at IIT Delhi during 22-24 March 2019.	Contribution of Arabian Sea on air pollution: A study over Thiruvananthapuram coastal region.
Remya R., Akhil T., Suresh Babu D. S., Mintu Elezebath George	31st Kerala Science Congress at Fatima Mata National College, Kollam during 02-03 February 2019.	Groundwater-Seawater interaction along Thiruvananthapuram coast, Kerala.
Ramesh Madipally, Sheela Nair L., Ramachandran K. K., Prakash T. N.	Young Scientist Conference - 4th India International Science Festival (IISF) at Lucknow, Uttar Pradesh during 5-8 October 2018.	Indigenous development of advanced video imagery methods for high-resolution observations of coastal processes.

11. Extension Activities

11.1 NCESS Foundation Day Lecture 2018

National Centre for Earth Science Studies celebrated its foundation day on 23rd April 2018. The Foundation Day Lecture was delivered by Padma Bhushan Dr. B. N. Suresh (President, Indian National Academy of Engineering, New Delhi; Chancellor, Indian Institute of Space Science and Technology, Trivandrum; Distinguished Professor, ISRO HQ, Bangalore). The title of the talk was on "Advanced Technologies and National Development". Dr. N. Purnachandra Rao, Director, NCESS gave the welcome address and also honoured the Chief Guest for his outstanding contribution on the field of space science and technology by offering 'Ponnada' and Memento. Dr. T.N. Prakash, Scientist-G & Group Head, Coastal Processes Group introduced the speaker and read the citation. The citation was then handed over to Dr. B. N. Suresh. The function concluded with the vote of thanks by Dr. K. K. Ramachandran, Scientist-F & Group Head, Atmospheric Processes Group.

11.2 International Day for Biological Diversity

As a part of celebration of International Day for Biological Diversity 2018, the Kerala State Biodiversity Board (KSBB), Government of Kerala arranged a training programme for the Biodiversity Management Committee (BMC) members at state level. The inaugural function was held in Nila auditorium on 22nd May 2018 in the gracious presence of two Honorable Ministers of Government of Kerala. Director, NCESS offered the felicitations.

11.3 International Day of Yoga 2018

National Centre for Earth Science Studies organized a Yoga training session on 21st June 2018 for all employees as part of the celebration International Day of Yoga 2018. The Yoga training session was carried out by Ms. Kavitha, Senior Faculty, The Art of Living, Thiruvananthapuram and introduced the basic concepts and practices of yoga to the participants.

11.4 Swachhata Pakhwada / Swachhata Hi Seva

As part of the Swachhata Pakhwada 2018, a "Shrama-daan" or campus cleaning program was organized at National Centre for Earth Science Studies on 13th July 2018. NCESS also undertook various maintenance and renovation activities including construction of toilets in Government Upper Primary School, Cheruvickkal as a part of the Swachhata Hi Seva 2018 campaign. Dr. N. Purnachandra Rao, Director, NCESS inaugurated the cleaning activities on 26th September 2018 at the premises of the Government Upper Primary School, Cheruvickkal. Also, in connection with Swachhata Hi Seva campaign, the staff of National Centre for Earth Science Studies undertook the cleaning of Akkulam-Pulayanarkotta road in front of the institute and its premises on 04th February 2019. Dr. N. Purnachandra Rao, Director NCESS, addressed the gathering and distributed the cleaning materials.

11.5 Contribution to Kerala Flood Relief

The entire NCESS community joined their hands together on 17th August 2018 for contributing relief items to the much-distressed people of Kerala affected by the worst natural calamity the State ever witnessed. The initiative under the banner of NCESS Recreation Club was well received by the community on a short notice and all the staff members pitched in by donating necessary items based on the requests from relief camps.

11.6 Hindi Fortnight Celebrations

Hindi fortnight during the year 2018-19 was organized during 3-17 September, 2018. Dr. J. C. Joshi IFS (Director, Kerala State Biodiversity Board) was the Chief Guest of the inaugural ceremony on 3rd September 2018. As part of the celebration, NCESS organized various competitions like noting, drafting, Hindi song, elocution, quiz etc. The valedictory function was held on 17th September 2018. Shri. Ramesh Chennithala (Member and Leader of Opposition, Kerala State Legislative Assembly) was the Chief Guest. The prizes for the winners of various competitions were awarded by the Chief Guest on the valedictory function.

11.7 Vigilance Awareness Week

As per the circular from Central Vigilance Commission, the Vigilance Awareness week was observed from 29th October to 3rd November 2018. NCESS employees took the integrity pledge to mark the solidarity with the vision of corruption-free India.

11.8 World Hindi Day

The World Hindi Day was celebrated on 10th January 2019 at National Centre for Earth Science Studies. The programme started with the welcome address by Dr. N. Purnachandra Rao, Director, NCESS. Dr. B. K. Bansal, Scientist-G & Programme Officer (NCESS) inaugurated the programme. A Hindi song competition was arranged as a part of the celebrations.

11.9 National Science Day

National Science Day was observed at National Centre for Earth Science Studies on 28th February 2019. Dr. Radhika Ramachandran, Director, Space Physics Laboratory, Thiruvananthapuram was the Chief Guest and delivered a lecture on "Dr. C.V. Raman: The person and Scientist".

11.10 International Day for Women

The staff of National Centre for Earth Science Studies celebrated the International Day for Women on 8th March 2019. Dr. J. Latha, Former Vice Chancellor, Cochin University of Science and Technology; Former Director, Technical Education Kerala was the Chief Guest on the occasion.

11.11 Earth Science Forum

The Earth Science Forum of NCESS organized 10 talks on different themes of Earth Science by eminent scientists and researchers from India and abroad. Dr. Thamban Meloth, Scientist-F & Group Director (Polar Sciences), National Centre for Antarctic and Ocean Research (NCAOR), Goa delivered a talk on "Cryosphere - Past, Present and Future" on 23rd April 2018. During May 2018, a talk on "Landslide prediction and monitoring of an active slide at Chibo Pashyar, Kalimpong, West Bengal" was given by Dr. Neelima Satyam, Associate Professor, IIT Indore. Ms. Mithra-Christin Hajati, Ph.D. Scholar, Working Group on Submarine Groundwater Discharge at Leibniz Centre for Tropical Marine Research (ZMT), Germany presented her work on "A new approach to model fresh Submarine Groundwater Discharge (FSGD)". In July 2018, Dr. Eswar Rajasekar, Assistant Professor, IIT Bombay) delivered a talk on "Thermal Remote Sensing and its hydrological applications". Dr. Kusumita Arora, Principal Scientist and Head of Magnetic Observatory, CSIR-NGRI, Hyderabad delivered a talk on "Geomagnetism in Equatorial Regions". Prof. Vinod Kumar Gaur, Honorary Emeritus Scientist, CSIR-Fourth Paradigm Institute, Bangalore delivered a talk on "After the Deluge: Towards Knowledge-guided Resilience" on 31st August 2018. On 11th October 2018, Dr. Niel Hamilton Williams (Teledyne Cetac Technologies, USA) delivered a talk on "LA-ICP-MS technique and its applications". During January 2019, Prof. Arun Chakraborty, Professor; Centre for Oceans, Rivers, Atmosphere and Land Science; IIT Kharagpur delivered a talk on "Coupled model study on upper ocean heat content and cyclone-eddy interactions over the Bay of Bengal". Prof. P.N. Vinayachandran, Professor; Centre for Atmospheric and Ocean Sciences, IISc, Bengaluru delivered a talk on "Encounters with a fascinating bay". Dr. Eric Wolanski, Adjunct Professor, Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University, Australia delivered a talk on "Field and model studies of the nepheloid layer in coastal waters of the Great Barrier Reef, Australia" on 18th March 2019.

11.12 NCESS Basic Geosciences Lecture Series for Young Researchers and Scientists

The NCESS Basic Geosciences Lecture Series in 2018-19 consisted 11 lectures by eminent scientists and researchers. The first lecture in the series was delivered by Prof. L. Elango, Department of Geology, Anna University on the topic "Hydrogeology: Theory and Methods" on 12th June 2018. The second lecture was delivered by Prof. S. Balakrishnan, Department of Earth Sciences, Pondicherry University on "Principles of Isotope Geology and its Applications". Prof. Gopal Krishna Panda, Utkal University, Odisha delivered lectures on "Map Basics, Cartography" and "Introduction to Geomorphology". Prof. Santhosh Kumar, Kumaun University, Nainital delivered a lecture on "Principles of Geochemistry & using Geochemical Data" on 26th June 2018. Dr. N. Purnachandra Rao, Director, NCESS delivered a lecture on "Introduction to Seismology". In July 2018, Prof. V. Sundar, IIT Madras delivered a lecture on "Wave Mechanics and Coastal Processes"; Prof. Mohan Kumar, CUSAT delivered a lecture on "Introduction to Atmospheric Processes and Dynamic Meteorology"; Prof. Anindya Sarkar, IIT Kharagpur delivered a lecture on "Introduction to Stable Isotope Geochemistry"; and Prof. K Vijaya Kumar, SRTM University, Maharashtra delivered a lecture on "Introduction to Igneous Petrology". The tenth lecture was delivered by Prof. T. R. K. Chetty, CSIR-NGRI & Visiting Fellow, University of Hyderabad on the topics "Introduction to Structural Geology: Shear zones, Suture Zones, Southern Granulite Terrane, Eastern Ghats Mobile Belt". In March 2019, Dr. B. Nagender Nath, National Institute of Oceanography, Goa delivered lectures on "Geochemical perspective of oceanic sedimentation" and "Oceanic mineral resources".

11.13 Technical Visits to NCESS

Students from various schools, colleges, university departments visited NCESS during the reporting year. On 17th January 2019, the participants of the one-week AICTE sponsored short-term course on "Research avenues in coastal engineering" conducted by Dept. of Civil Engineering, TKM College of Engineering, Kollam visited NCESS. As a part of 'Shastrapadam', a three-day science workshop by Samagra Shiksha Kerala and Kerala Higher Secondary Education Department, a batch of 60 students from XIth standard of selected schools in Kerala visited NCESS on 21st January 2019. On 6th February 2019, the students from Christ College, Thrissur visited our institute as a part of 'Walk with a Scholar' programme organized by Government of Kerala.

12. Staff Details

12.1 Director's Office

Dr. N. Purnachandra Rao	Director
Dr. N. Anilkumar	Scientist-F, Head DTC
Smt. Jinitha Madhavan	Coordinator Gr. III (since June 2018)
Shri. S. R. Unnikrishnan	Scientific Asst. Gr. A (since June 2018)
Smt. T. Remani	MTS
Shri. R. Binu Kumar	MTS

12.2 Crustal Processes (CrP)

Dr. V. Nandakumar	Scientist-G & Head
Smt. Sreekumari Kesavan	Scientist-E
Dr. Tomson J. Kallukalam	Scientist-D
Dr. A. Krishnakumar	Scientist-D
Dr. Chandra Prakash Dubey	Scientist-B
Dr. B. Padma Rao	Scientist-B
Dr. Nilanjana Sorcar	Scientist-B
Dr. Kumar Batuk Joshi	Scientist-B
Shri. Thatikonda Suresh Kumar	Scientist-B
Shri. Arka Roy	Scientist-B
Ms. Alka Gond	Scientist-B
Shri. N. Nishanth	Scientific Asst. Gr. B
Shri. S. Shivapriya	Scientific Asst. Gr. A (since June 2018)
Smt. G. Lakshmi	Scientific Asst. Gr. A (since June 2018)
Shri. Krishna Jha	Scientific Asst. Gr. A (since July 2018)
Shri. K. Eldhose	Technician Gr. B

12.3 Coastal Processes (CoP)

Dr. T. N. Prakash	Scientist-G & Head
Dr. L. Sheela Nair	Scientist-F
Dr. D. S. Suresh Babu	Scientist-F
Dr. Reji Srinivas	Scientist-D
Shri. Ramesh Madipally	Scientist-B
Shri. M. Ramesh Kumar	Scientific Officer Gr. III (till January 2019)
Shri. S. S. Salaj	Scientific Asst. Gr. B
Shri. M. K. Rafeeque	Scientific Asst. Gr. B
Shri. M. K. Sreeraj	Scientific Asst. Gr. B
Shri. Shibu Sasi	Scientific Asst. Gr. A (since June 2018)
Shri. N. Sreejith	Scientific Asst. Gr. A (since August 2018)

12.4 Atmospheric Processes (AtP)

Dr. K. K. Ramachandran	Scientist F & Head
Dr. E. A. Resmi	Scientist C
Shri. Dharmadas Jash	Scientist-B
Dr. S. Kaliraj	Scientist-B
Dr. C. K. Unnikrishnan	Scientist-B
Smt. Nita Sukumar	Scientific Asst. Gr. B
Shri. P. B. Vibin	Scientific Asst. Gr. B
Smt. M. Lincy Sudhakaran	Scientific Asst. Gr. A (since June 2018)

12.5 Hydrological Processes (HyP)

Dr. D. Padmalal	Scientist G & Head
Dr. K. Maya	Scientist-F
Dr. K. Anoop Krishnan	Scientist-D
Shri. Badimela Upendra	Scientist-B
Shri. Rajat Kumar Sharma	Scientist-B
Dr. K. Sreelash	Scientist-B
Shri. Prasenjit Das	Scientist-B
Smt. C. Sakunthala	Scientific Officer Gr. III (till November 2018)
Smt. T. M. Liji	Scientific Asst. Gr. B
Ms. P. V. Vinitha	Scientific Asst. Gr. A (since June 2018)

12.6 Library

Dr. D. S. Suresh Babu	Scientist-F & Head
Smt. K. Reshma	Scientific Asst. Gr. B

12.7 Administration

Dr. D. S. Suresh Babu	Chief Manager (i/c) (till December 2018)
Shri. D. P. Maret	Senior Manager (since January 2019)
Shri. M. A. K. H. Rasheed	Manager (Finance & Accounts) (till July 2018)
Smt. K. V. Padmaja Kumari	Joint Manager (till May 2018)
Shri. R. Haridas	Deputy Manager (till January 2019)
Shri. M. Madhu Madhavan	Deputy Manager
Smt. R. Jaya	Deputy Manager
Smt. G. Lavanya	Deputy Manager
Smt. Indu Janardanan	Scientific Asst. Gr. B
Shri. P. Rajesh	Executive
Smt. P. C. Rasi	Executive
Smt. Femi R. Srinivasan	Executive
Smt. Smitha Vijayan	Executive
Smt. D. Shimla	Junior Executive
Shri. P. H. Shinaj	Junior Executive
Smt. K. S. Anju	Junior Executive
Smt. V. Sajitha Kumary	Junior Executive
Smt. Seeja Vijayan	Junior Executive
Shri. M. K. Adarsh	Technician Gr. A (since June 2018)

Shri P. Rajendra Babu	*MTS*
Shri. P. Saseendran Nair	*MTS*
Shri. P. S. Anoop	*MTS*
Smt. P. S. Divya	*MTS*
Shri. K. Sudheer Kumar	*MTS*
Shri. M. R. Murukan	*MTS*

12.8 Retirements

Smt. K. V. Padmaja Kumari
Joint Manager
Finance & Accounts
Superannuated on
31st May 2018

Shri. M. A. K. H. Rasheed
Manager
Finance & Accounts
Superannuated on
31st July 2018

Smt. C. Sakunthala
Scientific Officer Gr. III
Hydrological Processes
Superannuated on
30th November 2018

Shri. M. Ramesh Kumar
Scientific Officer Gr. III
Coastal Processes
Superannuated on
31st January 2019

Shri. R. Haridas
Deputy Manager
Personnel & General Administration
Superannuated on 31st January 2019

12.9 New Appointments

Shri. D. P. Maret
Senior Manager

Smt. Jinitha Madhavan
Coordinator Gr. III

Shri. S. R. Unnikrishnan
Scientific Asst. Gr. A

Ms. P. V. Vinitha
Scientific Asst. Gr. A

Shri. Shibu Sasi
Scientific Asst. Gr. A

Shri. S. Shivapriya
Scientific Asst. Gr. A

Smt. G. Lakshmi
Scientific Asst. Gr. A

Smt. M. Lincy Sudhakaran
Scientific Asst. Gr. A

Shri. Krishna Jha
Scientific Asst. Gr. A

Shri. N. Sreejith
Scientific Asst. Gr. A

Shri. M. K. Adarsh
Technician Gr. A

13. Balance Sheet

ESSO- NCESS
National Centre for Earth Science Studies
(Ministry of Earth Sciences, Government of India)
Akkulam, Trivandrum

Audit for the year 2018-19

JVR & Associates
Chartered Accountants

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JVR ASSOCIATES

JVR & Associates, Chartered Accountants
2nd Floor, TC 15/182, Chennankara Buildings
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GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2018-19 IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID SALARIES AND GENERAL

1. Name of the Scheme : National Centre for Earth Science Studies(Autonomous Bodies)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :

(i) Cash in Hand/Bank : Rs. 3,58,19,564.75

(ii) Unadjusted advances : Rs (72,01,188.75)

(iii) Total : Rs. 2,86,18,376.00

4. Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
	*		Sanction No.	Date	Amount	(1+2+3+4)		(5-6)
2,86,18,376.00	10,26,436.00	0.00	#	#	11,13,00,000.00	14,09,44,812.00	13,14,56,774.50	94,88,037.50

#MoES/P.O(NCESS)/3/2015 – Part File dated 23.05.2018 – Rs. 3,50,00,000.00
MoES/P.O(NCESS)/3/2015 – Part File dated 24.08.2018 – Rs. 4,00,00,000.00
MoES/P.O(NCESS)/3/2015 – Part File dated 23.01.2019 – Rs. 3,63,00,000.00

*Including other receipts

Component wise utilization of grants :

Grant in aid General	Grant in aid Salary	Total
Rs. 3,92,46,080.50	Rs 9,22,10,694.00	Rs. 13,14,56,774.50

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 2,01,61,293.25

b. Unadjusted advances :Rs.(1,06,73,255.75)

c. Total : Rs.94,88,037.50

JVR & ASSOCIATES * FRN 011121S * Chartered Accountants

Excellence .... Integrity.... Independence.....

No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi- 682016, Phone: 0484 - 6598252, e-mail : jvr@airtelmail.in

JVR ASSOCIATES

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre For Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii) The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed.

Trivandrum
16.10.2019

For JVR & Associates
Chartered Accountants
FRN 011121S

JVR & ASSOCIATES FRN:011121S Chartered Accountants

Deputy Manager | Senior Manager | Director

RAMASUBRAMONIA IYER S, FCA
Partner

JVR & Associates, Chartered Accountants
2nd Floor, TC 15/182, Chennankara Buildings
Above SBI Althara Branch, Vellayambalam
Thiruvananthapuram - 695010
Ph: 0471- 4061392, 4061393
e-mail : jvrtvm@gmail.com www.jvr-cos.com

GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2018-19 IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID CREATION OF CAPITAL ASSETS

1. Name of the Scheme : National Centre for Earth Science Studies(Autonomous Bodies)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :

(i) Cash in Hand/Bank : Rs. 1,11,10,734.00

(ii) Unadjusted advances : Rs 1,98,49,380.00

(iii) Total : Rs. 3,09,60,114.00

4. Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
			Sanction No.	Date	Amount	(1+2+3+4)		(5-6)
3,09,60,114.00	0.00	0.00	#	#	2,00,00,000.00	5,09,60,114.00	70,93,156.00	4,38,66,958.00

#MoES/P.O(NCESS)/3/2015-part File dated 24.08.2018 – Rs. 1,00,00,000.00

MoES/P.O(NCESS)/3/2015 dated23.01.2019 – Rs. 1,00,00,000.00

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. Nil

b. Unadjusted advances : Rs.4,38,66,958.00

c. Total : Rs. 4,38,66,958.00

JVR & ASSOCIATES * FRN 011121S * Chartered Accountants

Excellence .... Integrity.... Independence.....

No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi- 682016, Phone: 0484 - 6598252, e-mail : jvr@airtelmail.in

JVR ASSOCIATES

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre For Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii)The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

Trivandrum
16.10.2019

JVR & ASSOCIATES * Chartered Accountants * FRN:011121S

For JVR & Associates
Chartered Accountants
FRN 011121S

Deputy Manager | Senior Manager | Director

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN:19203675AAAACV5258

National Centre for Earth Science Studies
Thiruvananthapuram 695 011
Govt. of India

JVR ASSOCIATES

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2nd Floor, TC 15/182, Chennankara Buildings
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GFR 12 - A

[See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2018-19 IN REPECT OF RECURRING/NON RECURRING GRANTS-IN-AID SEISMOLOGY AND GEODYNAMICS (SAGE)/R&D PROGRAMMES

1. Name of the Scheme : Seismology And Geosciences (SAGE)
2. Whether recurring or non recurring grants : Both
3. Grants position at the beginning of the Financial year :

(i) Cash in Hand/Bank : Rs. 62,86,187.00
(ii) Unadjusted advances : Rs 2,68,50,756.00
(iii) Total : Rs. 3,31,36,943.00

4. Details of grants received, expenditure incurred and closing balances: (Actual)

(Amount in Rupees)

Unspent Balances of Grant Received (Figure as at Sl. No. 3(iii))	Interest earned thereon	Interest Deposited back to the Govt	Grant received during the year			Total Available Funds	Expenditure Incurred	Closing Balance
1	2	3	4			5	6	7
			Sanction No.	Date	Amount	(1+2+3+4)		(5-6)
3,31,36,943.00	58,26,924.00	0.00	#	#	30,98,00,000.00	34,87,63,867.00	18,81,18,495.94	16,06,45,371.06

#MoES/P.O (Seismo)/8(14)-A/2017 dated 17.07.2018 - Rs 15,43,00,000.00
MoES/P.O (Seismo)/8(14)-A/2017 dated 23.01.2019 - Rs 6,95,00,000.00
MoES/P.O (Seismo)/8(14)-A/2017 dated28.02.2019 - Rs. 8,60,00,000.00

Component wise utilization of grants :

Non -Recurring	Recurring	Total
Rs. 8,86,21,064.00	Rs. 9,94,97,431.94	Rs. 18,81,18,495.94

Grants position at the end of the financial year

a. Cash in Hand/ Bank : Rs. 0.42
b. Fund Diversion : Rs. (1,28,97,749.00)
c. Unadjusted advances : Rs.17,35,43,119.64
d. Total : Rs. 16,06,45,371.06

JVR & ASSOCIATES FRN 011121S Chartered Accountants

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No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi- 682016, Phone: 0484 - 6598252, e-mail : jvr@airtelmail.in

JVR ASSOCIATES

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under National Centre For Earth Science Studies has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(viii)The utilization of the fund resulted in outcomes given in the financial statements duly enclosed.

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed.

Trivandrum
16.10.2019

For JVR & Associates
Chartered Accountants
FRN 011121S

JVR & ASSOCIATES Chartered Accountants FRN:011121S

Deputy Manager | Senior Manager | Director

National Centre for Earth Science Studies Thiruvananthapuram 695 011 Govt. of India

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN: 19203675AAAACW3143

JVR ASSOCIATES

JVR & Associates, Chartered Accountants
2nd Floor, TC 15/182, Chennankara Buildings
Above SBI Althara Branch, Vellayambalam
Thiruvananthapuram - 695010
Ph: 0471- 4061392, 4061393
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AUDITORS' REPORT

To,

The Director
National Centre for Earth Science,
Thiruvananthapuram

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of **National Centre for Earth Science, Thiruvananthapuram** which comprise the Balance Sheet as at 31st March 2019, and the Income and Expenditure Account for the year ended, and a summary of significant accounting policies and other explanatory information.

UNQUALIFIED OPINION

In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements give the information required by the Act in the manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India:

(a) In the case of the Balance Sheet, of the state of affairs of the Society as at 31st March 2019;

(b) In the case of Income & Expenditure Account, of the Excess of expenditure over income of the Society for the year ended on that date.

MANAGEMENT'S RESPONSIBILITY FOR THE FINANCIAL STATEMENTS

The Society's Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position and financial performance of the Society in accordance with the Accounting Standards notified and in accordance with the accounting principles generally accepted in India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

JVR & ASSOCIATES * FRN: 011121S * Chartered Accountants

Excellence .... Integrity.... Independence.....

No. 39/2790 A, Wilmont Park Business Centre, Pallimukku, Kochi- 682016, Phone: 0484 - 6598252, e-mail : jvr@airtelmail.in

JVR ASSOCIATES

AUDITORS' RESPONSIBILITY

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Society's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Society's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

For JVR Associates
Chartered Accountants
FRN. 011121 S

JVR & ASSOCIATES FRN:011121S Chartered Accountants

Ramasubramonia Iyer S, FCA
(Partner)
M.No. 203675
UDIN: 19203675AAAACX3774

Place : Trivandrum
Date : 16/10/2019

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Balance Sheet as on 31st March, 2019

Particulars	Sch No.	2018-19	2017-18
		Rs.	Rs.
Liabilities			
Capital Reserve	1	24,92,85,953.95	19,64,01,089.55
General Reserve	2	(2,55,53,371.00)	(2,55,53,371.00)
Unspent Balance GOI - MoES	3	21,40,00,366.56	9,27,15,433.00
Unspent Balance of Projects	4	15,83,89,024.34	13,39,80,131.20
Corpus Fund	5	15,02,10,904.71	12,79,86,166.71
Current Liabilities	6	1,75,42,704.75	1,08,66,643.75
Total		**76,38,75,583.31**	**53,63,96,093.21**
Assets			
Fixed Assets	7	24,92,85,953.95	19,64,01,089.55
Current Assets, Loans & Advances	8	51,45,89,629.36	33,99,95,003.66
Total		**76,38,75,583.31**	**53,63,96,093.21**
Notes forming part of Accounts	16		

Trivandrum
16.10.2019

Vide Report of Even Date
JVR & ASSOCIATES
FRN 011121S

JVR & ASSOCIATES FRN:011121S Chartered Accountants

Deputy Manager **Senior Manager** **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 19203675AAAACX3774

राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र National Centre for Earth Science Studies तिरुवनन्तपुरम Thiruvananthapuram 695 011 भारत सरकार

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Income & Expenditure Account for the year ended 31st March, 2019

Particulars		Sch No.	2018-19	2017-18
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	11,13,00,000.00	9	10,74,11,400.00	14,72,91,296.00
Less: Capital Expenditure	38,88,600.00			
Interest from Bank		10	2,60,386.00	1,88,473.00
Other Income			7,66,050.00	82,02,066.00
Depreciation Written Back			4,68,10,505.60	3,80,22,315.16
Total - A			**15,52,48,341.60**	**19,37,04,150.16**
Expenditure				
Staff Salary & Benefits		11	9,22,10,694.00	11,15,02,327.00
Other Institutional Expenses				
Total of Other Institutional Ex	3,92,46,080.50	12		
Less: Capital Expenditure	38,88,600.00		3,53,57,480.50	2,60,91,668.00
Depreciation			4,68,10,505.60	3,80,22,315.16
Total - B			**17,43,78,680.10**	**17,56,16,310.16**
Excess of Expenditure over Income (A-B)			(1,91,30,338.50)	1,80,87,840.00
Excess of Income over expenditure of Prev. Year			2,86,18,376.00	1,05,30,536.00
Total			**94,88,037.50**	**2,86,18,376.00**
Notes forming part of Accounts		16		

Trivandrum
16.10.2019

Vide Report of Even Date
JVR & ASSOCIATES
FRN 011121S

JVR & ASSOCIATES * FRN:011121S * Chartered Accountants

Deputy Manager **Senior Manager** **Director**

RAMASUBRAMONIA IYER S, FCA
Partner
M.No.203675
UDIN : 19203675AAAACX3774

राष्ट्रीय पृथ्वी विज्ञान अध्ययन केंद्र National Centre for Earth Science Studies तिरुवनन्तपुरम Thiruvananthapuram 695 011 भारत सरकार Govt. of India

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India
Receipts and Payments Account for the year ended 31st March 2019

Receipts	Amount	Amount	Payments	Amount	Amount
Opening Balance:			**Staff Salary & Benefits:**		
State Bank of India	5,32,16,485.75		Staff Salary	7,28,75,968.00	
SBI-E-tax	4,02,463.00		Salary to director	30,33,708.00	
Imprest Balance	28,694.00	5,36,47,642.75	Incentive/ awards to staff	1,32,500.00	
			Contribution to EPF/EPFIF/EPS/NPF	38,33,013.00	
Previous Year Advances/ Receipts:			LIC GG Scheme for Staff	67,48,880.00	
Advance Payments for purchases	4,08,25,906.00		EPF/IF Administrative Charges	1,89,848.00	
Advance Payments to Staff	40,12,829.00		LTC	14,79,276.00	
Margin Money On LC	71,53,560.00	5,19,92,295.00	Medical Expenses Reimbursement	1,68,680.00	
			Leave Salary & Pension Contribution	6,60,954.00	
Grant Received during the year:			NPS	19,14,794.00	
(a) Grant in Aid Salaries/ General	11,13,00,000.00		Contribution to Pension Scheme	4,23,750.00	
(Operations & Maintenance)			Children educational allowance	7,49,323.00	9,22,10,694.00
(b) Seismological & Geosciences	30,98,00,000.00				
(R&D Programes)			**Office Expenses/ Other Institutional Expenses:**		
(c) Grant in Aid for Creation of Capital asset	2,00,00,000.00		Advertisement	4,95,093.00	
(Major Works)		44,11,00,000.00	Audit Fee/ legal Charges	3,57,900.00	
			Consultancy Charges	7,46,215.00	
Other Receipts			Electricity Charges	15,16,655.00	
Interest from Bank	60,87,310.00		Water Charges	79,192.00	
Miscellaneous receipts	2,97,111.00		Hospitality Expenses	42,65,215.00	
Sales of tender form	2,478.00		Printing & Stationery	6,81,664.00	
Sales of usufructs	4,66,001.00		Repairs & Maintenance	37,23,652.00	
Application fee	460.00	68,53,360.00	Consumables	6,24,800.00	
			Remuneration to Project Staff	54,50,240.00	
Other Receipts - Payable			Books & Journals	10,65,212.00	
Nps staff	53,077.00		Furniture	3,59,396.00	
GPF Central	60,000.00		Computer System & Accessories	6,24,046.00	
Income Tax Staff	1,41,500.00		Electrical /UPS Installations	5,300.00	
LIC	15,332.00		Office equipments	16,62,337.00	
EMD Received	4,95,137.00		Canteen Equipments	1,72,309.00	
Term deposit	2,55,913.00		Sitting Fee/Honor - Visiting Expenses	3,01,140.00	
GST	72,75,175.00		Seminar/ Conference Expenses	33,96,357.00	

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India
Receipts and Payments Account for the year ended 31st March 2019

Receipts	Amount	Amount	Payments	Amount	Amount
Security deposit received	2,21,968.00		Travelling Expences	18,37,581.00	
Leave salary receivables	54,646.00		Vehicle Hire Charges	10,91,901.00	
Fund diversion	1,28,97,749.00		Contingency	82,94,789.00	
		2,14,70,497.00	Taxes & Insurance - Vehicles	22,306.00	
			Petrol, Diesel & Oil	1,69,594.00	
			Bank charges	17,474.50	
			News paper and periodicals	1,297.00	
			Postage & Communication	6,09,875.00	
			Research council expense	2,360.00	
			SB MISSION	15,95,044.00	
			Prior Period expenses	48,248.00	3,92,17,192.50
			Payment against R & D Funds:		
			Fixed assets	8,86,21,064.00	
			Manpower	2,82,73,436.00	
			Travel & Field DA	1,46,01,501.50	
			Consumables	3,64,80,414.00	
			Vehicle Hire Charges	54,92,291.00	
			Boat Hire charges	1,45,303.00	
			Repairs & Maintenance	58,08,482.00	
			Contingency	86,96,004.44	
			Advance Payments	10,67,19,011.64	
			Margin Money on LC	6,64,81,432.00	
			Prepaid expenses	1,77,361.00	36,14,96,300.58
			E. Creation of Capital Assets (Major Works)		
			Major Civil Works (Compound Wall)	70,93,156.00	
			Advance Payments	4,38,66,958.00	5,09,60,114.00

JVR & ASSOCIATES * Chartered Accountants * FRN: [illegible]S

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India
Receipts and Payments Account for the year ended 31st March 2019

Receipts	Amount	Amount	Payments	Amount	Amount
			Other Payments/ Receivables		
			Subscription to NCESS REC - CLUB	3,625.00	
			EPF staff	1,22,475.00	
			GSLIS	1,040.00	
			Discharge of gratuity insurance	12,04,875.00	
			Rolling contingent advance	1,50,000.00	
			Tour advance	27,110.00	
			Other Advance	1,22,251.00	
			Deposit with KSEB	15,850.00	
			Prepaid postage and telegram	1,01,573.00	
			Prepaid expenses - Others	98,554.00	
			Income tax contractors	2,42,114.00	
			Advance payments	57,28,585.00	
			NCESS Co-operative	11,999.00	
			Gratuity recieveable	29,98,600.00	
			GST TDS	12,600.00	1,08,41,251.00
			Closing Balance		
			Imprest cash	16,600.00	
			SBI-E-tax	1,60,349.00	
			State Bank of India	2,01,61,293.67	2,03,38,242.67
Total	**57,50,63,794.75**	**57,50,63,794.75**	**Total**	**57,50,63,794.75**	**57,50,63,794.75**

JVR & ASSOCIATES FRN:011121S Chartered Accountants 16/10/19

For JVR & ASSOCIATES
CHARTERED ACCOUNTANTS
FRN:011121S

RAMASUBRAMANIA IYER. S., FCA
PARTNER (M.NO. 203675)

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Balance Sheet as at 31st March 2019

Schedule 1 - Capital Reserve

Particulars	Sch.No	As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
Opening Balance		19,64,01,089.55	17,04,16,993.70
Add: Addition to Capital Asset		9,96,02,820.00	6,38,79,488.00
Add: Transfer from External Projects		92,550.00	1,26,923.00
Less: Depreciation		4,68,10,505.60	3,80,22,315.16
Less: Loss on Sale of Fixed Assets		-	-
Closing balance		**24,92,85,953.95**	**19,64,01,089.55**

Schedule 2 - General Reserve

Particulars	Sch.No	As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
Plan fund from GOK			
Opening Balance		59,67,205.00	59,67,205.00
Add: Receipts for R&D from operations and maintenance fund			
Less: Plan Revenue Expenditure for the year			
Less: Plan Capital Expenditure for the year			
Add: Interest Received and other income			
Add: Previous Year Adjustments			
Closing Balance		**59,67,205.00**	**59,67,205.00**
Non Plan Fund from GOK			
Opening Balance		(3,15,20,576.00)	(3,15,20,576.00)
Add: Receipts during the year			
Less: Non Plan Revenue Expenditure for the year			
Closing Balance			
Total		**(3,15,20,576.00)**	**(3,15,20,576.00)**
		(2,55,53,371.00)	**(2,55,53,371.00)**

Schedule 3 - Unspent Balance GOI - MoES

Particulars	Sch.No	As at 31.03.2019	As at 31.03.2018
Operation and Maintenance Fund		Rs.	Rs.
Grant in aid for salaries and general (OPMA)			
Opening Balance		2,86,18,376.00	1,05,30,536.00
Add: Grant Received during the year	9	11,13,00,000.00	15,32,00,000.00
Less: Revenue Expenditure	11 & 12	12,75,68,174.50	13,75,93,995.00
Less: Capital Expenditure	11 & 12	38,88,600.00	59,08,704.00
Add: Income from Interest & Other Income	10	10,26,436.00	83,90,539.00
Closing Unspent Balance of Grant		**94,88,037.50**	**2,86,18,376.00**
Grant in aid for creation of capital assets (Major works)			
Opening Balance		3,09,60,114.00	2,25,72,901.00
Add: Grant Received during the year		2,00,00,000.00	1,00,00,000.00
Less: Revenue Expenditure		-	13,90,625.00
Less: Capital Expenditure	15	70,93,156.00	4,95,666.00
Add: Income from Interest & Other Income		-	2,73,504.00
Closing Unspent Balance of Grant		**4,38,66,958.00**	**3,09,60,114.00**

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Balance Sheet as at 31st March 2019

Seismological and Geoscience (SAGE) (Research & Development Programme)			
Opening Balance		3,31,36,943.00	5,67,33,889.00
Add: Grant Received during the year		30,98,00,000.00	7,85,00,000.00
Less: Revenue Expenditure	13	9,94,97,431.94	4,49,65,501.00
Less: Capital Expenditure	14	8,86,21,064.00	5,74,76,289.00
Add: Income from Interest & Other Income		58,26,924.00	1,171.00
Add: Income from sale of assets		-	3,43,673.00
Closing Unspent Balance of Grant		**16,06,45,371.06**	**3,31,36,943.00**
Closing Unspent Balance		**21,40,00,366.56**	**9,27,15,433.00**

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.	As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
Research Projects	A	35,54,349.14	1,11,99,957.00
Divisional Core Research Projects	A	1,96,77,304.70	93,71,844.50
Service Component Projects	A	10,97,681.50	49,34,025.70
Consultancy Projects	B	13,40,59,689.00	10,84,74,304.00
Total		**15,83,89,024.34**	**13,39,80,131.20**

Schedule 5 - Corpus Fund

Particulars	Sch.No	As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
Opening Balance		12,79,86,166.71	10,08,29,303.71
Add: Interest Received Fixed Deposit		1,00,08,485.00	1,09,36,298.00
Add: Income from Consultancy Projects		24,70,600.00	18,22,616.00
Add: Overhead Charges		70,10,705.00	93,51,244.00
Add: Other Receipts		27,34,948.00	50,46,705.00
Closing Unspent		**15,02,10,904.71**	**12,79,86,166.71**

Schedule 6 - Current Liabilities

Particulars	Sch.No	As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
Common Fund		35,668.00	35,668.00
EMD		82,42,402.75	77,47,265.75
License Fee Payable		28,356.00	28,356.00
Tax Deducted at Source Payable Contractors		1,59,349.00	4,01,463.00
Tax Deducted at Source Payable Staff		5,41,500.00	4,00,000.00
Security Deposit		4,50,670.00	2,28,702.00
EPF Staff		4,27,170.00	5,49,645.00
Subscription to NCESS Rec- Club		1,575.00	5,200.00
Co-Operattive Recovery		8,000.00	8,000.00
NPS Staff		1,96,559.00	1,43,482.00
GPF Central		1,00,120.00	40,120.00
GSLIS		5,310.00	6,350.00
LIC		63,330.00	47,998.00
NCESS Co-Operative Soceity		7,520.00	19,519.00
Discharge of gratuity insurance		-	12,04,875.00
GST payable		66,24,946.00	-
GST TDS		6,50,229.00	-
Total		**1,75,42,704.75**	**1,08,66,643.75**

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Balance Sheet as at 31st March 2019

Schedule 7- Fixed Assets

Sl No.	Particulars	Balance as on 1st April 2018	Additions		Deletion / Adjustments	Balance as on 1st April 2018	Rate %	Depreciation Provided during the year	Balance as on 31st March 2019
			More than 180 days	Less than 180 days					
		Rs.	Rs.	Rs.	Rs.	Rs.		Rs.	Rs.
1	Buildings	1,83,61,618.38		21,50,838.00	-	2,05,12,456.38	10.00	19,43,703.74	1,85,68,752.64
2	Library Books	73,73,503.60	85,914.00	9,79,298.00	-	84,38,715.60	40.00	31,79,626.64	52,59,088.96
3	Computers	91,05,372.66	26,19,426.00	34,00,003.00	8.00	1,51,24,793.66	40.00	53,69,916.86	97,54,876.80
4	Furnitures & Fixtures	44,45,173.49	6,62,224.00	58,80,714.00	-	1,09,88,111.49	10.00	8,04,775.45	1,01,83,336.04
5	Laboratory Equipments	13,69,90,177.36	15,80,088.00	4,90,56,737.00	-	18,76,27,002.36	15.00	2,44,64,795.08	16,31,62,207.28
6	Office Equipments	34,66,575.57	19,04,092.00	50,04,165.00	-	1,03,74,832.57	15.00	11,80,912.51	91,93,920.06
7	Plant & Machinery	34,188.70	-	-	-	34,188.70	15.00	5,128.31	29,060.40
8	Electrical Installations	60,33,151.53	2,86,766.00	23,38,834.00	-	86,58,751.53	15.00	11,23,400.18	75,35,351.35
9	Vehicles	6,82,777.67	-	-	-	6,82,777.67	15.00	1,02,416.65	5,80,361.02
10	Research Boats	2,305.28	-	-	-	2,305.28	20.00	461.06	1,844.22
11	Softwares	99,06,245.31	3,40,387.00	2,34,05,892.00	-	3,36,52,524.31	40.00	86,35,369.12	2,50,17,155.19
	Total	**19,64,01,089.55**	**74,78,897.00**	**9,22,16,481.00**	**8.00**	**29,60,96,459.55**		**4,68,10,505.60**	**24,92,85,953.95**

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Balance Sheet as at 31st March 2019

Schedule 8 - Current Assets, Loans & Advances

Particulars		As at 31.03.2019	As at 31.03.2018
		Rs.	Rs.
A. Current Assets			
1. Stock - in - hand		10,22,572.00	10,51,460.00
2. Cash & Bank Balance			
SBI - Consultancy Projects	9,76,70,860.00		
SBI - External Projects	2,31,01,911.34		
SBI - NCESS	2,01,61,293.67		
SBI - Corpus Fund	451.71		
Treasury Accounts (GOK)	11,000.00		
SBI - NCESS E-TAX	1,60,349.00		
Term Deposits	13,83,01,333.00		
Imprest Balances	16,600.00		
		27,94,23,798.72	27,79,84,491.66
Total A (1+2)		**28,04,46,370.72**	**27,90,35,951.66**
B. Loans, Advances & Other Assets			
1.Deposits			
Deposit with EPF		55,80,486.00	55,80,486.00
Deposit with KSEB		5,63,080.00	5,47,230.00
Deposit with T K Varghese and Son		6,000.00	-
Deposit with BSNL		3,000.00	-
Deposit Projects		-	12,300.00
Deposit with drinking water		300.00	-
Caution deposit		3,000.00	-
2. Advances & other amount recoverable in cash or in kind or for value to be recovered			
Tour Advance		10,95,039.00	17,39,084.00
Other Advance		16,37,233.00	20,18,745.00
Rolling Contingent Advance		2,50,000.00	2,55,000.00
Margin Money on LC NCESS		6,64,81,432.00	71,53,560.00
Advance to staff - External/Consultancy Projects		81,129.00	11,12,582.00
Advance to Suppliers - External Projects		-	3,50,000.00
Advance to Suppliers - NCESS		13,30,23,990.64	4,10,66,253.00
Leave Salary Receivable		38,854.00	93,500.00
Salary Receivable		6,40,079.00	6,40,079.00
TDS Receivable - External Projects		1,76,415.00	1,45,200.00
TDS Receivable - Consultancy Projects		1,31,500.00	50,000.00
Grants to Other Institutes		2,08,48,000.00	-
Gratuity Recievable KSCTSE		29,98,600.00	-
GST Receivable		12,600.00	-
Prepaid expenses		3,77,488.00	-
Service Tax Interest Receivable		10,163.00	10,163.00
Service Tax Receivable		1,84,870.00	1,84,870.00
Total B (1+2)		**23,41,43,258.64**	**6,09,59,052.00**
Total (A+B)		**51,45,89,629.36**	**33,99,95,003.66**

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2019

Schedule 9 - Grant Received

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Grant in aid salaries and general (OPMA)		
Add: Grant Received During the Year	11,13,00,000.00	15,32,00,000.00
Total	**11,13,00,000.00**	**15,32,00,000.00**

Schedule 10 - Interest & Other Income

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Receipt From Other Projects	-	70,69,261.00
Miscellaneous Receipts	2,97,111.00	11,32,325.00
Sale of Usufructs	4,66,001.00	-
Sale of Tender Forms	2,478.00	-
Application Fee (Right to Information Act)	460.00	480.00
Interest on Fixed deposits	16,647.00	-
Interest From Bank	2,43,739.00	1,88,473.00
Total	**10,26,436.00**	**83,90,539.00**

Schedule 11 - Staff Salary & Benefits

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Salary Director	30,33,708.00	23,85,882.00
Salaries Others	7,20,30,879.00	8,61,14,749.00
Contribution to EPF	38,02,188.00	53,79,002.00
Contribution to EPS	4,23,750.00	4,67,500.00
EPF Administrative Charges	1,89,848.00	3,22,762.00
Contribution to EPF IF	30,825.00	37,425.00
IF Administration Charges	-	200.00
Contribution to NPS	19,14,794.00	17,67,823.00
Children Education Allowance	7,49,323.00	-
Leave Salary & Pension Contribution	6,60,954.00	5,35,899.00
Leave Travel Concession	14,79,276.00	6,97,452.00
Incentives to Staff	1,32,500.00	1,32,500.00
LIC GG Scheme for Staff	67,48,880.00	1,30,35,913.00
Medical Expenses Reimbursement	1,68,680.00	5,51,018.00
Previous Year Salary	8,45,089.00	-
Professional Update Allowance	-	74,202.00
Total	**9,22,10,694.00**	**1,76,22,694.00**

JVR & ASSOCIATES * Chartered Accountants *

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2019

Schedule 12 - Other Institutional Expenses

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Computer System & Accessories	6,24,046.00	7,18,878.00
Electrical /UPS Installations	5,300.00	2,600.00
Canteen Equipment	1,72,309.00	27,900.00
Major software	-	11,000.00
Library Books & Journals	10,65,212.00	33,37,043.00
Furniture	3,59,396.00	81,479.00
Office Equipments	16,62,337.00	17,29,804.00
Advertisement	4,95,093.00	3,96,891.00
Audit Fee	82,600.00	77,880.00
Bank charges	17,474.50	-
Consultant fee	7,46,215.00	61,935.00
Consumables	6,31,545.00	12,90,169.00
Contingency	82,94,789.00	77,73,934.00
Electricity Charges	15,16,655.00	-
Hospitality Expenses	42,65,215.00	21,20,003.00
Legal Charges	2,75,300.00	66,000.00
News Papers & Periodicals	1,297.00	-
Petrol , Diesel & Oil	1,69,594.00	82,152.00
Postage & Communication	6,09,875.00	3,24,024.00
Printing & Stationery	7,03,807.00	4,34,699.00
Prior Period Expenses	48,248.00	-
Remuneration to Project Staff	54,50,240.00	31,49,951.00
Repairs & Maintenance - Others	13,38,954.00	12,50,960.00
Repairs & Maintenance - Building	23,09,875.00	28,87,270.00
Repairs & Maintenance - Vehicle	74,823.00	1,27,557.00
Research Council Expenses	2,360.00	76,578.00
Seminar/Conference	33,96,357.00	17,03,250.00
Sitting Fee/Honor-Visiting Expenses	3,01,140.00	80,000.00
Swachh Bharath- Gardening	1,21,940.00	-
Swachh Bharath- House Keeping	6,86,406.00	-
Swachh Bharath Pakhwada	7,86,698.00	-
Taxes & Insurance Vehicles	22,306.00	23,933.00
Travelling Expenses	11,26,454.00	8,98,650.00
Travelling Expenses for Visiting Experts	7,11,127.00	8,86,979.00
Vehicle Hire Charges	10,91,901.00	19,24,947.00
Water Charges	79,192.00	4,53,906.00
Total	**3,92,46,080.50**	**3,20,00,372.00**

JVR & ASSOCIATES * Chartered Accountants * FRN 011121S

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2019

Schedule 13 - Research & Development Revenue Expenses

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Advertisement charges for R&D	4,80,379.00	3,16,521.00
Bank charges	2,08,290.00	51,616.00
Boat hire charges	3,01,486.00	1,85,500.00
Chemicals/ consumables	1,50,18,470.00	83,51,861.00
Cost Of Power/Electricity - Labs	21,47,687.00	33,16,253.00
Contingency	17,72,360.00	13,48,268.00
Consultants charges	29,63,909.00	18,18,306.00
Communication /postage charges	2,75,706.00	2,89,505.00
Equipments repair charges/ AMC	35,11,122.00	40,10,441.00
Field expenses	41,33,849.00	11,13,101.00
Hire charges of vehicles	53,36,108.00	21,69,304.00
Insurance labs & equipments	40,583.00	1,18,947.00
Membership / Registration	3,80,255.00	1,99,610.00
Printing & publication cost	10,98,553.44	-
Printing & stationery	1,37,371.00	52,051.00
Prior period expenses	89,424.00	-
Repairs and maintenance	22,07,936.00	-
Remuneration to project staff	2,53,09,527.00	1,28,34,462.00
Recognition Fee/ Doct Committee	3,00,000.00	2,00,000.00
Satellite Imageries	2,13,24,573.00	-
Seminar,symposium & workshop	1,20,484.00	2,29,086.00
Sitting fee Visiting Experts	1,98,000.00	62,000.00
Training Expense	-	-
Travelling Expense for visiting experts	17,58,229.00	16,81,809.00
Travelling expense	1,03,83,130.50	66,16,860.00
Total	**9,94,97,431.94**	**4,49,65,501.00**

Schedule 14 - Research & Development Capital Expenses

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
Computer System & Accessories	53,18,325.00	56,50,453.00
Electrical /UPS Installations	19,57,471.00	6,28,023.00
Major Software	2,37,46,279.00	89,86,060.00
Furniture	60,50,933.00	12,22,268.00
Office equipment	2,63,902.00	13,860.00
Laboratory equipment	5,06,21,325.00	4,03,36,755.00
Air conditioners	6,62,829.00	6,38,870.00
Total	**8,86,21,064.00**	**5,74,76,289.00**

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Schedules forming part of Income and Expenditure Account for the year ended 31st March 2019

Schedule 15 -Creation of capital assets (Major Works)

Particulars	As at 31.03.2019	As at 31.03.2018
	Rs.	Rs.
(a) Revenue Expenditure:		
Minor Civil Works (Repairs & Maintenance)	-	13,90,625.00
(b) Capital Expenditure:		
Major Civil Works	70,93,156.00	4,95,666.00
Total	**70,93,156.00**	**18,86,291.00**

JVR & ASSOCIATES * Chartered Accountants * FRN 11121S

NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry of Earth Science, Government of India

Sub Schedule A

Statement of Unspent Balance in respect of Grant in Aid received for Research from Ministries/Departments/ Organisations of Central/State Governments, Divisional Core Research Projects and Service Component Projects from 01/04/2018 to 31/03/2019

Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
Research Projects							
							-
COMAPS4	(4,70,782.00)	-		-	(4,70,782.00)	65,484.00	(5,36,266.00)
CSIR25	-	3,60,000.00		3,60,000.00	3,60,000.00	3,48,463.00	11,537.00
CSIR26	-	-		-	-	(20,000.00)	20,000.00
DMD2	1,99,839.00	-		-	1,99,839.00	1,95,949.00	3,890.00
DST79	14,538.00	-		-	14,538.00	-	14,538.00
DST80	2,00,350.00	6,981.00		6,981.00	2,07,331.00	-	2,07,331.00
DST82	16,433.00	168.00		168.00	16,601.00	11,660.00	4,941.00
DST84	2,35,919.00	5,40,000.00	2,31,664.00	3,08,336.00	5,44,255.00	5,44,255.00	-
DST85	16,07,260.00	50,553.00		50,553.00	16,57,813.00	3,28,982.00	13,28,831.00
DST86	3,40,000.00	519.00		519.00	3,40,519.00	3,34,633.00	5,886.00
DST87	-	3,68,000.00		3,68,000.00	3,68,000.00	3,39,487.00	28,513.00
DST88	-	15,37,208.00		15,37,208.00	15,37,208.00	5,52,419.00	9,84,789.00
DST89	-	19,24,750.00		19,24,750.00	19,24,750.00	14,15,266.86	5,09,483.14
DST90	-	3,35,000.00	-	3,35,000.00	3,35,000.00	25,000.00	3,10,000.00
DST91	-	3,68,000.00	-	3,68,000.00	3,68,000.00	2,24,516.00	1,43,484.00
FC	1.00	-	-	-	1.00	-	1.00
IDRB1	25,62,621.00	30,96,000.00	-	30,96,000.00	56,58,621.00	61,38,346.00	(4,79,725.00)
IGCS	2,10,247.00	2,10,247.00	4,20,494.00	(2,10,247.00)	-	-	-
KSCS28	4,61,207.00	16,140.00	-	16,140.00	4,77,347.00	-	4,77,347.00
KSCS29	40,41,841.00	77,28,804.00	-	77,28,804.00	1,17,70,645.00	1,17,20,645.00	50,000.00
KSCS30	1,477.00	-	1,477.00	(1,477.00)	-	-	-
KSCS31	1,46,775.00	-	27,978.00	(27,978.00)	1,18,797.00	1,18,797.00	-
KSCS32	11,479.00	-	-	-	11,479.00	-	11,479.00
KSCS34	594.00	3,33,439.00	-	3,33,439.00	3,34,033.00	3,34,033.00	-
KSCS35	1,504.00	3,48,188.00	28,422.00	3,19,766.00	3,21,270.00	3,21,270.00	-
KSCS36	65.00	3,49,389.00	-	3,49,389.00	3,49,454.00	3,44,368.00	5,086.00
KSCS37	2,84,000.00	-	-	-	2,84,000.00	2,82,638.00	1,362.00
KSCS38	-	2,84,000.00	-	2,84,000.00	2,84,000.00	2,69,960.00	14,040.00

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
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	Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
	KSCS39	-	2,84,000.00	67,570.00	2,16,430.00	2,16,430.00	2,16,430.00	-
	KSCS40	-	50,000.00	-	50,000.00	50,000.00	-	50,000.00
	MAPAN	1,62,478.00	-	-	-	1,62,478.00	14,165.00	1,48,313.00
	MOES10	(22,674.00)	-	-	-	(22,674.00)	13,871.00	(36,545.00)
	MOES11	17,458.00	-	17,458.00	(17,458.00)	-	-	-
	MOES12	5,252.00	-	-	-	5,252.00	-	5,252.00
	MOES9	3,32,075.00	-	-	-	3,32,075.00	3,22,075.00	10,000.00
	SAC15	8,29,737.00	1,96,263.00	-	1,96,263.00	10,26,000.00	7,75,481.00	2,50,519.00
	UGC6	10,263.00	-	-	-	10,263.00	-	10,263.00
								-
								-
	Total	**1,11,99,957.00**	**1,83,87,649.00**	**7,95,063.00**	**1,75,92,586.00**	**2,87,92,543.00**	**2,52,38,193.86**	**35,54,349.14**
	Divisional Core Research Projects							
1	ENDF	10,25,469.00	-	-	-	10,25,469.00	-	10,25,469.00
2	GEOMAT	42,60,885.00	-	-	-	42,60,885.00	-	42,60,885.00
3	MACIS	40,85,490.50	1,45,55,607.20	-	1,45,55,607.20	1,86,41,097.70	42,50,147.00	1,43,90,950.70
	Total	**93,71,844.50**	**1,45,55,607.20**	-	**1,45,55,607.20**	**2,39,27,451.70**	**42,50,147.00**	**1,96,77,304.70**
	Service Component Projects							
1	AAS	0.50	54,965.00		54,965.00	54,965.50	-	54,965.50
2	CPT3	2,11,940.20	-		-	2,11,940.20	1,86,740.20	25,200.00
3	CPT4	3,64,500.00	2,70,000.00		2,70,000.00	6,34,500.00	4,14,048.00	2,20,452.00
4	DECC2	(2,84,057.00)	-		-	(2,84,057.00)	13,711.00	(2,97,768.00)
5	DECC3	20,59,496.00	-		-	20,59,496.00	17,59,496.00	3,00,000.00
6	LDSP	13,122.00	-		-	13,122.00	-	13,122.00
7	PSA	-	1,800.00		1,800.00	1,800.00	-	1,800.00
8	RSA3	1,27,453.00	-		-	1,27,453.00	-	1,27,453.00
9	SDMA1	37,819.00	-		-	37,819.00	37,819.00	-
10	SEM	-	83,400.00		83,400.00	83,400.00	-	83,400.00
11	TKH1	1,34,391.00	-		-	1,34,391.00	-	1,34,391.00
12	UTL6	22,69,361.00	-		-	22,69,361.00	22,69,361.00	-
13	XRF	-	4,34,666.00		4,34,666.00	4,34,666.00	-	4,34,666.00
								-
	Total	**49,34,025.70**	**8,44,831.00**	-	**8,44,831.00**	**57,78,856.70**	**46,81,175.20**	**10,97,681.50**
	Grand Total	**2,55,05,827.20**	**3,37,88,087.20**	**7,95,063.00**	**3,29,93,024.20**	**5,84,98,851.40**	**3,41,69,516.06**	**2,43,29,335.34**

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
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Sub Schedule B

Statement of Unspent Balance of Consultancy Projects for the year 2018-19

	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
1	CONY	11,68,261.00	22,96,902.00			22,96,902.00			22,96,902.00	11,68,261.00
2	CONY196	12,26,857.00	-	-	-	-	-	-	-	12,26,857.00
3	CONY201	11,82,248.00	-	-	-	-	-	-	-	11,82,248.00
4	CONY281	4,95,088.00	-	-	-	-	-	-	-	4,95,088.00
6	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
7	CONY309	2,32,879.00							-	2,32,879.00
8	CONY312	97,059.00	-	-	-	-	-	-	-	97,059.00
9	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
10	CONY317	6,63,588.00	-	-	-	-	-	-	-	6,63,588.00
11	CONY329	7,35,944.00	-	-	-	-	-	-	-	7,35,944.00
12	CONY330	5,24,537.00	-	-	-	-	-	-	-	5,24,537.00
13	CONY334	15,58,102.00	-	-	-	-	-	-	-	15,58,102.00
14	CONY343	7,81,831.00	-	-	-	-	-	-	-	7,81,831.00
15	CONY344	10,22,999.00							-	10,22,999.00
16	CONY345	2,98,592.00	-	-	-	-	-	-	-	2,98,592.00
17	CONY346	2,51,375.00	-	-	-	-	-	-	-	2,51,375.00
18	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
19	CONY355	2,29,338.00	-	-	-	-	-	-	-	2,29,338.00
20	CONY356	5,83,332.00	-	-	-	-	-	-	-	5,83,332.00
21	CONY360	1,84,812.00	-	-	-	-	-	-	-	1,84,812.00
22	CONY361	1,22,79,218.00	77,36,675.00	13,96,310.00					13,96,310.00	1,86,19,583.00
23	CONY363	3,37,391.00	-	-	-	-	-	-	-	3,37,391.00
24	CONY365	2,29,166.00							-	2,29,166.00
25	CONY369	12,89,318.00							-	12,89,318.00
26	CONY370	8,88,532.00							-	8,88,532.00
27	CONY371	2,24,143.00							-	2,24,143.00
28	CONY372	2,05,925.00							-	2,05,925.00
29	CONY374	2,10,000.00							-	2,10,000.00
31	CONY378	7,24,19,535.00	2,14,47,080.00	41,27,429.00					41,27,429.00	8,97,39,186.00

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	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
32	CONY379	1,02,000.00							-	1,02,000.00
33	CONY380	2,52,460.00							-	2,52,460.00
34	CONY381	2,64,841.00							-	2,64,841.00
35	CONY383	99,904.00							-	99,904.00
36	CONY384	2,51,605.00							-	2,51,605.00
37	CONY385	2,80,099.00							-	2,80,099.00
38	CONY386	10,19,850.00							-	10,19,850.00
50	CONY446	3,08,783.00		3,08,783.00					3,08,783.00	-
51	CONY447	80,500.00							-	80,500.00
54	CONY450	2,39,430.00		2,39,430.00					2,39,430.00	-
55	CONY451	76,000.00		76,000.00					76,000.00	-
56	CONY452	2,39,400.00		2,39,400.00					2,39,400.00	-
58	CONY454	2,55,000.00		2,55,000.00					2,55,000.00	-
59	CONY455	3,80,000.00		3,80,000.00					3,80,000.00	-
60	CONY456	7,48,088.00		7,48,088.00	-	-			7,48,088.00	-
61	CONY457	59,348.00		2,108.00					2,108.00	57,240.00
62	CONY458	9,00,000.00		9,00,000.00	-				9,00,000.00	-
63	CONY459	36,729.00		36,729.00					36,729.00	-
64	CONY460	2,31,392.00		2,31,392.00					2,31,392.00	-
65	CONY461	2,09,400.00		2,09,400.00					2,09,400.00	-
66	CONY462	3,53,631.00		3,53,631.00					3,53,631.00	-
67	CONY463	1,04,400.00		1,04,400.00					1,04,400.00	-
68	CONY464	4,30,500.00		4,30,500.00					4,30,500.00	-
69	CONY465	2,09,400.00							-	2,09,400.00
70	CONY466	2,09,400.00							-	2,09,400.00
71	CONY467	2,09,400.00							-	2,09,400.00
72	CONY468	2,09,400.00							-	2,09,400.00
73	CONY469	2,09,400.00							-	2,09,400.00
74	CONY470	2,09,400.00		2,09,400.00					2,09,400.00	-
75	CONY471	2,09,400.00		2,09,400.00					2,09,400.00	-

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
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	Project	Opening Balance	Consultancy Fee Received	Consultancy Expenses	Incentive Money to Staff	Transferred to Corpus Fund	Transferred to CESS Fund	Transferred to Common Fund	Total Expense	Closing Balance
76	CONY472		3,15,000.00	3,15,000.00					3,15,000.00	-
77	CONY473		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
78	CONY474		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
79	CONY475		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
80	CONY476		5,00,000.00	1,20,000.00					1,20,000.00	3,80,000.00
81	CONY477		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
82	CONY478		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
83	CONY479		3,15,000.00	1,05,000.00					1,05,000.00	2,10,000.00
84	CONY480		2,00,000.00	48,000.00					48,000.00	1,52,000.00
85	CONY481		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
86	CONY482		20,00,000.00	6,84,682.00					6,84,682.00	13,15,318.00
87	CONY483		1,00,000.00	39,760.00					39,760.00	60,240.00
88	CONY484		8,00,000.00	2,58,093.00					2,58,093.00	5,41,907.00
89	CONY485		1,50,000.00	36,000.00					36,000.00	1,14,000.00
90	CONY486		3,15,000.00	1,05,000.00					1,05,000.00	2,10,000.00
91	CONY487		3,15,000.00	1,05,735.00					1,05,735.00	2,09,265.00
92	CONY488		3,15,000.00	1,05,000.00					1,05,000.00	2,10,000.00
93	CONY489		6,15,000.00	1,84,500.00					1,84,500.00	4,30,500.00
94	CONY490		15,00,000.00	3,60,000.00					3,60,000.00	11,40,000.00
95	CONY491		3,15,000.00	1,05,600.00					1,05,600.00	2,09,400.00
96	CONY492		3,15,000.00	1,05,000.00					1,05,000.00	2,10,000.00
97	CONY493		3,15,000.00	1,05,000.00					1,05,000.00	2,10,000.00
	TOTAL	**10,84,74,304.00**	**4,17,55,657.00**	**1,38,73,370.00**	**-**	**22,96,902.00**	**-**	**-**	**1,61,70,272.00**	**13,40,59,689.00**

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NATIONAL CENTRE FOR EARTH SCIENCE STUDIES
Ministry Of Earth Science, Government of India

Schedule 16

Notes on Financial Statements for the Financial year ended 31st March 2019

Organizational Information

National Centre for Earth Science Studies is a Society taken over by the Ministry of Earth Sciences, Government of India on 1st of January 2014 for perusing and promoting basic and applied advanced research in the frontier areas of Earth Sciences. The Centre has been registered under Travancore Cochin Literary, Scientific and Charitable Societies Registration Act, 1955 as an autonomous institution under the Ministry of Earth Sciences, Government of India.

Accounting Policies

The Society had followed mercantile system of accounting till the conclusion of financial year 2013-14. Financial year 2014-15 onwards, Society has changed the accounting system to cash basis. During the financial year 2018-19 the Society has not fully converted its accounts into mercantile system. But partial conversion has been made. The society is in the process of changing the accounting system from cash basis to mercantile basis. The conversion is not yet completed. Only certain heads of accounts are converted into mercantile basis.

Assets

The society has a satisfactory title to all assets and there are no liens or encumbrances on the asset acquired out of grants.

Fixed Assets

a) All the Fixed assets of Centre for Earth Science Studies (CESS) as on 31.12.2013 have been taken over by National Centre for Earth Science Studies (NCESS) other than the land owned by the Government of Kerala. As per G.O (Ms) No.468/2013/RD dated 24/10/2013, the Government of Kerala has accorded sanction in principle for leasing out an extent of 13.95 acres of land possessed by Centre for Earth Science Studies (CESS) to the Ministry of Earth Sciences, GOI for 99 years @ of Re1/- per acre per year for the operation of the Society.

b) The additions of fixed assets during the period are stated at cost. Fixed assets of the Centre are acquired out of grants received. Assets acquired for the sponsored projects (Grant in Aid) are capitalized on completion of the project/receipt of permission from the concerned Government Department. Funds utilized for acquiring fixed assets from Grants received are transferred to Capital reserve.

c) Depreciation is charged to the fixed assets on Written Down Value basis as per the rates prescribed under the Income Tax Rules. Depreciation has also been charged on fixed assets on written down value method for assets transferred from the externally funded

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Current Assets

Cash and bank balances represent the balances with the Society, grant in aid projects and consultancy projects accounts.Closing stock of chemicals, glassware, consumables and stationery items are at cost as certified by the management. Cash equivalents like term deposits and bank balances are as per the confirmations provided.

Loans and advances

Confirmations have been obtained regarding the advances given to staff and suppliers. The outstanding Staff Advance as on 31.03.2019 is Rs30.63 lakhsand
Advances to Suppliers outstanding as on 31.03.2019 is Rs. 1330.24 lakhs.

Interest accrued

The amount of interest accrued but not actually received on fixed deposits was not obtained from the bank and has not been reflected in the Annual Accounts.

Contingent Liabilities

The contingent liabilities are certain liabilities that may arise in the future on account of litigation against the Society. The effect of these cannot be quantified. The following are the legal cases pending in various courts:

Sl No	Writ Petition/ Case Number	Case Particulars	Present Status (as on 1st October 2019)	Likely financial Obligation
1	ATA No: 698 (07) 2013 before the EPF Appellate Tribunal, New Delhi	Petition filed by former employees of CESS seeking payment of Employers share of PF Contribution to the EPF on the pay revision arrears	Appeal Filed through Adv.Ajith S Nair and AdvNidoshRathore is appearing before the Tribunal. Stay granted by EPF Appellate Tribunal, New Delhi	Rs. 3.67 Crores (Approx.) Self-contained note with relevant details sent to MoES already
2	WP © No: 15845 of 2015 filed by P.Girija before the before the Honourable High Court of Kerala	Promotion to the post of Scientist B	Counter Affidavit furnished. Judgement awaited	Pay scale of Scientist B till date of retirement in 30.09.2006
3	WP © No: 13704/2016 filed K.V.Thomas& others	Pension Case	Judgement awaited	Not known at present

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4	Appeal filed on 10-08-2015 before the Appellate Tribunal, Bangalore	Demand to remit service tax against fund received towards grant-in-aid during period from 2002-05 and 2010-11	Case is pending before Customs Excise and Service Tax Appellate Tribunal, Bangalore	Against the Order-in-Appeal, NCESS had filed Appeals (A. Nos. ST/21752 & 21754/2015-DB) before the Customs, Excise and Service Tax Appellate Tribunal, Bangalore. The Registry of the Tribunal had raised a defect notice. The defect notice was to deposit 10% of the disputed tax as mandatory pre-deposit as per amended Section 35F of the Central Excise Act, 1944. The Appeals were posted for hearing on the defect before the Hon'ble Tribunal on 18.02.2016. After noting the submission, the Hon'ble Tribunal has directed NCESS to deposit 10% of the disputed tax amount

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				within 4 weeks and report compliance on 11.04.2016. Against A.No. 21752, NCESS had deposited Rs.3,70,740/- on 30.03.2016 and against A. No. 21754 deposited to Rs. 35,224/- on 28.03.2016. Outcome of the case is awaited
5	WP © No: 32888 of 2017 filed by Rajesh P and others before the Honourable High Court of Kerala	Consider placing the petitioners in PB 2 i.e. 9300-34800 with GP 4200/- and for other reliefs.	Counter Affidavit furnished.	Not Known
6	WP © No: 23371 of 2018 filed by Anju K S and others before the Honourable High Court of Kerala	Consider placing the petitioners in PB 2 i.e. 9300-34800 with GP 4200/- and for other reliefs.	Counter Affidavit furnished	Not Known
7	WP © No: 8515 of 2019 filed by Dr. C N Mohanan and others before the Honourable High Court of Kerala	Gratuity arrears in respect of employees who retired on or after January 2016	Counter Affidavit not furnished	-----
8	WP © No: 2953 of 2019 filed by Shri.N.Unni before the Honourable High Court of Kerala	Request for revised pay scale in 9th State Pay revision	Counter Affidavit not furnished	----
9	WPC 2181/2019 filed by M/s Summer Cabs before the Honourable High Court of Kerala.	To stay the retender process and to award the vehicle contract to M/s Summer Cabs	Counter Affidavit not furnished	-----

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Capital Work in Progress

As per the statement obtained from Central Public Works Department (CPWD) and Bharat Sanchar Nigam Limited (BSNL), there is no portion of work in progress which has to be transferred to the concerned fixed assets account. Since any of these assets are not put to use during the year, no depreciation has been charged.

Capital Reserve

The amount received from the Ministry of Earth Sciences and other institutions utilized for acquiring Fixed Asset is credited to the Capital Reserve and the depreciation charged in the Income & Expenditure statement is written back by debiting the Capital Reserve. The Capital reserve as on the date of taking over is carried forward after deducting the value of the land not taken over.

General Reserve

The negative figure of 2.56 crore was due to the non - receipt of Non - Plan grants from The Kerala State Council for Science, Technology and Environment (KSCSTE) and overspent during the erstwhile CESS period.

Corpus fund

In order to maintain corpus fund, approval from the Administrative Ministry is required. However no such approval has been obtained from MoES. Since receipts accrued to NCESS is utilized as main source of receipts for Corpus fund, obtaining approval from MoES is mandatory.The unspent balances of Consultancy projects that are concluded and closed are transferred to Corpus fund and MACIS (Divisional core research project).

Research Program Funds

The balance of the grant for the research programs remaining unspent is stated as Research Program fund under Unspent Balance GOI - MoES. During the year, the society has received Rs.3098lakhs funds towards Research Program Grant from the Ministry of Earth Sciences (MoES). Unspent balance as on 31st March, 2019 is Rs.1606.45 lakhs.

Unspent Balance of Projects

The unspent balances of the grant received for the conduct of sponsored R&D projects sanctioned by the Ministries/ Departments of Government of India/Government of Kerala, Consolidated service projects/ Consultancy projects from various agencies are carried forward as Unspent balance of Projects. During the year the Society received an amountRs.755.44 lakhs and unspent balance as at the end of the period amounts to Rs.1583.89 lakhs.

Operation and Maintenance Fund

Unspent balance of Grant received from the Ministry of Earth Sciences (MoES) for operation and maintenance expenditure and other income of NCESS is stated as the balance of Operation and Maintenance Fund. The excess of income over expenditure or

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deficit of income over expenditure in the Statement of Income and Expenditure is credited or debited in the account. Unspent balance as on 31st March, 2019 is Rs.94.88 lakhs.

Projects

The Committees consisting the heads of respective projects and other technical personnel are monitoring the status of the various projects, including the financial budgets etc., and noting the minutes of the output of such meeting. The various assets of the projects, purchased by NCESS are located at such projects.Income and Expense of the External/ Consultancy projects are accounted on cash basis.The unspent amount on the completion of consultancy projects is transferred to Corpus fund.

Treatment of GST

The Society has claimed GST input but no entry has been passed in the books of accounts regarding such set off made. The amount of GST collected (i.e. Rs. 66.25 lakhs) remains payable as per the books of accounts and is shown as GST payable under the head Current Liabilities.

Retirement Benefits

Leave encashment is accounted for on Cash basis. No provision for leave encashment is made in the accounts.

Interest received

The society parks fund in Short term deposit with bank and also in Savings Bank accounts of SBI. The Interest received in the said accounts is the income of the Society. Interest earned on corpus fund is added to the corpus fund itself and not included in the Income of the Society.

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