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National Centre for Earth Science Studies
राष्ट्रीय पृथ्वी विज्ञान अध्ययन केन्द्र
(ESSO, Ministry of Earth Sciences, Govt. of India)
(ई एस एस ओ, पृथ्वी विज्ञान मंत्रालय, भारत सरकार)
Akkulam, Thiruvananthapuram-695011, India
आक्कुलम, तिरुवनंतपुरम–695011, भारत

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Compilation	*Dr. D. S. Suresh Babu, H/PT & D*
Editorial Committee	*Dr. L. Sheela Nair* *Dr. A. Krishnakumar* *Dr. E. A. Resmi* *Dr. Nilanjana Sorcar*
Secretarial Assistance	*Smt. R. P. Rejani* *Smt. S. R. Reeja Raj*

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From the Director's Desk

During the Year 2015-2016, National Centre for Earth Science Studies (NCESS), Thiruvananthapuram, continued in solid earth research and particularly the natural hazards and environmental monitoring while maintaining its unique national position in developing integrated approaches for micro-level planning. The year has been very eventful for NCESS.

The basic mandate of NCESS under the MoES is to carry out research in frontier areas of geoscience provide quality database useful for societal applications. The major focus at NCESS during the year was to create a world class scientific institution in solid earth research with an intellectually alive research atmosphere by recruiting young scientist. Core research programmes of the NCESS have been reformulated after prolonged planning and discussions, both within the institute and beyond with other institutions in MoES.

The four scientific groups, viz., Crustal Processes (CrP), Coastal Processes (CoP), Natural Resource and Environment Management (NREM), and Atmospheric Processes (AtP) have carried out programmes giving thrust to both basic and applied aspects.

The Crustal Process Group continued focusing on their long cherished basic research programmes, such as petrological, geochemical, paleo-magnetic, fluid-inclusion, Quaternary geology and geo-hazard investigations. We were committed to take up several short-term investigations on landslides, groundwater, soil piping and watershed management from time to time based on certain demands and media reports. Additional palaeomagnetic site mean directions have helped to bring certain consolidation for path of the Indian shield during the Palaeoproterozoic Eon. Recent studies on petrology and geochemistry of Kerala Khondalite Belt throw light onto the lower crustal evolution, intracrustal melting and magmatic differentiation. Another unique achievement is improving methodology on the quality assaying techniques of the petroleum well samples for hydrocarbon fluid inclusions (HCFIs) based on photoluminescence emission studies using Laser Raman Micro Spectroscopy (LRMS). Fresh evidences towards the development of wetland systems and peatlands during the Quaternary have been collated from isotope and palynological studies of terrestrial and marine sequences. A new initiative has been made to study the landslides in the northern lobes of Western Ghats in Maharashtra region. Many site visits were made and reports were submitted to Government authorities on events of landslides and soil piping assuaging the fears of the local communities.

The Coastal Processes Group has been active on furthering their studies on coastal morphodynamics, coastal stability, nearshore and estuarine sedimentation, geomorphological evolution of the coast, Subsurface Ground water Discharge (SGD) along the coasts, etc. New sets of data from field observations on waves, currents, tides, temperature and sediments were obtained to build the interlinkages among the hydrodynamics vis-a-vis the coastal morphological settings. The study of SGD for a coastal stretch in north Kerala illustrated interesting results on considerable contribution of fresh groundwater flow to the sea. Substantial contribution of metals from anthropogenic sources in the nearshore sediments of the northern part of Kerala coast has been corroborated from the investigation. A comprehensive study of coastal flooding phenomenon has resulted in identifying the causative factors. Certain collaborative programmes with external funding, such as, maintenance of wave guage stations, shoreline mapping and monitoring, and impact of sea level rise along the Kerala coast have also been pursued robustly. NCESS being a recognized agency by the Ministry of Environment, Forest and Climate Change for Coastal Regulation Zone (CRZ) mapping, was involved in the preparation of Coastal Zone Management Plan for Kerala, mapped and prepared several CRZ reports on short-term consultancy mode for different agencies and extended services to Kerala/Maharashtra Governments on related issues.

The Atmospheric Processes Group in NCESS has been conducting observations related to cloud physics and monitoring parameters on clouds, their occurrence, altitudinal distribution and related parameters. Setting-up of high altitude state-of-the-art cloud physics laboratory in the Western Ghats is in final stage. The multi-purpose laboratory is intended to monitor microphysical parameters of cloud and precipitation, lightning activity, thermodynamic variables, atmospheric electric field and other parameters. Certain specific variance in pattern has

been observed in raindrop diameter and concentration during different monsoon seasons. From ground-based measurements of microphysical parameters, nature of convective and stratiform precipitation types were studied. Overview of the results depict that in the case of convective type rain, high intensity classes contribute a major part of water.

The Natural Resources & Environmental Management Group is actively engaged in basic and applied research on environmental aspects of land and water. A new programme has been initiated for studying the natural resources wealth and environmental management of the twin river basins of Netravathi-Gurpur in Mangalore and Periyar-Chalakkudi north of Kochi. Specifically, the Periyar River basin is studied for characterizing critical zones and climate change impacts. Sand auditing studies carried out for the Idukki District in Kerala highlights the concept of 'sand mining holidays' to minimize the negative impacts of sand mining. The EIA research of all mining and quarrying activities implies intense changes in the landforms and landuse. Measurements of seasonal and diurnal variations in atmospheric CO_2 over Thiruvnanthapuram reveal explicit patterns owing to certain meteorological parameters. Strong seasonality of black carbon aerosol concentration showing significant enrichment during winter and vice-versa during monsoon is correlatable to meteorological conditions. One of the significant contributions of the Group from socio-environmental framework is the environmental management action plan for ecorestoration of Vembanad Lake and connected river systems. Water and sediment quality parameters studied for the backwater of Cochin Port Trust has exposed explicit pollution source as industries. One of the major programme of the group in collaboration with ICMAM is the sea water quality monitoring, contributing to continuous valuable data set on the quality of water in terms of hydrochemistry, marine biology and microbiology. Practical applications of the research on kinetics and thermodynamics profile of adsorptive potential of surface modified clays and chitosan offers great potential.

NCESS aims to be a knowledge hub for solid earth research in India within the next decade. In this context, the institute plans on developing a synergetic network with other academic institutions both in India and abroad. Annual workshop on the science of climate change and sustainable development organized during August 19-20, 2015 future areas of research through distinct identification of study gaps. Interesting discussions and exchange of new knowledge ensued in the national workshop on Western Ghats held in the campus during 1-2 January 2016 which was inaugurated by Sri. Y.S. Choudary, Hon'ble Minister of State for Science, Technology and Earth Sciences. Brain storming meeting on January 28, 2016 brought together experts and erudite earth scientists in the country identifying future direction for research.

The Centre is looking forward towards setting up of exclusive Earth Museum and Training Centre in Geoscience professional need for continuing education and training of manpower in earth system sciences to catch up with the concurrent development. The success of NCESS, besides facilities is driven by technical, administrative, research fellows and project staffs.

Dr. Virendra M. Tiwari FNASc
Director

1.1 A new crustal evolution model for the formation of charnockites (felsic ortho granulites) of the Kerala Khondalite Belt, southern India

During the last few decades, petrological studies by NCESS on the Kerala Khondalite Belt (KKB) have focused largely on understanding of (1) formation of arrested charnockite, (2) dehydration-melting and formation of leucogranites and (3) geochemistry and thermobarometric evolution of dominant lithologies. Most of the studies regarded KKB as a large granulite-grade supracrustal unit with most of the felsic rocks including charnockites representing metamorphosed sediments. Only recently, Sreejith and Ravindra Kumar, (2013) documented subduction–accretion–collision related geochemical signatures from metagranites of the KKB and suggested them as intra-crustal melting products of the terrane assembly of the Palaeoproterozoic supercontinent fragments including India, Sri Lanka, and Madagascar.

In the earlier KKB studies, there was a significant omission in the classification and understanding of the interrelation between different charnockite types (incipient growth and large bodies of ortho-granulites) vis-à-vis their petrogenetic relations to the tectonomagmatic and crust-forming events. Unravelling the petrogenesis and geodynamic setting of the orthogneisses is important as it throws new light on the crustal evolution of this well-known high-grade terrane. There was a urgent need to fill this gap of knowledge by providing a comprehensive petrological-geochemical account on orthogneiss/granulite samples covering the entire spectrum of "charnockitic" felsic orthogneisses. In the last one year, we took up a detailed petrological and geochemical exercise on orthopyroxene-bearing, felsic ortho-granulites spread over the entire KKB. Over 100 samples trace and major element data was generated using XRF at NCESS. By integrating field, petrological and geochemical results, we propose a new petrogenetic and crustal evolution model (Ravindra Kumar and Sreejith, In Press). Following is an excerpt from our recent article accepted for publication in an international journal.

Orthopyroxene-bearing felsic ortho granulites (charnockite *sensu lato*) constitute an important lithological component within the metasediment-dominated HT-UHT terrane of the Kerala Khondalite Belt, southern India. These rocks have so far remained poorly studied with respect to their mode of occurrence, their petrological and chemical attributes, and the petrogenetic-geodynamic aspects of their formation. Our detailed study, coupled with field observations and petrological and chemical data allowed us to distinguish three distinct orthogneiss suites as (1) tonalitic (TC), (2) granitic (GC), and (3) augen (AC) suites. Members of the TC follow sodic, whereas those of the GC and AC follow calc-alkaline trends of differentiation.

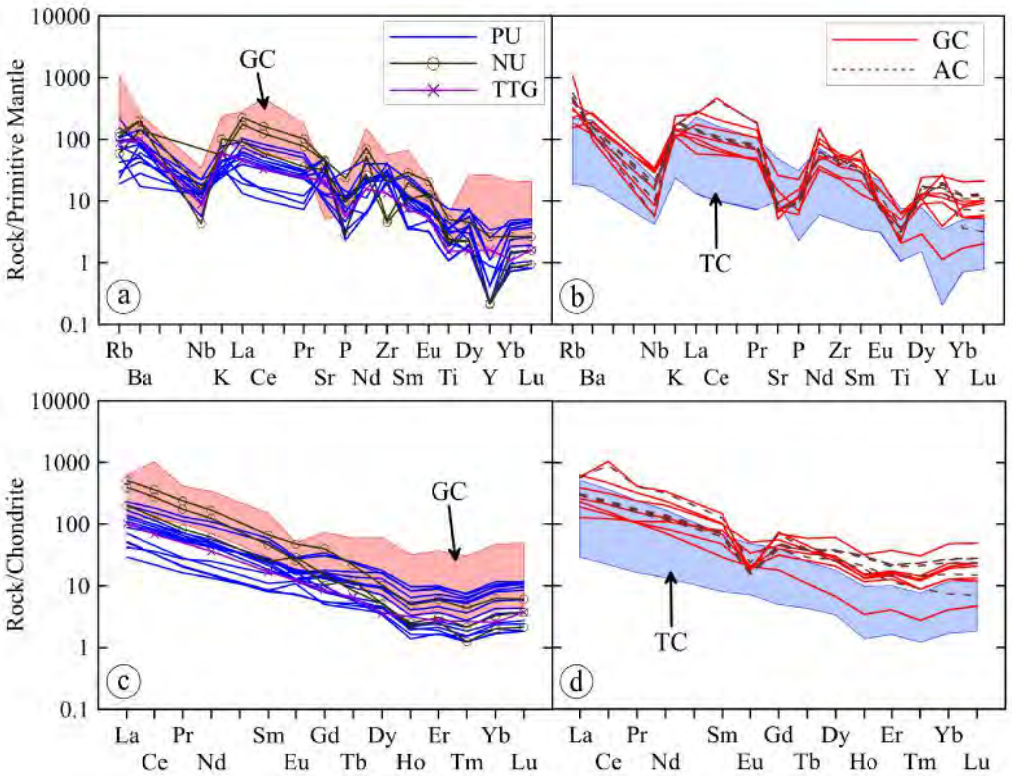


Fig.1.1.1 Primitive mantle- normalized multi-element diagrams (a and b) and chondrite-normalized REE patterns (c and d) for the KKB charnockite: (a and c) tonalitic and (b and d) granitic samples. Chondrite- and primitive mantle-normalization factors are from Boynton, (1984) and Sun and McDonough, (1989), respectively. Fields of the GC are shown with TC and the TC fields with GC plots for comparison. PU and NU represent tonalitic charnockite samples from Ponmudi and Nagerkovil Units respectively. Also shown on the tonalitic charnockite plots are the average composition of Archaean tonalite-trondhjemite-granodiorite (TTG) taken from Martin, (1994).

Geochemical patterns of the TC resemble those of the Archaean tonalite–trondhjemite–granodiorite (TTG) suites, with slightly magnesian character (average Mg# = 33), moderate LREE (average La_N = 154), low HREE (average Yb_N = 6) and Y (1–53 ppm; average 11 ppm). The GC and AC suites, on the other hand, resemble post-Archaean arc-related granites. The GC displays ferroan nature (average Mg# = 22), low to moderate degrees of REE fractionation (average $[La/Yb]_N$ = 34.84), high contents of Y (5–128 ppm; average 68), and low Sr/Y (1–98) ratios.

By integrating published whole rock isotope and geochronological data to assess the geodynamic setting and processes involved in the petrogenesis and chemical diversity of the magmatic precursors of the high-grade orthogneiss suites, we suggest a four-stage crustal evolution for KKB. The first stage is marked by the formation of an over-thickened oceanic-arc (2.8 to 2.6 Ga). The second stage corresponds to the production of TTG magmas by melting of the over-thickened oceanic-arc crust, subsequent to basaltic underplating during Palaeoproterozoic (ca. 2.1 Ga). The third stage was initiated by a transition in subduction style from shallow to steep due to continent-arc accretion. This stage is marked by the formation of granitic magmas through partial melting of the TTG crust and their differentiation into GC and TC. The zircon crystallization ages (1.89 and 1.85 Ga) of the GC indicate arc accretion occurred during the Palaeoproterozoic. The fourth stage of crustal evolution is correlated with the Mesoproterozoic (~1.5 Ga) emplacement of megacrystic K-feldspar granites (protoliths to the AC and augen gneisses). The distinct petrography, geochemistry and crystallization ages of the AC suggests recurrence of megacrystic, high-K calc-alkaline granitoids as the product of final phases of crustal-remelting marking subduction cessation. All these magmatic events are fairly well correlated with the major episodes of crustal growth observed in the once contiguous continental fragments of East Gondwana.

G. R. Ravindra Kumar & C. Sreejith

1.2 Mafic volcanic flows / sills in the Gwalior, Bijawar sedimentary basins

Integrated palaeomagnetic and geochemical investigations continued as part of the ongoing long-term program for understanding the geodynamic evolution of the Earth. In the previous years, our focus has been on the mafic dykes in the Dharwar and Bundelkhand cratons and the Archaean craton around the Palaeoproterozoic Cuddapah basin. New palaeomagnetic and geochemical investigations on the volcanic flows/sills in the Gwalior and Bijawar sedimentary basins in Central India were initiated. These works are aimed at deriving the geodynamic configurations of the Indian shield deep in time during the Palaeoproterozoic and to unravel the petrogenetic history of the continental magmatism and the evolution of the mantle processes under the Proterozoic Indian shield.

During the period, the palaeomagnetic investigations continued on the samples collected in the previous fieldwork. This is a collaborative project between the NCESS and the Bundelkhand University initiated with funding from the Department of Science and Technology, Government of India to study petrology, geochemistry and palaeomagnetism coupled with isotope dating of the igneous units occurring within the basins. Thermal demagnetisations have been carried out on six site samples of Bijawar and Gwalior igneous units for which alternating field demagnetisations have been completed earlier. Another fieldwork is planned to collect additional samples to improve the quality of data to constrain the characteristic remanent magnetisations and to obtain samples of more primitive compositions as most of our earlier collection represent differentiated products. This work also envisaged isotopic dating of mineral phases like zircon or baddeleyite, efforts have been mainly concentrated to setup the mineral separation laboratory for isotopic analysis. Magnetic Barrier Laboratory Seperator (sanctioned under the DST project) was procured and the procurement of other equipment and setting up of the laboratory are in progress.

The project is also aimed at integrating and comparing the data with the results produced on mafic dykes in the adjoining Dharwar and Bundelkhand cratons to identify linkages, if any, between them. Hence, detailed petrological and geochemical analysis of the major and trace element data on mafic dykes in the Bundelkhand craton have been attempted. Detailed petrological interpretations are in progress.

T. Radhakrishna, Tomson J. Kallukalam & Ram Chandra
Funding: DST, GoI

1.3 Proterozoic / Phanerozoic Mafic Dykes

As a part of the IGCP (UNESCO) 597 project on Amalgamation and breakup of Pangaea: the type example of supercontinent cycle, lamproite samples were collected in the Gondwana Group of sedimentary rocks in the Damodar Valley in a joint fieldwork with the Geological Survey of India. The samples were initially used for ther-

momagnetic study of temperature-susceptibility experiments. The thermomagnetic spectra are interpreted indicating that the chief magnetic carrier in the lamproites is high Ti- titanomagnetite, sometimes typically changing over to low Ti- titanomagnetite. Thus, these samples are likely to respond to alternating field demagnetisation experiments for isolating characteristic remanent magnetisations. Stepwise alternating field demagnetizations were completed. The magnetization directions and intensities were measured after each step of demagnetization using JR6 Spinner Magnetometer (AGICO Ltd; Czech) because of their low magnetisation behavior of the samples. The demagnetisations were carried out at successive fields of 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, 25, 27.5, 30, 35 and 40 mT. The initial NRM directions are very much scattered and attain better within-site coherence on alternating field demagnetizations. The responses of alternating demagnetizations from a representative sample are depicted in the form of orthogonal and stereographic projections in Fig. 1.3.1 Site-mean characteristic magnetisations, virtual geomagnetic poles (VGPs) were determined. The mean VGP is compared with the grand mean palaeomagnetic pole of Deccan traps, Rajmahal volcanics and the synthetic apparent polar wander path constructed from the global palaeomagnetic database. Based on comparisons and the proximity of these sites to the Rajmahal volcanics, the lamproites are suggested to belong to coeval with Rajmahal traps volcanism. The results were synthesized and submitted to form a part of the report by the Indian working Group of the UNESCO-IGCP 597.

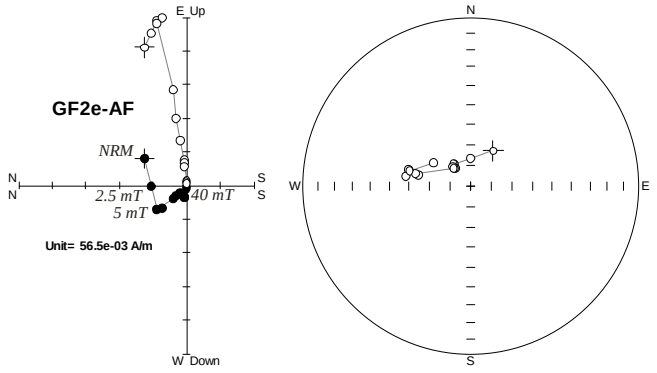


Fig. 1.3.1 Orthogonal and stereographic projections of magnetic remanence behavior during alternating field demagnetizations of representative sample from lamproite intrusions within the Gondwana Group of sedimentary formations. Open and closed symbols on orthogonal projections denote projections onto the horizontal and vertical planes, respectively. In the stereographic projections open symbols denote projections in the upper hemisphere.

A 1460 Ma palaeopole estimate based on reassessment of the data on dykes on the Eastern Ghat mobile front in the eastern Bastar craton in light of our recent results on Palaeoproterozoic dykes in the Indian shield is further refined. As part of this work another pole to represent an overprint at 1.65 Ga is also proposed. These palaeopole data are useful to constrain position of India in the Mesoproterozoic continental reconstructions. A manuscript based on these results is finalysed. In addition study of the geochemical results of mafic dykes in Bundelkhand craton are also in progress.

T. Radhakrishana & Ram Chandra
Funding: DST, GoI

1.4 Late Neoproterozoic anorthosites in south India

Palaeomagnetic and geochemical investigations on Oddanchatram and Kadavur anorthosites in Dindigal district, Tamilnadu were continued during this period. About ninety oriented core specimens were subjected to step-wise-alternating field demagnetizations at 2.5/5 mT steps up to 50 mT and thereafter at 10mT steps up to 100 mT. Thermal demagnetization experiments were carried out on eighteen representative samples of anorthosite and gabbro units at successive steps of 50°C interval up to 500°C and then at 20°C interval up to 600°C. Susceptibility determinations were carried out on all samples collected. Thermomagnetic experiments were carried out on at least one sample from each site during heating (up to 640°C) and cooling up to 100°C. Isothermal remanent magnetization measurements were conducted for at least one sample from each site during the forward and backward fields. Major oxides and trace elements (V, Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Ba, Pb) were analysed for eighteen samples by the XRF method.

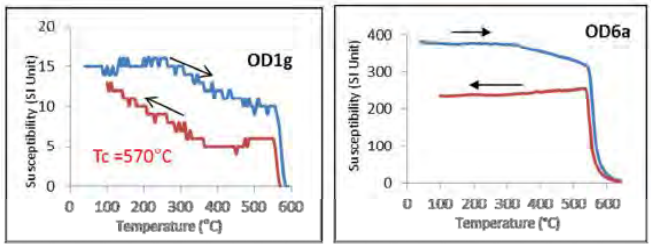


Fig. 1.4.1 Thermomagnetic curves of Oddanchatram anorthosite (left) and gabbro (right)

A second field work and additional sampling for the earlier sites was carried out to statistically improve the results and a few new paleomagnetic sites were also collected from both Oddanchatram and Kadavur areas. Three basement gneiss sites were also collected to perform baked contact tests. With this new collection the total number of sites becomes twenty four (14 from Oddanchatram anorthosite

and 10 from Kadavur anorthosite). Fifteen block samples were collected from new localities for geochemical study. Preparation of specimens and thin section making for petrography work are in progress. This work would also form a doctoral work of a UGC-CSIR Net qualified Junior Research Fellow.

G. Soumya, Tomson J. Kallukalam, T. Asanulla & T. Radhakrishna

1.5 Palaeomagnetism and geochemistry across the Koyna drill core

Core KBH-7 that recovered Deccan basalt to a maximum thickness of about 1200m has been taken for palaeomagnetic study. A first visit to the Borehole Geophysics Research Laboratory (BGRL) at Karad was made during October, 2015, examined in detail the top 350m section of the core and logged it. Eight flows were identified of which many are separated by the intermittent red boles of 15cm to less than 1m thick. One red bole between the flows 5-6 is about 2.4 m in thickness. A few pilot samples were taken from four flows (KBH-7 flow# 2, 4, 5 and 7) for a preliminary study.

Petrography of the collected samples was recorded and the samples were subjected for detailed rock magnetic study to ascertain their suitability for Palaeo-field determinations. Initial NRM was measured and magnetic susceptibility values were measured. Temperature-susceptibility curves were obtained for the heating-cooling cycle (room temperature to 650°C). IRM studies were conducted with a maximum forward and backward field of 1000 mT (Fig. 1.5.1). Using IRM forward and backward field values, magnetic parameter such as S-ratio, Soft IRM, Hard IRM and Hcr were determined. The Q-ratio value was estimated based on measured initial susceptibility and NRM values. Q value for the pilot samples from flow #2, 5 and 7 (except flow# 4) are greater than one which points out presence of a stable thermoremanent NRM with dominance of SD/PSD grains.

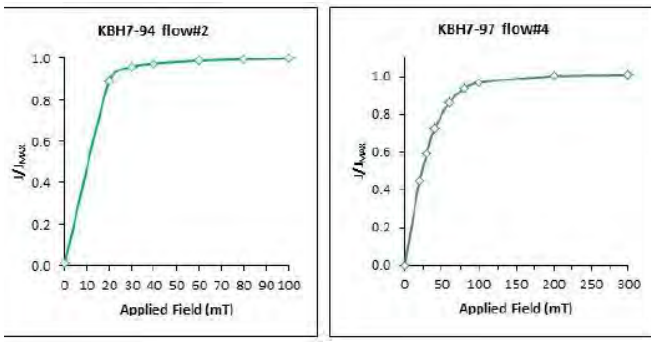


Fig. 1.5.1 IRM forward curves of samples from two Deccan trap flows of the Koyna drill core KBH-7

Thermomagnetic curves for the flow #2 sample show two curie point phases: first one between 265 - 360°C and second at 565°C with irreversibility of heating and cooling curves. The flows #5 and #7 samples also show irreversibility of heating and cooling curves but a single Curie point at 565 and 580°C respectively suggesting that the chief magnetic mineral is low-Ti Titanomagnetite. The flow #7 sample shows a good reversible heating and cooling curve with a phase having curie points at <490°C and 610°C. The results indicate usefulness of samples for polarity investigations and are less likely to yield reliable palaointensity. The results were presented at the Project Advisory Committee meeting in IIT Bombay during January 2016

During February, 2016 another visit was made to the BGRL and logged the entire core up to a depth of ~1250m where the basement was struck. Samples from almost all flows were collected for detailed palaeomagnetic study. The same samples are also chosen for geochemical and petrological investigations. Thin sections prepared and their petrography is being documented and laboratory drilling is in progress to prepare specimens for palaeomagnetic investigations.

T. Radhakrishna, Prachiti , R. Asanulla & M. Venkateswarlu
Funding: MoES, GoI

1.6 Participation in the IODP 355 Expedition and Basement of Laxmi Basin

Following the selection by the IODP as an on-board specialist for Igneous petrology and palaeomagnetism, taken part in the IODP Expedition 355 in the Arabian sea for two months from March 31, 2015 to May 31, 2015. The role of an igneous petrologist has been performed for the study of basement in the Laxmi Basin. Two holes (U1456 and U1457) were drilled in the Laxmi Basin during the expedition. Igneous rocks of basaltic composition were recovered in the core 96R to 98R of the U1457C hole at a depth of 1092.78 mbsf up to a depth of 1108.91 mbsf, the depth at which the drilling terminated. The basalt basement constitutes the lithostratigraphic unit VI in the hole. This unit underlies the Palaeocene claystone of the lithostratigraphic unit V. Macroscopic descriptions of the VCD (Visual Core Discriptions) were made and entered into the IODP- LIMS database using desklogic program during the expedition.

The petrography and geochemistry studies carried out onshore soon after the expedition because the basement was recovered only on the last day of the expedition. Detailed petrography was documented in a prescribed IODP format and supplied to the IODP along with

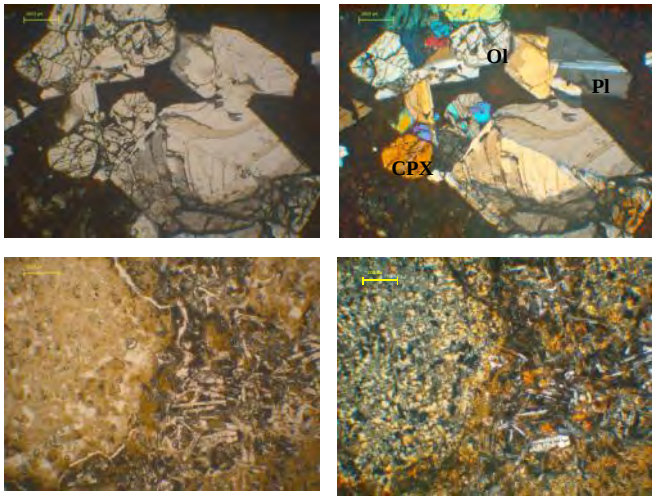


Fig. 1.6.1 Photomicrographs of basement basalt section recovered from IODP hole U1457C in the Laxmi Basin, Arabian Sea. Left side under polarized light and on the right are under crossed nicols

photomicrographs to upload into the IODP- LIMS database at the IODP official website. Representative photomicrographs are given in Fig. 1.6.1.The samples were pulverized and prepared for geochemical investigations. Major oxides and trace elements (V, Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Ba, Pb, La, Ce) were determined by the X-ray Fluorescence techniques for nine representative samples. Initial macroscopic observations have appeared in the preliminary report of the expedition. A more detailed report with petrography and major and trace element geochemistry was prepared and submitted to the Chief Scientist (Dr. Denise Kulhanek) of the Expedition for incorporating as Igneous petrology chapter in the Proceedings of the IODP Expedition. Based on the XRF data, the basement in the Laxmi basin is classified as tholeiitic basalt in composition. Compositionally the recovered basement is more close to the primary melt of the mantle.

T. Radhakrishna

1.7 Palaeo fluids in the petroliferous basins of Western offshore, India

Petrographic, microthermometric & Raman analyses of samples from RV-1 well (Ratnagiri offshore, Mumbai basin) have been completed. Based on the study results a draft report is prepared on HCFIs (hydrocarbon fluid inclusions) and Non-HCFIs in RV-1 well. In RV-1, HCFIs were reported from quartz and feldspar grains in the sedimentary rock cuttings, especially from the sandstone- silt stone lithologies towards the lower portion of the well depth ranging from 3270 to 3690 m. As per the litho stratigraphy of the Mumbai offshore basin, the hydrocarbon inclusions are observed mainly in the Panna Formation,

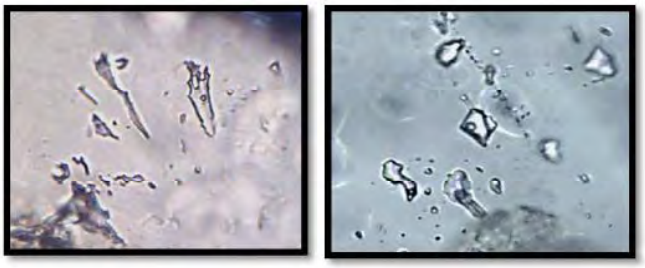


Fig. 1.7.1 Fluid inclusions in the study area

which is both a producing as well as a reservoir horizon. Minor quantities of hydrocarbon fluid inclusions are also noticed in the 1345-1360 m horizon which falls within the Mukta formation comprised mainly of limestone- shale lthologies. Petrographic studies confirmed the presence of the carbonic inclusions, aqueous inclusions as well as hydrocarbon inclusions (Fig. 1.7.1)

Fig. 1.7.2 Linkam heating freezing stage with imaging station for microthermometric studies of fluid inclusion

Hydrocarbon inclusions showing good fluorescence were observed during petrographic studies and are selected for PL and Raman studies. Micro thermometric analysis (Fig. 1.2.2) on coeval 109-biphase, secondary non-hydrocarbon fluid inclusion assemblages from six horizons of RV-1 well from Panna formation (2900-3500 m) provided a T_H ranging 80-135^{0}C, which is in tandem with the oil window. T_H range from 80-135°C showed by 100 fluid inclusion assemblages indicates that there is at least one episode of heating conducive for oil generation and T_H range 140-165 °C for 9- fluid inclusion assemblages show that there is at least one episode of high temperature heating favorable for gas generation.

Photoluminescence emission studies: The non-contact, non-destructive and rapid analysis of crude petroleum oils are desirable for quality control and oil exploration purposes.

Most petroleum oils are fluorescent because of the presence of cyclic aromatic hydrocarbons and therefore, fluorescence techniques can be employed for this purpose. The fluorescence behaviour of petroleum is primarily based on the chemical and physical composition of the fluorophores and on the excitation wavelength employed. Low-density fluids fluoresce at shorter wavelengths and as density increases the fluorescence emission shifts to longer wavelengths in the orange and red. American Petroleum Institute's (API) scale on qualitative assessment of oil is for denoting the 'lightness' or 'heaviness' of crude oils and other liquid hydrocarbons. The API is a measure of the density of a petroleum-based liquid compared to water and is a key factor in determining the market value of crude oil. Oil with API greater than 30^0 is termed light; between 22^0 and 30^0, medium; below 22^0, heavy; and below 10^0, extra heavy.

In general, light oils (high API gravities) have narrow, intense emission bands with small Stokes shifts while heavy oils (low API gravities) tend to have broad, less intense bands with greater Stokes shifts. This is due to the high concentration of fluorophores and quenchers present in heavy oils, which in turn leads to an increased rate of collisional energy transfer and quenching to produce broader, weaker, red-shifted emissions. Conversely, light oils, with more dilute fluorophore concentrations, have reduced rates of energy transfer, and so a narrower emission.

The potential of fluorescence emission technique to determine the API gravity of petroleum oils is applied to develop a standard data set of crude oils with known API gravities. Towards this, fluorescence emission from 12 fresh and pure petroleum oil samples (collected from the chemical analytical facility of the Regional Geological Laboratory of ONGC at Panvel, Mumbai) were recorded with a laser excitation at 405nm using Laser Raman Micro Spectrometer available at NCESS (Fig. 1.7.3). The fluorescence spectral data obtained were normalised to their maximum emission intensity. The emission ratio at F620/F560 shows a decreasing trend when the API gravity increases and these emission intensity values were plotted against API gravities of corresponding oil samples (Fig. 1.7.4). This standard data set can be used to determine the API gravity of oils present even in micron sized hydrocarbon bearing fluid inclusions (HCFIs) in the source/reservoir rocks itself prior to the initiation of large scale developmental activities in the oil exploration sites.

An empirical formula was derived for determining the unknown API gravity of oils in HCFIs from an API known oil standard data plot of fluorescence emission intensity

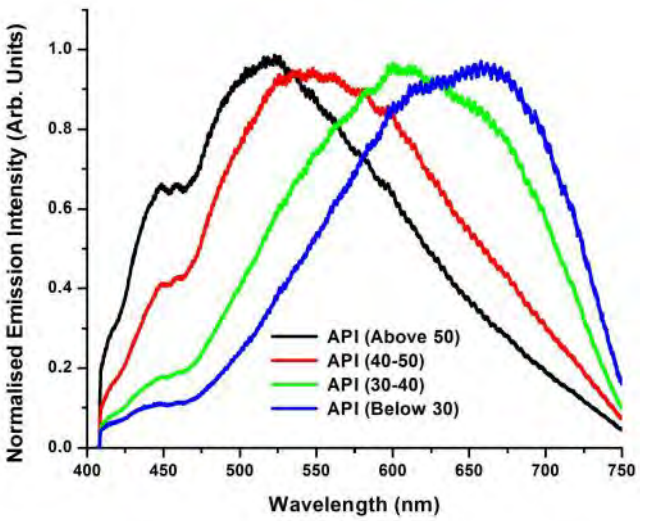


Fig. 1.7.3 PL emission of oils based on their API gravity at a laser excitation of 405 nm

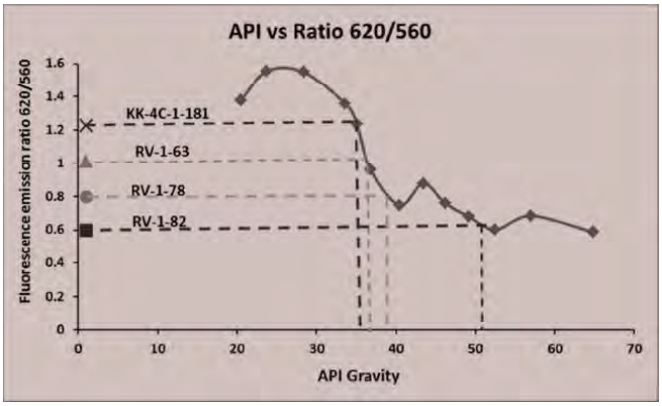


Fig. 1.7.4 Graphical method of determining the API gravity of oils in HCFIs

ratio at F620/F560 vs. API gravity. The efficacy of the empirical relation was tested by recording the emission from 11 HCFI samples from RV-1 at 405 nm. The intensity ratio value obtained at F620/F560 was inserted in the newly derived empirical formula and the API gravity value obtained is well matched with those obtained by the extrapolation of standard graphical plot. The results are submitted to Pan American Current Research on Fluid Inclusions (Pacrofi-2016) international conference.

Raman spectral studies: The main challenge with Raman spectral studies on natural fluid inclusions is the common presence of fluorescence emission from background minerals leading to the masking of Raman signals. Selection of optimum excitation wavelength is another challenge. Our study on Raman analysis of fluid inclusions from RV-1 well is a demonstration of how best the Raman signals from natural fluid inclusions could be detected using an excitation wavelength of 785 nm with suitable optical parameters and with special wafer preparation techniques to negate the background fluorescence (Fig. 1.7.5). Through

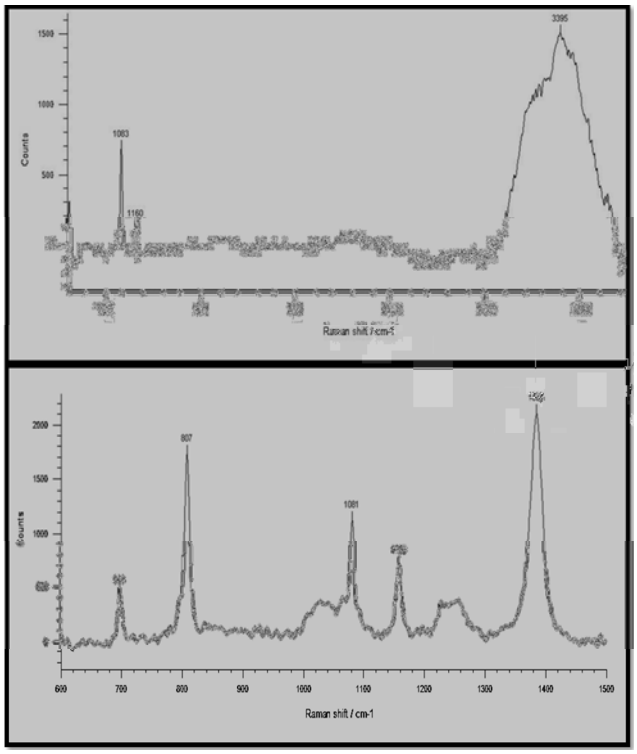


Fig.1.7.5 Raman spectra of non-HCFIs

Raman analysis we are able to locate the presence of aromatic hydrocarbons in HCFIs and this is the pioneer work in India.

V. Nandakumar & J. L. Jayanthi

1.8 Palaeoclimate and sea level records in the Late Quaternary sediments of the coastal wetlands of Pallikkal and Achankovil river basins, Kerala

The 590 km long Kerala coast in SW India is known for its outstanding natural beauty and economic resource potential. The coast hosts a spectrum of landform features such as beaches, lagoons, beach ridges and swales, lakes etc. A careful examination of coastal landforms in the area between Achankovil and Thenmala Shear Zones reveals that the inland wetlands in the area are nothing but the broadened remnants of the tributary channels of the then existed coastal plain rivers of Pre-Late Pleistocene age. The terrain evolutionary model developed from the study shows that Late Pleistocene transgressive events might have carved out a major portion of the land areas drained by the coastal plain rivers. The NNE – SSW trending beach ridges located close to the inland wetlands indicate the extent of transgression to which the region has been subjected to during Late Pleistocene period. The present beach parallel ridges in the younger coastal plains indicate the extend of the Mid Holocene transgressive phase.

Many factors including sea level oscillations and climate changes have played a pivotal role in shaping of the coastal lands. The coastline has oscillated many times due to marine transgression and regression in the Quaternary period. The transgression has enhanced the aerial spread of the sea submerging a greater part of the land under saline waters. Coastal deposition became extensive during the regressive phases. The change in sea level at a given location of the coastal area is the result of the combined effects of global climate change and local/regional land level changes due to neotectonism.

The borehole cores of the inland wetlands reveal many unique features. One of the inland borehole cores representing wetlands at Komallur represents a typical regressive sequence which ends up with a freshwater swamp facies. The formation of peat having an age of 20600±1030 yrs BP coincides with the regressive phase which attained its maximum around 18000 yrs BP. Palynological/ micro-paleontological analysis of the lower greyish green silty clay reveals that the wetlands are evolved due to the land-sea interactions that took place around 40-30ky BP. The medium to fine grained, well sorted quartzose sand lying directly above the greenish grey clay represents the beach/ littoral sediments formed under the regressive phase. This was followed by the development of peat and clay apron evolved under continental freshwater environments. Lithological characteristics and body fossils of pelecypodes and gastropods of Pathiyur and Ramapuram borehole cores reiterates the prevalence of Late Pleistocene sea which was in existence till 24450±710 yrs BP at Ramapuram. The basal unit of the Late Pleistocene sediments at Komallur and Pathiyur is represented by a hard laterite. However, at Ramapuram the laterite is lacking and the basal unit is represented by white clayey sands. The palynological contents, especially the presence of *Cullenia exarillata* is an indication of heavy rainfall and wet climate during Late Pleistocene. In short, the present study reveals that the chain of coastal wetlands that are seen in the eastern periphery of the old coastal plains of the study area have been carved into distinct landforms during Late Pleistocene higher sea levels.

An evaluation of the coastal plain rivers in the uplifted block south of Achankovil Shear Zone (ASZ) i.e., Trivandrum block reveals that the cliffed coast south of the Ashtamudi estuary host many coastal plain rivers like Ayiroor, Mamom, Kulathur thodu, Amayizhanchan thodu, etc. Surprisingly, such rivers are absent in the coastal low-lands of the study area north of Pallikkal river. Careful examination of the geomorphic signatures reveals that the inland wetlands in the coastal lands of the study area are

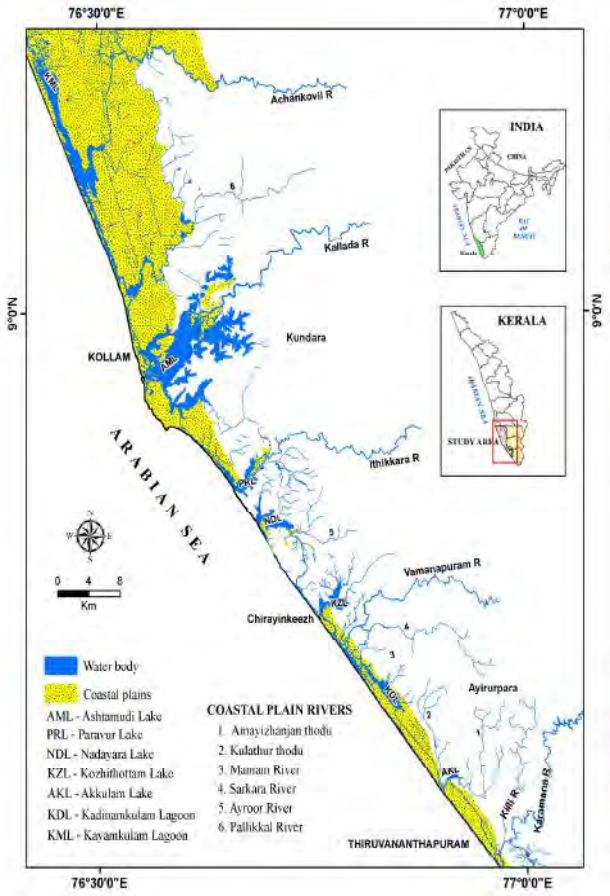


Fig. 1.8.1 Drainage map of the coastal lands of Trivandrum block. Note the small rivers (coast plain rivers) south of Ashtamudi lake.

the broadened remnants of the upper drainage channels of the coastal plain rivers that existed prior to Late Quaternary period. The Late Pleistocene transgressive events might have carved out a major portion of the land areas drained by the coastal plain rivers to the level of Mean Sea Level. The NNE – SSW trending beach ridges located close to the inland wetlands is indicative of the extent of the Late Pleistocene transgression to which the region has been subjected to. The younger coast (present) with parallel beach ridges on the other hand, indicate the extend of the Mid Holocene transgressive phase. The zone of convergence of the two sets of beach ridges coincides with the areas of economically viable heavy mineral placers. This clearly indicates that the heavy minerals, derived from the breakdown/coastal retreat of the uplifted Neogene deposits, underwent size and density based sorting at least in two transgressive phases – the Late Pleistocene and Middle Holocene. This is perhaps, the reason for the segregation of beach placers in the Needakara – Chavara and nearby areas.

The present Pallikkal river is a complex drainage system evolved to its present form from land – sea interactions of the Late Quaternary period. The river might have modified many times before attaining its present course which links most of the Late Pleistocene wetlands like Chunakkara *punja*, Komallur *punja*, Vatta *kayal* and Valummelpunja. The radiocarbon age of 7270±250 yrs BP at 6.9m of Karunagappalli borehole core drilled on the banks of the Pallikkal river indicate that the river might have carved out its channel over the Neogene sediments at the end of the Early Holocene.

D. Padmalal, K. Maya & S. Vishnu Mohan

1.9 Monitoring Indian shield seismicity with 10bbs to understand seismotectonics of the region using V sat connectivity

Broadband (BB) seismic observatory at Peechi, operated by NCESS in the campus of the Kerala Forest Research Institute (KFRI) is one of the 10 permanent stations set up by DST in 1999 for strengthening earthquake monitoring in the peninsular India and for improving the detection and location capabilities of earthquakes as well as azimuthal coverage in the shield region. The observatory is working well, generating high quality uninterrupted data that is being used for monitoring worldwide earthquakes and studies of local and regional earthquakes. The data recorded here are systematically archived on hard disks/ DVDs for future use. The observatory also provides data to government agencies as well as other research institutes, which is used in disaster management planning and various research works. The observatory acts as an educational facility by playing host to a large number of visitors, including students. The continuous and compiled data recorded here are being sent to IMD every six months, in SEED and SEISAN formats-latest being data till December 2015. We also supply continuous seismic data to NGRI and INCOIS. We share our data with other institutes like KSEB, IISc, GSI and NIRM on their request. We also offered one week training on 'Seismic station monitoring and data analysis with Seisan' to two researchers from Kerala State Disaster Management department.

A total of 1523 local, regional and global events were recorded during March 2015- Feb 2016. There were 30 tremors from Kerala, 6 events from nearby states, 15 events from other parts of India, 19 from Andaman-Nicobar region and 1453 global earthquakes recorded during the reporting period. The nearby state events were from Andhra Pradesh and Karnataka. Andhra tremors were mainly from Guntur, Adilabad and Nellore district. Karnataka tremors were from Kalburgi and Somwarpet. Other parts of India earthquakes were mainly from Gujarat, Chamoli, Maharashtra, Assam, Dharchula, Leh,

Table 1.9.1 Tremors recorded from Kerala

Tremors recorded from Kerala							
Sl. No.	**Date**	**Latitude**	**Logitude**	**Magnitude**	**Distance From Peechi**	**O.time(UTC)**	**Region**
1	07/03/2015	10.393	76.291	1.2	16 km	06:04:38.62	Nellayi, Thrissur
2	07/03/2015	10.325	76.678	1.6	43km	18:23:24.80	E Porigalkutthu reservoiur
3	18/03/2015	10.793	76.435	2.8	31 km	10:29:43.30	Ambalapara, Ottappalam
4	20/03/2015	10.463	76.418	1.3	11 km	05:10:45.10	Peechi Dam Area, Thrissur
5	21/03/2015	10.541	76.408	1.6	7 km	13:56:16	Peechi Dam Area, Thrissur
6	28/03/2015	10.547	76.415	1.0	7 km	07:55.48.55	Peechi Dam Area, Thrissur
7	02/04/2015	10.384	76.264	1.8	19 km	14:37:28.26	Near Kodakara, Trissur
8	29/04/2015	10.358	76.406	2.1	7 km	19.35.45.07	Vellikulangara, Thrissur
9	30/04/2015	10.505	76.373	1.5	4 km	10:29:59.79	Peechi Reserve forest, near Anakuzhy. Thrissur
10	30/04/2015	10.505	76.377	1.3	4 km	16:33:31.07	Peechi Reserve forest, near Anakuzhy, Thrissur
11	28/05/2015	10.562	76.409	1.0	8 km	01:10:37.86	Near Vaniyampara, Thrissur
12	18/06/2015	10.571	76.256	0.8	11 km	17:07:54.55	Thannikudam, Thrissur
13	*18/08/2015	9.806	77.033	1.4	112 km	23:57 :00	Venjoormedu, Idukki
14	20/08/2015	9.700	76.934	2.2	112 km	18:19:02.63	Near Kottamala, Idukki
15	23/08/2015	10.703	76.081	1.5	35 km	09:50:24.27	Near Karikkad, Perumpilavu, Thrissur
16	26/08/2015	10.630	76.390	0.7	12 km	10:50:03.35	Near Elanad, Thrissur
17	26/08/2015	9.806	77.033	1.7	112 km	23:28:54.68	Venjoormedu, Idukki
18	25/10/2015	10.738	76.184	1.0	29 km	17:03:0646	Near Deshamangalam, Thrissur
19	08/11/2015	10.462	76.25	3.0	13 km	20:54:53.48	Near Talore, Thrissur
20	13/11/2015	10.487	76.251	1.5	11 km	17:50:26.58	Padavarad, Near Thrissur
21	18/11/2015	10.521	76.364	1.7	2 km	05:01:00.50	Near Peechi Dam, Thrissur
22	08/12/2015	10.571	76.301	0.6	7 km	19:47:08.360	Near Chirakkakod, Thrissur
23	28/12/2015	10.475	76.257	1.9	12 km	09:53:42.99	Near Marathakkara, Thrissur
24	07/01/2016	10.481	76.266	1.5	10 km	07:10:12.40	Near Nadathara, Thrissur
25	09/01/2016	10.47	76.265	0.9	11 km	18:57:43.36	Near Mannavu, Thrissur
26	18/01/2016	10.471	76.26	3.4	12 km	21:28:31.47	Near Thalore, Thrissur
27	20/01/2016	10.467	76.262	1.1	12 km	17:37:12.31	Near Mannavu, Thrissur
28	23/01/2016	10.474	76.258	3.2	12 km	15:02:08.76	Near Marathakkara, Trissur
29	26/01/2016	10.476	76.256	0.5	12 km	00:09:01.88	Near Mannavu, Thrissur
30	01/02/2016	10.466	76.262	0.6	12 km	19:37:11.00	Near Mannavu, Thrissur
31	02/02/2016	10.478	76.262	1.0	11 km	08:02:47.15	Near Mannavu, Thrissur
32	*03/02/2016	9.748	77.088	1.2	112 km	22:02:03	Near Kattappana , Idukki
*** Not recorded at Peechi due to low magnitude**							

Off coast of Mumbai and Rajasthan. The 7.8 magnitude Nepal earthquake and 7.5 magnitude Hindukush, 8.3 magnitude earthquake of Chile and two 7.6 magnitude events near Peru were the other major teleseismic earthquakes recorded during the reporting period.

Seismic Observatory recorded 30 tremors from Kerala. These tremors mainly from Thrissur and Idukki district. No damage was reported due to earthquakes from Kerala during this reporting period. In Thrissur district tremors, were mainly from Peechi Dam area (Peechi forest region close to Peechi dam), Desamangalam, Ottappalam and Thalore-Mannav region. Magnitude range of these tremors was 0.7 to 3.4. Tremors from Idukki and Thalore were felt by a few people. Tremors from Kerala are listed in Table 1.9.1 and shown in Fig. 1.9.1

Sreekumari Kesavan

Funding: MoES, GoI

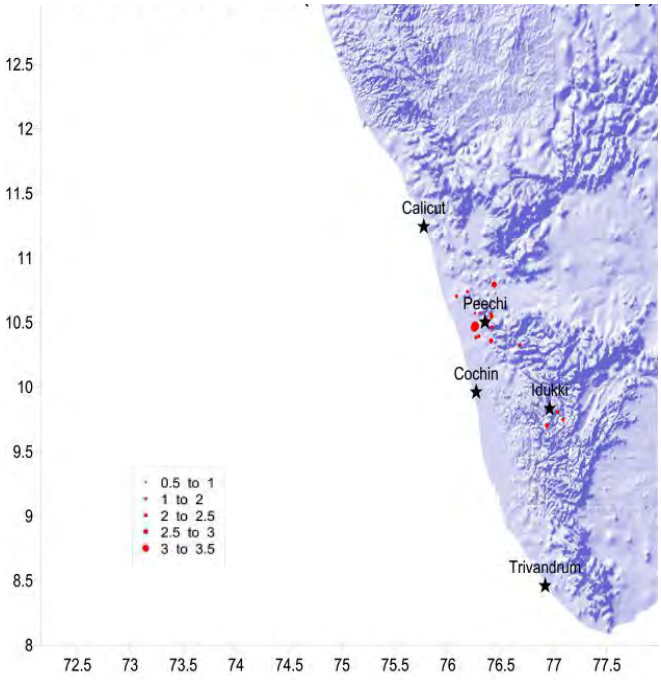


Fig.1.9.1 Tremors from Kerala (2015 March - 2016 February)

2.1 Integrated study on estuarine, beach and innershelf dynamics of west coast of India (core program-1 of CoP)

The second phase of hydrodynamic data collection (post-monsoon) was initiated along the Kadalundi-Nandhi coastal sector of the Kozhikode coast of north Kerala during the third week of December 2015. A set of marine instruments consisting of Directional Wave and Tide Recorders (DWTR) and Current Profilers, were deployed off the Kozhikode coast. Measurements were made at four pre-defined offshore locations in water depths ranging from 5 to 10 m, representing an alongshore stretch of 44km and an offshore distance of approximately 5km. Offshore data collected includes nearshore waves, currents, tide and temperature and also surficial sediment samples from offshore. In addition to this, shore line survey was also carried out for the 44km coastal stretch and beach profiles and sediment samples were obtained at previously established stations. The measured data were processed to understand the post-monsoon coastal processes. Since the dissipation and disappearance of mudbanks normally take place during the post-monsoon period the measured data is also being processed to obtain vital information on the mudbank process. The hydrodynamic data is also be used to study the interrelation between the beach building and the wave/current interaction processes as the beach building process normally takes place during the post-monsoon period.

As part of developing a reliable methodology to use video imaging for monitoring beach-surf zone morphodynamics and measurement of nearshore waves an ideal coastal location at Kozhikode was identified. The identified location is at the 12th floor of a multistory building situated at the beach road facing the coast. Procurement of the video-imaging system and appropriate software is in progress. Monthly beach profiling and LEO observations are continued from the already established 16 beach monitoring stations in the study area. The bathymetric data collected during 2013 were processed and bathymetric grid has been prepared. Being an integrated approach, some of the study components covered under this program are provided here under:

2.1A. Assessment of Submarine Groundwater Discharge (SGD) between Koyilandi and Kadalundi in Northern Kerala: Submarine groundwater discharge (SGD) is groundwater (fresh, saline or both) that escapes or recirculates from coastal margins into the marine environment; it commonly occurs as seepage, submarine springs, and tidally controlled groundwater discharge from unconfined as well as artesian aquifers. The flow may be driven by terrestrial hydraulic gradient, water level differences across a permeable barrier, along with different marine processes such as wave set up, tidally driven oscillations, density-driven convections and thermal convection. It acts as a pathway for material transport to marine environment. Different processes that cause significant impact on the hydrochemistry of surface and subsurface discharges to marine environment can be human use of surface water and groundwater for agricultural, industrial and domestic purposes and subsequent waste water treatment, reuse and disposal practices. Therefore, the study on SGD focuses on discharge rate and also pollution loads into ocean.

The significance of understanding SGD in the Indian context involves estimation of maximum pumping possibilities and defining the limit of seawater intrusion in the fresh-seawater interference zone. In short, such studies help in assessing the optimum exploitation levels of coastal fresh groundwater, locating feasible waste disposal sites in coastal zone and estimating seaward pollution transport levels.

Methodology adopted for the study includes direct measurements using seepage meters and piezometers, modeling, natural tracers using 222Rn, 226Ra, salinity, and temperature, isotopes, and conventional hydrochemical methods. In addition, water-balance approaches, hydrograph separation techniques, and numerical simulations would also be applied for basin-scale estimates of groundwater flow into the ocean. The sequential methods are (i) digital analysis of satellite data, (ii) EC measurements in coastal wells, (iii) Resistivity sounding, SP and resistivity cross section profile surveys in the interface zone, (iv) hydrochemical analyses, (v) water table elevation surveys w.r.to MSL, and (vi) groundwater modeling.

During the reporting period, we have downloaded thermal band satellite images for image processing, procurred GMS groundwater modelling software and conducted resistivity surveys in the study area to understand the hydrological layers and the nature of the shallow aquifer. It was observed that the sediment thickness in the area is more than 35m and the depth to water table is around 2m. In-

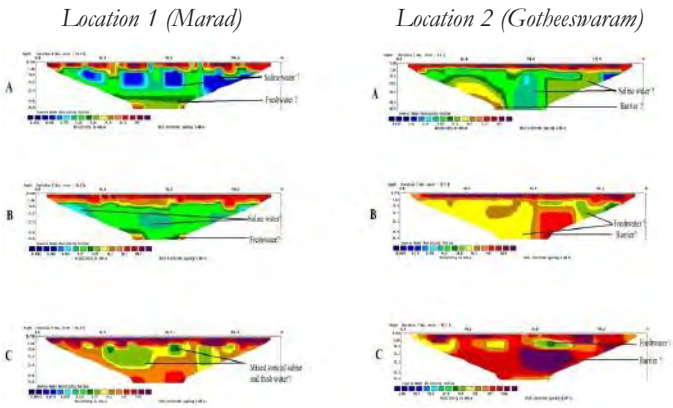


Fig. 2.1.1 Nature of aquifer at 250 m and 500m along Kozhikode coast

spection of open wells in the coastal zone under consideration indicated that the area releases fresh groundwater to sea during a considerable period of the year. Two cross section profiles showing the nature of aquifer along the beach and at about 250m and 500m inland are provided in the following figure (Fig. 2.1.1).

2.1B. Nearshore surface sediment characteristics off Kozhikode, south-west coast of India: As part of Coastal Processes (CoP) Group's core programme, coastal environment off Kozhikode was selected for sediment characterization. Main objectives of the project include (i) spatio-temporal characterization of sediments (ii) elucidations of causative factors controlling their distribution. The study area is influenced by the heavy fishing activities, in addition to timber industry discharging into the *Chaliya*r river finally debouching into the adjacent coastal sea. Despite the high energy coastal environment, certain locations of coastal region have sediment enriched in fine grained fractions. In order to achieve the above objectives, surface sediments were collected during pre-monsoon period using grab sampler at gridded sampling stations ranging in water depths from 3 to 20 m aligned perpendicular to the coast. Texture, clay mineralogy and geochemical characteristics of the sediments were determined following the standard laboratory procedure.

Mean grain size of sediments ranges between 3.1 to 5.9 ϕ. Sediments are coarser at shallow depths as well as adjacent to the river mouth. A general trend of sediment fining towards offshore is observed in the area (Fig. 2.1.2). Consistent increase of coarser fraction in the

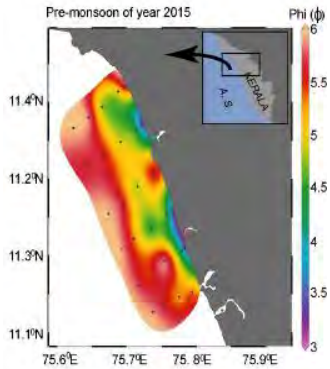


Fig. 2.1.2 Particle size analysis of surface sediments from off Kozhikode during Pre-monsoon of year 2015

onshore direction indicates the *in-situ* high energy regime, wherein the dynamics causes resuspension of fines that are carried away to offshore. Further, the high energy dynamics is more pronounced at the inlet of Beypore estuary resulting in abundance of coarser fractions. However, substantial increase in fine grained fractions beyond 15 m water depth is noteworthy as the low energy regime prevails. Neverthless, most of the sediment samples are of sandy-silt nature with a meager <10% presence of clay. The ternary diagram depicts that most of the points fall within the high energy regime (Fig. 2.1.3).

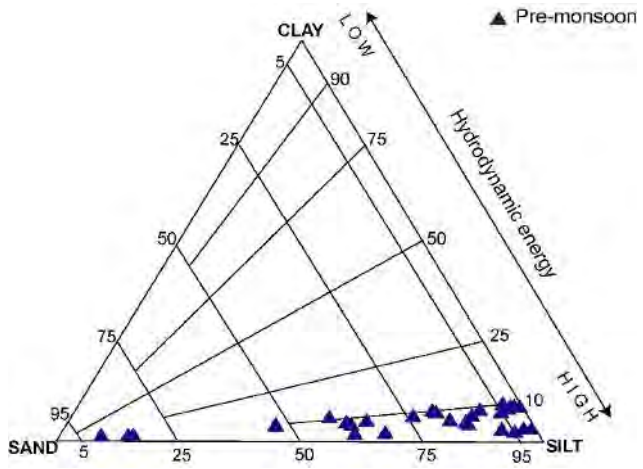


Fig. 2.1.3 Textural trend depicted by using ternary diagram

Mineralogical analysis of <2 μm fraction of surface sediments by X-ray diffraction methods revealed presence of clay minerals like kaolinite, chlorite, illite as the dominant ones with traces of smectite (Fig. 2.1.4). This indicates that majority of the nearshore sediments were derived from the gneissic rock assemblages under the influence of intense chemical weathering.

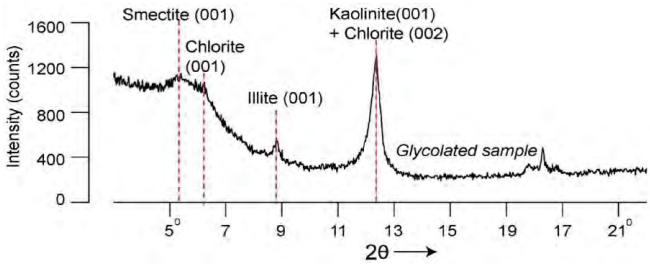


Fig. 2.1.4 X-ray diffraction diagram of clay minerals in the surface sediments

Geochemistry of surface sediments were analyzed for major elements (Al, Fe, Mn) and minor elements (Cu, Zn, Co, Pb, Ni, Cr) using X-ray fluorescence spectrometer (XRF). During pre-monsoon, the metal concentration varied considerably in the study area as given in the table-1. Spatial distribution pattern of most of the metal concentrations shows an increasing trend offshore. The metals Al (5.5 %), Fe (3.7 %), Cr (183.4 mg/kg), Ni (66.2

Table 2.1.1 Major (%) and minor (mg/kg) elements in the surface sediments during pre-monsoon

Elements	Minimum	Maximum	Mean
Al	3.05	8.66	7.42 ± 1.35
Mn	0.007	0.06	0.02 ± 0.00
Fe	0.74	9.35	6.86 ± 2.29
Cr	96	288	244 ± 46.9
Ni	34	119	89.5 ± 22.2
Cu	18	51	40.2 ± 7.8
Co	22	23	22 ± 0.3
Zn	22	71	48.5 ± 12.0
Pb	25	50	44 ± 5.7

mg/kg), Cu (31.6 mg/kg), Zn (43.0 mg/kg), Pb (37.8 mg/kg) show comparatively low concentration in the nearshore (3.5m water depth), whereas concentration increase gradually off-shore with high concentration of metals (Al~8.3 mg/kg; Fe~8.7 mg/kg; Cr~273.8 mg/kg; Ni~105.5 mg/kg; Cu~44.8 mg/kg; Zn~57.1 mg/kg; Pb~47.8 mg/kg) at 20 m water depth. Mn and Co are devoid of any specific trend with increase of water depth. Spatial variation of Cr concentration is shown in figure 4. In order to determine the probable source of these metals, enrichment factor (EF) was calculated using the equation: $EF=(Metal/Al)_{sample}/(Metal/Al)_{background}$. Where $(Metal/Al)_{sample}$ is the average concentration of metal in 29 samples in the study area and $(Metal/Al)_{background}$ is the metal value of upper continental crust. EF values ranging between 0.5 and 1.5 indicates that metals derived from the crust or through natural weathering process, whereas EF >1.5 suggest substantial contribution of non-crustal metals derived from both natural and anthropogenic processes. In the present study, EF value of metal concentrations are shown in box and whisker plot (Fig. 5). EF value of all the metals are higher than 1.5 except for Mn. Average metals enrichment is in the order of Cu<Zn<Co<Fe<Pb<Ni<Cr.

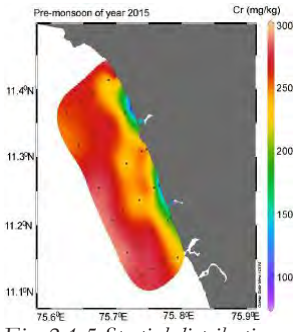


Fig. 2.1.5 Spatial distribution of metal concentration (Cr mg/kg) in surface sediments

Intense chemical weathering in the catchment usually associated with humid tropical climate releases fine grained sediments which eventually get deposited in the adjacent coastal sea through the rivers and estuaries. Clay mineralogy of surface sediment demonstrates dominance of clastic sediments derived from the terrigenous source. However, these fine grained sediments do not sustain in the offshore areas of coastal sea within the high energy environment, whereas it dominates the offshore where low energy environment prevails. Obviously, metal concentrations are more associated with fine grained sediments due to surface adsorption and ionic attraction. Thus, it is distinctly evident from the distribution of metal concentration that shallow nearshore area abundant in coarse grained particles register low metal enrichment. For example, Cr showed the highest mean of EF (=8), while metal concentration increased towards offshore co-varying with fine grained sediments (Fig. 2.1.5 and Fig.2.1.6). Further, significant positive correlation between fine grained sediments and metals suggest that grain size is an important controlling factor for metal concentration. This means that spatial distribution pattern of metal concentration in the study area is closely linked to the sediment texture. In general, metals that are brought into the environment due to both natural and anthropogenic activities and associated with fine grained sediments get deposited in the shallow coastal regions during river discharge. Subsequently, prevailing high energy environment transfer the fine sediments enriched with metals to the offshore resulting in their abundance towards higher water depths of 15 to 20 m.

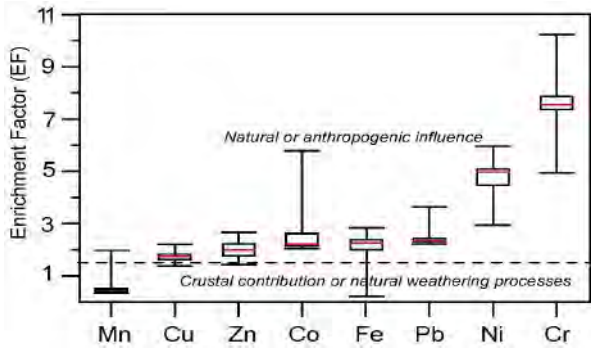


Fig. 2.1.6 Box and whisker plots for Enrichment Factor (EF) of metals in surface sediments

2.1C. Development of remote beach monitoring system: A continuous Beach Monitoring System is being developed for an open coastal stretch to validate the use of optical remote sensing system as an alternative method to study nearshore dynamics and beach morphology. Recorded video images were used for the purpose utilizing the image processing capabilities and techniques available with the MATLAB software. The main objectives are of the study:

- To develop a beach monitoring alternative based on processing of video imageries
- To validate the data derived from the recorded video
- Processing of the spatio-temporal data of video images to study the co-terminus beach morphology and coastal processes
- Delineate shoreline from the images to derive shoreline changes
- Understand the nearshore dynamics from the video image based study

The study has already been initiated in January 2016. Since procurement of the Beach Monitoring System has been delayed, alternatively, an ordinary mid-range DSLR camera

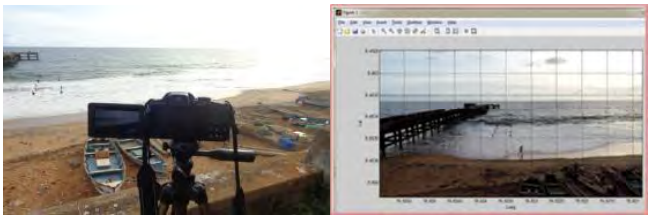


Fig. 2.1.7 A view of the Beach Monitoring System with screen-shot of an image processes using the tool developed in-hoouse

with optical zoom facility has been used for recording images for short-time durations of 5-10 minutes. The images were then processed using the tools developed using MATLAB. The data derived after analyzing the video images are then validated with *in situ* physical measurements obtained simultaneously. The results do show a reasonable comparison indicating desirability and scope of expanding this technique.

T. N. Prakash (co-ordinator), P. John Paul, L. Sheela Nair, D. S. Suresh Babu, K. Raju, Reji Srinivas, D. Raju, M. Ramesh Kumar, S. Mohanan, M. K. Rafeeque & M. K. Sreeraj
Funding: MoES, GoI

2.2 Study of coastal flooding along the southwest coast of India due to remote forcing

A comprehensive programme to study the coastal flooding along the Kerala coast due to rise in sea level caused by the coincidence of high tide event and arrival of swell waves has been initiated. This type of coastal flooding is not uncommon along the low lying sectors of the Kerala coast, particularly during the post-monsoon and pre-monsoon periods (i.e. from October – May). There has been a significant increase in the number of such events reported in the recent years. The intensity or impact due to occurrence of such an event (i.e. due to the arrival of long period waves from the Southern Indian Ocean with peak wave periods more than 15s) on a low lying coastal area can be severe when it coincides with the spring tide events. The presence of coastal currents directed towards south due to the influence of other factors like wind can make it even more worse. The term 'Kallakadal' (arrival of sea like a thief without being noticed) borrowed from the parlance of fishermen and proposed by Dr. N. P. Kurian (former Director of NCESS) was accepted by UNESCO in 2012 for describing such freak events of coastal flooding. This terminology has also been recognized by the World Meteorological Organization and the Intergovernmental Oceanographic Commission.

During 2015, the first Kallakadal event was reported during the last week of January and the lastest one during 29 Aug. – 1 Sep., 2015. On both occasions the events coincided with the spring tide and the data obtained from the offshore Wave Rider Buoy deployed by NCESS (in collaboration with INCOIS Hyderabad) in 22m water depth off the Kollam and Kozhikode coasts revealed the presence of long period waves of 18-20 s magnitude and significant wave heights in the range of 1.5-2 m. (Fig. 2.2.1).

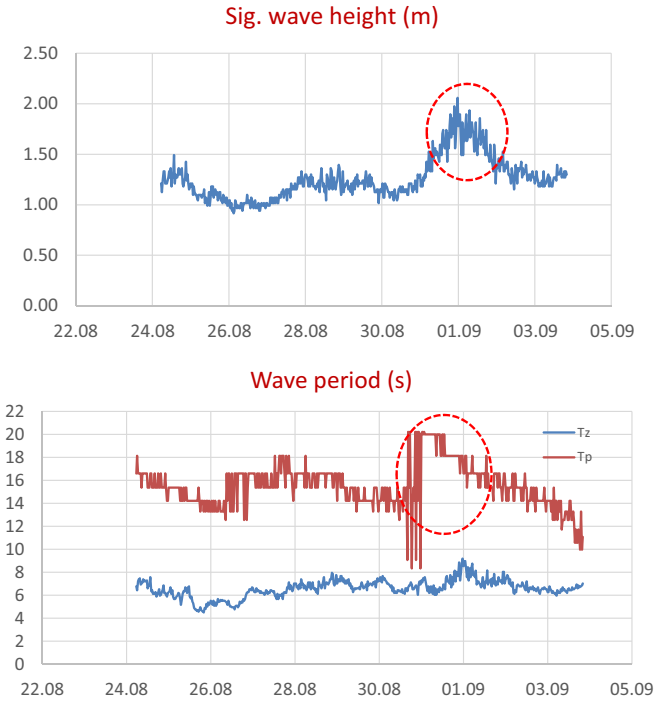


Fig. 2.2.1 Recorded wave height and period off Kolam coast during August- September 2015

For the September event the coastal wind data available for one location showed the influence of moderate wind speed of 5m/s blowing from WNW-NW direction. Apart from identifying the causative factors responsible for such freak events, it is important to conduct a detailed investigation on the influence of such events in the nearshore hydrodynamics (wave climate and circulation pattern) and its effect on the adjoining coast, particularly on beach morphodynamics. A comprehensive study linking offshore, nearshore and beach processes is crucial for adopting appropriate site-specific measures for disaster mitigation and also for assessing of hazard vulnerability during such extreme events. In this perspective NCESS has embarked upon a pilot study along the coastal stretch between Thangassery and Kayamkulam of the Kerala. This coastal stretch has been witnessing coastal flooding frequently in recent years. The coastal morphology of the area is complex with the presence of a number of hard structures and also being influenced by other anthropogenic activities like extensive sand mining altering beach morphology and shoreline orientation. The presence of Ashtamudi estuary (on the southern side of the study area)

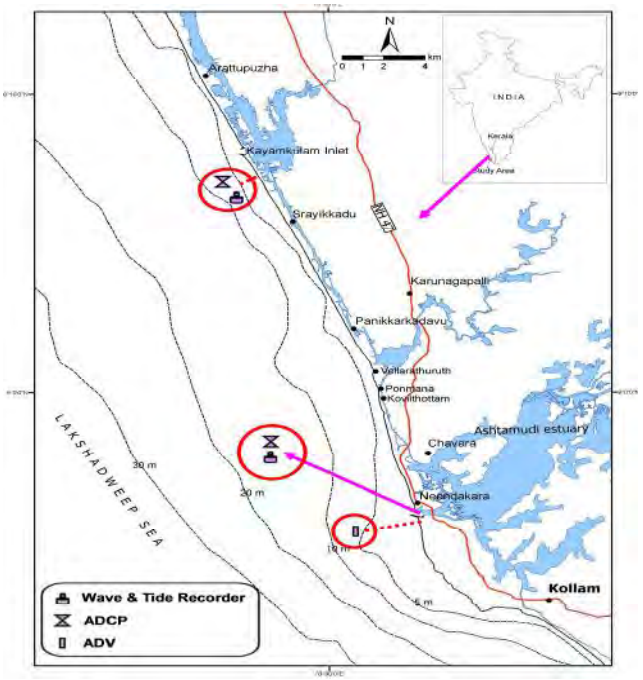


Fig. 2.2.2 Three locations off Kollam coast where instruments were deployed during September 2015

into which the Kallada river joins and ultimately debouching into the Arabian Sea is also being investigated in this study since drastic reduction in the sediment supply through the river over the years has been reported thus adversely affecting the beach morphology. Further, human intervention has resulted in modifying the natural settings of Ashtamudi inlet. Certain reports of partial flooding of the Munroe *Thuruthu* island which is a backwater island within Ashtamudi lake located on the eastern side has to be looked into the light of such inlet modification affecting the flood and ebb tides. The proposed programme involves field measurements and numerical modeling studies. The work was initiated during September 2015 by deploying a few marine instruments for hydrodynamic data collection at three coastal locations along the Thangasserry-Kayamkulam coastal stretch (Fig. 2.2.2).

Fig. 2.2.3 Withdrawal of sea on 3rd September 2015 at Alleppey

Wave gauges and current meters were deployed in the nearshore region to the south of Kayamkulam fishing harbor at about 5m water depth, Asthamudi estuary (7 m depth to the east of the Neendakara inlet) and further south between Thangasseri and Neendakara (5 m depth). This data was further supplemented by beach profile measurements taken at regular intervals during the offshore hydrodynamic data collection periods. The deployment period for the pilot study was judiciously decided to cover the Perigien Spring Tidal event on 28th September 2015. The hydrodynamic data would give valuable information on the influence of Perigien Spring Tide in the study area.

L. Sheela Nair & T. R. Anoop

2.3 Establishment and maintenance of Wave Gauge Stations in the Coastal Waters of the SW coast of India

This is an ongoing project being carried out in collaboration with ESSO-INCOIS, Hyderabad for continuous monitoring of wave climate and collection of wave data along the southwest coast of India. To achieve the objective it was proposed to establish Wave Gauge Stations at three pre-defined locations along the southwest coast of India, by deploying Wave Rider Buoys (WRB) at about 22m water depth. Out of the three stations proposed (locations shown in Fig.1), two stations have already been established in 22m water depth off the Kerala coast (off Kollam and Kozhikode representing northern and southern part of the coast). Arrangements are being made for the installation of the third WRB off Colachal (representing the southwest coast of Tamil Nadu) which will be deployed soon after the monsoon season. The site specific real time wave data received (through INSAT communication as well as HF receiver units) from the WRBs operating off the Kerala coast are currently being used by INCOIS for the validation of the daily Ocean State Forecast (OSF) issued by the Centre.

Fig. 2.3.1 location of Wave Gauge Stations along the southwest coast of India

The real-time wave data recorded by the two WRBs installed off Kollam and Kozhikode coast during 2015-16 are presented in Figs. 2.3.2-Fig. 2.3.4.

Apart from the regular monitoring and wave data collection the recorded data are being used for a couple of ongoing research programmes of NCESS, such as, in the study of

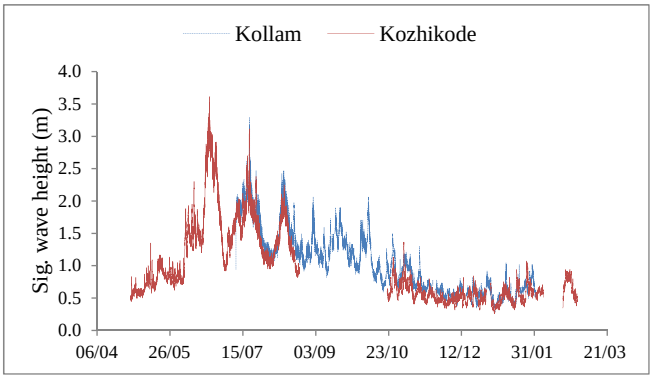


Fig. 2.3.2 Significant wave heights recorded in the Kollam and Wave Rider Buoys during April 2015-March 2016

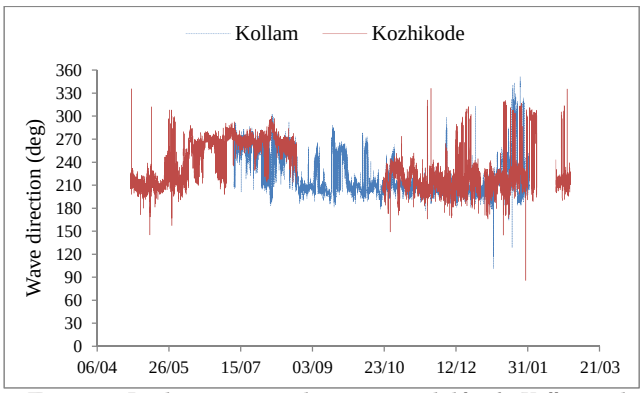


Fig. 2.3.3 Predominant wave directions recorded by the Kollam and Kozhikode Wave Rider Buoys during April 2015-March 2016

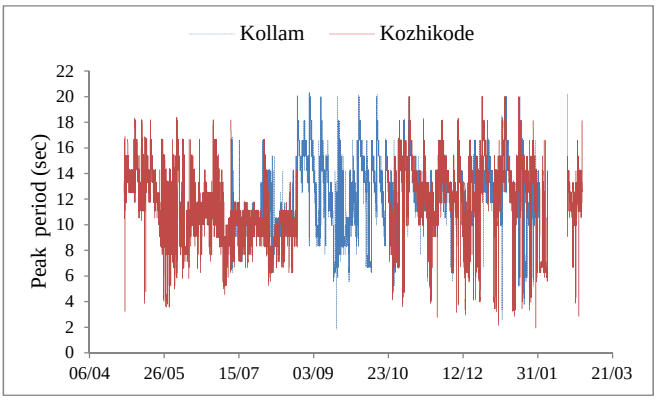
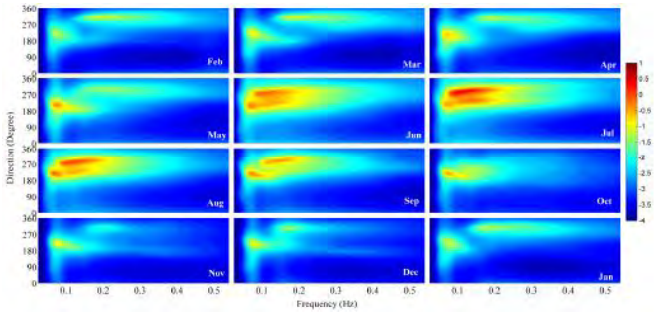
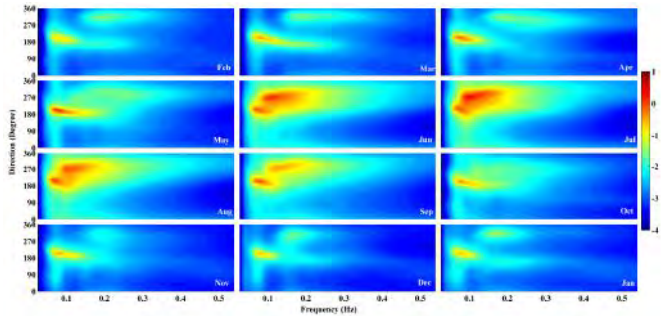


Fig. 2.3.4 Peak wave period recorded by the Kollam and Kozhikode Wave Rider Buoys during April 2015-March 2016

wave pattern along the SW shelf sea of the Indian coast and the influence of nearshore waves on the beach processes. The data are also being used for computing spatio-temporal variations in the nearshore wave climate off the Kerala coast. The real-time data recorded by the two WRBs deployed off Kollam and Kozhikode, during the period 2014-15, were analysed in detail. The computed monthly averaged 2D wave energy spectrum off the Calicut and Kollam coast during the one year period of Februry 2014 to January 2015 are presented in Fig. 2.3.5 and Fig. 2.3.6 respectively. Both the locations depict influence of southern Indian Ocean swells throughout the year. But during the monsoon season, both monsoon swell waves



Note: Contour lines are plotted in logarithmic (base 10) scale
Fig. 2.3.5 Monthly averaged 2D wave energy spectrum off Kozhikode during February 2014-January 2015



Note: Contour lines are plotted in logarithmic (base 10) scale
Fig. 2.3.6 Monthly averaged 2D wave energy spectrum off Kolam from February 2014-January 2015

and southern ocean swells co-exist. The influence of local wind waves is prominent for the Kozhikode location in general compared to that of Kollam.

L. Sheela Nair, R. Prasad,
E. K. Sarathraj & T. R. Anoop
Funding: MoES, GoI

2.4 Shoreline Mapping and Monitoring along the west coast of India

The prime objectives of this project entitled "Shoreline mapping and monitoring along the west coast of India" are to provide systematic information on shoreline change trend, erosion hotspots, sediment transport and morphological modifications along the west coast of India. To achieve this objective both GPS measured shoreline data and the shoreline data derived from multi-date satellite imageries are compared. In order to facilitate the process of periodic and systematic updation of shoreline changes, reliable and replicable state-of-the-art technologies are being developed for mapping and presentation of shoreline data. The main deliverables of this project are the thematic maps prepared in 1:25000 scale corresponding to toposheet grid (Fig. 2.4.1). The accomplishments during the reporting period are briefly described.

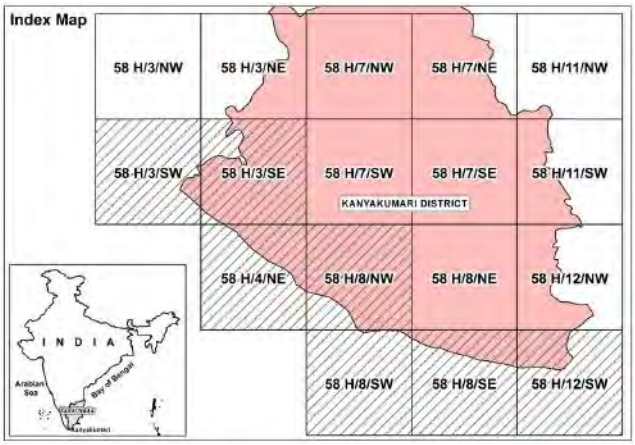


Fig. 2.4.1 Index map Showing the toposheet grid for the Kanyakumari coast

The shoreline data compiled and collated from various sources are processed for assessment of both long-term and short-term changes along the west coast of India. In the present study, for delineation of the shoreline from satellite imagery, the boundary line between the wet and dry sand interface is taken as the shoreline for sandy coasts. For eroding coastal stretches with shore protection, the landward side of shore connected structures like the seawall, revetment, gabion, groin and breakwater is considered as the shoreline. Detailed analysis of the satellite data is done to study the morphological modifications that have

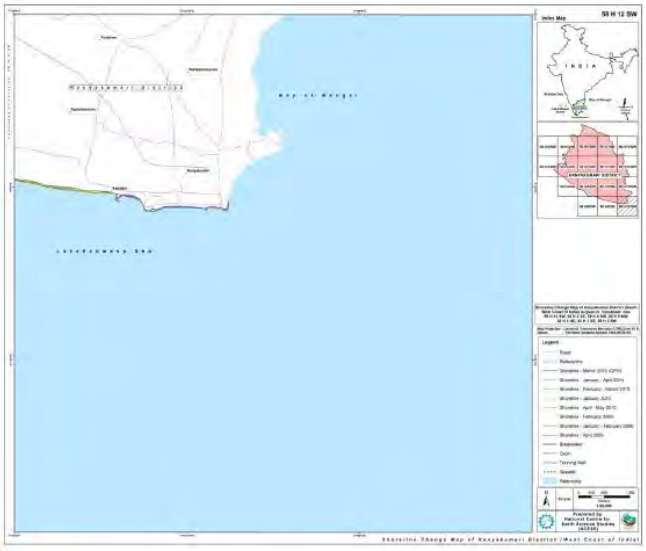


Fig. 2.4.2 Shoreline change map prepared for the Kanyakumari coast (58 H 12 SW)

occurred along the coast. The analyzed data along with field observations are then used to identify the causative factors responsible for the shoreline changes.

The short-term and long-term shoreline changes for the Kerala coast, west coast of Tamil Nadu and parts of Maharashtra (2 coastal districts) have been completed. Shoreline from re-rectified IRS P6 LISS-III, LISS IV and World View imageries were extracted for the southern part of the west coast from Kanyakumari (southern tip of the west coast) to Thalappady (northern boundary of Kerala coast). The shoreline derived from satellite imageries for the years 2004-06 and 2011-12 have been compared to assess the shoreline changes and also for computation of the short-term accretion/erosion rates. A sample shoreline change presented in map prepared is Fig. 2.4.2. As part of this study the monsoon erosion hotspots along the Kanyakumari and Kerala coasts also have been identified based on field observations. The maps have been compared with those of the previous two years to study the erosion trend along the SW coast and to analyse the factors responsible for the changes if any. Attempts are also being made to study the impact of newly introduced hard structures on the short-term changes in shoreline.

L. Sheela Nair & K. C. Vimal
Funding: MoES through ICMAM P. D., Chennai

2.5 Impact of Sea Level Rise along Kerala coast

Coastal zones throughout the world have historically been among the most heavily exploited areas because of their rich resources. The problems of the coastal community in Kerala are unique due to the high density of population, loss of the otherwise scarce land due to coastal erosion, saline intrusion, flooding, destruction of wetlands, hazardous nature of sea-dependent livelihood, seasonality of fish catch and above all, the development related degradation of the environment. Climate change has posed new threats to many of the coastal areas. Sea Level rise (SLR) consequent to climate change is of great concern for a micro-tidal coast like Kerala with long coastline, large expanse of backwaters, estuaries, low-lying areas, backwater islands, filtration ponds, paddy fields and coastal wetlands. Sea level rise is a new challenge to the coastal community who live in this sector. Considering the scanty information available on the above aspects along this coast, the present study has been undertaken to monitor the phenomenon and study its impacts along the shoreline and surrounding areas.

According to Intergovernmental Panel on Climate Change (IPCC), the global sea level rise for this century is in the order of 18cm to 59cm (IPCC Technical Paper, 2007). The Tide data analysis on SLR study in Kerala revealed upward trend of 1.76 mm/yr for Kochi during 1939-2003, and of 0.82 mm/yr for Mangalore for the period 1977-2009. Unnikrishnan and Shankar (2007) estimated the sea level change trend of 1.75 mm/yr for Kochi for the same period. Various studies on SLR along Kerala coast agree on an upward graph and conservative estimation of about 100 to 200 mm over the next 100 years is projected.

Fig. 2.5.1 (a) Low lying backwater islands-hot spots, (b) Salinity ingress-affects Paddy, (c) DGPS surveys at control points

About 28 low lying fishing villages spread over nine coastal districts were identified as morphological hot spot locations along the Kerala coast. They are situated in Trivandrum, Alleppey, Ernakulam and Kasaragod districts. Morphological, ecological, and socio-economic hot spots with respect to SLR for backwaters and the banks were prepared separately. The primary reference points for the nine coastal districts were examined to determine the low lying areas. The Latitude/Longitude, elevations and the reduced level derived from the GCP'S of the new CP stones were examined to identify the hot spot locations.

Areas covered by mangroves, backwater islands, paddy fields, wetlands, flooding areas under the influence of tides, fish breeding, biodiversity and natural habitat areas that are sensitive to the coastal environment are grouped under ecological hot shots. Increase in salinity in estuaries and wetlands can damage its biological environment. Ground water also will be contaminated in the SLR scenario.

The socio economic hotspots are directly connected to the fisherman community. Large numbers of clustered houses occupy the coastal fringes. These houses/hutments are semi permanent structures made with mud/ thatched roof/tiles. They are extremely congested fisherman colonies/slums/ sheds/ that lack the basic facilities. Hot spot locations were identified based on the topography, geology, environment and landuse parameters.

The subsurface lithology and subsurface groundwater flow along the coast were determined using Resistivity meter for two different resistivity arrays (Schlumberger and Wenner configuration). The 50cm and 100cm projected SLR inundation maps for Ground Control Points (GCP'S) pertaining to 28 low lying coastal villages need to be prepared. The Resistivity and DGPS surveys for Trivandrum, Ernakulam and part of Kozhikode districts are available. The work for the rest of the low lying coastal villages will be completed shortly.

The output of this project is the creation of a strong database on different thematic aspects of the coastal zone, making use of GIS technology. The archival data collected for the project from NCESS and other organizations helped to project a comprehensive picture of the different aspects of the coast. The database will be useful to be ready with mitigation and rehabilitation programmes in case of a SLR threat due to climate change against the impending threat of SLR.

P. John Paul & D. S. Suresh Babu
Funding: Department of Environment and Climate Change, GoK

2.6 Preparation of Coastal Zone Management Plan (CZMP) for Kerala

As per the Coastal Regulation Zone Notification 2011, it has become necessary to prepare Coastal Zone Management Plan (CZMP) consisting of CRZ maps depicting High Tide Line HTL) , Low Tide Line (LTL), ecologically sensitive coastal areas and CRZ categories. KSCSTE entrusted NCESS to prepare the CZMP for the state as per the guidelines issued as Annexure-I of the CRZ Notification 2011.

The CZMP preparation involves two parts:

(a) Preparation of CZM Maps in 1:25K, which is essential to submit to MoEF for approval of CZMP ; and

(b) Preparation of local level CZM Maps in 1:4K scale, for application at local level with cadastral base and survey plot information (to be modified based on the approved CZMP in due course)

- The State has 10 districts where CRZ is applicable.
- With the new delimitation of Local Self Government Bodies in Kerala, there are 5 Municipal Corporations, 24 Municipal Councils and 178 Gramapanchayats where CRZ based CZMP has to be prepared. The details of the LSG Bodies in each of the 10 districts are provided in the Table 2.6.1

Extensive ground truth has been collected in all the districts where CRZ is applicable and modifications are being made to the maps prepared on the GIS platform. GIS digital conversion of the CRZ maps of 1995 is being undertaken

Table 2.6.1 Local Bodies within the 10 districts of Kerala where CRZ is applicable

Sl. No.	Name	Panchayaths	Muncipalities	Corporations
1.	Kasargod	14	2	0
2.	Kannur	27	3	1
3.	Kozhikkode	14	3	1
4.	Malappuram	12	3	0
5.	Thrissur	24	2	0
6.	Ernakulam	19	3	1
7.	Kottayam	5	1	0
8.	Alappuzha	25	3	0
9.	Kollam	21	2	1
10.	Thiruvananthapuram	17	3	1
Total		178	28	5

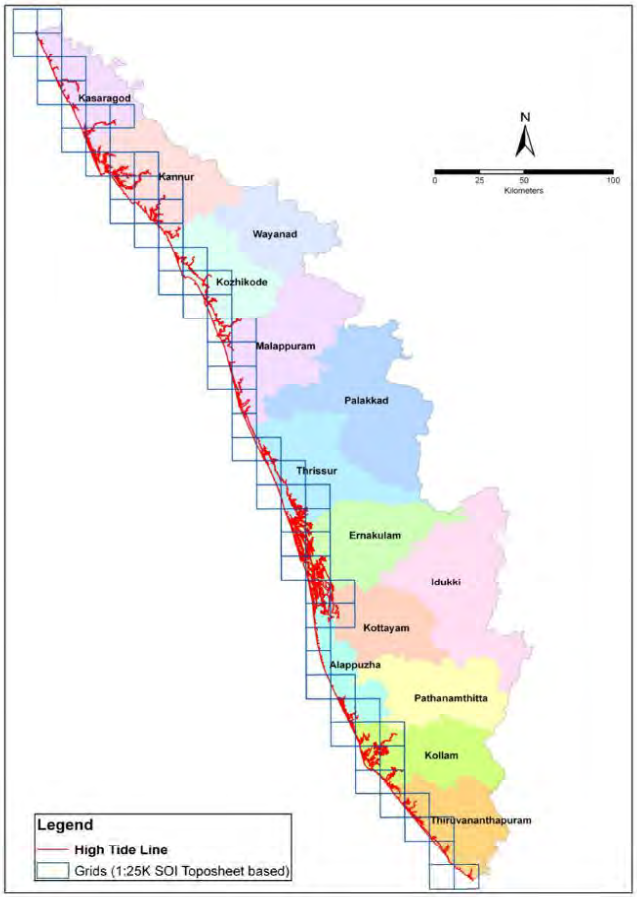


Fig. 2.6.1 Map showing the HTL and the map Frames of areas within CRZ in Kerala

to archive the maps and to compare with the new CZMP. The entire HTL and LTL geodatabase of the State has been sent to the Nation Centre for Sustainable Coastal Management (NCSCM) for its validation as per the direction of the MoEF&CC in November 2015. The geodatabase of the HTL and other CRZ categories along with the cadastral base was taken for verification and validation at the NCSCM, Chennai on 29th & 30th of March 2016. Validation of Kasaragod and Kannur Districts were completed.

CRZ Maps are being prepared in 1:25K scale as per standard specification in the Annexure-I of CRZ Notification 2011 and is being composed into frames of 7.5 minutes X 7.5 minutes Grids of Latitudes and Longitudes. A total of 77 such frames constitute the CRZ area within the Kerala state.

K. K. Ramachandran(co-ordinator), T. N. Prakash, D. S. Suresh Babu, M. Ramesh Kumar, S. Mohanan, M. K. Rafeeque & M. K. Sreeraj
Funding: KSCSTE, GoK

2.7 Development of Vembanad Management action Plan through a Geological Perspective

Vemaband Lake has been subjected to multifarious studies by many researchers. Its evolution, water-sediment chemistry, biology, pollution indices, siltation, tourism potential etc have been addressed in several publications over the years. The decline of spatial coverage and reclamation of water body in many sectors have also been reported. The two main geological processes that are reportedly responsible for the formation of Vembanad Lake include an initial tectonic phase and the subsequent natural sedimentation process by waves, currents and tides.

Vembanad Lake (Vembanad Kayal) is the longest back water body in India and the largest in the Kerala state. Considering its ecological significance and high biodiversity, this lake had been designated as the Ramsar site (No. 1214) by the UNESCO and also classified as an Ecologically Sensitive Zone by the Ministry of Environment and Forests, Govt. of India. The Vembanad lake and cover areas in Alappuzha, Kottayam, Thrissur and Ernakulam districts of Kerala. This oxbow shaped lake extends for a distance of 96.5 km from Azheekode in the north to Alappuzha in the south with a Northwest-Southeast orientation, which is connected to the Arabian Sea at two places, one at Cochin and the other at Munanbam.This lake is unique due to its distinct topography and circulation pattern and consists of two arms. Northern arm (30 km) extending from Cochin bar mouth(450 m wide) to Azheekode bar mouth (250 m wide) is generally narrow and shallow. The southern arm(62 km) on the other hand is wider and deeper extending from the Cochin bar mouth to Alappuzha, which is further divided by the construction of the salinity barrier (Thaneermukkom Bund, constructed in 1976) to seperate brackishwater downstream and freshwater upstream. Several rivers debouch into the lake. Manimala, Meenachil, Pamba and Achankovil rivers flow into the lake in the southern side of Thanneermukom bund and Muvattupuzha, Periyar and Chalakudy rivers debouch in the north of this bund. These rivers carry annually

732560MT of sediments into the lagoon. The present study is confined to the southern arm of the lake. The study area is drained mainly by Meenachil and Muvattupuzha rivers. The map of the study area is given in Fig. 2.7.1.

Satellite image Analysis: Remote sensing is a very useful tool in monitoring the spatial changes on the perimeter of lake. In recent years, this estuary had undergone shrinkage due to various developmental and agricultural activities, which has been computed using remote sensing and GIS techniques coupled with field validation. The water spread

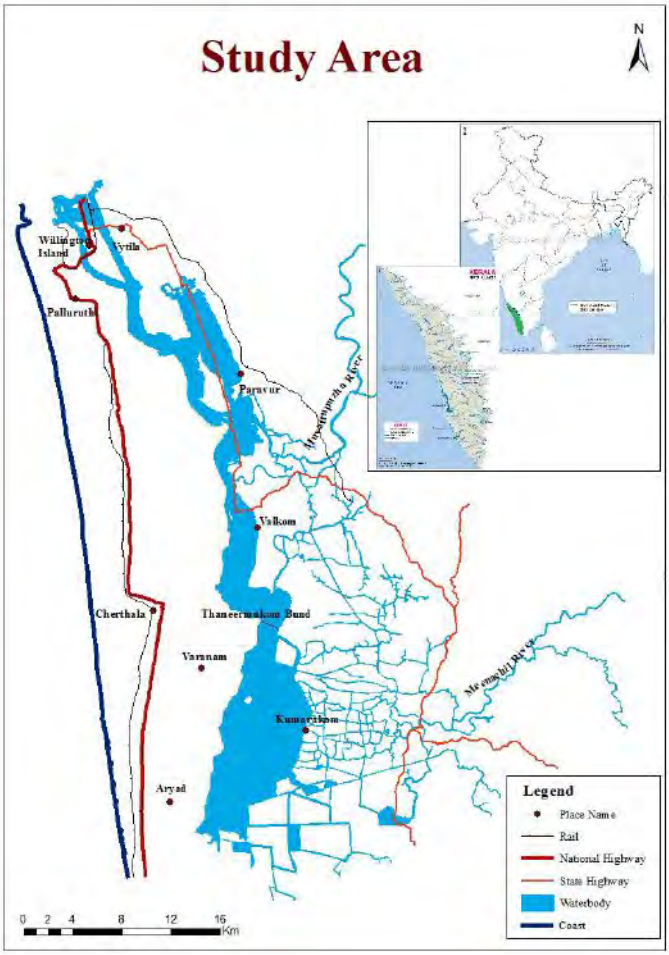


Fig. 2.7.1 Study area

area in the estuary over the past four decades were computed from satellite images using water indices. The main purpose was to estimate surface area change in the Vembanad Lake over the past four decades from Landsat satellite images using water indices and GIS techniques. Normalised Difference Water Indices (NDWI) and Modified Normalised Difference Water Indices (MNDWI) were employed for delineating lake boundary from the surrounding wetland systems and the shrinkage of estuary was delineated. The NDWI computed for the extraction of water body information from 1973, 1992 images and MNDWI from 2005 and 2015 images.

Data used: Landsat satellite data acquired by US Geological Survey (USGS) and Global Land Cover Facility (GLCF) were downloaded. Satellite images pertaining to the years 1973, 1992, 2005 and 2015 were used for this study. The details of the satellite data and toposheets are given in the Tables 2.1.1 and 2.1.2.

Table 2.1.1 Satellite data used for the present study

Sl. No.	Sensor	Acquisition Date	Source	Resolution (m)	Path/ Row
1	MSS	10-02-1973	GLCF	60	155/53
2	TM	31-12-1992	GLCF	30	144/53
3	ETM+	10-02-2005	USGS	30	144/53
4	ETM+	22-02-2015	USGS	30	144/53

Table 2.1.2 Toposheets used for the present study

Toposheets No	Year	Scale	Source
58C/6,58C/5,58B/8 58B/4	1968	1:50,000	Survey of India

Image processing: In the present study the Erdas imagine and ArcGIS software were used for the processing of satellite data. The information stored in satellite imagery is not in real spectral indices but it is in the form of digital numbers (DN).The radiance was calculated from these digital number, from which reflectance was calculated. In the present study, the DN values were converted as top of the atmosphere (TOA) radiance using the following equation of Wilson and Rocha (2012).

$$L_\lambda = \frac{L\,MAX_\lambda - LMIN_\lambda}{Q_{cal}MAX}\,(Q_{cal} - Q_{cal}MIN) + LMIN_\lambda$$

Where, L_λ is spectral radiance received at the sensor in watts permetre squared * ster * µm (Wm-2 sr-1 µm-1), Gain is rescaledgain contained in the image product header file (Wm-2 sr-1 µm-1),Qcal is quantised calibrated pixel values in DN, Bias (or offset) is therescaled bias contained in the image product header file(W m"2 sr"1 ìm"1), QcalMAX is the maximum quantised calibrated pixel value (corresponding to $LMAX_\lambda$) in DN, QcalMIN is the minimumquantised calibrated pixel value (corresponding to $LMIN_\lambda$) in DN,$LMAX_\lambda$ is spectral radiance that is scaled to QcalMAX(W m"2 sr"1 ìm"1), and $LMIN_\lambda$ is spectral radiance that is scaledto QcalMIN (W m-2 sr-1 µm-1).

The atmosphere has a significant impact on satellite data, such as information loss caused by scattering by the atmospheric constituents and aerosol. Atmospheric correction for the scattering of aerosols can be assumed to be of the order of one percentage of the total reflectance of ground resolution cell. $L_{1\%}$ was estimated using the

equation given below (Pacheo et al., 2014).

$$L_{1\%} = \frac{0.01\, E_{Sin\,\lambda i}\, Cos\theta_0}{\Pi d^2}$$

Where $E_{sun\lambda i}$ is the exo-atmospheric solar irradiance for band $\lambda i (Wm^{-2}\ \mu m^{-1})$, and d is the Earth–Sun distance (in astronomical units).

The surface reflectance was estimated from the TOA radiance reduced for aerosol scattering by using the following equation, (Nazeer, M., 2014).

$$\rho = \frac{\Pi d^2 (L_{sat\lambda} - L_{haze\lambda})}{E_{Sun\lambda} cos\theta s}$$

Where $L_{haze\lambda}$ is the path radiance for band λ (W m–2 sr–1 μm–1), $E_{sun\lambda}$ is the Exoatmosphericsolar irradiance for band λ (Wm–2 μm–1), and d is the Earth–Sun distance (astronomical units).

Different pairs of band combinations are used to calculate the wetness index (Kumar et al 2015). In general, green and near infrared (NIR), NIR and Middle infrared (MIR), Green and MIR, were used to calculate wetness index. In the present study, NDWI and MNDWI were used to extract water body information. The NDWI is expressed as follows.

NDWI= (Green-NIR)/ (Green + NIR) (McFeeters, 1996).

Where green is the green band, such as in MSS it is band 4 and band 2 in TM and NIR is the near infrared band, such as band 6 in MSS, band 4 in TM.

NDWI is computed using the green and NIR bands of the spectral band. Using this index water features have positive values while the vegetation and soil usually have zero or negative values. However, the application of NDWI in water region with a built-up land background doesn't achieve its goal as expected. The extracted water information in those regions was often mixed with built up land noise. This means that many built up land features also have positive values in NDWI images. As, a result the computation of the NDWI also produce a positive value for built up land just as for water. However, a detailed examination of the signatures revealed that the average digital number of the TM band 5 representing MIR radiation, is much greater than that of TM band 2 (green). Therefore, if MIR band is used instead of the NIR band in the NDWI, the built up land should have negative value. Based on this assumption, the NDWI is modified by substituting the MIR bands for the NIR band.MNDWI can be expressed as follows (Tebbs et al., 2013 and Feizhang et al., 2015).

MNDWI= (Green –MIR)/ (Green + MIR)

In MNDWI index water will have greater positive values than the NDWI, because it absorbs more MIR light than NIR lights, the built-up land, soil and vegetation will have negative values in this wetness index. MNDWI was applied only to 2005 and 2015 satellite images, because the MSS images of the year 1973 and 1992 were lacking the MIR band. So NDWI was applied only for those images which lacked MIR band. These calculation was done using the spatial analyst extension in ArcGIS. After calculating the NDWI and MNDWI index for corresponding satellite images, the estuary area was manually digitized using Arc GIS software and area was calculated using the same.

Dynamic Degree of the lake area: In this study, the estuary area of different study periods was derived using following equation (Feizhang, 2015 and Li et al., 2009).

$$K = (U_b - U_a) / U_a \times 1/T \times 100$$

Where, K is the dynamic indicator for lake area, U_a and U_b are the areas of the lake at start date and at the end date and T is the time scale under consideration.

Spatio-temporal changes of Vembanad lake: In this study, the NDWI to extract water body information for 1973, 1992 images and MNDWI to extract water body information for 2005 and 2015 images. As shown in Fig. 2.1.2 the estuarine areas have changed in each of the years for which study was under taken. The result shows that the overall decrease of the estuarine area during the study period is 12.28 sq km (6.93%). The change in the Vembanad

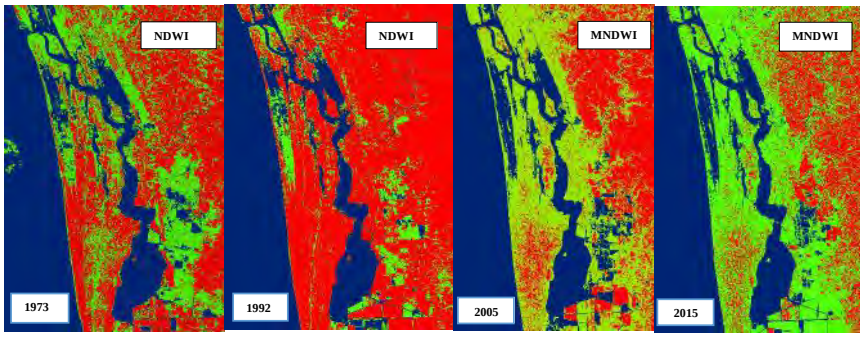


Fig. 2.7.2 The 1973 and 1992 image shows the water body (blue color) as extracted from NDWI, 2005 and 2015 image (blue color) shows the water body estimated from MNDWI

Lake surface area is shown in Fig. 2.7.3, which reveals that there occurred a noticeable shrinkage during the study period (42 years). In 1973, estuary had an area of 177.29 sq km and in 1992 the area was reduced to 169.22 sq km. The estuary continued to shrink to 166.29 in 2005 and 165.01 in 2015. The total areal loss of the estuary was 12.28 sq km between 1972 and 2015.

From the Table 2.7.3 during the period 1973-1992 the lake area decreased by 8.07 sq km and the dynamic degree is -0.25 %. ; during1992- 2005 the estuarine area had declined by 2.93 sq km and the dynamic degree is -0.14%; during 2005-2015 the estuarine area decreased by 1.28 sq km and the dynamic degree is -0.18%. This indicates a declining trend. Using the ArcGIS software the area of the estuary is delineated and analysed. The overall decline of 6.93% estuary during the study period is shown in Fig. 2.7.4.

The result shows that the overall decline of the the estuarine area during the study period is 12.28 sq.km (6.93%). The change in the Vembanad Lake surface area is shown in Fig. 2.7.3, which reveals a noticeable shrinkage during the study period (42 years). In 1973 estuary had 177.29 sq km area and in 1992 the area was reduced to 169.22 sq km. The estuary continued to shrink to 166.29 in 2005 and 165.01

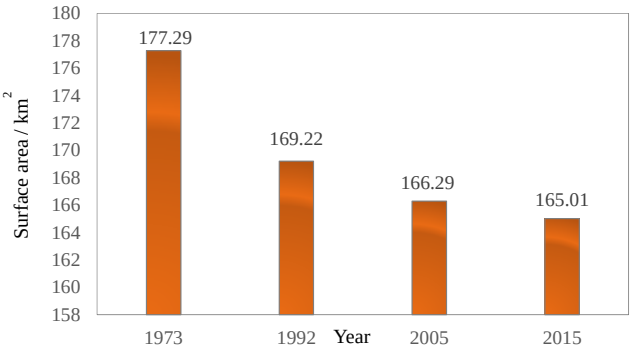


Fig. 2.7.3 Surface area change of Vembanad Lake between 1973 and 2015

Table 2.7.3 Change in estuarine area from 1973 to 2015

Period	Lake area decreases in sq km	Dynamic degree (K) %
1973-1992	8.07	-0.25
1992-2005	2.93	-0.15
2005-2015	1.28	-0.08
1973-2015	12.28	-0.18

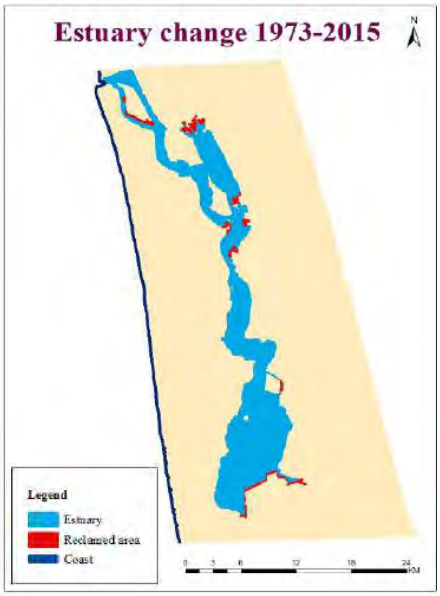


Fig. 2.7.4 Spatial Changes of Estuary during 1973-2015

Fig. 2.7.5a Spatial Changes of Estuary during 1973-1992

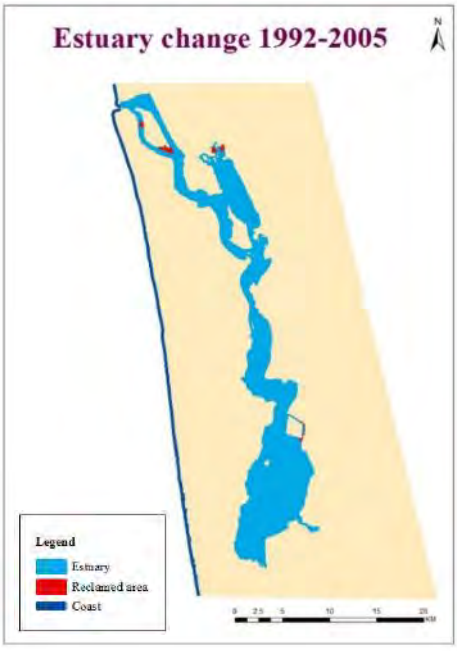


Fig. 2.7.5b Spatial Changes of Estuary during 1992-2005

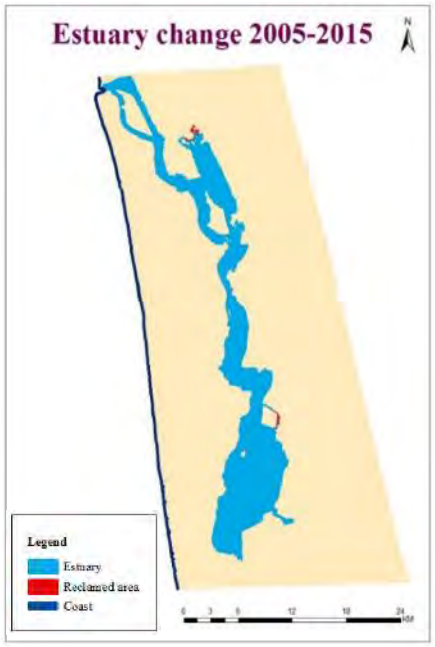


Fig. 2.7.5a Spatial Changes of Estuary during 2005-2015

Fig. 2.1.6a Lake area reclaimed for Willington Island development

Fig. 2.1.6b Lake area reclaimed for paddy cultivation in Southern part of the lake

in 2015. The total areal loss of the estuary was 12.28 sq km between 1972 and 2015.

During 1973 -1992 the estuary has decreased by an area of 4.45%, where 1.15 sq km estuary near R and H blocks were reclaimed and 0.46 sq km of estuary area was reclaimed for the extension of Willington Island.The spatial changes during this period is given in Fig. 2.7.5a. During 1992-2005 the estuarine area apparently declined by 1.73% from which a big portion of the estuary (0.61 sq km) was reclaimed for the development of Willington Island and 0.32 sq km area in the northeastern arm of the estuary is reclaimed for paddy cultivation. Spatial changes during this time are shown in Fig. 2.7.5b. In 2005-2015 periods 1.16 sq km of estuary area is reclaimed for cultivation and plantations which is shown in Fig. 2.7.5c.The field verification of these studies are given in Fig. 2.7.6a and Fig. 2.7.6b.

Two sets of systematic field work were carried out to map the water quality of lake and also to observe groundwater quality around the lake in a 2 km stretch during pre-monson period. The physico-chemical parameters of the water were determined with the help of a multi parameter water quality analyzer (Aquaread AP 2000). In situ measurements of different parameters like temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC), Resistivity, Total Dissolved Salt (TDS), Oxidation Reduction Potential (ORP), Salinity, pH and Turbidity were carried out. 204 wells surrounding the lake in the south and north of Thanneermukkom bund were monitored to understand lake and aquifer dynamics. These parameters were plotted on map using ArcGIS 10.2.1. Fig. 2.7.7 shows physico-chemical parameters of the water samples of wells. Among these wells, 51 wells around the lake were found to be contaminated with saline water and they were plotted in Fig. 2.7.8.

Table 2.7.4 Borehole details from literature survey

Sl. No.	Borehole Location	Latitude	Longitude	Depth (m)
1	Alappuzha	9°29'30"	76°20'51"	34
2	Aryad	9°32'15"	76°19'45"	400.1
3	Mannamchery	9°34'08"	76°20'48"	152
4	Muhama	9°36'15"	76°21'50"	32
5	Kumarakom	9°35'10"	76°26'20"	169
6	Cheruvaranam	9°37'43"	76°21'50"	80
7	Vechoor	9°39'53"	76°26'42"	62
8	Kottaram	9°41'50"	76°18'55"	326.45
9	Turavur	9°45'18"	76°19'10"	222.8
10	Udayapuram	9°46'0"	76°23'30"	69.49
11	Panavally	9°47'45"	76°21'28"	42
12	Chellanam	9°50'34"	76°16'29"	295.6
13	Kanjiramattom	9°51'17"	76°24'59"	60
14	Edakattuvayal	9°52'02"	76°25'51"	30
15	Narakal	10°02'44"	76°12'57"	118.15
16	Mararikullam	9°37'35"	76°20'0"	357

From the field observation it is clear that contaminated wells were reported in the eastern part of the lake. These wells were contaminated with respect to salinity, EC and TDS. These parameters show a similar trend. The hydrochemical data reveal that lake water and the ground water have direct interactions to make its observed changes.

Lithological data help in understanding evolution of lake and aquifer geometry of the region. Lithological information on underlying strata from various sources were collected. The details of the borehole data collected from various sources are listed in the Table 2.7.4. Based on these,stratigraphic model of the study area was prepared using Groundwater Modelling Software. Based on this model the study area consists of sand, clay, laterite, limestone, lignite, gravel and Precambrian basement rocks at varying depths (Fig. 2.7.9).

The pace of developmental activities focused around the Vembanad Lake area has eventually led to the decline of the estuarine area. The developmental activities include

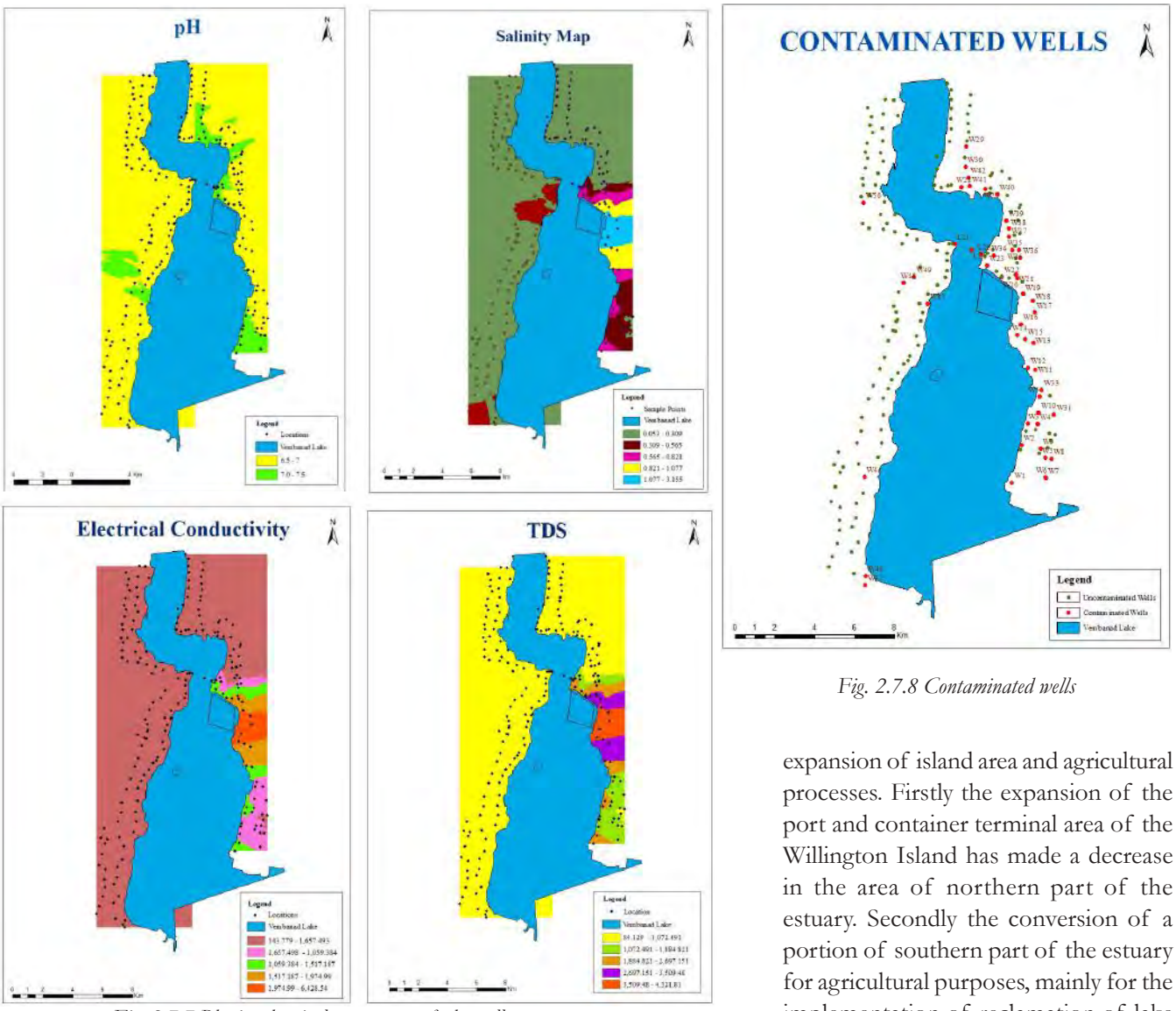


Fig. 2.7.8 Contaminated wells

Fig. 2.7.7 Physico-chemical parameters of the wells

expansion of island area and agricultural processes. Firstly the expansion of the port and container terminal area of the Willington Island has made a decrease in the area of northern part of the estuary. Secondly the conversion of a portion of southern part of the estuary for agricultural purposes, mainly for the implementation of reclamation of lake waters into paddy fields. These factors have gradually reduced the area of the lake during this period as evident from the study conducted. The combined use of satellite images and NDWI & MNDWI techniques has proved to be flawless in the estimation of differences in area of the Vembanad Lake. The study also warrants ceasing unauthorised encroachment of lake area and seeks intervention of authorities to implement necessary regulation and better estuary protection protocols for Vembanad Lake.

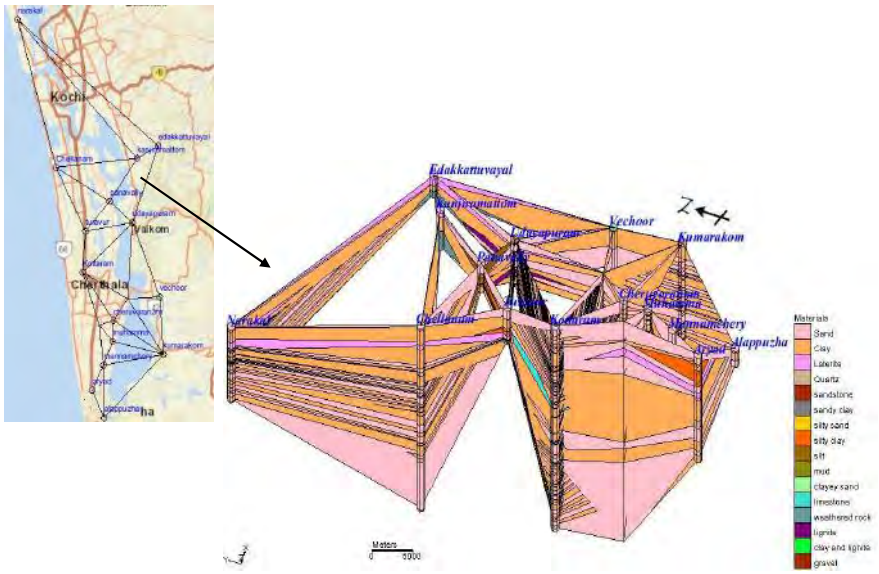


Fig. 2.7.9 Lithostratigraphy of the study area

2.8 Submarine Groundwater Discharge (SGD) in SW Coast of India and its implications

Information on Submarine Groundwater Discharge (SGD) is of major interest for coastal water resources managers as it provides transport for contaminants and/or nutrients, thereby potentially threatening marine ecosystem health. It also lead to a loss of substantial volumes of freshwater to the ocean (Michael Schubertet.al., 2014). Greater supply of inorganic nutrients into the coastal environment may lead to phytoplankton blooms, eutrophication, and general ecosystem deterioration and so this seriously influence the primary production of coastal region and also the biogeochemical cycles even affect the functioning of coral reefs and sea grass meadows. Besides the difficulty that SGD can occur as both, diffuse seeps across wide patches of sea floor and focused flow emerging from a distinct submarine spring, it is the high temporal variability that complicates the localization of SGD areas and the assessment of the associated environmental impacts.

Fig. 2.8.1 Study area from Koyilandi to Kadalundi of Northern Kerala, SW India

The study area (Fig. 2.8.1) falls within the coastal and near shore zone of the southwest coast of India between Koyilandy and Kadalundi-Puthiyapa (~45km) along the Kozhikode coast in northern Kerala. This coast has a complex morphology consisting of tidal inlets at Kadalundi, Beypore, Kallayi and Elathur; coastal plains along Beypore – Kozhikode sector; promontories at Elathur and Kollam; seawalls along Beypore-Kozhikode and Elathur-Koyilandi sectors; groins at Kallayi and Kapad and harbor breakwaters at Beypore, Puthiyapa and Koyilandi. Occurrence of mudbanks was observed along the Koyilandi-Kapad sector. The rivers that drain into the district are Chaliyar, Kuttiadi, Mahe, Kadalundi, Kallayi and Korapuzha. Alluvial soil, laterite soil, and forest loamy soil are dominant in the area.As coastal zone of Kozhikode is highly dynamic in nature, the associated geomorphology and land forms are also highly dynamic. Some of the coastal landforms like pit, bar, beach, tidal flat are modifying its nature from season to season. Some of the land forms like dunes, flood plains, ridges etc. are destroyed or constructed within few years by different geomorphic processes.

Different factors that affect SGD include pH values, dissolved and particulate organic matter concentration, salinity and temperature. The methodology adopted for the present study are (i) electrical conductivity measurements in coastal wells, (ii) water table elevation surveys with respect to mean sea level, (iii) hydrochemical analyses of water samples, (iv) Radon measurements, (v) resistivity surveys and (vi) groundwater modelling. Studies revealed that in-depth understanding of SGD and related processes demands approaches that apply environmental tracers, i.e., naturally-occurring hydrochemical indicators or dissolved tracers that show substantial gradients at the groundwater/seawater interface. Indicators that are frequently used in detecting SGD include the water parameters specific electrical conductivity (EC)/salinity and the naturally-occurring radioactive noble gas radon, the four naturally-occurring radium isotopes 226 Ra, 228 Ra, 223 Ra, and 224 Ra. (Michael Schubertet.al., 2014). Water table elevations with respect to mean sea level are significant as it helps in identifying the hydraulic gradient of the region. The multi-electrode direct-current (DC) geophysical methods have also been used to better constrain SGD rates, forcing factors, scales, and potential ecological impacts. Electrical resistivity is ideally suited to coastal groundwater studies, as subtle shifts in the fresh water / salt water interface can be readily visualized using standard inversion routines.

Based on the fact that inflow of cooler groundwater into warmer near shore waters results in buoyant plumes of low salinity water and lower temperatures at the sea surface in the zones of groundwater discharge [Jean Wilson and Carlos Rocha (2012)], SGD will be identified as cooler water in the near shore region.

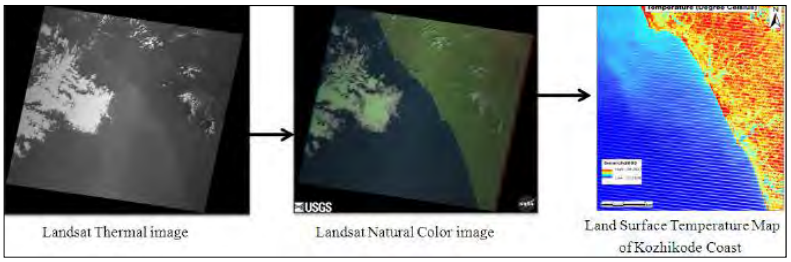


Fig. 2.8.2 Thermal image of Kozhikode coast

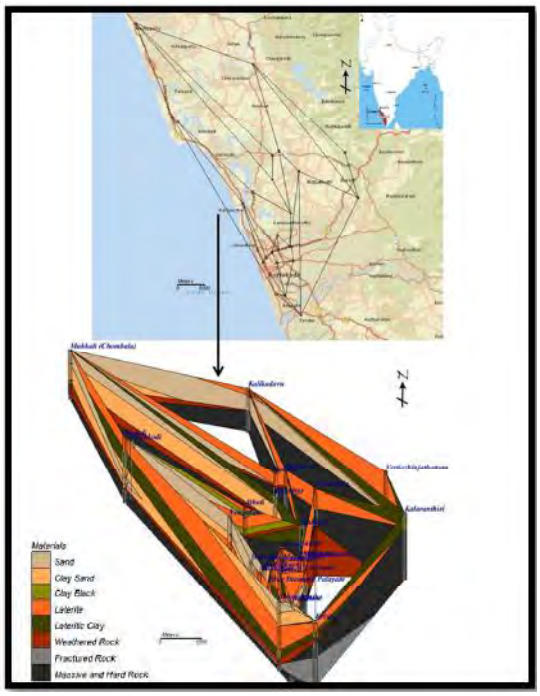


Fig. 2.8.3 Lithostratigraphy of the study area (CGWB, 2008 and Nazimuddin M., 1993)

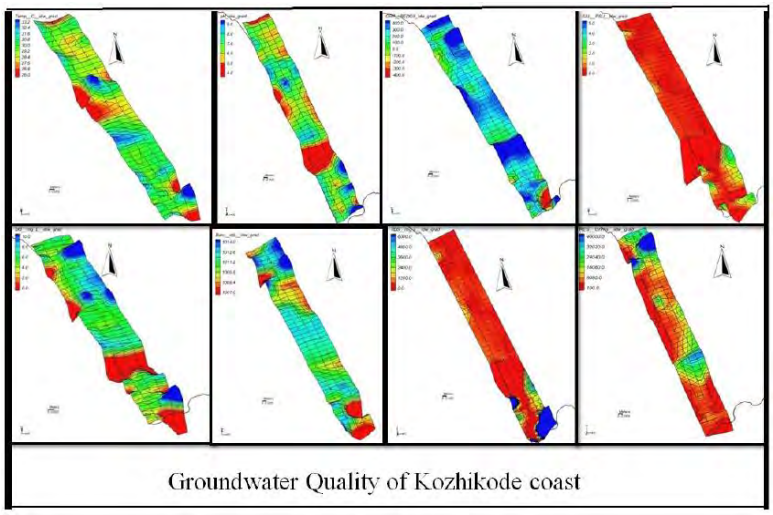


Fig. 2.8.4 3 D modelling of groundwater quality variations of Kozhikode coast

Fig. 2.8.5 locations of Hydrochemical and resisitivity survey

Thus for identifying SGD in Kozhikode coast, Landsat 7 (Band 6) imagery of Kozhikode district was downloaded. TIR image of the study area was downloaded from http://earthexplorer.usgs.gov/ and processed to identify the hotspots in the study area. The image after processing is shown in Fig. 2.8.2. But significant traces of SGD couldn't be identified from the thermal data.

Lithologically, the Kozhikode district consists mainly of sand, clay, laterite and hard rock (Charnockite and Hornblende Biotite gneiss). Three types of crystalline rock aquifers can be identified along the Kozhikode coast namely (i) weathered rock aquifer above the crystalline rock; (ii) a combination of weathered and fractured rock aquifer and (iii) fractured crystalline aquifers at depth between 50 and 80m depth where the fractures are horizontal to sub-horizontal. In most of the regions hard rock was found to be below 30m depth. Coastal stretch of Kozhikode shows a surface lithology of coastal sand, coastal alluvium and coastal laterite and a subsurface lithology of coastal sand and clay (0-15m), laterite (15-20m) and bed rock (30-80m).

In-situ water quality measurement along the coast of Kozhikode was carried out in 118 open wells using a multi-parameter water quality analyser. Different parameters such as pH, temperature, pressure, salinity, TDS (total dissolved solids), EC (Electrical Conductivity), Resistivity, DO (Dissolved Oxygen), ORP (Oxidation-Reduction Potential) were measured using Aquaread AP-2000. These data were modelled using the Groundwater Modelling Software (GMS) 'Geostatistics module' which uses IDW (Inverse Distance Weighted) interpolation. Out of the 118 wells studied, 39 were identified with salinity higher than 0.2 PSU with 30 wells in coastal region and 9 wells upto 2 km inland. Among the 30 wells, 7 wells are located in the northern segment of Kozhikode coast between promontories of Koyilandi and Elathur. Four wells in the Koyilandi region and three wells located to the south of Kappad were also found to be saline, which could be due to sea water

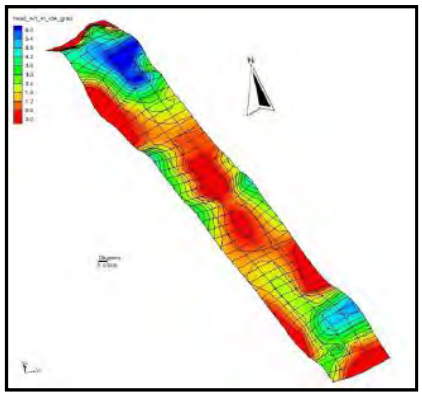


Fig. 2.8.6 hydraulic head variation of kozhikode coast

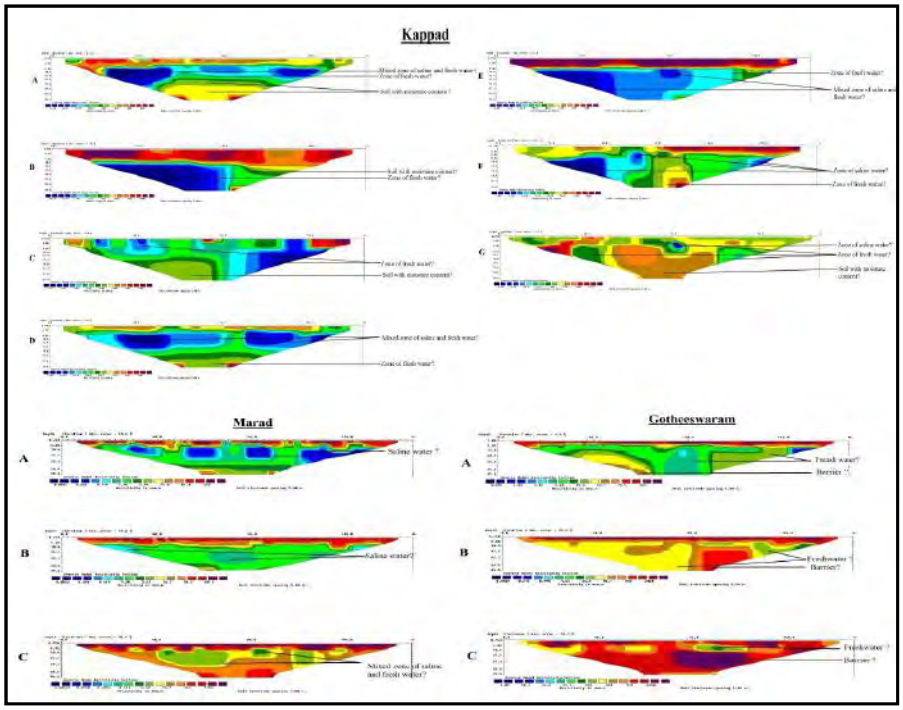


Fig. 2.8.7 ERT of Kappad, Marad and Gotheeswaram

ingression in summer. But the region between Koyilandi and Kappad presented salinities below 0.2 PSU suggesting presence of fresh water discharging to coast. In the southern segment of Kozhikode coast between Kallayi and Beypore, 32 wells were identified to be saline, out of which 23 are located very near to shoreline. The presence of tidal inlets at Beypore and Kallayi is responsible for the higher salinity in the wells near to Chaliyar River. On the other hand, the region between Marad and Beypore (Gotheeswaram) is another suspected region of SGD, as it shows the presence of fresh water in the coast even during summer.

Identification of hydraulic head at different sampling points using DGPS has helped in delineating the hydraulic gradient of Kozhikode coast (Fig. 2.8.5). Beypore, Marad, Kallayi and Kappad showed a dipping trend towards sea which marks the potential zone of ingression. The region between Koyilandi and Kappad and Gotheeswaram (region between Marad and Beypore) is suspected to be a potential zone of discharge.

Multi-channel electrical resistivity (ER) imaging data can be used to examine marine and terrestrial forcing on the freshwater—saltwater interface. Further, time-series ER images can be used to derive hydrologic transport information. Detection of subsurface apparent resistivity through different configurations of electrodes (such as wenner, schlumberger, dipole-dipole, and pole-dipole) helps in delineating the subsurface lithology as well the presence of water. We have completed one set of image analysis in 2015-16. Resistivity surveys at suspected SGD locations (Marad, Gotheeswaram and Kappad) were carried out using an electrode spacing of 3m with a total stretch of 180m. Wenner configuration of electrodes was used to obtain subsurface details upto a depth of 30-40m. Electric resistivity tomograph was prepared using RES2DWIN software and north of Kappad and Gotheeswaram showed presence of fresh water at shallow depths, whereas resistivity values obtained in Marad and South of Kappad showed presence of saline water. This information is in tandem with the hydrochemical data generated using in situ water quality testing in open wells.

It is postulated that subsurface lithology as well as hydraulic gradient of Kozhikode coast permit fresh water discharge to sea through the sandy coastal aquifer. Further evaluation using (a) accurate determination of water table elevation above msl using DGPS, (b) time series procurement of hydrochemical and resistivity imaging data and modelling of aquifer using Groundwater Modelling Software (GMS) would allow explaining the saltwater-freshwater dynamism of Kozhikode coast.

Mintu Elezebath George and D. S. Suresh Babu

2.9 Sediment dynamics, Heavy Mineral depletion and morphological Changes of a Placer Mining Beach of SW Coast of India

The Chavara coast of southwest India is well known for its rich beach placer deposits which are being commercially exploited by two Public Sector Undertakings. Depletion of heavy minerals in the beach sediments has been reported by these industries in the recent years. In addition, severe

erosion and caving in of the beach at the mining sites have also been reported. The reported depletion of heavy mineral content in the beach sediments and the drastic beach morphological changes offered an exciting topic for research under a Ph.D. programme of the CUSAT. The research programme, started in 2010, was initially funded by the Indian Rare Earths Ltd. The objectives of the investigation were to study the sediment dynamics and beach processes of the Chavara coast, estimate the short- and long-term changes in the heavy mineral content and morphology of the beach-innershelf system and decipher the morphological changes and heavy mineral depletion with reference to the hydrodynamic and other forcing factors.

The longshore and cross-shore sediment transport rates in the surf zone and innershelf region of this coast have been estimated adopting the validated LITDRIFT and LITPROF modules of the LITPACK modelling system. Detailed analysis of the computed results shows domination of onshore transport over offshore transport. The beach volume change estimated from the measured beach profile on the other hand shows a reduction in the annual replenishment. A detailed investigation of sedimentology and heavy mineral (HM) content of the beach and innershelf has been carried out based on surficial sediment sampling from the beach and innershelf and core sampling from the innershelf. The study confirmed a drastic reduction in the HM concentration in the beaches of the Chavara coast after 2000. The analysis of the multi-dated shoreline and bathymetry data showed an overall retreat of the shoreline and a relative deepening of the innershelf. The shoreline retreat has been quite alarming at the mining sites with one of the mining sites showing a retreat of nearly 400 m. The sediment deposition adjacent to the breakwater (built during 2000-2007) at the northern inlet has defused to some extent the high erosion observed earlier in the northernmost sector, and the presence of well-maintained seawalls has nearly maintained the shoreline south of the mining site. The erosion of the beach is accompanied by a deepening of the innershelf which is more pronounced in the shallower portions up to 10 m depth.

The observed depletion in HM content and changes in the beach-innershelf morphology are analysed with respect to the nearshore sediment transport regime and the causative forcing factors. It is found that the combined intake of sediments from the beach by the two firms during the past one and a half decade is much above the sustainable mining level. Another contributing factor is the 2004 tsunami which drained off a sizable quantity of HM in the innershelf sediments to the hinterland regions. The breakwaters constructed at the Kayamkulam inlet during the period 2005 coupled with the ones already existing at the Neendakara inlet in the south have virtually compartmentalized this coast from the rest of the coast. The recent spate in construction of shore protection structures like groins and seawalls is another contributing factor to the morphological changes. The study points to the urgent need for regulating the mining volumes to the sustainable levels as well as controlling the introduction of hard structures without proper impact analysis.

R. Prasad & N. P. Kurian

3.1 Establishment of High Altitude Cloud Physics Laboratory in the Western Ghats

Atmospheric Processes Group is setting up a high altitude state-of-the-art cloud physics laboratory in the Western Ghats (WG) to understand the relationship between vertical variations of atmospheric parameters in a monsoon environment and the associated lightning activity. In addition to establishing continuous monitoring stations at (a) NCESS campus close to coastal side (lat: 8°52´N, and long: 76°91´E), (b) Braemore (Lat.: 8°45'N, Long.: 77°5'E; high ranges of Thiruvananthapuram) which is around 400 above MSL and (c) Agumbe (lat: (13°58´N and long: 75°09´E) reserved forest which is at an elevation of about 640 m above sea level, one more site planned at Shankumala (Lat: 10°08 and Long: 77°01) at the Eravikulam National Park, which is around 2100 above MSL. Munnar is considered as an ideal site for measurements of the microphysical parameters of cloud and precipitation. This program is conceived as an inter-departmental/inter-institutional collaborative program involving ESSO-IITM and Pune University.

Table 3.1.1 Instruments are proposed to be installed in the Munnar Weather Station for long-term monitoring of the clound and climate parameters

No.	Instrument	Parameters
1	Ceilometer	Cloud base height
2	Disdrometer	Raindrop size-velocity distribution and rain intensity
3	Automatic weather station	Wind, temperature, pressure, moisture etc.
4	Micro rain radar	Measures profiles of doppler spectra
5	Lightning detector sensor	Lightning strike rate
6	Eddy Covariance System	Surface-atmosphere flux measurements
7	Atmospheric Electric Field mill	magnitude of vertical electric field in the atmosphere
8	Raindrop charge sensor	Electric charge and fall speed of raindrops
9	Gerdien Condenser	Electrical polar conductivity (polarity) of air
10	Air-Earth current sensor	Air-Earth current
11	Respirable Dust Sampler	Total Suspended Particulates in ambient air
12	Gaseous Sampling Attachment	Measuring SO_2, NO_2, O_3, NH_3 in ambient air
13	Fine Particulate Sampler	Particulate matter with size < 2.5 micrometers and 10 micrometers in diameter
14	Portable Aerosol Spectrometer	Air-bone particles and particle count distribution

Network of observation sites in WG Mountains involve measurements of thermodynamic variables, atmospheric electric field, lighting variability, cloud and precipitation parameters. The atmospheric pollution and impact of climate change over the Western Ghats is another program is envisaged. In India, Kerala State is known to have relatively high lightning incidence. The nature of spatial and temporal distribution of past incidents, type of thunderclouds which cause lightning, the topography, proximity to a mountain range and sea point to the possibility of the mountain weather aiding in cumulonimbus cloud formation. A study on the role of mountain weather in convective cloud formation in the nearby Western Ghats mountain range could lead to a better understanding of the lightning incidences.

3.2 Characteristic of rainfall during different seasons over a coastal tropical station using Disdrometer

Drop size distribution over the tropical regions exhibits pronounced variations during different monsoon seasons. Measurements from a Parsivel Optical Laser Disdrometer are used for characterization of rain drops and intensity over Thiruvananthapuram. Rain events during the pre-monsoon, summer monsoon and post-monsoon seasons of the year 2011 were identified and their duration (min) and accumulated rainfall (mm) were computed. Rain intensity/Rain rate RI (mm/h), mass-weighted mean diameter D_m (mm) and total number concentration of raindrops N_T (m^{-3}) are calculated on each sampling interval. RI is classified into 6 categories as per the WMO (World Meterological Organisation) norms. Moreover, D_m, and N_T are categorized into different arbitrary bins for detailed analysis.

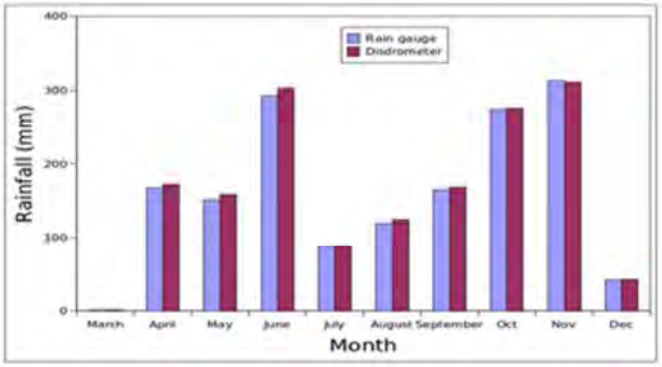


Fig. 3.2.1 Monthly distribution of rainfall for the year 2011 based on rain gauge and disdrometer

Table 3.2.1 Classification of RI, mean drop diameter and number of rain drop concentration

Rain Intensity classification (RI)			Raindrop mean diameter classification (D_T)		Number of raindrop concentration (N_T)	
Variable	Range, mm/hr	Rain Type	Variable	Range, mm	Variable	Range, m^{-3}
R1	0.1 – 0.5	M.D.	D_m1	< 1	N_T1	10 – 1000
R2	0.5 – 2.5	H.D./L.R.	D_m2	1 – 2	N_T2	1000 – 2000
R3	2.5 – 10	M.R	D_m3	2 – 3	N_T3	2000 – 3000
R4	10 – 50	H.R	D_m4	3 – 4	N_T4	3000 – 4000
R5	50 – 100	V.R	D_m5	4 – 5	N_T5	4000 – 5000
R6	> 100	H.V. R	D_m6	> 5	N_T6	> 5000

The different ranges of RI and their relative contribution towards total rainfall is different for different seasons. Maximum events were reported on the R2 (Moderate Drizzle) type, however, contribution of rainfall (mm) is mainly registered on R4 (Heavy rain) type. Similarly the N_T and D_m are also showing different characteristics during different monsoon seasons. Frequency of occurrence of D_m is higher in D_m2 (1-2 mm) followed by D_m1 (D_m<1 mm) and then D_m3 (2-3 mm) with difference in magnitudes for different seasons. On analyzing relative rainfall contribution from different mean diameter bins, it can be observed that D_m2 and D_m3 (1-3 mm) are the major contributors. Both frequency and accumulated rainfall are almost same or comparable from drop concentration bins in the three seasons. The D_m and N_T are positively related with different RI types. The lower rainfall intensity bins show higher duration during the summer monsoon season and lower duration during the pre-monsoon season, the higher intensity range bins show lower duration for the pre-monsoon season and higher duration for the post-monsoon season.

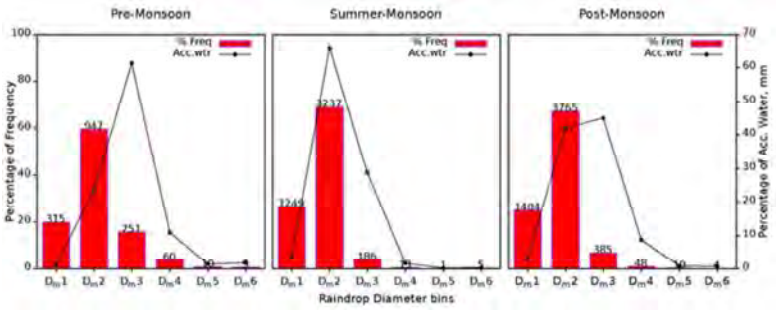


Fig. 3.2.2 Percentage of occurance and contribution to the total water from the different mean diameter bins. Frequency value in each bin is displayed above respective bar

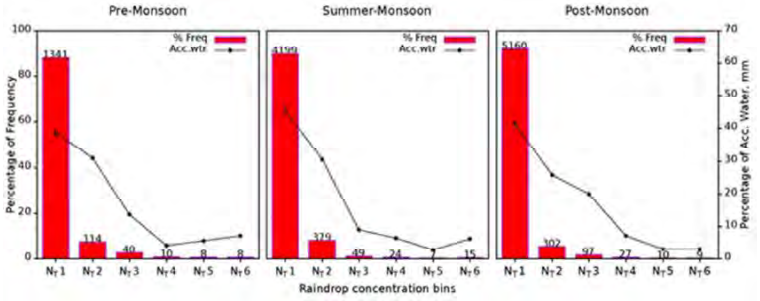


Fig. 3.2.3 Percentage of occurrence and contribution to the total water from the number concentration bins. Freequency value in each bin is displayed above respective bar

An attempt was made to characterize tropical rain in terms of different integral parameters derived from rain drop size distribution. RI, Dm and N_T are derived from DSD and analyzed the rain in terms of its different intensity ranges. From the analysis of available data for the year 2011, an attempt was made to explore temporal characteristics of the integral parameters of DSD during pre-monsoon, summer monsoon and post monsoon seasons. The rainfall intensity is classified into seven categories and found that maximum frequency of occurrence is found in intensity range R2. However, the second maximum of occurrence is found at R1 for pre-monsoon and for other two seasons, it is at R3 range bin. The relative contribution is peaked at R4 for all the seasons, but the pattern is different for all the seasons. In the case of mean diameter, the bin Dm2 found to be higher in occurrence whereas , the second and third maxima are different for different seasons. The relative contribution of rainfall for different diameter range is also different for different seasons.

The notable difference is the maximum contribution is from D_m2 during summer monsoon period and it is from D_m3 for other two seasons. The higher number of concentration of drops found during the post monsoon season in N_T1 range bin the relative contribution is also higher from the same range bin and the result is consistent with other monsoon seasons with difference in magnitudes. The relative contribution from different N_T is different for different seasons. Moreover, the D_m and N_T are related with rainfall intensity in such a way that the rate of increase is lower in the lower intensity ranges and higher for higher intensity ranges. The intensity duration curve also exhibit almost similar profile in all the seasons. However, lower intensity range bins show higher duration during summer monsoon season and lower duration for pre-monsoon season. In the higher intensity range bins (RI > 60 mm/hr), lower duration is for pre-monsoon season and higher duration is for post-monsoon season.

T. S. Sreekanth, Hamza Varikoden, Nita Sukumar and G. Mohan Kumar

3.3 Classification of stratiform and convective precipitation based on drop size distribution and analysis of their microphysical parameters using ground-based measurements

The primary aim of the present study is to distinguish stratiform, convective and transition rain effectively at a tropical high altitude station, based on the DSD measurements from an optical laser disdrometer PARSIVEL. The duration and total rainfall collected from each and every events in the pre-monsoon season, 2015 on the Western Ghats. Parsivel data from this station is used for this study. From this stratiform and convective

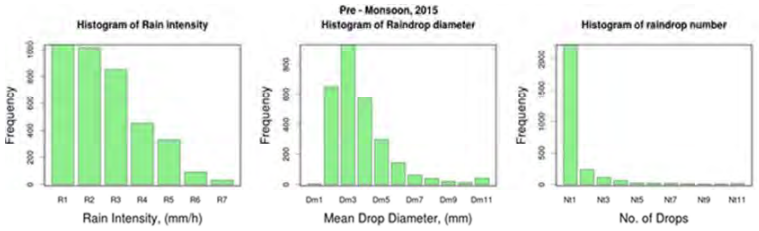


Fig. 3.3.1 Histogram of rain Intensity (RI), Raindrop Mean diameter (Dm) and Total number of raindrops (Nt) for full Pre-Monsoon 2015

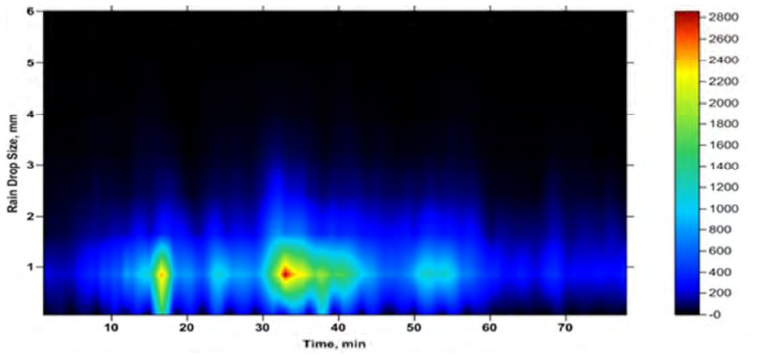


Fig. 3.3.2 Time evolution of drop of size distribution

events Rain Intensity RI, raindrop mean diameter Dm and total number of drops, Nt are calculated on each sampling interval (1 minute).

Frequency of occurrence and accumulated water from each class of RI, Dm and Nt were calculated for the entire spell of the 2015 pre-monsoon season and resultant histogram and accumulated water are plotted in Fig. 3.3.1 & Fig. 3.3.2 respectively. Frequency of light drizzle to heavy violent rain shows a decreasing tendency in full season. Both drizzling precipitation classes (R1 & R2) were recorded upto 1000 minutes. But the contribution of water from them was least. Even though the frequency of moderate to heavy violent rain is less, their contribution to total rain water is high. Heavy rain (R5) was noticed for about 300 minute only, but its contribution to total rain is about 140 mm out of 367mm. By analyzing full pre-monsoon rain, it can be seen that the major contribution of water is from higher intensity classes. From the mean diameter classes, Dm3 (1-1.5 mm) records highest of number of occurrence of about 1000 minutes and other diameter classes from Dm3 shows continuous decreasing tendency. In case of accumulated water, Dm5 & Dm6 (2-2.5 mm & 2.5-3 mm) contribute about 220 mm rain and is about 60% of total. Coming to total number of raindrops Nt1 (10-500 drops) hits the highest frequency of 2200 minutes and frequency of all other number classes are very less. Regarding accumulated water Nt1 to Nt4 contribute major part of water. ie, major contribution of water is from smaller drops.

The full season rainfall is classified into convective and stratiform types and were analysed separately. It can be observed that higher intensity classes contribute much water to the total accumulated rain water in convective type rain. Mid value range classes of mean diameter Dm5 to Dm7 hit higher frequency and contribute major part of water to total. In case of number of drops lower number classes record higher frequency and contribute much water to the total. From Fig. 3.3.1 & Fig. 3.3.2 it can be seen that the frequency is higher for lower values and major contribution of water is also from lower classes for stratiform type. For stratiform events, raindrop size varies from 0.35 to 3.5 mm and drop velocity varies from 1.7 to 9 m/s. Drop concentration varies maximum upto 380 in size distribution and 180 in velocity distribution in stratiform events. In case of convective events, raindrop size varies from 0.35 to 5 mm and drop velocity varies from 1.7 to 10 m/s. Drop concentration varies maximum upto 2800 in size distribution and 1800 in velocity distribution in stratiform events.

T. S. Sreekanth, V. Sasikumar and G. Mohan Kumar

3.4 Case studies of raindrop size distribution: pre-monsoon, monsoon & post-monsoon

NCESS is equipped with instruments like Optical Disdrometer & Micro Rain Radar (MRR), which gives raindrop size distribution. To be more precise, disdrometer gives size-velocity distribution of raindrops at the level and MRR gives raindrop size distribution at many height levels (adjustable) i.e, distribution profile. Few case studies have been made with data from the NCESS station in (a) pre-monsoon (b) monsoon & (c) post-monsoon rain event cases.

Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (a, upper panel) shows the raindrop size distribution measured from MRR at 4 different levels. Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (b, middle panel) shows the distribution at the surface obtained from an optical disdrometer and Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3(c, lower panel) gives the drop distribution (from disdrometer) in terms of both size and fall velocity of the raindrops.

Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (a, upper panel), it can be very clearly seen that the distribution varies with altitude. Many processes are responsible for this variation in the distribution e.g. nucleation of new drops, drop growth by vapour deposition, collision and coalescence, drop break

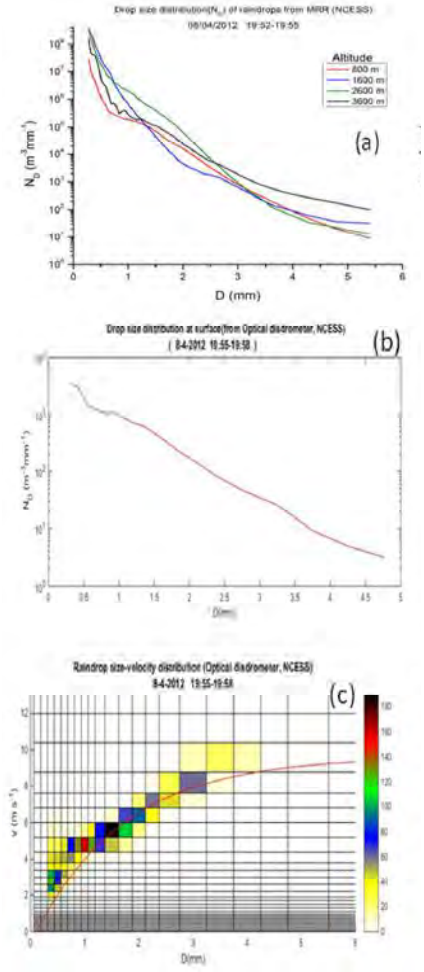


Fig. 3.4.1 The raindrop size distribution in a pre-monsoon rain event on 08 April, 2012.

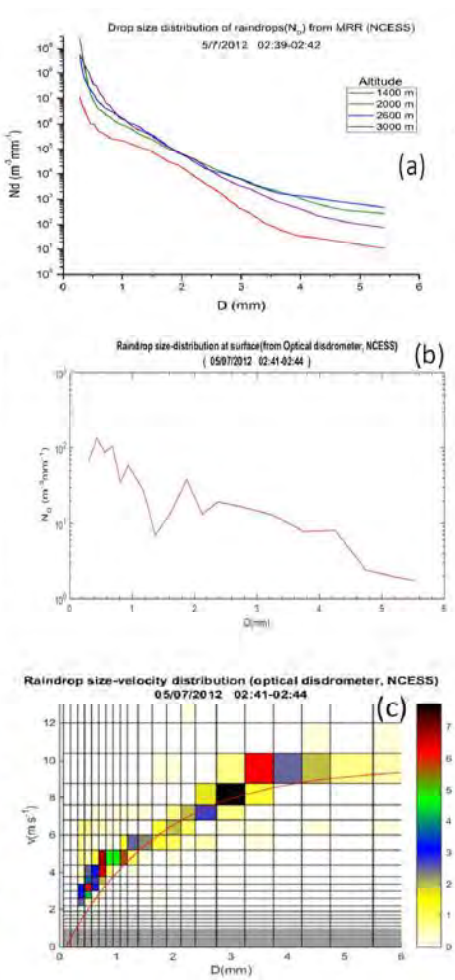


Fig. 3.4.2 The raindrop size distribution in a monsoon rain event on 05 July, 2012.

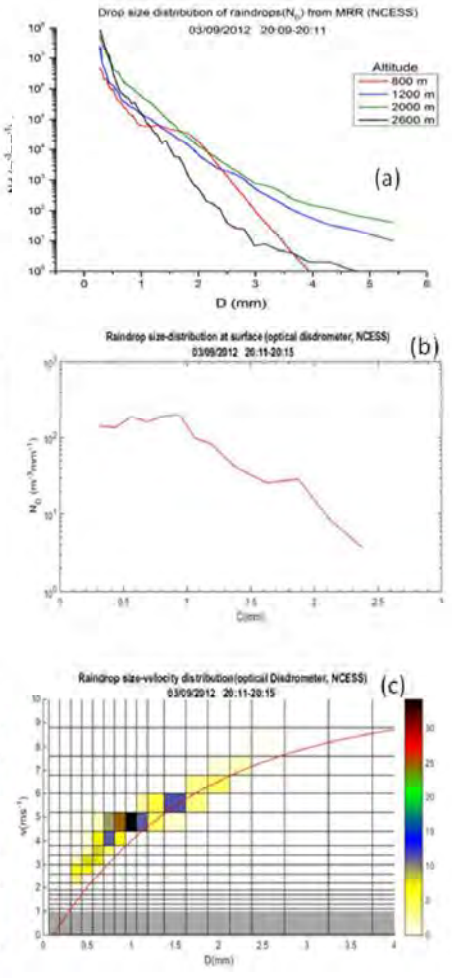


Fig. 3.4.1 The raindrop size distribution in a post-monsoon rain event on 03 september, 2012.

up, evaporation etc. Also the distribution will be very much dependent on the dynamic condition (e.g. turbulence) available at different levels. If we compare the black (3600m) and green (2600m) levels it is clear that larger drops at 3600m level break and comes into the smaller size bins at 2600m level. Then by the time the drops reaches 1600m level, number of larger drops have increased due to coalescence of smaller drops to larger drops. From Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (b) we see that the distribution at surface is quite different from the ones at upper levels. The numbers has reduced by almost a factor 100. Most likely lower humidity at lower levels and high relative (to moving drops) wind speed leads to higher evaporative decay of drops. Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (c) is the actual size-velocity distribution given by the optical disdrometer in 32*32 size and velocity classes. From this the size distribution (Fig. 3.4.1, Fig. 3.4.2 and Fig. 3.4.3 (b) has been obtained by using appropriate formula.

Dharmadas Jash, E. A. Resmi, T. S. Sreekanth & Nita Sukumar

3.5 Diurnal and seasonal variations of Atmospheric CO_2 over Trivandrum, Kerala, India

Continuous measurements of CO_2 mixing ratio and meteorological parameters have been made in National Centre for Earth Science Studies campus from June 2014 to May 2015 and the diurnal and seasonal variation of CO_2 mixing ratio was analyzed. The average atmospheric CO_2 during study period was 321±14.78 ppm. The diurnal variation with a maximum during the early morning and late night and a minimum in the afternoon is clearly observed. Photosynthetic and atmospheric boundary layer play an important role in diurnal variation of CO_2. The analysis of its seasonal trend indicated that highest value of CO_2 mixing ratio (382 ppm) was found in summer and the lowest (274.3 ppm) during monsoon season.

Fig. 3.5.1 shows the variation of CO_2 with wind speed and the scatter plot between CO_2 and wind speed. It clearly shows an inverse relationship of CO_2 with wind speed. The observations with maximum mixing ratios of CO_2 (407

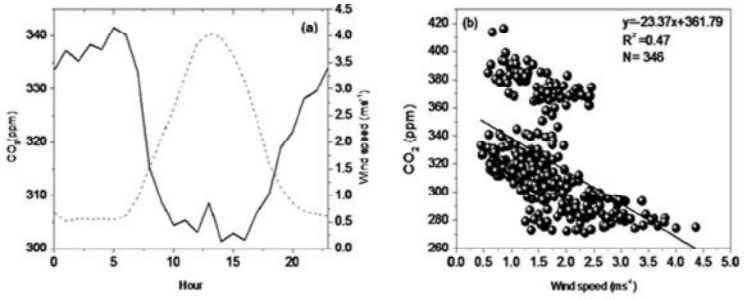


Fig. 3.5.1 (a) Variation of Co_2 with wind speed solid line indicates co_2 and dashed lines indicate wind speed. (b) Scatter plot betwen wind speed and co2 during the period of study.

ppm) have wind speeds of 0.5 m/s, and minimum mixing ratios of CO_2 (301ppm) wind speed of 4.0 m/s. Thus, wind speed played an important role in the CO_2 con-centrations during this period. As these observations are monthly means, the impact of winds on the mixing rations is very significant. High winds have the scavenging effect besides reducing the stability of the atmosphere due to which, high (low) concentrations are observed with low (high) winds. Thus the scavenging effect of wind magnitude and speed plays a dominant role in controlling the CO_2 mixing ratios at this station. The mean day-night ratio (D/N) for the study period was 0.94. All through the months, the night time concentration of CO_2 is found to be higher than the day time concentrations since photosynthetic activity is higher during day time.

K. Rajeevan & R. K. Sumesh

3.6 Characteristics of black carbon aerosols over a tropical coastal station

Continuous and near-real-time ground based measurements of Black Carbon (BC) concentrations were carried out during October 2014 to September 2015 at Trivandrum. Diurnal and seasonal variation of BC aerosols in relation to changes in the regional meteorological conditions and frequency distribution in different seasons is studied. The variations of daily mean mass concentrations of BC is shown in Fig. 3.6.1 (a).The annual average concentration of BC is 3.82± 1.92 μm^{-3}over the period of observation. The highest peak of BC is observed on 10th December 2014 (11.8μ m^{-3}). The temperature (20.8°C) and wind speed (0.5 ms^{-1}) were found to be very low on the day. The calm condition of the mean wind speed and low temperature in the boundary layer in the winter period are the responsible factors for the higher BC concentration. During December most of the time wind was in calm condition (mean wind speed: 1 m/s) with low temperature (mean: 24.2 °C). Lowest BC concentration is found in the beginning of monsoon season i.e., on 20th June 2015 (0.5 μm^{H3}). The surface temperature (29.7 °C) and wind speed (3.6 ms^{-1}) is found very high.

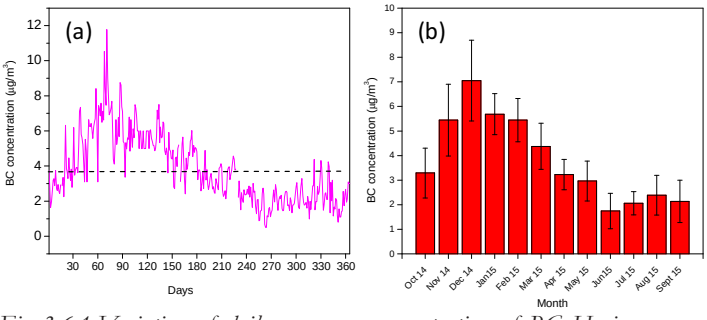


Fig. 3.6.1 Variations of daily mean mass concentrations of BC. Horizontal dashed lines indicate the mean value (b)Monthly means variations of BC mass concenration during October 2014- September 2015. Vertical bars representing standard deviation obtained from the mean

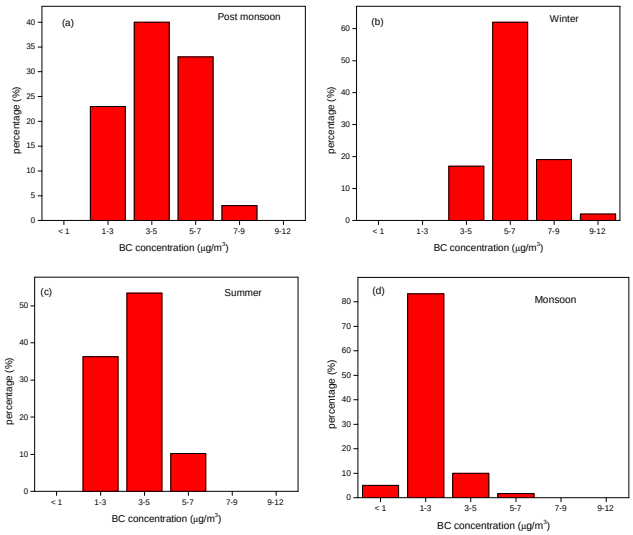


Fig. 3.6.2 Frequency distribution of BC concentration in different seasons

The frequency distributions of BC concentration during different seasons are given in Fig. 3.6.2 In winter the BC concentrations were highest (62%) in the range between 5 -7 μm^{-3}; however fewer BC mass concentrations (2%) were in the range between 9-12 μm^{-3}. Only in winter season is characterized by higher concentration of BC in the range 9-12 μm^{-3}. During post monsoon and summer the maximum contribution of BC is found in 3-5 μm^{-3} (approximately 40% and 54%) range. Most of the BC concentrations (84%) were found to be between 1-3 μm^{-3} in monsoon period. From the analysis it is concluded that in monsoon season even if the wet deposition prevails smaller range particles persists over the region i.e., <1μm^{-3}. Using the HYSPLIT model, back-trajectories were studied to assess the sources for transported particles. BC exhibited well-defined diurnal as well as significant seasonal variations. The annual average BC mass concentration during the study period was 3.82 ± 1.92 μm^{-3}. Strong seasonal variation is observed with

high average values during winter (6.07 ± 1.98 μm^{-3}) and low in monsoon (2.08 ± 0.86 μm^{-3}) season. The relationship with co pollutants ($PM_{2.5}$, PM10 and CO) and meteorological parameters were also studied.

K. Rajeevan, R. K. Sumesh and E. A. Resmi

3.7 The effect of anthropogenic emissions and meterology in the variation of particulate matter at a semi-urban site in Trivandrum city

Simultaneous measurement of PM 2.5 and PM10 mass concentrations was carried out for the past two years from March 2010 to February 2016 with BAM1020 particulate matter analyzer placed at the roof top building of NCESS campus. The diurnal and monthly variations of particulate matter concentrations are analyzed. Both particulate matter shows mass concentrations gradually increase just an hour after the local sunrise in the morning and attains a sharp peak at around 8:00 to 10:00 hours local time. From 12:00 to 17:00 hours the concentrations remain more or less steady and in the evening, at around 18:00 hours the concentration is seen gradually increased. The morning buildup of local anthropogenic activities associated with the vehicle traffic through the unpaved roads near to the sampling site is found to be responsible for this peak. During early night, the wind speed has been generally low and a low ventilation coefficient has caused confinement of particulate matter, which again increases the concentration.

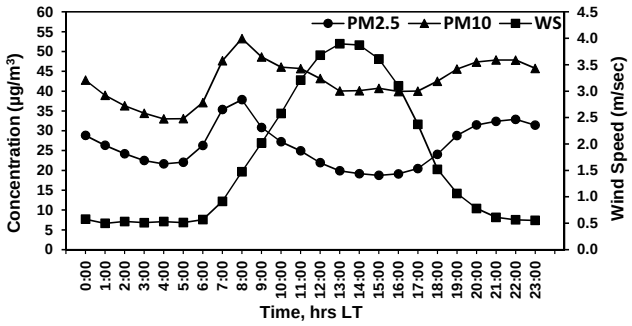


Fig. 3.7.1 Average diurnal variation of PM 2.5 and PM 10 concentrations in correlation with wind speed from March 2014 to February 2016

The maximum monthly mean concentration of PM2.5 occurs on December 2014 with a value of 56.92±23.5 µg/m^3 and minimum was 9.73±3.8 µg/m^3 observed on August 2014. For PM10, the maximum mean concentration was 76.9±25.5 µg/m^3 in December 2014 and the minimum concentration was 22±6.9 µg/m^3 in September 2015. The distribution is positively skewed with a wide range of values from 3 to 153 µg/m^3, with most of the values lying in the range of 10-30 µg/m^3.

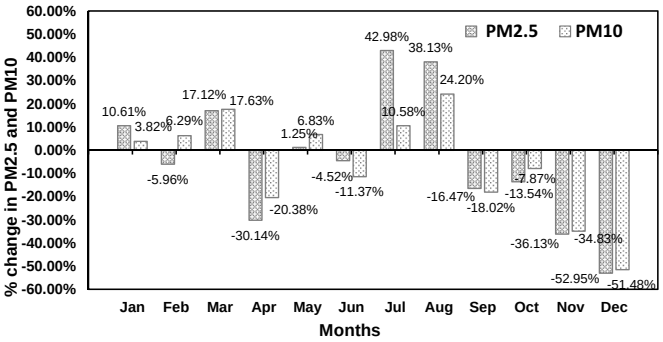


Fig. 3.7.2 Percentage change in mass concentration of PM 2.5 and PM10 during the months of 2015 with respect to 2014

In order to observe the variation trend of PM concentration, the percentage change in PM10 and PM2.5 was calculated during 2015 and compared with that in 2014. There is an increasing and decreasing trend of both particulate matter concentration for different months during the past two years. It was observed that the changes in the distribution of particulate matter concentration are governed by meteorological factors as well as anthropogenic emissions.

R. K. Sumesh and Rajeevan

Natural Resources and Environmental Management

4.1 Water Resources

4.1.1 Critical zone characteristics and climate change impacts: A case study from Periyar river basin, Southern Western Ghats, India

Most of the South Indian Rivers have their origin in the Western Ghats, the 'Water Tower'. The 1600 km long mountain stretch of the Western Ghats forms a complex barrier for the circulation of air masses over Southern India. It exerts an orographic uplift to the south-westerly winds coming from the Arabian Sea during summer monsoon which results in contrasting rainfall patterns on the two sides of the Ghats. Analyses of rainfall trends and its projections shows significant changes in precipitation patterns over the country and also in Kerala State which is the "Gateway of Indian Summer Monsoon" (ISM). The decrease in southwest monsoon rainfall and increase in post-monsoon season significantly change the climate and hydrological regime of the State. A recent study highlighted the intense drought events during the twentieth century which is consistent with the reports of drought in the highly humid tropical monsoon dominated State with around 120-140 rainy days per year. Even though, river basins/catchments are the ultimate unit of life sustenance, studies are very scanty relating to the climate linked river health. Also, the prevailing water circulation mechanism with its probable linkage to the existing climate system is yet to be understood. Hence, for the present study, Periyar River Basin (PRB) has been chosen as it is the highest rainfall receiving area of the State.

Gridded rainfall data (0.25^0 resolutions, 16 grids) obtained from Indian Meteorological Department (IMD) over a period of 1901 to 2013 was analysed using LOWESS regression curve to identify patterns over time. Also, the homogeneity of the series was tested and most probable change year was detected using Pettitt's test and Buishand's test. In the lowlands (grids 1, 2, 6 & 7), which hosts major urban agglomerations of the basin, the break points were during 1961-1964 indicating a remarkable variation in rainfall trend in the study area.

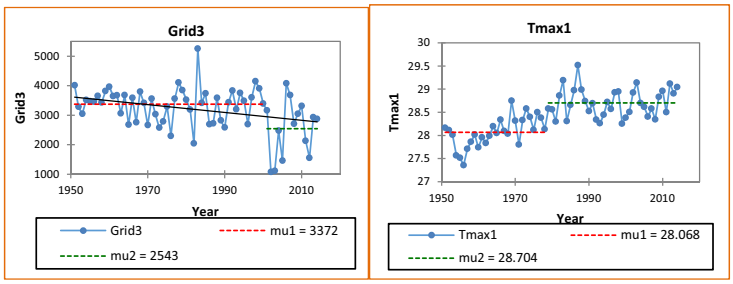


Fig. 4.1.1.1 Change year in annual rainfall and temperature series (a) Rainfall, (b) Temperature (mu1 and mu2 represents the mean rainfall and temperature before and after the change point)

As part of the hydrochemical study, major ions and stable isotopes have been used as tracers for understanding the regional water cycle and sources dynamics. About 60 water samples (monsoon) were collected from fixed locations falling in the highland and midland regions of Periyar River Basin. The samples included rainwater, river water and ground waters. The isotopic analysis for $\delta^{18}O$ and $\delta^{2}H$ (Fig. 4.1.1.2) has been carried out using Isotope Ratio Mass Spectrometer (IRMS). The monsoon samples show $\delta^{2}H$ values in the range of -1.41 to -30.11 and $\delta^{18}O$ values in the range of -1.78 to -5.73.

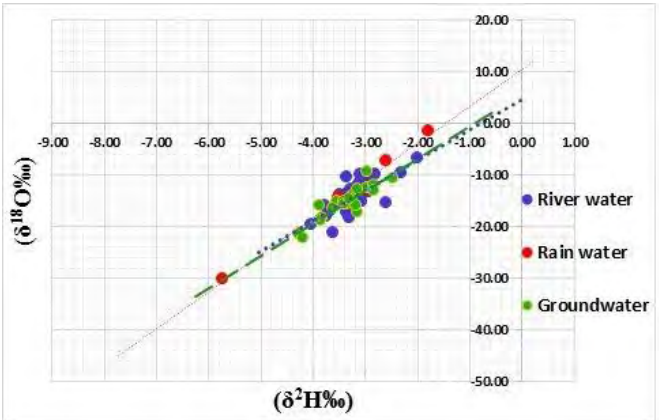


Fig. 4.1.1.2 Relationship between $\delta^{18}O$ and $\delta^{2}H$ of river water and groundwater in the Periyar river basin

The physical parameters and major ion chemistry of the water samples were also analysed. For major ions, Ion Chromatographic (IC) techniques have been used and the ionic balancing of the respective samples were also done before using the data for hydrogeochemical computations. The Piper trilinear diagram thus obtained show that samples are Ca and Na HCO3 type. There is not any regular trend observed among different ionic parameters at different stations and this may be due to the land derived effects of monsoon in the highland, midland and lower reaches in the basin.

P. Saranya and A. Krishnakumar

4.2 Environmental Monitoring & Assessment

4.2.1 Sand audit of the rivers of Idukki district

River sand auditing methodology is used for evaluating the process of sand mining in a river or a portion of a river after a specific period of sand mining. This exercise helps to know how far mining of sand in a river or a part of it adversely affected the system. The information will help to minimise the negative impacts of sand mining on one side and to maximize the positive effects on the other. In accordance with the provisions of sand auditing of Kerala rivers within the ambit of the legislation "The Kerala Protection of Rivers and Regulation of Removal of Sand Act, 2001", a methodology has been evolved by CESS, predecessor of NCESS. The present study deals with the major observations and findings on the sand audit carried out in the rivers of Idukki district such as Periyar, Muvattupuzha, Pambar and Manimala.

The ideal methodology of sand auditing is developed for regulating sand mining activities in the alluvial reach, especially the storage zones, of the rivers where sand is getting aggraded in the form of fluvial deposits. But in the case of the present study, the drainage network lies generally in the production zone of the Muvattupuzha, Manimala and Pambar rivers. The sand deposit in the channel environment of the rivers draining through Idukki district is exhausted almost completely consequent to its unabated extraction over the years. Therefore, the sand auditing methodology adopted for the storage zones of rivers in the midlands and lowlands cannot be applied as such in the case of the river channels in the production zones. But it should be remembered that thick deposits of sand were in existence in many stretches of the rivers of Idukki district a decade or two ago. But due to indiscriminate sand extraction, such sand deposits were totally exhausted. Realizing this, the District Level Expert Committee (DLEC), Idukki has banned sand mining from the Muvattupuzha, Manimala and Pamba rivers draining through Idukki district.

It is clear that many parts of the Muvattupuzha, Pambar and Manimala rivers in Idukki district are in the juvenile phase which do not have the required width specifications for river sand auditing. Only a few stretches of the Kaliyar and Thodupuzha tributaries of the Muvattupuzha river in their downstream possesses the width specifications. But such reaches are either with rocky river bed or falls within the prohibited areas of engineering constructions like bridges, rural water supply schemes, etc. Although repeated

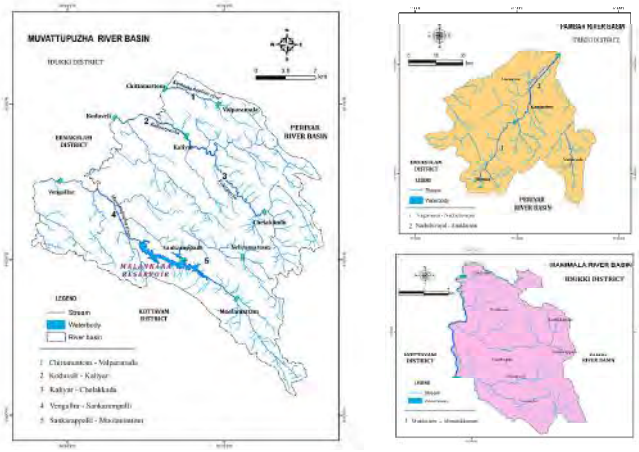


Fig. 4.2.1 Rive segments in Muvattupuzha, Pambar and Manimala rivers, Idukki district

field visits and data collections have been made in the area, sand accumalations feasible for mining could not be traced out in the Muvattupuzha, Manimala and Pambar rivers flowing through Idukki district. The latest field work in the series was performed in the middle of January 2015. The present observations and analyses support the views of the District Level Expert Committee (DLEC), Idukki district to allow sand mining holidays to the Muvattupuzha, Manimala and Pambar rivers. The sand mining holidays applied to these rivers has to be extended to a minimum of one more audit period.

D. Padmalal and K. Maya

4.2.2 Study on the environmental effects of mining and quarrying in the Periyar river basin, central Kerala

Periyar is the longest river of Kerala with a river length of 244 km and a catchment area of 5398 km^2. Of all the disruptive human interferences in the basin environment, mining and quarrying is of special significance and is often more damaging to the environment than any other developmental initiative. Quarrying of hard rock and soil, sand extraction from instream and floodplain areas, clay mining from the floodplains/ wetlands, laterite block cutting, etc., are the major resource extraction activities noticed in the river basin. Spatial distribution of mining/ quarrying locations reveals that the midlands and the highlands are most affected due to the activity than the lowlands. Unplanned and haphazard mining imposes marked environmental impacts on land, water, atmosphere and socio economic conditions of the people in the river basin. In the present study, the matrix method is used to assess the environmental impacts of the different extractive activities in the river basin. The rampant and unscientific extraction of resources is major threat to the very existence

Fig. 4.2.2.1 Some selected scenes of hard rock quarrying and related environmental issues in the PRB: an active hard rock quarry (above left), an abandoned derelict site of past quarrying (above right), cracks and damages to structure due to vibration effects of blasting (below right & left)

of the Periyar river in particular and the small rivers in general. The impact assessment reveals that the adverse environmental impacts of mining and quarrying dominate over the marginal and short term benefits. The major driving force behind indiscriminate mining and quarrying activities is the rising demand of building materials for the mega developmental projects in Kochi city, one of the fast developing urban-cum-industrial centres in South India. The study covers almost all the components of the land and water systems of the Periyar river basin. Based on the study, a set of guidelines have been put forth, with special reference to the existing minor mineral extraction policies, for achieving the goal of sustainability in the case of resource extraction and management.

Widespread mining and quarrying for building materials (minor minerals) in the river basin is one of the major drivers of deterioration of the overall environmental quality of the region. The decreasing availability of aggregates, especially due to the indiscriminate extraction of the alluvial sources (instream and floodplain), has heightened the demand for crushed sand/ manufactured sand (M sand) in the State. Kerala State, especially in areas around the urban centers, are now inclined towards rock based fine and coarse aggregates for meeting the demands from construction sector. A total of 1644 labourers are engaged in hard rock quarrying sector (in 136 active quarries) in the Periyar river basin. Hard rock quarrying is mainly concentrated in the midlands which fall within the Ernakulam district directly catering to the burgeoning developmental needs of Kochi City. Out of 9.5716 x 10^6 ty^{-1} of hard rock quarried from the basin area, the bulk i.e., 7.9312 x 10^6 ty^{-1} comes from the midlands alone. Extraction activities are also widespread in the highlands of the basin (1.4596 x10^6 ty^{-1}) that falls mainly within the jurisdiction of Idukki district. The hills and hillocks in the basin are at present in a steady state of degradation caused by mechanized soil quarrying. Soil is being quarried rigorously from the hill ecosystems in the highlands and midlands of the basin (0.72 x 10^6 ty^{-1}). Apart from soil quarrying, mining for brick clays was also widespread in the lowlands and midlands of the basin. Approximately 1864089 m^3 of clay has been extracted from the wetlands of the basin. Spatial analysis shows that the midlands contributed a major share of clay (57%) to the construction sector compared to lowlands (43%). Due to the indiscriminate extraction, over the years, and resultant dearth in clay resources, the activity has decreased drastically in the basin. At present, there are no active tile/brick clay mines in the basin. The numerous brick kilns operating in the midland and lowland regions of the river basin utilize clay from adjacent basins for making bricks and tiles. Altogether, 81 clay-based industrial units are functional in the study area. As per our previous studies, there is a drastic reduction in the number of clay based industrial units in the basin area. As more and more paddy lands are being filled for infrastructure development and other non-agricultural purposes, the dearth in clay resource availability in the state has aggravated. The tile and brick manufacturers in the State now depend greatly on clay resources from neighboring states; although this includes the added liability of transportation costs. Periyar river is subjected to rampant sand mining all along its system including the main channel as well as the tributary / distributary systems. A total of 15 local bodies and a Municipality located on either side of the river are engaged in sand extraction. The annual instream sediment extraction from Periyar was 0.37 x 10^6 ty^{-1}, in which 0.30 x 10^6 ty^{-1} is extracted from the midland part of the river and the rest from the highland regions (0.063 x 10^6 ty^{-1}). In addition to mining of sand and gravel from the active channels (ie., instream mining), a substantial portion of sand is also being extracted from the overbank areas (foodplain mining) of the river.

The Environmental Impact assessment of all the mining and quarrying activities has revealed profound changes in landscape and landuse of the study area. Due to the rampant mining activities, the surface area of land for sustainable purposes has reduced significantly. A comparative evaluation of present situation of the Periyar basin with Muvattupuzha (previous study) reveals that the

human interventions, especially extractive activities are much more rampant and destructive. Indiscriminate hard rock quarrying activities in the Ecologically Sensitive Western Ghats has destructed many first and second order feeder channels of Periyar river and has now become a major threat to the hydro geological setting of the entire basin. A case study conducted in the Panniar sub-basin of PRB reveals that almost 10 hard rock quarries in the sub-basin directly affect the drainage channels and results in the destruction of 16 first order and 2 second order streams. The rampant floodplain and instream mining activities, over the last few decades, have led to severe river bank erosion, river bed lowering, lowering of water table in adjacent areas of mining, and depletion of river sources of sand. As a result of indiscriminate sand mining, the riverbed in the storage zone has lowered alarmingly over the years. Analysis of the cross-proûle measurements of CWC gauging station (Neeleswaram) reveals that the riverbed has been lowered to about 7.4 m during the period 1980- 2010 (av. 18 cmy^{-1}). The magnitude of channel response to sand extraction will depend mainly on the quantity of sand extraction in relation to sand replenishment. As per the previous studies, sand extraction in the river was found to be much higher than the replenishment rates Ground water level in some of the watersheds has gone down by nearly one meter in the last two decades. Widespread soil quarrying negatively affects the surface and ground water regime, directly affecting the agricultural productivity in the area. In the Periyar basin, laterite block cutting is very nominal. This may be due to the readily available clay bricks and hollow bricks in the region. Although mining activities provide short term positive benefits with regards to employment, the negative impacts that adversely affect the overall environmental security of the region cannot be ignored.

The study stresses the need for immediate interventions, both in terms of regulation and enforcement, for restoration and management of river channel as well as mined areas.. The impact can be permanent, even after closure and decommissioning, unless carefully planned rehabilitation is undertaken. The damage can be arrested or may even be reversed, but this requires long-term investments and efforts by all levels of government and by individual stakeholders. Mining operators and stakeholders must be aware of the potential impacts of the activities, and accordingly plan and execute appropriate management strategies to create net positive outcomes that are sustainable in the long term. Carrying capacity based planning and clearance mechanism, innovative technologies for enhanced materials and energy effective production and consumption, change towards less resource-intensive sectors and preventive environmental management are some of the strategies for achieving sustainable developmental goals in mining sector. At present, resource extraction continues to be part of a liberalised system of public and private enterprises that runs on unscientific extraction measures and act as a triggering factor of environmental degradation. Thus it is of utmost importance to control indiscriminate and unscientific extraction of resources by ensuring effective, efficient and purposive enforcement of the existing mining regulations. Administrative reforms are to be made at grass root levels and the local self governments should be made fully responsible and accountable for mining activities in their jurisdiction. When properly planned and integrated into regional development and biodiversity conservation strategies, mining and quarrying operations can enhance the resource utility while improving the socio-economic and infrastructural settings of a region. If implemented in concurrence with proper Environmental Management Plan and ecosystem restoration objectives, growth in economic as well as environmental stand point can be achieved in the mining sector.

K. Maya, D. Padmalal & Sheika E. John

4.2.3 In-situ bioremediation of landfill pollutants: maximising the remediation potential of select indigenous and exogenous microorganisms

Land filling is an economic and popular solid waste disposal alternative, but it causes environmental concern in the form of generation of landfill gas and leachate. Through this study, an attempt is made to use an in-situ bioremediation to reduce the toxicity of Municipal Solid Waste (MSW). The landfill was considered as a bioreactor in the study, in which, the stabilisation of waste was accelerated by incorporating various interventions. Combined methane oxidation and in-situ treatment of leachate were effected inside the landfill using a consortium of microorganisms. The methane from the landfill soils was oxidised using

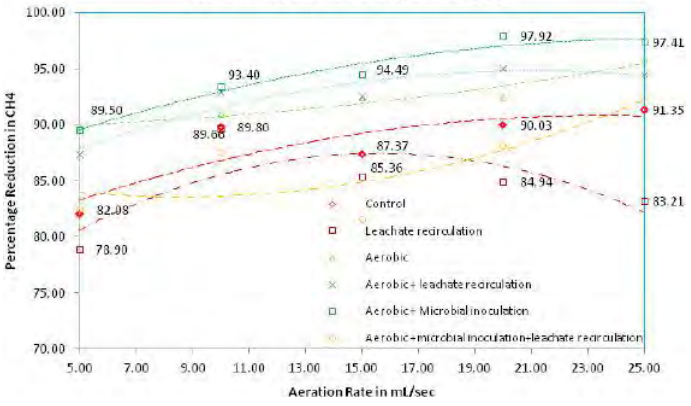


Fig. 4.2.3.1 Percentage reduction in CH_4 with aeration rate

methanotrophic bacteria. The organics, inorganics and heavy metals in leachate were reduced using select chemoautotrophic bacteria as well as fungal species. The technique does not require costly installations for recovery and purification of LFG or for leachate treatment units.

The aim of the study was to develop a comprehensive procedure to reduce the toxicity of landfill pollutants and design a landfill system to cater to the disposal of municipal solid waste with minimum environmental cost. Physical models were set up to suit the purpose of landfill simulation and fitted with the installations for aeration, inoculation of microorganisms, recirculation of leachate, collection of landfill gas from various locations and collection of leachate. In the models indigenous micro-organisms were identified and the exogenous microorganisms were selected based on their source, prospective remediation capability and growth conditions. These microorganisms were cultured in the lab and inoculated into the two of the landfill models for enhanced bioremediation and accelerated waste stabilization.

The results show that the generation of methane as well as methane bioxidation is directly proportional to the ambient atmospheric temperature, which indicates the presence and action of mesophilic microorganisms in the system. Maximum methane bioxidation was found in the aerated model inoculated with exogenous aerobic methylotrophic microorganisms . The model with only leachate recirculation has the highest concentration of generated methane) and the lowest bioxidation rate on the same day which showed maximum bioxidation rate by aerobic models (Fig. 4.2.3.1). The aerated model inoculated with exogenous aerobic methylotrophic microorganisms showed the minimum generation of methane. The aerated model inoculated with exogenous aerobic methylotrophic microorganisms and leachate recirculation showed higher generation of methane than that without leachate recirculation and lesser bioxidation of methane.

The analyses of leachate samples from the landfill models also points out the improvement caused in waste stabilisation and reduction of toxicity of MSW leachate on utilising exogenous chemoautotrophic microorganisms in. It has been found that the landfill model with aerobic exogenous microorganisms reduces COD by 760mg/L (Fig. 4.2.3.2). Heavy metals were reduced to non-detectable levels in all aerobic models.

K. Deepa Nair
Funding: DST, GoI

4.2.4 Environmental Management action plan for the Ecorestoration of Vembanad Lake and connected river systems

Vembanad Lake System (VLS) is the longest in India, and the largest in the State of Kerala. The geological distinctiveness, geographical significance, ecological importance, cultural contribution and economic strength of VLS are very unique. It is one of the three Ramsar Sites of Kerala and covers an area of over 1,513km^2. In recent years, great concern has been expressed with regard to the deterioration of Vembanad Lake and consequent loss of supportive functions of the wetland system, especially due to high levels of anthropogenic pressures.During the course of the programme, it is realized that the revitalization of Vembanad lake ecosystem is linked to the environmental upkeep of the inflowing rivers as well as the critical environmental dynamics of the lake. Therefore, a study

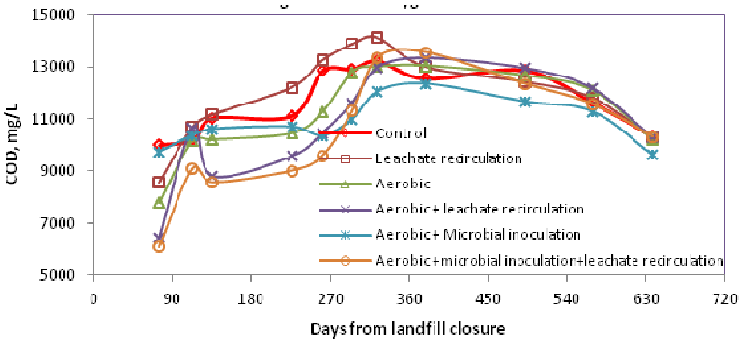


Fig. 4.2.3.2 Chemical Oxygen demand on leachate

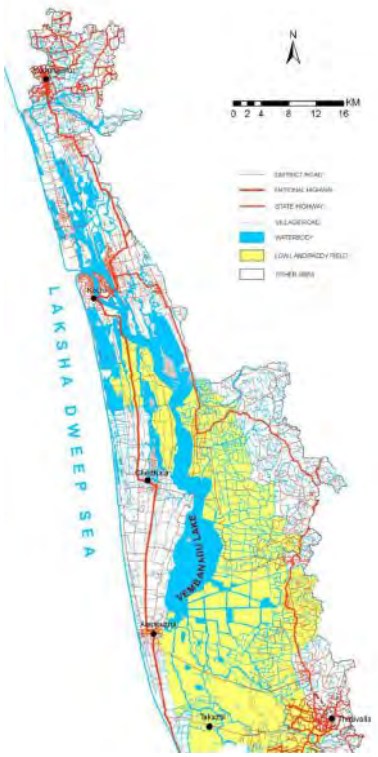


Fig. 4.2.4.1 Vembanad estuary and its environs

has been initiated to understand the state of environment of the whole ecosystem involving the lake and inflowing rivers and evolve a management action plan for implementation with an aim to conserve the entire ecosystem in an integrated manner. The Vembanad lake and its environments is shown in Fig. 4.2.4.1

Ecological issues: Various human interventions, economic activities, exploitation and neglect of lake environment have led to deterioration of ecosystem functions and various ecological issues. Some of these include (i) shrinkage of the VLS, (ii) increasing flood frequency and duration, (iii) pollution and eutrophication (iv)biodiversity loss and (v) public health concerns.

For the systematic study the position papers of each river basin were prepared based on details of physiography, geomorphology and geology of each basin, land use/land cover data, watershed characteristics, climatic parameters, hydrology and hydrogeology, water balance, water quality, sediment characteristics, biodiversity aspects, agricultural practices, socio-economic aspects, minerals and mining etc. The position paper provided a preliminary environmental appraisal of the ecosystem considering different aspects such as land, water, biological, social, atmospheric and aesthetics. An environmental analysis has been carried out using these details to highlight the environmental status of the study area in terms of pollution, mining and land degradation, deterioration of river and river flow regime, solid and liquid waste accumulation, hazards etc. Based on these analysis, action plan has been evolved for river bank failure and protection, storm water management, catchment area treatment, solid waste management, septage/fecal sludge management, water quality surveillance, environmental awareness and safeguard and maintenance of aesthetics.

Catchment area treatment plan: The catchment area treatment involves (i) understanding of the erosion characteristics of the terrain and (ii) suggesting remedial measures to reduce the erosion rate.

1. Arable land Treatment Measures: This treatment plan includes stone Pitched Contour Bund, earthern bund, graded bund, repair of stone bund, agrostolological measures, agroforestry, vegetative hedges /boundary planting,bamboo planting,moisture conservation pit, compost pit,recharge pit/percolation pit, centripetal terrace, inward slope terracing, inward slopping strip terracing, strip terracing, staggered trench, staggered trench with embankment, contour trench,sunken ponds, dugout / percolation, dry rubble pitching, roof water harvesting structure and mulching.

2. Drainage line Treatment: These treatments were carried out by the construction of different check dams, percolation pond, renovation of pond, small pond for multipurpose use, sunken pond /dug out pond/excavated pond, Farm pond (Water harvesting structure), structural stream bank stabilization, sub drain protection wall,tractor passage/ramp, foot slab, field channel, leading channel, diversion channel, cross over slab, sluice, engine thara with sluice, pitching, revetment,water harvesting structure, rainwater harvesting structure, roof water harvesting structure -ferro cement tank, dug out wells with concrete ring, renovation of wells /ring well, well curbing: resection of thodu/drains: deepening of stream/thodu and coir-geo textiles.

Sanitation and waste management

1. Municipal Solid Waste (MSW) Management: The quantity and characteristics of MSW generated, their physico-chemical quality, technology appropriateness for their treatment and management, administrative and managerial capacity of local governments, social engineering aspects necessary for building an appropriate attitude to waste management etc. are considered while evolving the action plan.Considering the diversity of MSW and its sources, it is desirable to adopt multi-mode technologies with one lead technology for the dominant waste generated. There are two major technology streams for processing the MSW namely biological and thermal methods.

2. Management of Septage and Fecal Sludge: The septage can be managed on a centralized or decentralized manner. A centralized septage management system for OSS includes desludging, transportation and treatment of septage/fecal sludge and management of the effluent discharge and solid waste.

River and canal bank protection: Generally, three processes such as subaerial preparation, fluvial entrainment, and mass failure act on river banks throughout the catchment. The riverbank protection is conceived to be done through a combination of different methods namely, vegetative measures, windrows and trenches, sacks and blocks, gabions and mattresses, articulated concrete mattresses, soil-cement, retaining walls, geo-textile reinforced mud walls etc. A consolidated picture of the surface area of river and canal banks that need to be protected and indicative cost requirements are given in Table 4.2.4.1

Table 4.2.4.1 Length and surface area of river and cananl banks to be protected and cost

Sl. No.	Rivers/Canals	Length to be protected (m)	Area to be protected (m^2)	Unit cost (Rs/m^2)	Total cost (Rs.in Lakh)
1	Muvattupuzha	51000	127500	2200	2805
2	Meenachil	59800	149500	2200	3289
3	Manimala	36000	90000	2200	1980
4	Pamba	17210	43025	2200	947
5	Achankovil	18400	46000	2200	1012
6	Kuttanad canals	325500	651000	1400	9114
	Total	**507910**	**1107025**	**12400**	**19147**

Water quality monitoring: The quality of water is of vital concern for mankind since it is directly linked with human health. The water quality were checked in the chemical laboratories of High Schools and Higher Secondary Schools. The school laboratories were strengthened with basic minimum facilities for water quality testing equipments.

Conclusion: The environmental evaluation of the lake system and river basins indicated that the environmental stress due to river sand mining, removal of hills and natural vegetation, filling up of valley formations, indiscriminate quarrying of hard and soft rocks, encroachment and loss of natural and riparian vegetation and other undesirable land use changes have caused deterioration of the river and lake ecosystem.The state of the environment of the lake system including its river basins indicates the urgent necessity for strengthening the environmental safeguards, interventions and governance of the VLS ecosystem. The various proposals suggested for the protection and conservation of the catchment of five rivers involves biological and engineering measures for preservation and regeneration of the natural vegetative cover, soil and terrain of the area, reduction of the flow velocity and cutting action of water and sustenance of effervescent flow in the watershed. Various conservation measures are evolved through spot specific studies in each micro watershed region and the overall cost requirement for the entire intervention as well as for implementation management is worked out as Rs. 1020 Crore. However, 50% of the cost could be saved through the government sponsored job guarantee programmes as well as streamlining the agricultural interventions. The budget requirement for establishging full-fledges sanitation and waste management facilities in each river basin is estimated as Rs. 2637 Crore. A significant portion of this can get generated by invoking the provision of 'polluter pay principle' and extended producer responsibilities. The action plan also includes measures for river bank protection necessitated due to indiscriminate sand mining, storm water management as a measure to channelise the rainfall appropriately and environmental monitoring plan, especially water quality, invovling educational institutions with an indicative estimate of Rs. 192 crore, Rs.3388 crore and Rs. 14 crore respectively.

R. Ajayakumar Varma
Funding: 13th Finance Commisiion Award, GoK

4.2.5 Environmental monitoring of water and sediment quality parameters in the backwaters of Cochin Port Trust

Kochi is one of the rapid growing industrial province in India known as the industrial capital of Kerala. The Kochi backwaters represent a tropical estuary in Kerala. It is one of the largest estuaries on the west coast of India. It is permanently connected with the Arabian Sea by a gut, about 450 m wide 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. Seven rivers flow into these backwaters, of which, two; the Periyar on the north and the Pamba on the south, are the largest. Two major rivers discharge fresh water into the Cochin estuarine system; the Periyar River flows into the northern parts and the Muvattupuzha River into the southern parts. The bordering areas and islands in the estuary are centers of intense human activity. 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 in to the water bodies besides municipal wastes. Therefore, the continuous

Station No:	Latitude	Longitude	Average depth of water (meter)
Station 1	09° 58′ 15" N	76° 14′ 47" E	14.5
Station 2	09° 58′ 19" N	76° 15′ 43" E	5.70
Station 3	09° 57′ 24" N	76° 16′ 00" E	9.75
Station 4	09° 57′ 42" N	76° 16′ 51" E	9.50
Station 5	09° 56′ 14" N	76° 16′ 01" E	4.50
Station6	09° 56′ 44" N	76° 17′ 20" E	9.50
Station 7	09° 55′ 23" N	76° 17′ 50" E	8.00

Fig. 4.2.5.1 Detauls of sampling locations at Cochin harbour

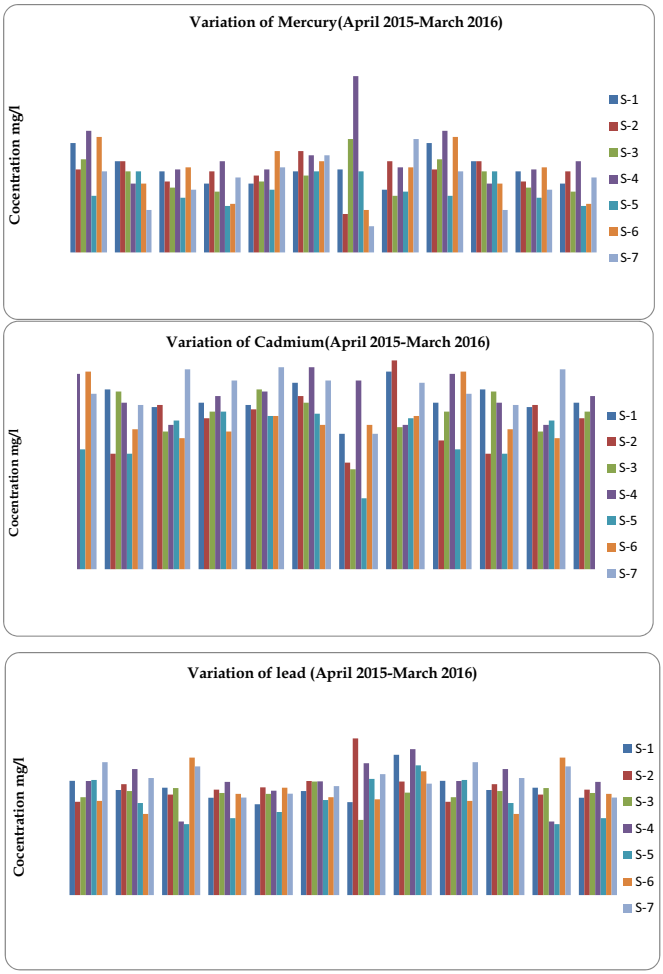


Fig.4.2.5.2 Heavy metal concenration in sediments from the study area

monitoring of water and sediment quality in the backwater system is inevitable to address the health of the system. 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 February 2012 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. 4.2.5.1 with details of sampling stations. . The work is normally carryed out during the last week of every month (April 2015-March 2016).

The surface water was collected using a clean polythene bucket and bottom water was collected using a Van Dorn bottom water sampler. The sediment samples were collected from the seven stations using a Van Veen Grab. Collected samples were stored in pre-rinsed polypropylene containers at ambient temperatures. For water samples, i*n situ* measurements were made for physical parameters such as temperature, pH, turbidity, transparency and depth. Lab analyses were carried out for determining the chemical parameters such as dissolved oxygen, inorganic phosphorus, ammonia, nitrate, nitrite, total phosphorus, total nitrogen, petroleum hydrocarbon and gross production. For sediments, the amount of heavy metals such as Cd, Pb and Hg were determined.

Water samples were analysed using the methods suggested by Grasshoff (1983) and APHA (2001). Nutrients were analysed after filtering the water through 0.45µm Millipore membrane filter. All the colorimetric estimations were done using double beam spectrophotometer (Shimadzu, UV-1800). The sediment samples were digested using HNO_3, $HClO_4$ and HI and were analysed for Heavy metal content using Atomoc Absorption Spectrophotometer (Perkin Elmer AAS200).

Water and sediment quality in terms of physico-chemical parameters in the backwaters around Cochin port was monitored from April 2015 to March 2016. The surface water temperature varied from 27.5 ^{0}C to 34.8 ^{0}C and bottom water temperature varied from 27.1 ^{0}C to 33.9 ^{0}C. The inorganic phosphate concentration varied between 0.12-1.40 µmol/L, and increased organic phosphate concentration was noticed, which may be due to the flushing of external sources such as land drainage and fresh water runoff. Nitrate and nitrite values varied from BDL to 6.65µmol/L and 0.02 to 2.78 µmol/L, respectively. But the values showed an irregular pattern in distribution between months and seasons. The highest concentration of 2.36 and 12.93 µmol/L of total phosphate and total nitrogen were observed at station 7 of July bottom sample and station 5 of May surface sample, respectively. The general trend of inorganic phosphate and nitrates generally showed lower values in bottom waters than surface water. As regards sediment quality parameters, the pH showed marked variation from 6.82 to 8.91 during the study period. The pH of water showed fluctuations from surface and bottom due to the influence of saline water and rainwater inflow. The values of other water quality parameters were pH: 7.1-8.4, Salinity: 14.81-34.03 ppt, Turbidity: 3.69-287.7 NTU, DO_{sw}: 3.39-7.73 mg/L, DO_{bw}: 2.93-6.89 mg/L. The salinity of surface water was minimum during November and January and maximum during August. Bottom water recorded prominent values in salinity, which may be due to the saline water intrusion. In surface water, Petroleum Hydrocarbon (Oil and Grease) varied from 12 mg/l to 28.3 mg/l during the study period. Petroleum Hydrocarbon in bottom water varied from 0.2 mg/l to 1.94 mg/l. Surface water always showed higher values for Petroleum Hydrocarbon. Station 4 reported the high values of PHC 35.2 mg/l both in surface and bottom water which may be due to oil shipment activities carried out in this area.

Turbidity was low in surface water when compared to the bottom water. In surface water, gross production showed higher value upto 114.1 mgC/m^3/hr and bottom water showed upto 22.4 mgC/m^3/hr. As regards sediment quality parameters, the pH showed marked variation from 7.8 to 8.94 during the study period. The concentration range of cadmium, lead and mercury in the sediment environs around Cochin Port Trust were 0.32 to 0.94 ppm; 21.9 to 48.35 ppm; and 0.28 to 0.87 ppm respectively during the study period. The river Periyar may bring heavy metals in the form of fine grade suspended particulate matter from effluent discharge points of various industries. The sediment quality parameters are indicative of industrial pollution in the study area.

K. Anoop Krishnan and T. M. Liji
Funding: Cochin Port Trust

4.2.6 Sea Water Quality Monitoring

Coastal-nearshore environments are one of the most dynamic and fragile ecosystems in the world that are more responsive to human interferences due to economic developments. Coastal areas are important in many ways. Apart from its extreme ecologic values, a considerable section of the coastal community depends on this system for their survival. Satisfactory environmental conditions are of great importance for sustaining the life and productivity of the ocean in addition to ensuring human well-being. Monitoring the health of India's coastal ocean system is the drive behind the introduction of Sea Water Quality Monitoring (SWQM) programme by the Ministry of Earth Sciences (MoES), Government of India. Among the various institutes pursuing coastal ocean monitoring research coordinated by ICMAM, the National Centre for Earth Science Studies (NCESS) covers three important and environmentally sensitive coastal hotspots in the Arabian Sea such as Kochi, Mangalore and Kavaratti. The physico-chemical and biological aspects/parameters in the sediment and overlying waters of these environmental hotspots are monitored seasonally and temporally to assess the current status of environmental health of this part of the coastal environments. Such a study is most essential not only to understand the local bio-geochemical/oceanographic processes occurring in the coastal waters and its global relevance but also to lay down strategies for mitigating the ill-effects of human interferences including pollution of the coastal waters.

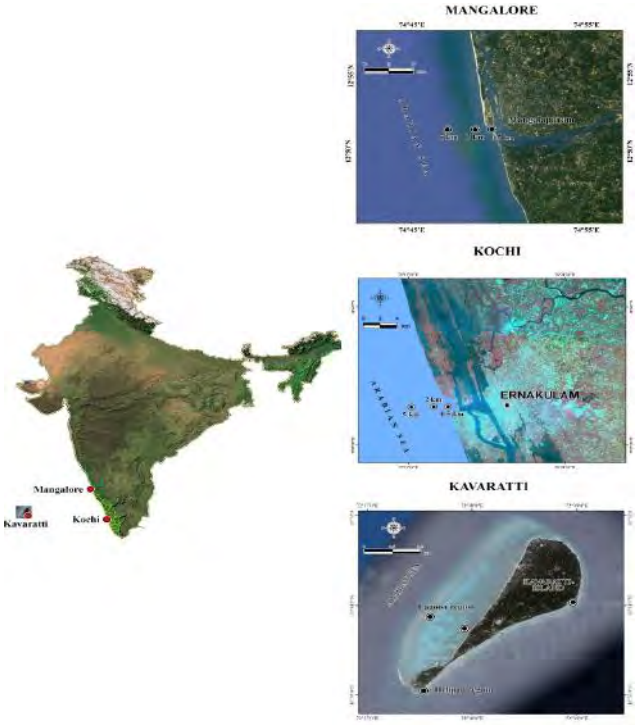


Fig. 4.2.6.1 NCESS-SWQM hotspot monitoring areas: Kochi, Mangalore and Kavaratti

Samples were collected from the mouths of estuaries/creeks/lagoons, shore (0.5 km), near shore (2 km) and offshore (5 km), during both low and high tides, for water analysis. Collection of surface waters from all the three zones (shore, near shore and offshore) and bottom waters from near and offshore transects is mandatory. Samplings were carried out for 48 hrs (3 hourly) at creek/river/backwater mouths and during low and high tides at 2 km on either side of the shore station (along the shore). The 36 hrs sampling is mandatory and both surface and bottom samples need to be analyzed. Samples collected during 4 seasons include three dry seasons and one wet season with an interval of 3 months for each sampling. It was essential to collect samples separately for low and high tides. Seasonal sampling indicates month, date and tidal condition maintained for comparison of data during past year. All the samples were analyzed for, chemical, biological, microbiological, and sediment logical parameters. The sampling parameters include hydrochemical, marine biological and microbiological parameters which cover the whole spectrum of quality aspects of coastal ocean systesm. This in turm helps us to study the extent of pollution and thereby possible to assess the health the coastal systems. The location of study area are given in Fig. 4.2.6.1.

Hydrochemistry: pH didn't show much variation during premonsoon but shows decreasing trend towards post monsoon in all the three stations Kochi, Mangalore and Kavaratti. The low pH during post monsoon is due to fresh water influence and precipitation. The variation of pH in Kochi station is shown in Fig. 4.2.6.2. In Kochi estuary, the observed low salinity values of post monsoon than

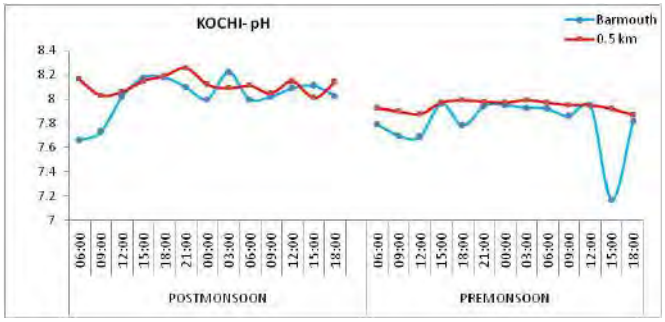


Fig. 4.2.6.2 Variation of pH in Kochi

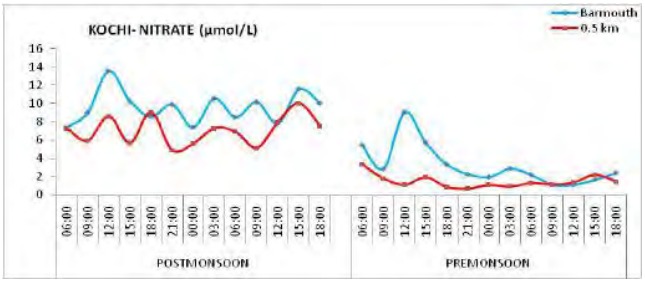


Fig. 4.2.6.3 Variation of Nitrate in Kochi

that of pre monsoon is resulted mainly from the excess fresh water discharge in to the area from the hinterland rivers. Concentration of nitrate (Fig. 4.2.6.3) showed higher values during post monsoon than that of pre monsoon season. In post monsoon season, nitrate values exhibited threefold increase as compared to pre monsoon values. Ammonia showed higher values during post monsoon season than pre monsoon which implies monsoonal draining of untreated sewage into the Kochi coast. Effect of monsoonal flushing in attributing chemical parameters like nitrate, ammonia etc., was well recorded in the bar mouth station than that of the near shore counterparts. Temporal distribution of silicate shows higher values during post-monsoon than pre-monsoon. The general hydro chemical variations observed in the Mangalore coast are almost similar to that of Kochi.

In Kavaratti, concentration of nitrate shows higher values at the lagoon area owing to monsoonal flushing from settlement areas. Ammonia showed an erratic pattern in the sampling stations at Kavaratti. Low ammonia values indicate that at Kavaratti coast, nitrification process predominates over de-nitrification.

Marine biology: Chlorophyll *a* values in Kochi was found to be three times higher than Mangalore and nearly four times higher than Kavaratti stations. On the basis of chlorophyll concentration, Kochi could be classified as Ultra Mesotrophic Region (UMR), Mangalore as Mesotrophic Region (MR) and Kavaratti as Oligotrophic region (OR). In Kochi and Mangalore, a significant shift in phytoplankton community was observed. Proliferation of dinoflagellates in postmonsoon season is replaced by diatoms in pre monsoon season. Dinoflagellate density could be positively correlated with N:P values and negatively with silicate values.

Copepod density was found to be decreasing from nearshore to offshore while microzooplankton density exhibited a reverse trend. A similar trend was noticed in Mangalore and Kavaratti stations as well. No Harmful Algal Blooms (HABs) were reported from any of these stations during the reporting period. However, in Kavaratti stations, proliferation of nitrogen fixing blue green algae, *Trichodesmium erythraeum,* is a common phenomenon. Bioluminescence was also reported from the lagoonal areas of Kavaratti. The organism responsible behind this phenomenon was the ostracod *Cypridina hilgendorfii*.

Fig. 4.2.6.4 Bioluminescent crustacean Cypridina hilgendorfii

Microbiology: Higher number of Coliforms and faecal indicator bacteria were preponderant during non monsoon season at Kochi and Mangalore stations. Their higher population indicates very recent flux of untreated sewage/ land drainage in to the coastal waters. There is a remarkable presence of *Vibrio sp.,* bacteria in Kavaratti coastal waters which need surveillance its potential for proliferation.

K. Anoop Krishnan and D. Padmalal
Funding: MoES (ICMAM), GoI

4.2.7 Adsorptive potential of surface modified clays and chitosan for the recovery of certain inorganic toxic metal ions from aqueous media using batch and column studies: Kinetics and thermodynamics profile

The adsorption procedures are introduced as a favorable way for the remediation processes because of its practicality, efficacy, environmental friendly and economical feasibility

factors. The nature and availability of precursors for developing the adsorbents are also important in terms of real system approaches. Chitosan is a linear polysaccharide is one among the suitable adsorbent adopted for modification through the graft co-polymerization technique, they composed of randomly distributed β-(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). The chemical modification of chitosan to the Carboxylate functionalized Chitosan Co-polymer (CFCCP-COOH) derivative conformed the improvement in the adsorption property of later one as compared to that of the former one.

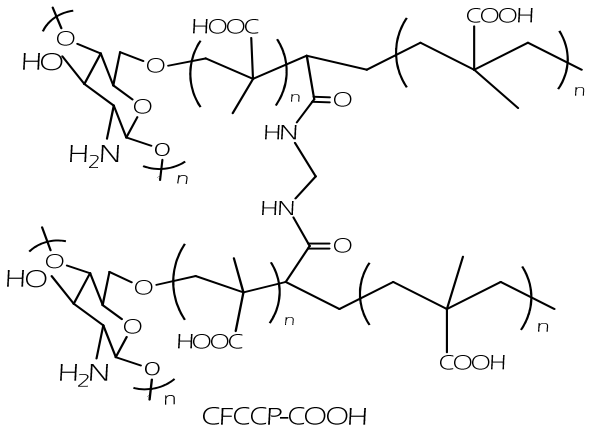


Fig. 4.2.7.1 The structure of CFCCP-COOH

Methodology includes a novel organic synthesis propagating through a free radical chain reaction mechanism leads to the formation of a highly active graft co-polymer possessing improved adsorption properties. The effects of pH, contact time, initial concentration, and adsorbent dose, on removal process were evaluated using batch adsorption technique for chitosan and the chitosan derivative. The expected structure of newly synthesized chitosan based co-polymer CFCCP-COOH is shown in Fig. 4.2.7.1. The Carboxylate Functionalized Chitosan Co-polymer (CFCCP-COOH) was prepared by reacting chitosan free radical molecule (CFRM) and a monomer methacrylic acid (MA) in the presence of a cross linker N,N'-Methylenebisacrylamide (MBA), Mn IV/Citric acid as initiator. Studies on adsorption behavior of newly synthesized chitosan based graft co polymer CFCCP-COOH for the removal of lead (Pb) were well studied and the results are summarized.

The CFCCP-COOH adsorption of Pb(II) is maximum at the pH range 4.5– 5.5, about 99.2% and 95.2% of Pb(II) is removed from the solution of initial concentrations 25 mg/L and 50mg/L, respectively at pH 5.0. The formation of $Pb(OH)_2$ species retards the percentage of adsorption in higher pH >5.5. The influence of initial concentration

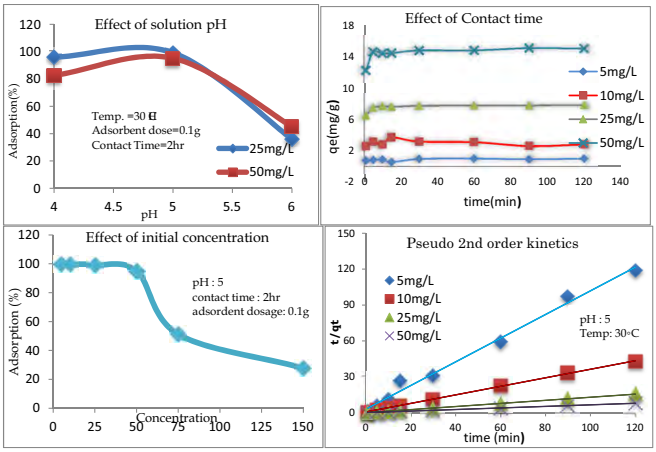


Fig. 4.2.7.2 Effect of pH, contact time.initial concentration and pseudo-second order kinetic plot on the adsorption of pb (II) onto CFCCP-COOH

was studied by varying the concentration of adsorbate from 5 mg/l to 50 mg/l. The adsorption efficiency was consistent up to 50 mg/l, which suggests saturation point of the mono layer adsorption onto CFCCP-COOH at this concentration. This is due to the availability of large number of adsorption sites initially for adsorption process. For determining the adsorption capacity Langmuir and Freundlich isotherms were evaluated for the equilibrium date and the isotherm constants were calculated. Langmuir isotherm gives the best fit for the entire range of concentrations similar to that of chitosan. There for the adsorption of Pb(II) on chitosan and CFCCP-COOH is mono layer type.

The adsorption potential of CFCCP-COOH was investigated in batch technique. The parameters like pH, contact time, initial concentration and temperature were optimized and modeling of adsorption isotherms were carried out using the equilibrium data. The details of effct of pH, contact time, initial concentration and pseudo-second order kinetic plot on the adsorption of Pb(II) onto CFCCP-COOH is presented in Fig. 4.2.7.2. The maximum adsorption of Pb(II) was observed at pH 5.0 and the removal of Pb(II) reaches maximum at 45 minutes of contact time. Kinetics of adsorption indicates that the process follows a pseudo-second order rate equation. Adsorption process is well described by Langmuir isotherm model and suggests that the adsorption is mono molecular layer. The adsorption capacity of CFCCP-COOH for the Pb(II) was found to be 50 mg/l at 45^0C. The characterization of the chitosan and the modified form, CFCCP-COOH is being pursued for the interpretation of adsorption pattern and the morphology of the surface layer and some more surface chracteristics studies may be done using FTIR, SEM-EDS, Raman Spectroscopy and XRD/ XRF techniques. Now we are in a way to explore the best

method to synthesise, characterize and modify the egg shell based ceramic namely hrdroxyapatite in removing hevy metals such as Pb(II), Cd(II), Cu(II) and Zn(II) from their mixture in aueous strata.

Vinu V. Dev and K. Anoop Krishnan

4.2.8 Appraisal of Marine Ecosystem of Kavaratti island in South West coast of India with special reference to Lagoon system

Oceans, the big blue, source of life and the hallmark of Earth: Vast, tranquil, and treacherous, the oceans bear the signature of our planet. The oceans are the largest repositories of organisms on the planet, with representatives from all phyla from the obvious large whales, fish, corals, to the microscopic bacteria. The marine and coastal areas harbour a variety of specialized ecosystems like mangroves, coral reefs, islands, salt lakes, sand, mud flats, which provide unique habitats for a myriad of flora and fauna. Pollution causes unfavourable alteration of environment that poses threat ultimately to the survival. Pollutants can be natural or anthropogenic, but even when it is natural, its adverse effect may be primarily due to human contributions and exposure in populated area. The present study discusses the unique hydrochemical, marine biological and geochemical characteristics of Kavaratti Island at Lakshadweep Archipelago (Fig. 4.2.8.1). A detailed study on physicochemical and marine biological studies has been carried out to characterise the considerable influence on the composition of coastal and ground waters of the lagoon system. Fig. 4.2.8.2 shows the spatial and temporal nutrient status and biological observations from lagoon and offshore at Kavaratti Island during monsoon in the year 2015. The upcoming research includes biogeochemical candidature in view of speciation aspects and their impact on the health of the system.

In Kavaratti, concentration of nitrate shows higher values at the lagoon area owing to monsoonal flushing from settlement areas. Ammonia showed an erratic pattern in the sampling stations at Kavaratti. Low ammonia values indicate that at Kavaratti coast, nitrification process predominates over de-nitrification. Land activities such as sewage effluent, agriculture run-off as well as the sewage outfall might have contributed to the high ammonia concentrations in the near shore waters. In the north near shore coastal region, the distribution of TN was high and showed an offshore decrease. There was not much disparity in the concentration in both near shore and offshore during monsoon season. Depending on the wind direction, the diffusion of this anthropogenic nitrogenous load can affect its distribution. The temporal changes of reactive phosphate and total (organic + inorganic) phosphorus generally showed a definite seasonal trend with slightly lowest during Monsoon. The phosphorus content in the water is mainly affected by anthropogenic nutrient inputs and run off. In Kavaratti, Oligotrophic conditions prevailed throughout the year where chlorophyll *a* value was found to be less than 1.0 mg m^{-3} (Fig. 4.2.8.3). This trend is attributed to lack of dynamic bodies entering in to lagoon and less anthropogenic activities along the lagoon shore. Kavaratti lagoon is poor in phytoplankton species density as low nutrient enrichment favours oligotrophic marine

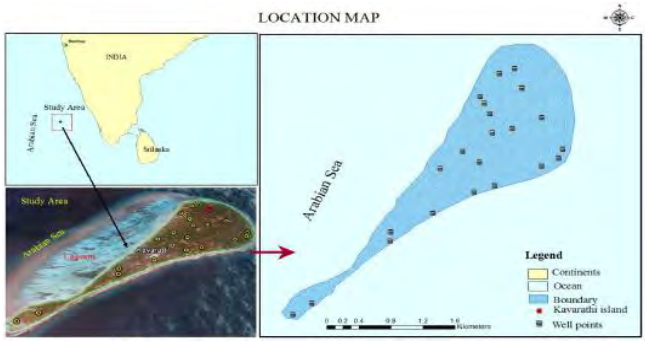


Fig. 4.2.8.1 Map showing the study area

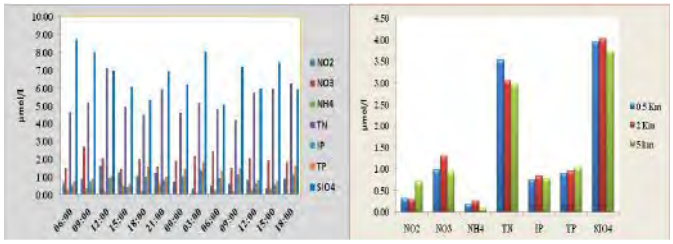


Fig. 4.2.8.2 Nutrient statuses of lagoon and off shore (Monsoon 2015)

Fig. 4.2.8.3 Seasonal variation of Chlorophylla

Table 4.2.8.1 Total Viable Count (TVC), Escherichilla coli (ECLO) and Faecal Streptococci (SFLO)

Mean spatial distribution for selected indicator bacteria along Kavaratti coastal waters (In CFU/mL)			
	Monsoon (2015)		
	TVC	ECLO	SFLO
Lagoon	9082.31	27.69	13.85
Open Sea	6126.67	37.50	37.50

environment. The dominant phytoplanktons are the diatoms like *Bellerochea malleus* (62.3%) and blue green algae *Trichodesmium erythraeum* (24.2%). Proliferation of *Trichodesmium erythraeum* was a common feauture in Kavaratti lagoon.

Sibin Antony and K. Anoop Krishnan

4.2.9 Assessment of nutrient flux in urban drainage system: Identification of sources, pathways and remedial measures

Phosphorous (P), an essential macronutrient required for the growth of organisms in ecosystems and also has a major role in primary production. However the limit beyond 1ppm leads to eutrophication and hence affect water quality and disturb the ecological balance of organisms present in water bodies. The eutrophication scenario may be due to the continuous discharge of municipal wastes from urban areas and that may affect the healthy life of water bodies in and around the city areas. Thus the removal of phosphate from water and wastewater is of great concern before the sewage entering into the surrounding water. A number of methods have been reported for the removal of phosphate, which includes chemical precipitation, ion exchange, biological treatment, crystallization and adsorption. Among these methods, adsorption is one of the best methods identified for the removal of trace amounts of solute from aqueous solution due to the availability of economically sustainable adsorbents. Recently, low cost and easily available adsorbents such as clay, activated carbon, chitosan, lignin, dolomite, hydrotalcite and graphene were reported for sewage treatment purposes. Nowadays for water treatment process clay materials such as bentonite and kaolinite has been used. Bentonite, a low cost, clay mineral belongs to smectite group, consists mainly of montmorillonite and has permanent negative charges on its surface. It is a typical 2:1 layered structure in which octahedral sheet is sandwiched between two tetrahedral silica sheets.

The adsorption capability of zirconium pillared bentonite to remove phosphate was studied and characterized by XRD, FTIR, SEM, Raman spectroscopy, AFM techniques. Batch adsorption experiments were carried out to evaluate the optimum conditions such as pH, contact time, initial phosphate concentration and temperature for the maximum removal of phosphate from aqueous phase.

Bentonite appeared in block-like crystals (Fig. 4.2.9.1a), with lamellar surfaces at high magnification. The prepared ZPB morphology (Fig. 4.2.9.2 b) is slightly differed. The pillared samples became rougher due to zirconium pillaring. From the IR characterisation there were shifts in the structural –OH vibration from 3622cm^{-1}(bentonite) (Fig. 4.2.9.2a) to 3641cm^{-1} (Fig. 4.2.9.2b) for phosphate modified bentonite. The –OH bending frequency of water at 1631cm^{-1} (Fig. 4.2.9.2a) to 1639cm^{-1} (Fig. 4.2.9.2b) when it was modified with phosphate. The band located near 1024cm^{-1} (Fig. 4.2.12.2b) can be assigned to P-O stretching vibration.

Zirconium pillared bentonite (ZPB) is found to be an effective adsorbent for the removal of phosphate from aqueous phase and the maximum adsorption fall at pH 3.0. An amount of 19.22 mg/g (91.3%) of phosphate is removed from the solution of initial concentration 50mg/L. The decrease in phosphate adsorption after pH 3.0 would be due to change in surface charge densitycaused by inorganic pillared bentonite becoming more negative at higher pH. The equilibrium contact time for adsorption is 30 minutes, beyond that it is almost saturated and the amount adsorbed are 6.97, 11.32, 19.36, 19.22mg/g respectively for 15, 25, 50,100 mg/L of initial concentrations of phosphate. This is due to the availability of large number of adsorption sites initially for adsorption. For determining the adsorption capacity Langmuir and Freundlich isotherms were evaluated and the isotherm constants were calculated. Langmuir isotherm gives the best fit for the entire range of concentration with R^2 value 0.984. There for the adsorption of phosphate onto ZPB is mono molecular layer.

The adsorption capacity of ZPB was investigated by batch adsorption technique. The parameters like pH, contact time,

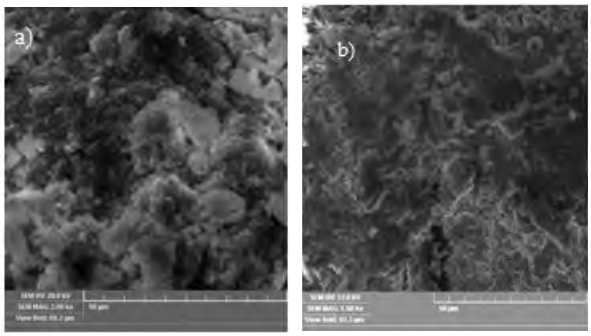


Fig. 4.2.9.1 SEM images of (a) sodium bentonite, (b) Zirconium pillared sodium bentonite (ZPB)

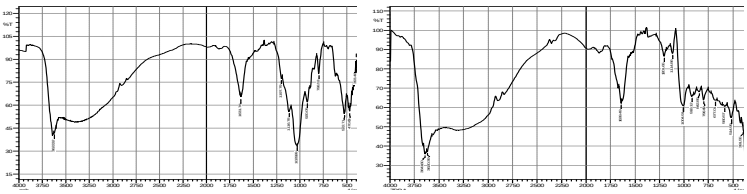


Fig. 4.2.9.2 IR analysis of (a) sodium bentonite, (b) Zirconium pillared sodium bentonite

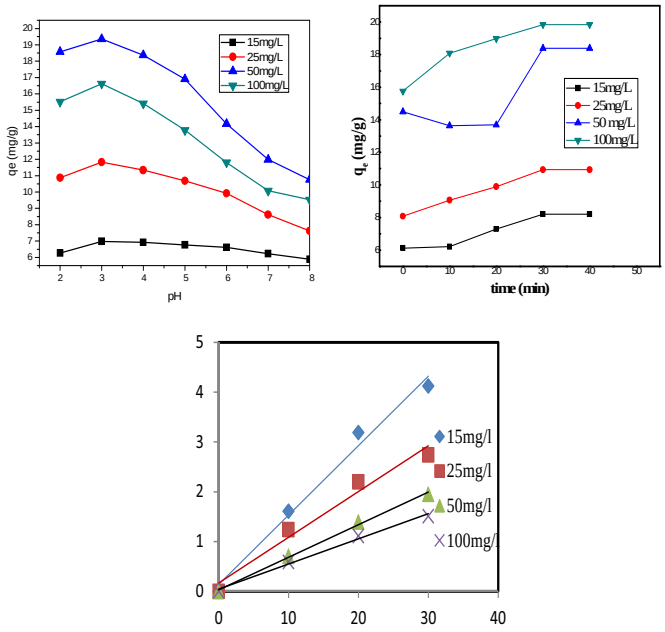


Fig. 4.2.9.3 (a) Effect of solution pH (b) Effect of contact time and (c) Pseudo second order kinetics

initial concentration and temperature were optimized and the isotherm models are applied. The maximum adsorption of phosphate was observed at pH 3.0 and the removal of phosphate reaches maximum at 32 30 minutes of contact time. Kinetics of adsorption indicates that the process follows a pseudo-second order rate equation. Adsorption process is well described by Langmuir isotherm model and suggests entire process attains equilibrium after the formation of a mono molecular layer. The adsorption capacity of ZPB for the adsorption of phosphate was found to be 29.41 mg/g for 0.1g ZPB. The newly synthesized ZPB can be a better option and the adsorption studies are pursuing to introduce better results.

Harsha Mahadevan and K. Anoop Krishnan

4.3 Coastal Zone Management

4.3.1 Integrated Island Management Plan for Lakshadweep islands-criteria for fixing setback in the islands

Fixing of set-back line in the islands is an important work carried out as part of IIMP plan preparation. As island ecosystems are extremely fragile and island communities strive to raise their living standards for growing populations, there is always a tendency to sacrifice the fragile ecosystems that are among their most valuable assets. Further there is always a chance to overexploit their natural resources and to pollute the environment. Another alarming scenario is the predicted Sea Level Rise (SLR) and increased coastal erosion, which could damage the coastal areas and submerge the islands. This will cause irreparable loss or serious damages to the island environment necessitating precaution while initiating the developmental activities in the island. Taking into account all the above a setback zone in the island becomes highly essential.

Setback line and International Practices: The setback or buffer zone is a planning and operational tool practiced/ implemented in many countries around the world. This was practiced mainly to protect human activities from extreme and chronic physical processes such as coastal erosion and coastal flooding and climate change. Further aim is to preserve ecosystem functions and morphology/ landscape along a coast by regulating interference of human settlements and activities with ecosystems. In USA the coastal states can decide their own setback line as per the guidelines of Ocean Coastal Resource Management (OCRM). For example in North Carolina, South Carolina and Florida have setback lines based on annual erosion rate. Usually 30 or 50 times the annual erosion rate is considered but they often update the setback lines and erosion rate data every 10 years. In Minnesota, the Superior coast considers 50 times the annual erosion rate as the setback line. The coast does not have long term erosion details they consider arbitrarily limit of 125 ft as a buffer zone. Washington State follows a setback of 200 m from MHT (Mean High Water Line) for regulation and inland boundary of coastal counties for planning. Australia also has similar setback approach as practiced in India. They consider almost 100 year planning period to accommodate the long term erosion, acute storm erosion and SLR. Maximum water level based on tide, surge, run up of waves on beaches were considered by Spain. Some of the setback lines practiced in other countries are as follows: Sri Lanka - 330m, Spain - 100m, Italy - 300 m, Australia - 100m. In India there are different setback lines for different activities. Hazard line for the country is being demarcated by Survey of India. For this tide, wave setup, sea level rise and shoreline changes parameters are being considered.

Setback Zone for the island: A setback is an area within the islands' coastal zone wherein certain development activities are prohibited or significantly restricted as detailed in the Annexure II. The setbacks are a means of accomplishing a number of objectives including:

- Providing livelihood security to the local communities including the fisher folk and tribals.
- Promote conservation and protection of Island's unique environment and its marine area
- To promote development through sustainable integrated management plan based on scientific

principles taking into account the vulnerability of the coast to natural hazards

A setback area is composed of the reservation area or reservation line lying between seaward reference line of High Tide Line (HTL) and the landward reference line of the particular coastal segment to be decided scientifically on a case to case basis along the Island's coast. In the islands' coast the reference line is the HTL which is generally 2 to 2.5 m above the Mean Sea Level (MSL) has been well documented.

Criteria for Setback Line: The IPZ Notification clearly says that the Integrated Island Management Plan *'shall address vulnerability to human life and property based on elevation, geomorphology, sea level trends and horizontal shoreline displacement'*. It further says that the IIMP may indicate suitable areas that are safe for locating dwelling units, infrastructure and also appropriate safeguards measures to protect the life and property of the local communities from natural hazards. A No Development Zone or Setback area is determined so as to achieve the above objectives as required in the IIMP for the island.

The criteria for establishing the setback line for each segment of the islands' coastline has been worked out based on the hazard perception. The segments have been rated based on the hazards experienced by the islands. The major hazards considered are:

- Severe monsoon wave activity and wave set up (due to waves and tides)
- Coastal flooding (geology, geomorphology and land elevation as base parameters)
- Horizontal shoreline displacement (erosion / accretion)
- Sea level trends (Elevation)
- Cyclones, storm surges and tsunami

Though islands face many hazards the most important ones which need to be considered are high monsoonal waves and coastal flooding, shoreline displacement and sea level trends. The cyclones, storm surges and tsunami have not been considered for setback line, as they are rare events and have been accounted in the disaster management plans included in the IIMP by providing cyclone shelters, road communication, etc.

(i) High monsoon waves: Waves are one of the most frequent hazards that are active in the island. It is one among the parameters that significantly contribute to shoreline changes. The impact of waves increases due to wave and wind set up. The impact is more during the high tidal conditions. The changes in the shoreline truly reflect the impact of the waves, tides and wind. Hence it is more practical to examine the long term shoreline changes to account for the above effects.

(ii) Horizontal shoreline displacement: The long-term shoreline changes are considered as an important parameter to determine the setback line. The shoreline erosion / accretion phenomenon along the island's coast is not continuous but the coast which has been traditionally eroding may be accreting after a few a years. This can happen due to anthropogenic factors as well like the construction of coastal structures, development of harbour, foreshore based activities, etc. The long-term shoreline changes for a period of 32 years were computed for this purpose

(iii) Sea level trends: It is now well known that the sea levels are increasing in most part of the world due to the global warming phenomenon. Though local studies specific to the islands are not available the Intergovernmental Panel for Climate Change (IPCC) has given a projection of 45 cm of sea level rise globally as a moderate scenario for the period 2000-2100. To be on the conservative side this projection is adopted for the island and a rise of 50 cm is accounted for the purpose of the setback line. This means a coastal zone falling within this rise is vulnerable to the impact of the sea level rise projected. It is to be remembered that the impacts of the day to day waves and tides are also accommodated within this elevation. Hence the area falling within this elevation can be taken as the setback zone. Since the present day impacts are felt up to the HTL and the projections are intented for the future, the elevations are taken above the HTL.

From the above discussion the two measurable criteria for determining the set back line in the islands are horizontal shoreline displacement (erosion and accretion) and elevation. Since the shoreline erosion / accretion is a dynamic process wherein the coast which has been traditionally eroding may turn to an accreting coast and vice versa after a few years of time due to many factors including anthropogenic like construction of coastal structures, development of harbor and port, foreshore based activities, etc. Hence the shoreline changes independently may not give the correct measurable criteria

for identifying the setback line. The other parameter is the elevation of the island with respect to HTL. Considering all the above a distance upto the elevation of 0.5 m above HTL is taken as a general parameter for fixing the setback line.

For fixing the distance to the 0.5m elevation from the HTL the island is divided into several segments and the parameters were determined scientifically for each. Though there is no considerable variation in the segments examined, as a conservative measure the maximum value for the block of segments is taken as the setback distance for that portion of the island.

It has been noted that some part of the island is thickly populated and highly developed. To cater to the greater demands of coastal area in the developed zones it may not always be acceptable if a uniform setback is provided for the entire island. Taking clue from the criteria adopted in categorizing the coastal zone as CRZ-II and CRZ-III and allowing more development in CRZ-II in the original CRZ Notification, the setback in the island is determined based on the criteria whether the portions of the island are developed or undeveloped, availability of free space and differential exposure to natural hazards. Based on the scientific approach a moderate setback distance is considered for the developed area. For the portion which has sparse settlement or is undeveloped with more open space the maximum observed setback distance is provided as a conservative measure.

T. N. Prakash
Funding: DST, UT of Lakshawdeep

4.4 GIS and Remote sensing applications in natural resources manangement

4.4.1 Proximal Remote sensing of Biotic stresses in Tuber Crops using Sunlight-induced fluorescence and Reflectance Imaging

The immense increase in world population and depletion of fertile land available for cultivation has generated an increased need for food production. To meet the increased demand in vegetation, the focus lies on increasing the cultivation output by reducing crop loss due to various factors, like natural hazards, and other biotic and abiotic stresses. This study examines the potential of sunlight-induced chlorophyll fluorescence (SICF) and reflectance imaging along with the application of photochemical reflectance index (PRI), normalized difference vegetation index (NDVI) and chlorophyll fluorescence image ratios for proximal remote sensing of biotic and abiotic stresses in crop plants. Field grown plants are continuously subjected to various environmental stresses that affect plant physiology, leading to impairment in their photosynthetic activity. Major stresses that affect plant growth and health are virus infection, water and nutrient deficit, and the side effects of pesticides and herbicides application. Timely monitoring and detection of early symptoms of vegetation stress is very essential to improve health and yield crops by resorting to appropriate remedial measures to restore plant vitality.

Chlorophyll fluorescence emission of plant leaves on absorption of sunlight is one of the means of releasing excess energy from chlorophyll and occurs in the visible spectrum between 650 nm to 800 nm, consisting of two bands, one in the red region near 690 nm and the other in the far-red region near 735 nm. Vegetation fluorescence provides unique information about the photosynthetic activity and represents a specific signature of the fundamental physical processes occurring within the plant.

Plant monitoring systems based on reflectance and chlorophyll fluorescence has the potential to provide valuable data about photosynthetic activity. When sunlight is used as light source to induce chlorophyll fluorescence and the intensity of fluorescence emitted by plants is very small as compared to the solar reflectance, special techniques are required to extract the fluorescence

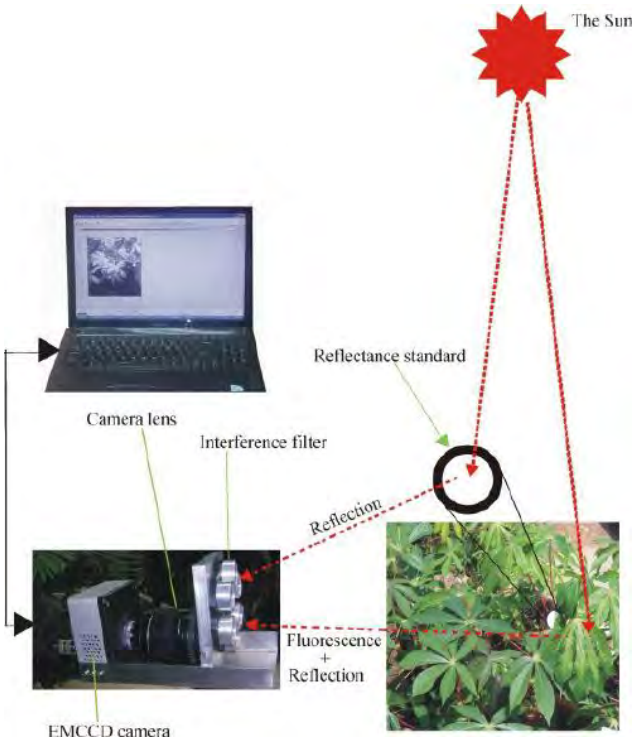


Fig. 4.4.1.1 Experimental set up of the multi-spectral fluorescence and reflectance imaging system.

component from the high solar reflectance background. In the present study, Fraunhofer Line Discrimination (FLD) technique was used to extract the chlorophyll fluorescence component from the solar reflectance background by recording reflectance images through narrow band filters centered on the B- and A-bands the O_2 molecule, at 687 and 761 nm respectively, where the intensity of the incoming radiation is comparable to the fluorescence emission. However, commercial systems for proximal remote sensing of plants are not available and the technique has not reached desirable levels for mass adoption. Therefore, in the present study, a multi-spectral imaging system (MSIS) was developed, which is compact and portable for proximal sensing of plants under both laboratory and field conditions (Fig. 4.4.1.1).

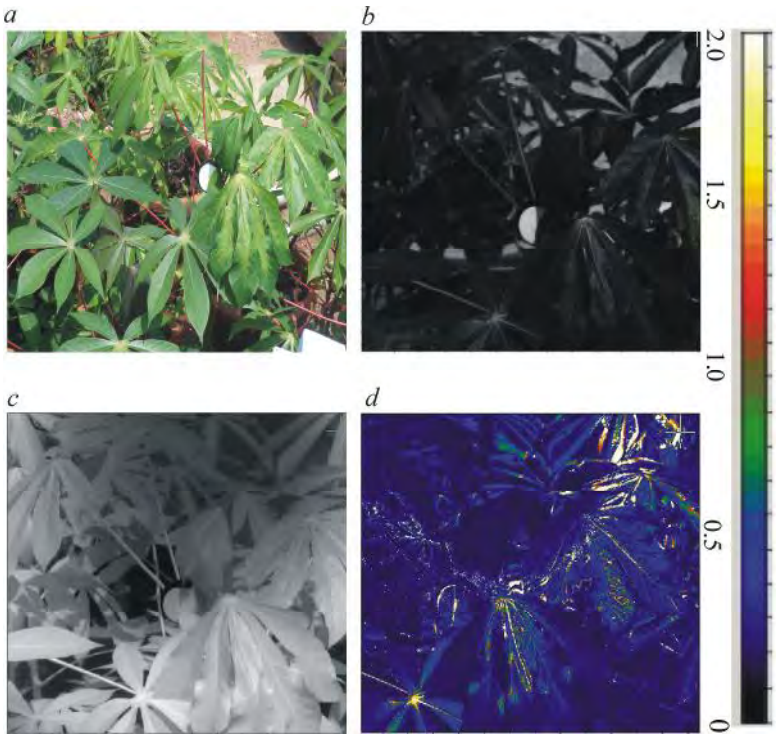


Fig. 4.4.1.2 Images recorded from a typical cassava plant; 9a) a color photo, (b) monochrome image recorded at 687 nm, (c) monochrome image recorded at 760 nm, (d) false-colored image ratio (F_{687}/F_{760}) obtained by FLD images (b) and (c)

For the discrimination of different levels of Cassava mosaic virus disease (CMD) infection SICF and PRI imaging techniques were used. It was observed that plants with no visible CMD could be discriminated from initial stages of CMD infection, which shows that SICF and PRI imaging could be useful for detection of early symptoms of CMD. Fig. 4.3.1.2 shows photograph and typical images recorded from irrigated cassava plants with the multi-spectral imaging system developed for SICF imaging. Distinction between healthy and CMD infected regions marked by yellow discoloration (chlorosis) is clearly noticeable and these changes increase and spreads to neighboring regions with disease progression. The SICF monochrome images recorded at 687 and 760 nm are used to derive the monochrome ratio image F_{687}/F_{760}, which is then pseudo colour mapped for easy visualization of ratio variance across the affected leaves. It is observed that in each pseudo coloured image, the fluorescence ratio values increase with CMD stress and is represented in different colours as depicted by the colour bar.

As can be seen in Fig. 4.4.1.2, healthy areas are blue in colour, which gradually turns to green, red, yellow and white as the CMD infection progresses. It was also observed that the Chl fluorescence image ratio (F_{687}/F_{760}) of stressed plant leaves is always greater than that of healthy leaves and it increased with the level of CMD infection. A classification algorithm was developed, which could effectively classify between different levels of CMD infection. SICF and PRI were used to find water stress tolerant variety of cassava and sweet potato from among 10 varieties each. The prospective use of SICF and reflectance imaging in the assessment of physiological conditions in field grown plants were experimented using colocasia and sweet potato plants which were subjected to water and herbicide stress. These results show that the chlorophyll fluorescence image intensity ratio (F_{687}/F_{760}) and PRI values varies according to the photosynthetic activity of the plants and could be used for monitoring the health of vegetation and to identify early symptoms of stress induced changes in plants. The imaging system was also used to derive NDVI at canopy level by proximal reflectance imaging that assesses the greenness of vegetation.

Remote sensing has the advantage of monitoring a larger area of vegetation within a short span of time and it provides information on plant physiological parameters at the leaf or canopy level. These techniques are considered to be of great significance in understanding productivity models that depend on plant photosynthetic parameters. The major advantage of proximal remote sensing is that it can gather spatial information about the vegetation status in near real-time from ground level platforms or low-flying airplanes or drones utilizing passive sunlight to induce fluorescence.

Raji S. Nair and N. Subhash

External and Consultancy Projects

5.1 External Grant-in-aid projects

Sl. No.	Project Title	Funding Agency	Principal Investigator	Group	Co-Investigators	Project Period	Total Outlay (Rs. in lakh)	Fund received during the year (Rs. in lakh)
1.	Sea water quality monitor-ring (COMAPS 4)	Ministry of Earth Sciences, Govt. of India (through ICMAM)	Dr. R. Ajayakumar Varma Dr. D. Padmalal (since 01.03.2016)	Natural Resources and Environmental Management	Dr. K. Anoop Krishnan	2013-17	323.00	53.00
2.	Monitoring of water sediment quality parameters in the back waters of Cochin Port Trust (CPT 3)	Cochin Port Trust	Dr. K. Anoop Krishnan	Natural Resources and Environmental Management	---	2012-17	27.80	2.29
3.	Impact of sea level rise in Kerala coast (DECC 2)	Directorate of Environment & Climate Change, Gok	Sri. P. John Paul	Coastal Processes	Dr. T. N. Prakash, Dr. D. S. Suresh Babu, Dr. L. Sheela Nair	2013-16	67.80	15.75
4.	Coastal Hazard Monitoring and early warning (DMD 1)	HVRA, GoK	Sri. G. Sankar Dr. T. N. Prakash (Since 18.01.2016)	Coastal Processes	---	2013-16	23.22	0.00
5.	In-situ bioremediation of land fill pollutants: maximizing the remediation potential of select indegenous and exogeneous microorganism (DST 79)	Department of Science & Technology	Smt. K. Deepa Nair	Atmospheric Processes	---	2013-16	20.00	8.00
6.	Geochemistry, paleomagnetism and isotope studies of mafic bodies in the Gwalior, Bijawas and Cuddapah basins: A synthesis of paleoproterozoic large igneous provinces in India (DST 80)	Science and Engineering Research Board, GoI	Dr. T. Radhakrishna	Crustal Processes	Dr. Tomson J. Kallukulam	2013-16	39.20	0.00
7.	Environment Management Training (KSCS 28)	Kerala State Council for Science, Technology & Environment	Dr. D. Suresh Babu	Coastal Processes	---	2014-15	4.00	0.00
8.	Coastal Zone Management Plan of Kerala with respect to Coastal Regulation Zone (KSCS 29)	Kerala State Council for Science, Technology & Environment	Dr. T. N. Prakash	Coastal Processes	Dr. D. S. Suresh Babu, Dr. K. Raju, Sri. B. K. Jayaprasad, Dr. Reji Srinivas	2014-15	299.75	50.00

9.	Investigation of underground structures at Over-bridge to SL theater stretch of road using Imaging Resistivity Water (KSUDP 2)	Kerala Sustainable Urban Development Project, Local Self Government Department, Govt. of Kerala	Dr. R. Ajayakumar Varma	Natural Resources and Environmental Management	---	2014-15	1.29	0.46
10.	Modelling Atmospheric Pollution & Networking (MAPAN)	Indian Institute of Tropical Meterology	Dr. R. Ajayakumar Varma Dr. M. Samsudhin (since 08.07.2016	Atmospheric Processes	---	2013-17	20.32	0.00
11.	Establishment and maintenance of wave guage stations along the southwest coast of India (MoES 9)	INCOIS, MoES, Govt. of India	Dr. L. Sheela Nair	Coastal Processes	Dr. Reji Srinivas	2013-17	98.49	22.84
12.	Shoreline mapping& monitoring for west coast of India (MoES 10)	ICMAM, MoES, Govt. of India	Dr. L. Sheela Nair	Coastal Processes	---	2013-17	190.00	20.62
13.	Paleomagnetic investigation across the one km long Koyna drill core (MoES 11)	Ministry of Earth Science, Govt. of India	Dr. T. Radhakrishna	Crustal Processes	---	2014-16	10.84	4.22
14.	Monitoring Indian Shield Seismicity with 10 bbs to understand Seismotectonics of the region using VSAT connectivity-continued operation of the Broadband station at Peechi-Kerala (MoES 12)	Ministry of Earth Sciences, Govt. of India	Smt. Sreekumari Kesavan	Crustal Processes	Dr. C. K. Soman (KFRI)	2014-17	13.04	2.47
15.	Research on soil piping in the high-lands and foot-hill of Kerala to avoid the disaster (NDMA 1)	National Disaster Management Authority, GoI	Sri. G. Sankar	Crustal Processes	Dr. R. Ajayakumar Varma, Dr. Sekhar L. Kuriakose (HVRA Cell), K. Eldhose	2012-15	87.11	0.00
16.	Sand auditing of Rivers (Manimala, Periyar & Muvattupuzha) in the Idukki district (RSA3)	Revenue Department, GoK	Dr. D. Padmalal	Natural Resources and Environmental Management	Dr. K. Maya	2012-15	9.84	0.00
17.	Drought research and mitigation in Vatakarapathy Panchayath (SDMA1)	Kerala State Disaster Management Authority	Shri. John Mathai	Crustal Processes	---	2016-17	25.00	21.83

5.2 Consultancy projects: Demarcation of HTL and LTL for Coastal Regulation Zone

Table 5.2.1 List of CRZ Reports prepared during the period 2015-16

Sl. No.	Project Tittle	Institution/ Agency/Person	Location
1.	HTL, LTL and CRZ for proposed multiuser liquid terminal (MULT) at Puthuvypien Kochi Kerala	Cochin Port Trust	Kerala, Ernakulam
2.	HTL, LTL and CRZ for proposed LPG terminal in Haldia port area at West Bengal	Aegis Logistics Ltd. Mumbai	West bengal, Kolkatta
3.	CRZ status report for the medical trust institute of Medical science at Irumbanam Ernakulam	Pulikkal Medical foundation Enrakulam	Kerala, Ernakulam
4.	HTL, LTL and CRZ for proposed LPG pipeline port area at Haldia West Bengal	Aegis Logistics Ltd., Mumbai	West bengal, Kolkatta
5.	Demarcation of HTL and CRZ for the proposed resort at Nattika in Thrissur Kerala	Yandra Ayurvedic Resorts Ltd., Thiruvananthapuram	Kerala, Thrissur
6.	HTL, LTL and CRZ for the proposed route plan for heat traced pipeline from NTB/STB to BPCL-Kochi refinery	Bharat Petroleum Corporation Ltd., Kochi	Kerala, Ernakulam
7.	HTL, LTL and CRZ for the proposed residential building at Kochu Kadavanthra in Kochi Corporation	Mr. M. Raveendran 22, Choice Village, Tripunithura	Kerala, Ernakulam
8.	Proposed Fishing Harbour	Harbour Engineering Department, Parappanangadi	Malappuram, Kerala
9.	HTL, LTL and CRZ for the proposed crude oil storage tanks (ST- T- 15 and ST - 16) at shore tanks Puthuvype, Ernakulam	Bharat Petroleum Corporation Ltd., Kochi, a Govt. of India Enterprise	Kerala, Ernakulam
10.	HTL, LTL and CRZ for the proposed residential complex at Payyannur Municipality, Kannur, Kerala	Yem Cee Infrastructure and Realtors Pvt. Ltd.	Kerala, Kannur
11.	Delineation of HTL, LTL and CRZ for the proposed Vadodara-Mumbai expressway (VME) crossing at Narmada River (Phase 1)	National Highway Authority, Govt. of India	Vadodara, Gujarat
12.	Delineation of HTL, LTL and CRZ for the proposed Vadodara-Mumbai expressway (VME) and SPUR-JNET alignment (Phase-2), Thane and Raigad district.	National Highway Authority, Govt. of India	Thane and Raigad, Maharashtra
13.	Delineation of HTL, LTL and CRZ for the proposed Vadodara-Mumbai expressway (VME) crossings at Vasai-creek (Phase-3), Thane	National Highway Authority, Govt. of India	Thane, Maharashtra
14.	Demarcation of HTL and CRZ for the proposed sewage treatment plant at Poovar, Thiruvananthapuram	Poovar Gramapanchayat, Thiruvananthapuram	Kerala, Thiruvananthapuram
15.	HTL, LTL and CRZ for the proposed Fishery Harbour contruction at Poonthura	Harbour Engineering Department, Govt. of Kerala	Kerala, Thiruvananthapuram
16.	Comparison of HTL delineated in the maps prepared by CESS versus the approved CZMP for the village Bandra, Andheri Taluk in Mumbai.	Dr.Akhtar Hassan Rizvi, Mumbai	Andheri, Mumbai
17.	HTL, LTL and CRZ for the proposed star hotel project at alappuzha.	9 Architects, Kollam	Kollam, Kerala
18.	HTL, LTL and CRZ for the proposed Alappuzha port development site in Alappuzha Municipality	The Directorate of Ports ,Thiruvananthapuram	Kerala, Alappuzha
19.	HTL, LTL and CRZ for the proposed Limestone mining project site at Lodhva Village, Sutrapada Taluka of Gir- Somnath District, Gujarat	Ambuja Cements Limite(ACL)	Gujarat
20.	CRZ map superimposed with new layout plan and brief report.	T.P Shan, MD, Joys beach Resort and Deedi Resort PA Ltd.	Kerala
21.	HTL, LTL, and CRZ for the proposed resort construction project at Ajanur Gramapanchayat, Kasaragod	Joys Enterprises Pvt. Ltd., Thrissur	Kasargod, Kerala
22.	HTL, LTL and CRZ for the proposed commercial/residential building project at Maradu Municipality, Ernakulam	Bhasi K. Nair Bhavanam, Kochi	Kerala, Ernakulam
23.	HTL, LTL and CRZ for the proposed construction of beach resort project at Ozhinhavalappu, Kanhangad Municipality, Kasaragod	Malabar Front Resort and Spa, Nileswar	Kerala, Kasaragod
24.	Delineation of HTL, LTL and CRZ the proposed revamping of facilities of MS/HSD/SKO storage installation at Elathur, Kozhikode District	Hindustan Petroleum Corporation Ltd., Mumbai	Kerala, Kozhikode

Table 5.2.2 Ongoing Consultancy Projects

Sl. No.	Project Title	Funding Agency	Group	Project Period	Total Outlay (Rs. In lakh)	Fund Received during the year (RS. In lakh)
1.	Delineation of HTL / LTL and Preparation of CRZ Status Report	CZMP Vasai-Virar-Thane	Coastal Processes	2015-16	266.99	86.51
2.	-do-	CZMP Thane-Sindhurg district	Coastal Processes	2015-16	30.00	26.20
3.	-do-	Mighty group, Montana Developers Pvt. Ltd., Mumbai	Coastal Processes	2015-16	8.40	0.00
4.	-do-	Cochin Port Trust, Cochin	Coastal Processes	2015-16	15.00	0.00
5.	-do-	Indian Rare Earths Ltd., Kollam	Coastal Processes	2015-16	4.35	2.18
6.	-do-	Shelter Constructions	Coastal Processes	2015-16	15.00	0.00
7.	-do-	Hazira Infrastructure, Adani House	Coastal Processes	2015-16	8.10	0.00
8.	-do-	Adani Petronet, Dahej	Coastal Processes	2015-16	20.25	0.00
9.	-do-	Jousha Generation Ministries, Ernakulam	Coastal Processes	2015-16	3.45	0.00
10.	-do-	NHAI- Vadodara, Mumbai Express Way	Coastal Processes	2015-16	6.18	1.36
11.	-do-	Yantra Ayurvedic Resort Pvt.Ltd	Coastal Processes	2015-16	3.15	0.00
12.	-do-	Meritra Homes Pvt. Ltd. Cochin	Coastal Processes	2015-16	0.26	0.00
13.	-do-	Bharat Petroleum Corporation Ltd, Kochi	Coastal Processes	2015-16	3.15	0.00
14.	-do-	Aegis Logistics , Mumbai	Coastal Processes	2015-16	5.25	0.00
15.	-do-	Malt at Puthuvypeen, Cochin Port Trust, Ernakulam	Coastal Processes	2015-16	3.15	0.00
16.	-do-	YEM CEE Infrastructure, Kannur, SKerala	Coastal Processes	2015-16	3.15	0.00
17.	-do-	Raveendran, Ernakulam	Coastal Processes	2015-16	0.68	0.00
18.	-do-	Bharat Petroleum Corporation Ltd, Kochi	Coastal Processes	2015-16	3.15	0.00
19.	-do-	Pulikkal Medical Foundation	Coastal Processes	2015-16	0.50	0.50
20.	-do-	Harbour Engineering Department,GoK	Coastal Processes	2015-16	1.05	1.05
21.	-do-	Vichus Constructions Pvt. Ltd.	Coastal Processes	2015-16	3.15	3.15
22.	-do-	9 Architects	Coastal Processes	2015-16	3.15	3.15
23.	-do-	Poovar Grama Panchayath	Coastal Processes	2015-16	0.60	0.60
24.	-do-	Aegis Logistics Pvt. Ltd.	Coastal Processes	2015-16	5.25	5.25
25.	-do-	Ambuja Cements Ltd., Mumbai	Coastal Processes	2015-16	8.00	8.00
26.	-do-	Alappuzha Port	Coastal Processes	2015-16	1.05	1.05
27.	-do-	Joy Enterprises Pvt. Ltd.	Coastal Processes	2015-16	3.15	3.15
28.	-do-	Malabar Ocean Front Resort	Coastal Processes	2015-16	3.15	3.15
29.	-do-	Akhtar Hasan Rizvi, Mumbai	Coastal Processes	2015-16	0.50	0.50
30.	-do-	Bhasi K. Nair, Kochi	Coastal Processes	2015-16	3.15	3.15
31.	-do-	Joy's Beach Resort	Coastal Processes	2015-16	0.50	0.50
32.	-do-	Indian Rare Earth Ltd.	Coastal Processes	2015-16	4.35	2.18
33.	-do-	Penna cement Industries Pvt. Ltd.	Coastal Processes	2015-16	3.15	3.15
34.	-do-	Hindustan Petroleum Corporation	Coastal Processes	2015-16	3.15	3.15
35.	-do-	Indian Coast Guard, Cochin	Coastal Processes	2015-16	3.15	3.15

Infrastructure Development

6.1 Scanning Electron Microscope-Energy Dispersive Spectrometer (SEM-EDS) Laboratory

The SEM-EDS Laboratory houses a TESCAN VEGA 3 LMU high-performance, Variable Pressure Analytical SEM with LAB6 having high resolution of 2 nm, along with the most advanced LN2-free high-resolution, high-speed EDS (QUANTAX 200 with XFlash®6/30 SDD Detector) from Bruker with Energy resolution < 126 eV and a 30 mm2 active window area. It is also equipped with SE, R-BSE, Colour + Panchromatic Cathodoluminescence (CL) Detectors with digital image processing and storage capabilities.

The SEM-EDS is capable of capturing ultra structural details of samples as images in digital mode which in turn permits the observation and characterization of heterogeneous organic and inorganic materials, thereby providing high-resolution and high depth-of-field images of sample surface and near-surface. The instrument can magnify specimens up to 10,00,000 times. SE Detector provides Topographic Contrast Imaging using Secondary Electrons. Retractable BSE detectors with YAG scintillator provides compositional contrast, material contrast, phase contrast imaging and phase Identification using Back Scattered Electrons.

The state of the art EDS facility provides qualitative and semi quantitative compositional analysis of different phases, grains and selected points of the samples including Multi Point, Line Scan and elemental mapping of the selected area. Elements from Be (5) to Americium (95) with a detection limit of 1000 ppm can be analyzed. Conductive coatings of gold or carbon is deposited for sample preparation of non-conducting samples using a Quorum SC7620 sputter coater or Quorum CA7625 evaporative carbon coater.

Samples of rocks, minerals, fossils, ores, biological, pharmaceutical, metallurgical, polymer materials can be studied using SEM-EDS facility. NCESS primarily uses the equipment for mineralogical investigations, petrological studies, characterisation of palaeontological samples and interpretation of sedimentological and depositional environments.

6.2 Gas Chromatography-Mass Spectrometer (GC-MS)

Gas Chromatography-Mass Spectrometry (GC-MS/MS) is a combination of two different analytical techniques, Gas Chromatography (GC) and Mass Spectrometry (MS) and is used to analyse complex organic, biochemical mixtures and permanent gases. It is also referred as GC-QQQ system. The GC-MS/MS system consists of two main components, Gas Chromatography (GC) unit which separates different compounds in the sample into "pulses" of pure chemicals based on their volatility (volatile and semi-volatile compounds) with great resolution, by flowing an inert gas (mobile phase), which carries the sample, through a stationary phase fixed in the column. The second, the Mass Spectrometry (MS) unit provides detailed structural information as the pure compounds exits the chromatographic column and can exactly be identified and quantified (with reference to standards) according their mass-to-charge ratio (m/z). Hence, the combination of

GC - MS is unique in identifying the compound with very high sensitivity and selectivity. And the MS/MS system involves the mass spectrometric analysis of the precursor ions which are obtained by GC-MS system, this feature generally useful in the detection and potential identification of chemicals in the presence of other chemicals (in a complex mixture) with high sensitivity.

Applications:

Environmental monitoring: GC-MS has become a highly recommended tool for monitoring and tracking organic pollutants in the environment. Determination of chlorophenols in water and soil, polycyclic aromatic hydrocarbons (PAH), unleaded gasoline, dioxins, dibenzofurans, organochlorine pesticides such as endrin, dieldrin, herbicides, phenols, halogenated pesticides are very convenient to be screened by this technique.

Biological and pesticides detections: GC-MS is exclusively used in bio-analysis of blood, urine for the presence of barbiturates, narcotics, alcohols, residual solvents, drugs like anaesthetics, anticonvulsant, antihistamine, anti-epileptic drug, sedative hypnotics, narcotics and food items. This technique could be used for detecting adulterations, fatty acid profiling in microbes, presence of free steroids, blood pollutants, metabolites in serum, organo-chlorinated pesticides in river and drinking water.

6.3 Total Organic Carbon (TOC) Analyser

The Total Organic Carbon (TOC) is an integral part of soil or sediment and it includes all carbon compounds as one mass and is measured in terms of an absolute quantity. Total organic carbon (TOC), is often used as a non-specific indicator of water quality or cleanliness of pharmaceutical manufacturing equipments. In relation to the TOC, parameters like Total Carbon (TC) and Total Inorganic Carbon (TIC) are also measured; TC is the sum of the TOC and TIC. Analytical technologies utilized to measure TOC share the objective of completely oxidizing the organic molecules in an aliquot of sample to carbon dioxide (CO2) and there of measuring the resultant CO2 concentration, and expressing this response as carbon concentration. The TOC Analyser (Figure 2) first digests the inorganic carbon with the help of ortho phosphoric acid, which may be present in the water from sources such as dissolved CO2 and bicarbonate, and then the CO2 generated from the oxidation of organic molecules in the sample is measured.

Applications of TOC Analyser: Total Organic Carbon (TOC) measurement is commonly used to determine its content in sediments and the degree of organic contamination in water. It is frequently a measured parameter in many industries and fields, such as the chemical, pharmaceutical, food and beverage, oil and gas, power and energy, petrochemical, and pulp and paper industries. This parameter is also used for monitoring drinking and surface water, waste discharges, and run-off as well as controlling some internal processes.

6.4 Fourier Transform Infra-Red-Attenuated Total Reflectance Spectrophotometer (FTIR-ATR Spectrophotometer)

Infrared (IR) spectroscopy is an extremely reliable and well recognized fingerprinting method for detection of the functional groups present in the organic molecule such as alcohols, aldehydes, ketones, esters, alkenes and alkynes and other many substances can be characterized, identified and also quantified. One of the strengths of IR spectroscopy is its ability as an analytical technique to obtain spectra from a very wide range of solids, liquids and gases. IR (infrared) spectroscopy is useful in organic chemistry

because it enables to identify different functional groups. This is because each functional group contains certain bonds, and these bonds always show up in the same places in the IR spectrum. An IR instrument consists of an IR light source, a sample holder, a means of selecting individual wavelengths or frequencies of the light, some means of detecting the amount of incident light that the sample absorbs, and a device for plotting the amount of light absorbed as a function of wavelength or frequency. This plot is referred to as the 'IR Spectrum.' Since IR light is absorbed by most materials, the optics of an IR Spectrophotometer requires special materials while most frequently they are built of NaCl or KBr - water soluble salts. To generate the IR spectrum, different frequencies of infrared light are passed through a sample, and the transmittance of light at each frequency is measured. The transmittance is then plotted against the frequency of light. Different functional groups produce bond absorptions at different locations and intensities on the IR spectrum. Recognizing where the absorptions generated by the common functional groups occur will help you to interpret IR spectra. The technique of Attenuated Total Reflectance (ATR) has in recent years revolutionized solid and liquid sample analyses because it combats the most challenging aspects of infrared analyses, namely sample preparation and spectral reproducibility.

Applications of FTIR-ATR Spectrophotometer: FTIR spectra reveals the composition of solids, liquids, and gases and the most common use is in the identification of unknown materials and confirmation of production materials. Infrared spectroscopy is a valuable technique for monitoring air quality, testing water quality, and analysing soil to address environmental and health concerns caused by increasing pollution levels. The technique offers a "green" method of testing and fast, accurate results with the added benefit of saving money on the cost of consumables.

6.5 CHNS Elemental Analyser

The CHNS Elemental Analyser finds utility in determining the percentages of Carbon, Hydrogen, Nitrogen, and Sulphur in water, soil or sediment samples. The working principle is based on "Dumas method" which involves the complete and instantaneous oxidation of the sample by "flash combustion". The combustion products are separated by a chromatographic column and detected by the thermal conductivity detector (TCD.), which gives an output signal proportional to the concentration of the individual components of the mixture. Here the present CHNS Analyser uses the built in chromatographic column

which converts the sample compound and elutes it in the form of NO2, CO2, SO2, H2O which are then detected with the help of Thermal Conductivity Detector.

Applications of CHNS Elemental Analyser: CHNS Elemental Analyser has been used in analytical laboratories since long time and is used extensively across a wide range of applications, including pharmaceuticals, chemicals, oil-related products, catalysts and food. The organic C/N ratios can be used to identify the origin of organic identify the origin matter in sediments. The C,H,N and S analysis environmental samples is a pre-requisite in the chemical characterisation of soils and sediments.

6.6 Voltametric trace metal Analyser (V–Analyser)

Voltammetry deal with applying a time-dependent potential to an electrochemical cell and measure the resulting current as a function of that potential. The resulting plot of current versus applied potential is called a "voltammogram" and it is the electrochemical equivalent of a spectrum in spectroscopy, providing quantitative and qualitative information about the species involved in the oxidation or reduction reaction. Voltammetry is characterized by its high sensitivity, its insensitiveness against interferences caused by high concentrations of dissolved solids, and its low of operation/analytical costs. It can be used for speciation

analysis, e.g., to differentiate between different oxidation states of elements. The basic principle of voltammetry involves applying a time-dependent potential excitation signal to the working electrode-changing its potential relative to the fixed potential of the reference electrode-and measure the current that flows between the working and auxiliary electrodes. The auxiliary electrode is generally a platinum wire, and the reference electrode is usually a SCE or a Ag/AgCl electrode.

Applications of V–Analyser: V-Analyser is used to carry out metal analyses (for example Iron, Lead, Mercury, Molybdenum, Nickel, Platinum and Rhodium.) in ppt (ng/kg) level. With V-Analyser it is also possible to differentiate various oxidation states of metal ions or free and bound metal ions. This allows statements to be made about the biological availability and toxicity of heavy metals and makes this technique a valuable tool for environmental analysis.

6.7 Spectrofluorometer

Spectrofluorometer uses high intensity light sources to bombard a sample with as many photons as possible. This allows for the maximum number of molecules to be in an excited state at any one point in time. The light is either passed through a filter, selecting a fixed wavelength, or a monochromatic in nature, which allows a wavelength of interest to be selected for use as the exciting light. The emission is collected at 90 degrees to the exciting light. The emission is also either passed through a filter or a monochromatic before being detected by a photomultiplier tube, photodiode, or charge-coupled device detector. The signal can either be processed as digital or analogue output. The Spectrofluorometer consists of a light source, an excitation monochromatic, a sample holder, an emission monochromatic, and a detector. The reference is generally a solution of a strongly fluorescent molecule with a broad absorbance spectrum such as rhodamine. The reference is necessary to correct for lamp output, especially when varying the excitation wavelength, and to correct for differences in detector sensitivity.

Applications of Spectrofluorometer: Spectrofluorometer measures the fluorescence signature of an analyte in a sample based on its specific excitation and emission wavelengths. The fluorescence signature can be correlated to the concentration level of the analyte in the sample. A spectrofluorometer can be used in basic and applied research, biofuels analysis, biotechnology applications etc. It can be used for Petroleum Hydrocarbon (HPC) detection in environmental samples.

Honours, Awards & Academic Activities

7.1 Honours & Awards

Dr. G. R. Ravindra Kumar, Senior Consultant, NCESS has been awarded National Award in Geoscience & Technology for the year 2015 by the Ministry of Earth Sciences in recognition of his outstanding contributions to Geoscience & Technology.

Dr. V. Nandakumar, Scientist-F, Crustal Processes Group has been awarded 'Certificate of Merit Award-2015' by the Ministry of Earth Sciences, Govt. of India.

Shri. M. Madhu Madhavan, Deputy Manager, Purchase has been awarded 'Award for Best Employee-2015' by the Ministry of Earth Sciences, Govt. of India.

Shri. N. Nishanth, Scientific Assistant, Gr. B, Crustal Processes Group has been awarded 'Award for Best Employee-2015' by the Ministry of Earth Sciences, Govt. of India.

Shri. N. Jayapal, Executive, Store section has been awarded 'Award for Best Employee-2015' by the Ministry of Earth Sciences, Govt. of India.

Shri. Tiju I. Varghese, has been awarded Ph. D Degree under the Faculty of Marine Sciences, Cochin University of Science and Technology for his thesis "Sedimentology and Geochemistry of core sediments from the Ashtamudi Estuary and the adjoining Coastal plain, Central Kerala, India" on 5th May, 2015. Dr. T. N. Prakash, Scientist-G, Coastal Processes was his supervising guide.

Shri. C. Sreejith, has been awarded Ph. D degree under the Faculty of Science, University of Kerala for his thesis "Evolution of the lower crust in the Kerala Khondalite Belt (KKB), southern India: petrological and geochemical constrains and insights into a new arc-accretion model" on 10th April, 2015. Dr. G. R. Ravindra Kumar, Scientist-G, Senior Research Consultant was his supervising guide.

Shri. S. Vishnu Mohan, has been awarded Ph. D degree under the Faculty of Marine Sciences, Cochin University of Science & Technology for his thesis "Late quaternary geology of the coastal lands of southern Kerala, India with special reference to Paleoclimate and Coastal evolution" on 18th December, 2015. Dr. D. Padmalal, Scientist-F, Natural Resources & Environmental Management was his supervising guide and Dr. K. Sajan, Professor, Department of Marine Geology & Geophysics, School of Marine Science, CUSAT was his Co-guide.

7.2 Membership in Committees outside NCESS

Dr. R. Ajayakumar Varma

Chairman, Committee for assessing the damages to the properties of local people due to the blasting operations in a 7 km long tunnel of Sengulam Augmentation Scheme.

Member, Committee for preparing Project Report for modernization of the Department of Mining and Geology, Govt. of Kerala.

Chairman, Expert Committee to assess the impact of blasting operations in the tunnel of Thottiyar Hydro Electric Project, Kerala State Electricity Board.

Member, Expert Committee for drafting guidelines for the preparation of District Development Plan, Kerala State Planning Board.

Member, Task Force on Greening Rural Development constituted by the Ministry of Rural Development, Govt. of India.

Member, Management Committee of Centre State Technology Transfer Institute.

Member, Technical Support Group of Solid Waste Management by Govt. of Tamil Nadu.

Member, Academis Committee of the Advanced Centre for Environemental Studies & Sustainable Development (ACESSD), Mahatma Gandhi University, Kottayam

Dr. T. Radhakrishna

Member, Evaluation of the UGC-Kothari PDF applications.

Member, MoES representative for a JRF interview at PSG Institute Coimbatore.

Member, Committee constituted for selection of Associate Professor in the Indian Institute of Geomagnetism, Mumbai.

Member, UNESCO-IGCP 597 National Working Group.

Member, Assessment Committee of Scientific and Technical personnel of the Indian Institute of Geomagnetism, Mumbai.

Shri. John Mathai

Member, State Expert Appraisal Committee, Government of Kerala, under the State level Environment Impact Assessment Authority (SEIAA), Kerala.

Member, Expert Committee for the formulation of Scientific Mining Policy of Kerala State.

Member, Technical Committee, Disaster Management-Mullaperiyar Dam, Govt. of Kerala.

Dr. T. N. Prakash

Member, Expert Committee, constituted by the Hon'ble Supreme Court of India (under the Chairmanship of Justice R. V. Raveendran, Former Judge, Supreme Court) for the preparation of Integrated Island Management Plan (IIMPs) for the inhabited islands of Lakshadweep.

Convenor of the Research Committee of CUSAT.

Member of the Permanent Doctoral Committee of Geography, constituted by the University of Kerala.

Expert Member, Technical Review Committee on Mineral Mapping of Indian Coasts, National Centre for Sustainable Coastal Management (NCSCM), MoEF, Chennai.

Shri. G. Sankar

Member, Technical Committee for validation of security schemes at Sree Padmanabha Swami Temple constituted by the Govt. of Kerala.

Member, Ecologically Fragile Land (EFL-CDRC), Chalakudy division, Govt. of Kerala.

Member, Expert Committe for making recommendations in the modernisation of Kerala Forest Department, Govt. of Kerala.

Member, Research and Management Committee of HVRA Cell, Department of Revenue, Govt. of Kerala.

Member, Expert Committee constituted by the State government as well as the Ministry of Earth Sciences to suggest immediate mitigation measures to Varkala Cliff Vulnerability.

Shri. P. Sudeep

Member, Board of Studies under the Faculty of Social Sciences (social work), University of Kerala.

Dr. G. R. Ravindra Kumar

Member, Programme Advisory Committee on Earth Sciences (PAC-ES), Department of Science & Technology, Govt. of India, New Delhi (2012-2015).

Dr. D. Padmalal

Member, Editorial Board, Geoscience Research, Journal of the Gondwana Geological Society, India.

Member, Editorial Board, Journal of Ocean Science.

Dr. K. K. Ramachandran

Member, Co-ordination committee by the Govt. of Kerala for preparation of the State Environment Report, Kerala

Member, Technical Committee constituted as part of the tendering of DGPS, GPS and ETS by the Director of Survey & Land Records of Govt. of Kerala.

Expert for site verification of CRZ status in respect of a plot in Goregoan West, Mumbai as per the request of the Maharashtra Coastal Zone Management Authority in con-

nection with a Bombay High Court order.

Chairman of the team of experts for the evaluation of Extended abstracts and Papers in the subject area of '**Earth and Planetary Sciences**' in connection with 28th Kerala Science Congress and attended evaluation meetings at CWRDM, Kozhikode

Shri. B. K. Jayaprasad

Member, Technical Committee of Kerala State Remote Sensing and Environment Centre (KSREC) for the procurement of Servers.

Member, Technical Advisory Committee for the procurement of GIS software and hardware for the Kerala State Forest Department

Dr. D. S. Suresh Babu

Member, PG (Geology) Board of Studies of the University of Kerala under the Faculty of Science.

Member, Assessment Committee for Scientific Staff, Kerala State Remote Sensing and Environment Centre (KSREC), Govt. of Kerala.

Member, Committee for framing Confidential Report and work report for Scientific staff of Kerala State Remote Sensing and Environment Centre (KSREC), Govt. of Kerala.

Member, 13th Committee for Society for All Round Development (SARD), Kerala State Council for Science, Technology and Environment (KSCSTE), Govt. of Kerala.

Member, Research Fellowship Programme-Expert Committee, Kerala State Council for Science and Technology (KSCSTE), Govt. of Kerala.

Dr. A. Krishnakumar

Member, Expert Committee for the scientific study of Athani Quarry, constituted by the District Collector, Wayanad.

Member, Expert Committee constituted by the District Collector, Malppuram for studies on environment and water flow in the site proposed for the construction of hospital in the Kottakkal village, Tirur taluk, Malappuram District.

7.3 Intership / Summer Training

Sl. No.	Name	Affiliaation	Supervising Guide
1.	Nalina Sasi	Central University of Karnataka	Dr. V. Nandakumar
2.	Priyanka Priyadarshini T.		
3.	Narmada A. S.	NITK, Suratkal	Dr. L. Sheela Nair
4.	Shabnum Suhra Shamsudeen		
5.	Pousali Mukherjee	IISER, Kolkata	
6.	Rajasree B. R.	IIT, Bombay	
7.	Sivapriya	University of Madras	Dr. K. Maya
8.	Pooja Gulumbe	Savitribai Phule University	Dr. A. Krishnakumar

7.4 M. Sc./ B. Tech/ M. Tech Dissertation Programmes

Sl. No.	Name	College / Affiliation	Topic of Dissertation	Supervising Guide
1.	M. S. Sruthy	CUSAT	Study on the depositional history and microfaunal assemblage of the late Quaternary sediments of Central Kerala, SW India	Dr. D. Padmalal
2.	Silpa Thankan	Central University of Karnataka	Comparative analysis of fluid inclusions from different formations, Mumbai offshore basin, India	Dr. V. Nanadakumar
3.	M. S. Aneesh	CUSAT	Study on the coastal sands of Kazhakuttom, Kaniyapuram belt (Southern Kerala, India) – Implication on late Quaternary coastal evolution.	Dr. K. Maya
4.	Arya Dileep	Anna University, Chennai	Petrographic studies of representative samples from major rock types in Trivandrum Block, South India	Dr. Tomson J. Kallukalam
5.	T. S. Parvathy			
6.	Kunal Pandit	Savitribai Phule University, Pune	Structure, petrography and geochemistry of Granulite facies rocks along the southern margin of Achankovil shear zone, South India	
7.	R. S. Linchu Raj	S. N. College, Chempazhanthy, Thiruvananthapuram	Appraisal of hydrochemical parameters of well water systems located in an urbanized residential area at Ulloor, Trivandrum, India	Dr. K. Anoop Krishnan
8.	S. L. Malu		Modeling of groundwater quality parameters: A case study conducted at Sreekariyam, Trivandrum, South India	
9.	K. N. Asna	Women's College, Trivandrum	Adsorption of cadmium from aqueous solution using chitosan	
10.	Krishna V. Nair		Hydrochemical candidature of Kavaratti coastal waters in view of quality aspects	
11.	G. Aswathy	Govt. College, Attingal	Adsorption of Ni(II) onto surface modified chitosan	
12.	A. Akshara Babu		Adsorption of Cu(II) onto surface modified chitosan	
13.	V. Viji		Adsorption of Co(II) onto surface modified chitosan	
14.	O. C. Ershana	Govt. College, Madappally	Distribution of physico-chemical and biological components in Trivandrum urban water-sediment system: A case study	
15.	R. V. Nidhin		Evaluation of hydrochemical parameters of Veli Lake, Trivandrum, South India	
16.	K. Arjun		Water and sediment characteristics of Karamana river near Parasurama Swami Temple, Thiruvallam, Trivandrum, India	
17.	P. V. Arjun		Studies on Phosphate Speciation in the Cochin Estuary Sediments, Willington Island, Cochin, South India	
18.	V. Mehga	Govt. College, Kasaragod	Hydrogeological studies of Periyar river basin, Kerala, Southwest India with special reference to groundwater fluctuation.	Dr. A. Krishnakumar
19.	K. R. Thushara		Water quality and drinking water potential of groundwater resources of Periyar river basin, Kerala, Southwest India	
20.	V. Reshma Raj	S. N. College, Varkala	Identification of drought prone areas in Periyar river basin: A geo-mathematical approach	
21.	S. Divya Dinesan		Groundwater fluctuation trend and hydrochemical quality in Periyar river basin: A GIS based study.	

7.5 Ph. D Students

1.	Sreekanth T. S. / Project C	Characterization of tropical rain fall in terms of drop size distribution at surface, its variation with altitude and comparison of rain rates with satellite measurements	Dr. G. Mohan Kumar	Kerala / 17.08.2009
2.	Raji S. Nair / Plan 111	Multi Spectral Imaging	Dr. N. Subhash	Kerala / 29.04.2010
3.	Divya V. / KSCSTE	Ecological Studies along Elevational Gradients in a Transect in Southern Western Ghats, with special reference to Forest Soil	Dr. C. N. Mohanan	Kerala / 04.11.2010
4.	Prasad R. / MoES 9	Sediment Dynamics in Coastal Waters	Dr. N. P. Kurian	CUSAT / 18.11.2010
5.	Hema C. Nair	Water quality and drinking water potential of the ground water resources of Kallada and Ithikkara river basin, Kerala, SW India	Dr. D. Padmalal	CUSAT / 04.08.2011
6.	Unnikrishnan U. (Part time)	Common Property Resource (CPR) Management in the lowlands of Thiruvananthapuram district with special reference to surface water resource	Dr. Srikumar Chattopadhyay	Kerala / 06.03.2012
7.	Shaji J. (Part time)	Coastal Zone Management: A case study of Thiruvananthapuram coast	Dr. Srikumar Chattopadhyay	Kerala / 06.03.2012
8.	Ganapathy C. / SC/ST Department	Impact of Human Activities in the generation of Land Disturbances in Humid Tropical Highland Areas- A case study in Idukki district, Kerala	Dr. K. Raju	Kerala / 04.05.2012
9.	Ragi N. P. / UGC	Causes and Impacts of landslides in Panamaram and Mananthavadi watersheds of Kabani river basin, Kerala	Dr. K. Raju	Kerala / 15.07.2012
10.	Soumya G.S. / UGC	Neoproterozoic Anorthosites in South India, a comparative study to delinete petrogenesis and India's position in Rodinia Assembly	Dr. T. Radhakrishna	Kerala / 19.07.2012
11.	Sheikha E. John / Plan 103	Mining and quarrying in the river catchments of Central Kerala around Kochi city, SW India-Consequences and sustainable development strategies	Dr. K. Maya	Kerala / 06.03.2013
12.	Jayalekshmy S. S.	Urbanization trend of Kerala over a period of 1961-2011.	Dr. Srikumar Chattopadyay	Kerala / 19.08.2013
13.	Revathy Das / UGC	Integrated geoenvironmental studies of the locustrine wetlands of Kerala in climate change paradigms for conservation and management.	Dr. A. Krishnakumar	Kerala / 25.11.2013
14.	Arun T. J. / MACIS	Studies on selected rivers in different climatic regimes, southern India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
15.	Aneesh T. D. / Project D	Hydrological Studies of an Urban agglomerate, Ernakulam district, Kerala	Dr. Reji Srinivas	CUSAT / 13.12.2013
16.	Krishna R. Prasad / KSCSTE	Wetland Studies of Akathumuri-Anchuthengu-Kadinamkulam Esturine System, Southwest coast of India.	Dr. Reji Srinivas	CUSAT / 13.12.2013
17.	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
18.	Salaj S. S. (Part time)	Coastal aquifer Vulnerability assessment and mapping along the Kozhikode coast-A Geospatial approach	Dr. D. S. Suresh Babu	Bharathidasan/ 18.03.2014
19.	Mereena C. S / DST	Inland waterways of Kerala: A geographical and economical analysis of west coast canal	Dr. Srikumar Chattopadhyay/ Dr. K. Raju (Co-Guide)	Kerala / 17.03.2014
20.	Jobish E. A. / SC/ST Department	Coastal Zone Management: A case study of Eranakulam coast	Dr. K. Raju	Kerala / 28.03.2014
21.	Parvathy K. Nair / KSCSTE	Development of Vembanad Management action plan through a geological perspective	Dr. D. S. Suresh Babu	Kerala / 30.04.2014
22.	Sibin Antony / COMAPS 4	Appraisal of marine ecosystem of Kavarathi island in southwest coast of Kerala with special reference to lagoon system	Dr. K. AnoopKrishnan	Kerala / 23.05.2014
23.	Vinu V. Dev / CPT-3	Adsoptive potential of surface modified ceramics, clays and chitosan for the removal of toxic heavy	Dr. K. AnoopKrishnan	Kerala / 09.06.2014

		metals from aqueous media using batch and column studies: kinetic and thermodynamic profile		
24.	Praseetha B. S. / KSCSTE	Geochemistry of estuarine and innershelf sediments	Dr. T. N. Prakash	CUSAT / 18.12.2014
25.	Praveen M. N. / (Part time)	Geological aspects of the eastern part of betal belt, Central Indian Tectonic Zone	Dr. G. R. Ravindra Kumar	CUSAT
26.	Kunhambu V. / CGWB (Part time)	Characterisation and evaluation of the aquifer system of Kuttanad area, Kerala for Sustainable Groundwater Development	Dr. D. S. Suresh Babu	Kerala / 05.01.2015
27.	Harsha Mahadevan	Assessment of Nutrient Flux in Urban Drainage Systems: Identification of Sources, Pathways and Remedial Measures	Dr. K. Anoop Krishnan	Kerala / 01.05.2015
28.	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
29.	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
30.	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

Library and Publications

8.1 Library

NCESS Library is a part of the knowledge Resource centre being established by MoES Earth System Science Knowledge Resource System (A project under Digital India Initiative of Government of India). Books are arranged according to the Dewey Decimal Classification (DDC) system. In addition to the scientific community of NCESS, the library is open to scientists and researchers of other Institutions and Universities for reference. Library Management Software KOHA upgraded to latest version. The Major service provided by the library are reference service, article alert, e mail alert and document delivery service. Library has Institutional Membership at KN Raj Library – Centre for Development Studies. During 2015-16 NCESS Library continued subscription of 15 national and five international journals (print as well as online) and 129 full text journal through MoES-Science Direct consortium. The Institute has a Life membership of Geological Survey of India (GSI) through which e-access of GSI publications is available. During this year 20 books were added to the collection. Free computing, internet and WiFi facilities are provided to library users. Online Public Access Catalogue(OPAC) search is provided to users through WLAN of NCESS.

8.2 Research Papers

8.2.1 In Journals

Anoop Krishnan, K., Ajmal, K., Faisal, A. K. and Liji, T. M. (2015). Kinetic and isotherm modeling of Methylene Blue absorption on to Kaolinite clay at the Solid-Liquid interface, Journal of Seperation Science and Technology, 50(2015) pp.1147-1157

Anoop Krishnan, K., Sreejalekshmi, K. G., Vimexen, V. and Vinu V. Dev (2015). Evaluation of adsorption properties of sulphurised activated carbon for the effective and economically viable removal of Zn(II) from aqueous solutions,Journal of Ecotoxicology and Environmental Safety, Elsevier, pp. 418-425

Dubey, C. P. and Tiwari, V. M. (2016) A MATLAB algorithm to calculate the gravity potential and gravity gradient tensor of arbitrary shape bodies, Computer and Geosciences, DOI 10.1016/j.cageo.2015.12.007.

Nair, D. N. K., Zachariah, E. J. and Vinod, P. (2015). Investigations on enhanced in situ bioxidation of methane from landfill gas (LFG) in a lab scale model, Springer, DOI 10.1007/s10163-015-0397-4.

Noujas, V., Thomas, K. V. and Badarees, K. O. (2016). Shoreline management plan for mudbank dominated coast, Ocean Engineering, Elsevier, Vol. 112, pp. 47-65.

Padmalal, D. and Staff Reporter (2015). Kerala's dwindling fresh water resources, Geography and You, Vol. 15 (91), pp. 33-37

Rajeevan K and Sumesh R K (2016) Diurnal and seasonal variations of Atmospheric CO_2 over Trivandrum, India. International Journal of Current Research. Vol 8 (2), pp.26085-26092.

Resmi, R. R., Deepa Nair, K., Zachariah, E. J. and Salom Gnana Thanga Vincent (2015). Methanogenesis: Seasonal changes in human impacted regions of Ashtamudi estuary (Kerala, South India), Estuarine, Coastal and Shelf Sciences, Vol. 156, pp. 144-154.

Sadasivan Nair Raji, Narayanan Subhash, Velumani Ravi, Raju Saravanan, Changatharayil N. Mohanan, Sukumar Nitha and Thangaraj Makesh Kumar (2015). Detection of mosaic virus disease in cassava plants by sunlight-induced fluorescence imaging: a pilot study for proximal sensing, International Journal of Remote Sensing, Vol. 36 (11), pp. 2880-2897

Sadasivan Nair Raji, Narayanan Subhash, Velumani Ravi, Raju Saravanan, Changatharayil N. Mohanan, Sukumar Nitha and Thangaraj Makesh Kumar (2015). Detection and classification of mosaic virus disease in cassava plants by Proximal Sensing of Photochemical Reflectance Index, Journal of Indian Society of Remote Sensing, pp. 1-9

Sheela Nair, L., Sundar, V. and Kurian, N. P. (2015). Longshore sediment transport along the coast of Kerala in Southwest India, Procedia Engineering, Vol. 116, pp. 40-46.

Vishnu Mohan, S., Shiekha E. John, Rajimol, T. R., Maya, K., Sajan, K. and Padmalal, D. (2015). Human interventions and consequent environmental degradation of a protected freshwater lake in Kerala, SW India, Geosciences Journal, DOI 10.1007/s12303-015-049-7.

Zachariya, E. J., Sabulal, B., Nair, D. N. K., Johnson, A. J., Kumar, C. S. P. (2016). Carbon dioxide emission from bamboo culms, Plant Biology, DOI: 10.1111/plb. 12435.

8.2.2 In Conference Proceedings

Ajayakumar Varma, R. (2015). Degenerating Water resources systems and declining water security in Kerala, Proc. of International Congress on Kerala Studies, pp. 9-17

Ajayakumar Varma, R. (2015). Septage and Fecal sludge Management in Kerala, Proc. of International Congress on Kerala Studies, pp. 115-121

Krishnakumar, A. and Saranya, P. (2016). Studies on soil texture, soil erosin and land use practices in Neyyar and Karamana basins, Thiruvananthapuram district, Kerala, Proc. of National seminar on Emerging Approches in Land Use Planning, Kerala State Land Use Board, pp. 104-109.

Padmalal, D., Maya, K. and Shiekha, E. John (2015). Environmental effects of soil quarrying in Kerala: An overview, Proc. of National seminar on soil pollution and paradigms for sustainable soil management (SPSSM-2015), pp. 22-27

Padmalal D., Maya K and Ajayakumar Varma R (2016). Geochemical fluxes through the small rivers of southern Western Ghats, India. Proc. of National Workshop on'Western Ghats: Evolution and Environmental Issues'. Pp 16.

Revathydas and Krishnakumar, A. (2016). Fresh water resources of Kerala: Water quality and emerging land use concerns, Proc. of National seminar on Emerging approches in Land use planning, Kerala State Land Use Board, pp. 195-199.

Shiekha E John and Maya K (2016). Hard rock quarrying from Periyar river basin, Central Kerala, India – Consequences and strategies. Proc. of National Workshop on'Western Ghats: Evolution and Environmental Issues'. p 57.

Shiny, R., Rajimol, T. R. and Maya, K. (2016). A study on the coastal plain rivers of Thiruvananthapuram, Kerala India. Proc. of National Workshop on'Western Ghats: Evolution and Environmental Issues'. p 58.

Vishnu Mohan S., Shiekha E John., Rajimol T R., Maya K and Padmalal D (2016). Environmental degradation of Paravur Estuary, Kerala, SW India. Proc. of National Workshop on'Western Ghats: Evolution and Environmental Issues'. p 62.

8.3 Project Reports

Ajayakumar Varma, R., Anoop Krishnan, K., Faisal, A. K., Ratheeshkumar, M., Vimexen, V., Shibu, R., Aneesh, K. S., Ajamal, R., Arya, S., Greeshma, V. L., Sibin Antony, Mohind Mohan, Sreejambika, B. S. and Suraj Krishna, R. (2015). Sea Water Quality Monitoring, p. 59

Ajayakumar Varma, R., Anoop Krishnan, K., Faisal, A. K., Ratheesh Kumar, M., Vimexen, V., Shibu, R., Aneesh, K. S., Ajmal, K., Arya, S., Greeshma, V. L., Sibin Antony, Mohind Mohan, Sreejambika, B. S. and Suraj Krishna, R. (2015). Sea Water Quality Monitoring (SWQM), National Centre for Earth Science Studies, Thiruvananthapuram, p. 46.

Ajayakumar Varma, R., Eldose, K. and Prasobh, P. Rajan (2015). Investigation of underground structures along the road between over-bridge and SL Theatre, Thiruvananthapuram using Resistivity Imaging Technique, p. 26

Ajayakumar Varma, R., Padmalal, D., Jayaprasad, B. K., Shiny, R., Ragi, M. S., Kalaraj and Krishnapriya, S. (2015). Pampa River Basin, p. 74

Ajayakumar Varma, R., Padmalal, D., Suresh Babu, D. S., Jayaprasad, B. K., Maya, K., Shiny, R., Ragi, M. S., Kalaraj, Krishnapriya, S. and Anila, M. T. (2015). Manimala River Basin.

Ajayakumar Varma, R., Suresh Bau, D. S., Jayaprasad, B. K., Padmalal, D., Maya, K., Thomas, K. V., Shiny, R., Ragi, M. S., Kalaraj, Krishnapriya, S. and Sreedevi, S. (2016). Environmental management action plan for the ecorestoration of Vembanad lake and connected river systems, project report submitted to Kuttanad development project, Department of Agriculture, Govt. of Kerala, p. 194

Anoop Krishnan, K. and Liji, T. M. (2015). Environmental Monitoring of Water and Sediment Quality Parameters in the Backwaters around Cochin Port Trust, Half yearly report submitted to Cochin Port Trust (CPT), Kochi.

Anoop Krishnan, K., Krishnakumar, A., Liji, T. M., Baiju R. S., Sibin Antony, Arya, S., Noufal, K. N., Arunima, R., Faisal, A. K., Ratheesh Kumar, M., Aneesh, K. S., Ajmal, K. and Sreejambika, B. S. (2015). Appraisal of drinking water potential of springs in Pathanamthitta, Kottayam and Idukki districts of Kerala, National Centre for Earth Science Studies, Thiruvananthapuram, p. 118.

Maya, K., Padmalal, D., Baburaj, B. and Shiekha E. John (2015). Study on the environmental effects of mining and quarrying in the Periyar river basin, Central Kerala

Padmalal, D., Maya, K. and Nair, K. M. (2015).Palaeoclimate and sea level records in the late quaternary sediments of the coastal wetlands of Pallikkal and Achankovil river basins, Kerala-its implications on coastal evolution, Project report submitted to the Kerala State Council for Science , Technology and Environment (KSCSTE), Thiruvananthapuram, pp. 36.

8.4 Books / Edited Volumes / Monographs

Krishnakumar, A. (2015). *Keralathinte Urja susthirathayum Vidyabhyasa Gaveshana Mekhalakalum (*Kerala: Energy sustainability and the Educational-Research sectors) Article in regional language (Malayalam) - Chapter in an edited book published by the Department of Post Graduate Studies and Research in Geology, MES College, Ponnani. Book published as part of the Environmental Education and Awareness Campaign of the Department of Environment and Climate Change, Govt. of Kerala.

Conference, Seminar and Workshop

9.1 7th Annual Workshop on the Science of Climate Change and Sustainable Development

Indian Institute of Tropical Meteorology (IITM), Pune, Centre for Climate Change Research(CCCR), IITM, and NCESS, Thiruvananthapuram jointly organized the 7th Annual Workshop on the Science of Climate Change and Sustainable Development at NCESS during August 19-20, 2015.

The proceedings of the Workshop began with an inaugural session on August 19, 2015. Dr. M Sudhakar, Director NCESS and Dr. M Rajeevan, Director, IITM welcomed the delegates and guests and explained the expected outcome of the workshop. This was followed by lighting of the lamp which marked the commencement of the proceedings. Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences kindly gave the opening remarks through the video conference facility set up in the hall. The Secretary, MoES explained the importance of the Workshop and the expectations of Government of India from this workshop and called upon the experts to seriously consider the outstanding scientific issues in Climate Change Studies, elaborate on the gap areas and evolve future research directions. This was followed by the inaugural address by Prof. P. V Joseph who made a detailed presentation on the large scale changes that the environment surrounding our monsoon has undergone during the last 60 years. The inaugural session concluded with a vote of thanks by Dr. R. Krishnan, Executive Director, CCCR, IITM.

Subsequently the deliberations of the Workshop was done in 4 sessions. The 1st session was on the Research overview by various institutions under the Earth System Science Organizations (ESSO). This was followed by a session on Climate forcing and Science of Climate Change, Climate Observations and Projections and Sustainable Development and Capacity Building. The Workshop concluded on 20th August 2015 afternoon with a brief session wherein the overall deliberations were reviewed and broad conclusion were arrived at. This session was chaired by Dr. M Rajeevan, Director, IITM. He appraised that the current research activities on climate change could be classified into Observed Climate, Climate models and Climate change impacts. Whereas this workshop deliberated upon, in detail, the first two aspects. He has gathered opinions from the participants for compiling the recommendations of the Workshop to which there were very many responses. A total of 51 participants attended the workshop proceedings. The workshop came to end with vote of thanks to all the Scientific Contributors, participants and invited guests.

9.2 National Workshop on Western Ghats-Evolution and Environmental Issues

Sri.Y.S.Chowdary, Hon'ble Minister of State for Ministry of Science & Technology and Ministry of Earth Sciences inaugurated by lighting the lamp and delivered the inaugural address on the occassion of National Workshop on "Western Ghats – Evolution and Environmental Issues" at NCESS,

Thiruvananthapuram on 01 January 2016. Dr.Ajayakumar Varma, Scientist-G & Group Head, NREM, NCESS, Dr.V.M.Tiwari, Director, NCESS, Dr.Suresh Das, Executive Vice President, Kerala State Science, Technology and Environment, Government of Kerala, Dr.B.K.Bansal, Advisor, Ministry of Earth Sciences, Government of India and Prof.Somnath Dasgupta, Former Vice Chancellor, Assam University & Chairman, Research Advisory Committee, NCESS are seen on the dias.

NCESS is organised a National Workshop on Western Ghats – Evolution and Environmental Issues for delineating critical gaps in the geo-environmental knowledge base on Western Ghats and to plan for more focused research on natural resource management. The workshop organised at National Centre for Earth Science Studies (NCESS) had invited lead lectures from distnguished scientists to speak on four themes (i) Evolution of Western Ghats, (ii) Western Ghats- A climate regulator, (iii) Ecosystem dynamics and (iv) Environmental management. In addition, presentations and poster sessions under the above themes were also organised. The workshop was held at NCESS, Thiruvananthapuram on January 1 & 2, 2016. On this occasion Sri. Y. S. Chowdary, Hon'ble Minister of State for Ministry of Science & Technology and Ministry of Earth Sciences inagurated the workshop and launched new webportal and eOffice system of NCESS.

9.3 NCESS Foundation Day 2016

NCESS has celebrated its first Foundation Day with a talk by Dr. Shailesh Naik, Distinguished Scientist and Former Secretary, MoES, Government of India on Friday, 08 January 2016.

Dr. Shailesh Naik, former Secretary, MoES delivering a talk on the occasion of NCESS Foundation Day.

On the celebration of Foundation Day a momento being presented by Dr. M. Rajeevan, Honarable Secretary, MoES to Dr. Shailesh Nayak former Secretary, MoES. Dr. V. M. Tiwari, Director, NCESS also seen

9.4 Brain Storming Meeting on GRACE Mission-Opportunities for India

The Brainstorming meeting on 'GRACE Mission - opportunities for India' was organized by the National Centre for Earth Science Studies, Ministry of Earth Sciences (NCESS) at Thiruvananthapuram on Thursday, January, 28, 2016 with the financial support of DST, Govt. of India. The meeting was chaired by Prof. P. Rajendra Prasad, Andhra University. Nine presentations on various aspects of GRACE mission were scheduled in the forenoon session and a panel discussion with all participants to formulate R&D and capacity building strategies on how to move forward with GRACE and GRACE Follow on data in India was conducted during the afternoon session.

At the outset, Dr.V.M.Tiwari, Director, ESSO-NCESS greeted and welcomed Dr. Debapriya Dutta, Advisor, DST, Prof. P. Rajendra Prasad, Chairman of Brainstorming session and all participants of the meeting.

Prof. P. Rajendra Prasad in his opening remarks, opined that the basic purpose of the Brainstorming Meeting was to formulate subtle ideas that can be implemented in India using GRACE satellite data. He stressed that time-bound programs that are applicable for planning purposes need to be undertaken. Prof. Prasad felt that the GRACE can be integrated with other remote sensing data and determination of potential field from a synoptic perspective would be useful for many applications. He proposed to introduce 50 to 60 "GRACE Fellowships" to research scholars in India so as to improve the knowledge base on collection, processing and interpretation of data for different fields. He

suggested to identify potential areas in which GRACE and GRACE 'Follow on' data can be used and also leading experts in India, who can contribute to the GRACE research programs.

Dr. D. Dutta gave an overview on the initiative and rationale of the Brainstorming meeting on GRACE. In his talk, he emphasized the importance of GRACE mission to India as well as on its several applications. He furthered the discussion by specifying the main applications of Mission in areas like thinning of glacier, sea level rise, global ocean circulation, geophysical process, hydrological processes etc. Dr. Dutta suggested that GRACE data can assist in R&D programs on climate change, glaciology, changing hydrological cycle, ocean circulation studies, prediction of monsoon etc. The factors like availability of supercomputing facilities in India and different university research activities on GRACE would be helpful in tapping the capabilities of these space borne data in the years to come. He sought the cooperation of all participants for deliberation on various issues related to GRACE mission and its Follow on and further requested to come out with specific recommendations regarding research and capacity building to move forward. Subsequently, Dr.V. M. Tiwari presented an overview on the concepts, data gathering and various applications of GRACE. In his talk, the spatial and temporal constraints as well as advantages of GRACE mission were highlighted. He reviewed the analysis of GRACE data already carried out in India over the years and brought out the specific findings in key areas like glacier mass change, water budget in river basins, crustal deformation due to hydrological loading etc. Dr. Tiwari also emphasized on complexity in deriving mass estimates from GRACE data and informed that GRACE Follow On would improve the spatial resolution. In this context, Dr. Dutta opined that GRACE can be useful, while we consider the interlinking of rivers on a national basis. Prof. Rajendra Prasad commented that impact on land due to water masses and water balance of basins has to be studied prior to the interlinking of rivers and GRACE can really support in such initiatives.

Prof. S.K. Subramanian elaborated on the advances in Geoinformatics and recent trends in space technology in ground-water resources estimation. He informed that the NRSC, Hyderabad has a large database on various thematic and Groundwater Prospect maps of India prepared in 1:50,000 scale, using ground truth data collected for about two decades. Hence, the scaling up of GRACE data to 1:100,000 would help in more realistic evaluation of natural re-sources.

Prof. Rajendra Prasad thanked the participants for joining the Brainstorming meeting and contributing for its success. Dr. Dutta praised the efforts taken by Dr.V.M.Tiwari and Prof. Rajendra Prasad for efficiently handling the things. Dr.Tiwari expressed gratitude to the Chair and every one, who have responded to the invitation at short notice and travelled to Thiruvananthapuram. He also acknowledged Dr. D. Dutta and DST, Government of India for the guidance and financial assistance to conduct meeting.

9.5 Invited Lectures / Chairing of Technical Sessions

Dr. R. Ajayakumar Varma

Delivered a lecture on "Technology options for solid waste management" in the international summer school for Architects organized by the Laurie Baker Centre for Habitat Studies, Thiruvananthapuram on May 25, 2015.

Delivered a keynote address on "Landuse, Global Warming, Waste and Environment" in the two day national seminar on "In Search of Alternative Development Policies", organized by Costford, Thrissur on June 13-14, 2015.

Delivered a lecture on "Transitions in Urbanscapes, Civil Society and policies" for the students of PG Environmental Studies, faculty of other students of the Thunchath Ezhuthassan Malayalam University at Tirur on July 22, 2015.

Dr. D. Padmalal

Delivered a lecture on " Holocene cimate and coastal evolution a case study from southern Kerala, SW India" at the 7th National workshop on Science of Climate Change and Sustainable Development at National Centre for Earth Science Studies on 20th August 2015.

Dr. C. P. Rajendran

Delivered a lecture on " A perspective on the Nepal earth quake of 25 April, 2015" Organized by National Centre for Earth Science Studies, Thiruvananthapuram as part of Earth Science Forum on May 28, 2015.

Dr. K. K. Ramachandran

Delivered a lecture motivating inaugural address on the Orientation Programme to the fresh batch of B.Tech Students of the LBS College of Engineering Kasaragod, on August 3, 2015.

Chaired a brain storming session on 'Development of Strategic Perspective Plan for C-STED (Centre for Science & Technology based Entrepreneurship Development)' and presented the summary in the concluding session on August 19, 2015.

Delivered a talk on "Remote Sensing" in Malayalam to the batch of selected high School Students from the Kannur District at the Science Centre, Kannur on Septermber 13, 2015 as part of the lecture series known as 'Sasthra Mukulam' in vernacular organized by the Science Centre.

Delivered a talk on "Role of Remote Sensing & GIS in identification of potential water source – A case study" in connection with the State Level Workshop on 'Water Security in Kerala – Challenges & Options' on October 14, 2015 at Thiruvananthapuram conducted by Central Ground Water Board.

Invited as a resource person and made a brief presentation on "Climate Change impact and river conservation" in connection with the Workshop on Conservation and Management of Rivers of Kerala organized by the CWRDM on November 18, 2015 at Thiruvananthapuram.

Attended 'NISAR Science & Applications' workshop during 19-20 November 2015 at Space Application Centre, Ahmadabad and made a brief presentation on the "Retrospect and Prospect of Remote Sensing Activities in NCESS" .

Chaired a session on Technology Initiatives on January 14, 2016 and delivered a talk on "Urban Land Use Planning" in connection with a National Seminar on Emerging Approaches in Land Use Planning conducted by the Kerala Land Use Board, at Kanakakunnu Palace, Thiruvananthapuram.

Delivered a talk on on "Geodesy and Map Projections" in the Department of Civil Engineering, College of Engineering Trivandrum on December 2, 2015.

Chaired the technical session on Earth & Planetary Sciences in the 28th Kerala Science Congress during 28 to 30 January, 2016 in the Calicut University Campus, Malappuram.

Delivered a lecture on "Coastal Regulation Zone Notifications vis-a-vis Sustainability of Mangrove Ecosystem: An Example from Kannur District" in connection with the International Conference on Towards a Sustainable Blue Economy, held in Cochin during 4-6 February 2016 organised by KUFOS.

Delivered a Keynote Address on "Coastal Wetlands and CRZ Notification" in connection with the one-day seminar on 'Wetland for our future: Sustainable Livelihood' to mark the World Wetland Day, organized by KUFOS on February 17, 2016.

Delivered an invited talk on "Coastal Zone Management Plan as per CRZ Notification 2011 for Kerala" in connection with the one day workshop on Coastal Environment Day: 25 years of CRZ on February 19, 2016 in the NCESS campus.

Delivered a talk on "Remote Sensing" to the students and faculty of Geology Department of S.N. College Chempazhanthy in connection with the Spectrum 2016 Seminar series on March 2016.

9.6 Papers presented in Conference / Workshop / Symposium / Seminar

Name	Conference / Workshop / Symposium / Seminar	Title of Paper / Poster
Nandakumar V. Jayanthi J. L.	International Symposium on Photonics applications and Nanomaterials (ISPAN-2015) organized by SCIMST, Thiruvananthapuram during 28-30 October, 2015.	Determination of API gravity of petroleum oils using flurescence emission technique
		Characterisation of hydrocarbon fluid inclusion by Raman spectroscopy
Rafeeque M. K. Rameshan M. Sreeraj M. K. Suresh Babu D. S. Ramachandran K. K.	35th INCA International Congress held at JNU, New Delhi during 15-17 December 2015.	Geoenvironmental appraisal of Mangrove ecosystem along the Sindhudurg coast of Maharashtra
Raji S. Nair Subhash N. Ravi V. Mohan C. N. Nita S. Renju U. A	National workshop on Western Ghats: Evolution & Environmental issues organized by National Centre for Earth Science Studies (NCESS), Thiruvananthapuram during 1-2 January, 2016	Integration of a multispectural imaging system consisting of EMCCD camera and Liquid Crystal Tunable Filter using LABVIEW
Aneesh T. D. Reji Srinivas Krishna R. Prasad Arun T. J. Archana M. Nair Krishnakumar A.		Effects of land use changes on the hydrology of an urban area, a case study in a Tier-II metro in South India
Arya S. Sibin Antony Anoop Krishnan K. Krishnakumar A.		Conservation of Spring resources in the western Ghats: focus on its quality and management for preserving the biodiversity
Saranya P. Krishnakumar A.		Assessing rainfall trends in twentieth century (1916-2005) over Munnar, an ecologically sensitive high altitudinal area of Western Ghats
Parvathy K. Nair		Development of Vembanad Management Action plan through a Geological Perceptive
Rameshan M. Roy A. Ramachandran K. K. Ramaswamy E. V.		Southern Western Ghats is on the right track of protection? A case study of Munnar Landscape
Krishnakumar A. Revathy das Saranya P.	International conference on Geosciences and Environment and XXXII convention of Indian Association of Sedimentologists held at Annamalai University, tamil Nadu During 7-10 January, 2016	Geochemical analysis and evaluation of Anthropogenic effects in an urban lake basin of Kerala State, India
Saranya P. Krishnakumar A. Anoop Krishnan K. Reji Srinivas		Heavy metal accumulation and biological risk assessment in a protected wetland, South West coast of India
Krishnakumar A. Saranya P.	National seminar on Geospatial information systems: Emerging trends and Utilities organized by the International and Inter University Centre for Natural Resources Management (IIUCNRM), University of Kerala during 28-29 January, 2016	Spatio-temporal changes of forest cover in Thiruvananthapuram district, SW India; A GIS based approach
		Land cover change analysis of Paddy wetlands on Neyyar and Karaman rivr basins, Kerala, SW India using GIS and Remote sensing
Resmi E. A. Neelam Malap Gayatri Kulkarni Murugavel P. Thara V. Prabha	National Space Science Symposium 2016 (NSSS-2016) organized by Space Physical Laboratory , VSSC, Thiruvananthapuram during 9-12 February, 2016	Diurnal Cycle of convection during CAIPEEX 2011experiment

10.1 Hindi Fortnight Celebrations

Hindi fortnight was observed during 14-28th September 2015. The programme was inaugurated by Shri. A. N. Nanda, Chief Post Master General Kerala. He had stressed the importance of using Hindi for official communication. As part of the celebrations, a workshop on 'Role and Responsibilities of Officers in implementation of Official Language Policy of Govt of India' was conducted by Dr. S Ramdulari, Principal, Government College, Karivattom and Shri D. Krishna Panikar, Rtd. Deputy Director, Dept. of Official Language, Govt. of India delivered a lecture on usage of Hindi in routine works. The various competitions like just a minute talk, Hindi translation competition, handwriting competition, news reading and poetry recitation were judged by eminent dignitaries. For improving the language skill, Hindi hand books were also distributed to all employees.

At the valedictory function of the fortnight celebrations, Dr..V. M. Tiwari, Director, NCESS said that while we use English to communicate globally we could use Hindi to communicate nationally and this can also be of help to exchange our scientific ideas among ourselves. Dr. Anil Bharadwaj, Director, Space Physics Laboratory, VSSC in his valedictory address stated that Hindi bridges the gap between all Indians. Dr. Bharadwaj also gave away certificate and cash awards to the winners of various competitions. Shri. P. Sudeep, Chief Manager, NCESS shared his Hindi Language experience with the audience and also appreciated the employees for participating in various competitions with enthusiasm. The event concluded with a vote of thanks.

10.2 Observance of Communal Harmony Campaign Week

Communal Harmony Campaign Week was observed during 19-25 November, 2015 and the Flag Day of the National Foundation for Communal Harmony on 25th November were observed at NCESS. NCESS Employees contributed to augment the resources of the National Foundation for Communal Harmony (NFCH) to continue on its activities on various schemes and projects. During the campaign week, flags and stickers were distributed and posters displayed.

10.3 Swachch Bharat Abhiyan

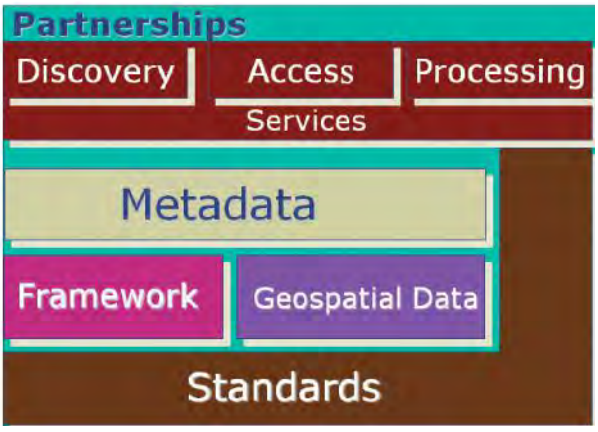
The Government of India has stressed upon the need for ensuring an improved work culture and work environment, including hygiene and cleanliness of work places across the country. Accordingly, the Central Cabinet has decided to undertake a fortnight of cleanliness drive in all the offices across the country during February 2016 and issued instruction to carry out the task. In accordance with the Govt. of India decision, two weeks of cleanliness drive during 3-17 February 2016 was conducted in NCESS campus. Persuant to this, a day long cleanliness drive on Friday, 9th October 2015. Activities were undertaken for Swachch Bharat Ahbiyan were Upkeep and cleaning of the office space & laboratories, including common area premises, toilets, stairs, roof etc. and weeding out of unwanted old records. Chairman, CD & GC would co-ordinate of cleanliness drive. All group heads gave necessary leadership and guidance to all the participants. All employees of NCESS including scientific & administrative staff, project personnel & research scholars actively participated and extended full cooperation for the cleanliness drive.

10.4 Setting up of Modular Data Centre

NCESS has established a modular data centre, which was inaugurated by Dr. M. Rajeevan, Secretary, MoES on 7th February, 2016. The infrastructure comprises of modular rack, 3 physical servers, 2 SAN switches, a SAN storage and tape library. If there is a resource crunch for VM's running on a particular host due to lack of resources in the host, then the DRS feature will migrate those VM's to the alternate host where there is less resource utilization. SAN Storage comprises of dual controllers and an enclosure module and disks and are grouped using appropriate RAID, thus ensuring high availability for controllers and disks respectively. Connectivity between SAN switches, Storage and Servers are through FC cables in such a way that the entire infrastructure is redundant. Zoning also is done in the SAN switch for security purposes. The servers and data storage are hosted at the Central Geomatics Lab, which is the central depository of the digital database of the institute.

10.5 Digital data dissemination through a centralized data infrastructure

In the present digital geo-enabled content, there are massive legacy repositories, such as satellite archives, to real time sensor feeds, such as traffic monitors and the need is greater than ever to be able to discover, access, process, and share distributed geospatial content. However, most of these data are stored in different data formats, using different data models, coordinate reference systems, geometry models etc. Thus, sharing geospatial data has required considerable time, expertise and special software. Open Geospatial Consortium (OGC) manages a consensus process, in which standards for common interfaces and encodings are developed to enable users to maximize the value of past and future investments in geoprocessing systems and data.



The structure of the Spatial Data infrastructure

Over the past decade, exhaustive GIS databases at district/ local level to support the process of Local Level Planning at the levels of district, taluk and village has been developed by NCESS. In order to improve accessibility of users to up-to-date geo-spatial data or information databases, potential of web/ communication technologies has to be put to use. There are a number of possible technical solutions for the configuration of a common, integrated GIS management system, whether by making use of a single central system, via decentralized systems, or via a hybrid system.

The Spatial Data Infrastructure is an initiative intended to create an environment in which all stakeholders can cooperate with each other and interact with technology, to better achieve their objectives at different political/administrative levels. It encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilization of geospatial data in a global community. Spatial Data Infrastructure is seen as mechanism to promote geospatial data sharing at all levels of government, private, non-profit sectors and academia. The SDI is conceived as a single window-access to the spatial/non spatial data for both the professional and amateur users, by building an open, interoperable and decentralized architecture accessible from a common web portal.

The implementation of the Open Geospatial architecture enables a secure, high performance spatial web services infrastructure necessary for the next generation of net-centric and geo-spatial intelligence. The application are to be built on 'Service Oriented Architecture' (SOA) with OGC/ISO standards. The Central repository will be on standard RDBMS package (Open Source). The portal shall cater to WMS/WFS/WCS/CS-W and other Portal services. Map services shall be created to access the spatial data from the repository. Based on the security features of the Web Portal, users will be allowed to access the various services

10.6 Coastal Environment Day

Inaguration of the Coastal Environment day 2016 by Dr. B. Madhusoodhana Kurup, Vice Chancellor of KUFOS

A view of the delegates and invitees participated in the Coastal Environment Day

To mark the 25 years of the Coastal Regulation Zone Notification 1991, one day workshop on 'Coastal Environment Day' was organized in NCESS campus jointly by NCESS (National Centre for Earth Science Studies), KSCSTE (Kerala State Council for Science, Technology and Environment, SISEM and St. Xavier's College on 19th February 2016. The workshop was inaugurated by the Vice Chancellor of the Kerala University for Fisheries and Ocean Studies (KUFOS), Prof. B. Madhusoodhana Kurup. Prof. George Varghese, Member Secretary, KSCSTE; Dr.V.M. Tiwari, Director, NCESS; Dr. C.T.S. Nair, Former Executive Vice President, KSCSTE; Fr. Sunny Jose, Principal, St Xavier's College, Thumba; Dr. K.V. Thomas, President, SISEM and Dr.Kamalakshan Kokkal, Joint Director, KSCSTE attended the inaugural function.

This was followed by technical session in which Dr Kerry Black, Dr. M. Baba and Dr. K.K. Ramachandran made presentations on beach protection, climate change, Indian initiatives of CRZ and coastal zone management plan for Kerala. Speakers Dr. B. R. Subramanian, Dr. Titto Dcruz and Prof. Khaleel Chovva highlighted the advantages of CRZ, concern of communities and distribution of mangrove ecosystem in Kerala respectively. Various aspects of coastal zone such as fishery resources, coral ecosystems, climate change, Vembanad Lake and anthropogenic interventions were discussed by Prof. K.V. Jayachandran, Dr. M. Wafer, Dr. K. Ajith Joseph, Dr. R. AjaykumarVarma and Dr. L. Sheela Nair, Many experts, scientists, academicians such as, Dr. N. P. Kurian, Dr. R. S. Kankara, Dr. Joseph Mathew, Dr. M. V. Ramana Murthy, Dr. T. N. Prakash, Prof. K. Padmakumar, Dr. Biju Kumar, Fr. Mathias etc., have actively participated in the workshop.

10.7 National Science Day

National Science Day 2016 was celebrated on 29th February. Dr. Suresh Das, Executive Vice President of the Kerala State Council for Science Technology & Environment (KSCSTE) delivered the National Science Day Lecture. 29th February 2016 was declared an Open Day for NCESS. 65 students and 5 teachers from the LBS College of Engineering, Thiruvananthapuram visited NCESS on that day. The students had detailed interactions with the scientists in the following laboratories: Centralised Geomatics Lab, National Facility for Geofluids Research and Raman Analysis, Palaeomagnetism Lab, Particle size analyzer, Petrology Lab, XRF, XRD, Atmospheric Chemistry Lab, AtP- MAPAN Facility, and Chemical Lab & Thin Section Lab.

10.8 Earth Science Forum

Nine invited lectures by eminent scientists in India and abroad, were organized during 2015-16. Dr. C. P Rajendran, former Scientist-G, NCESS, Govt. of India delivered an invited lecture on the topic: "*A perspective on the Nepal Earth quake of 25 April 2015*". Prof. Somnath Dasgupta, Chairman, Research Advisory Council lectured on the topic: "*Some Insights into Time Scale of Orogenic Processes*". Dr. D. D Ozha, Senior Science Communicator & Scientist, Member, Joint Hindi Advisory Committee, DST, DBT and MoES delivered a invited lecture on the topic: "*Promotion of Rashtrabhasha Hindi in Scientific and Administration fields*", Prof. H. Nagaraj, Head, Department of Geography, University of Mysore delivered a lecture on "*Agro climate, Agriculture and Food Security*"; Prof. Tad Murty, Adjunct Professor, Department of Civil Engineering, University of Ottawa, Canada delivered a talk on "*Early warning systems to mitigate loss of life and damage to infrastructure for sustainable development*"; Prof. Srinivas V. Bettadpur, Faculty at the Department of Aerospace Engineering and Engineering Mechanics, University of Texas, Austin, USA lectured on "*From GRACE to GRACE Follow-On* "; Mr. Pankaj Khanna, Ph. D. student at the Rice University, Houston, USA deliverd a lecture on the topic: "*Understanding of the modern reef systems in the Maldives and Gulf of Mexico utilizing multi beam bathymetry system*"; and Prof. Dr. R. Srinivasan, FNA, FNAsc, FASc, INSA Senior Scientist & Chief Editor, Current Science, Bangalore lectured on "*A critique of sutures in the Dharwar craton*". On the National Science Day celebration 2016, Dr. Suresh Das (EVP, KSCSTE, PS, Science & Technology Department, Govt. of Kerala delivered a special talk on "Science in India".

Presentations by the research Scholars of NCESS affiliated to various Indian universities were also organized.There were two in-hous Ph. D presynopsis submission presentations and four work progress presentations by the Research Scholars of NCESS during this period.

10.9 Recreation Club

The activities of recreation club of NCESS continued to very vibrant and celebrated with great fanfare with participation of staff members, students and family members

Committees

11.1 Statutory Committees

11.1.1 Governing Body (GB)

Dr. Madhavan Nair Rajeevan *Secretary, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*President*
Dr. (Mrs.) Swati Basu *Scientific Secretary & Advisor* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Mrs. Anuradha Mitra *JS & FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. B. K. Bansal *Scientist-G & Advisor* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Director, *National Centre for Antartic & Ocean Research (NCAOR)* *Ministry of Earth Sciences, Government of India* *Headland Sada, Vasco-da-Gama, Goa*	*Member*
Director, *National Institute of Ocean Technology (NIOT)* *Velacherry-Tambaram Main Road, Narayanapuram* *Pallikaranai, Chennai*	*Member*
Dr. Virendra M. Tiwari *Director, National Centre for Earth Science Studies* *Akkulam, Thiruvanathapuram*	*Member Secretary*

11.1.2 Governing Council (GC)

Dr. Madhavan Nair Rajeevan *Secretary, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Chairman*

Dr. Somnath Dasgupta *Vice Chancellor, Assam University,* *Silchar, Assam*	*Member*
Mrs. Anuradha Mitra *JS&FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. M. Sudhakar *Director, Centre for Marine Living Resources & Ecology (CMLRE), Kochi, Kerala*	*Member*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. K. J. Ramesh *Scientist-G & Advisor,* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. Suresh Das *Executive Vice President* *Kerala State Council for Science, Technology & Environment* *Sasthra Bhavan, Pattom* *Thiruvananthapuram*	*Member*
Dr. M. Ravichandran, Director *National Centre for Antartic & Ocean Research (NCAOR)* *Ministry of Earth Sciences, Government of India* *Headland Sada, Vasco-da-Gama, Goa*	*Member*
Dr. B. K. Bansal *Scientist G & Advisor* *Programme Officer, ESSO-NCESS* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Special Invitee*
Dr. V. M. Tiwari *Director, National Centre for Earth Science Studies* *Akkulam, Thiruvanathapuram*	*Member Secretary*

11.1.3 Finance Committee (FC)

Mrs. Anuradha Mitra *JS & FA, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Chairman*
Shri. Anand S. Khati *JS, Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*

Dr. B. K. Bansal *Scientist G & Advisor* *Programme Officer, ESSO-NCESS* *Ministry of Earth Sciences, Government of India* *Prithvi Bhavan, Lodhi Road, New Delhi*	*Member*
Dr. Virendra M. Tiwari *Director, National Centre for Earth Sceince Studies* *Akkulam, Thiruvananthapuram*	*Member*
Shri. P. Sudeep *Chief Manager* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member*
Shri. M. A. K. H. Rasheed *Manager (Finance)* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member*
Dr. D. S. Suresh Babu *Head, Projects, Training & Documentation* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member Secretary*

11.1.4 Research Advisory Committee (RAC)

Dr. Somnath Dasgupta *Vice Chancellor, Assam University,* *Silchar, Assam*	*Chairman*
Director, NIOT/ Nominee *National Institute of Ocean Technology* *Velacherry-Tambaran Main Road, Narayanapuram* *Pallikaranai, Chennai*	*Member*
Director, NGRI/ Nominee *National Geophysical Research Institute* *Uppal Road, Habsiguda, Uppal* *Hyderabad, Andra Pradesh*	*Member*
Prof. A. D. Rao *Centre for Atmospheric Sciences* *Indian Institute of Technology* *New Delhi*	*Member*
Dr. M. V. Ramanamurthy *ICMAM Project Directorate* *NIOT Campus* *Velacherry-Tambaram Main Road* *Pallikkaranai, Chennai*	*Member*

Dr. M. Baba *Former Director, CESS* *"Barkath", TC 7/53(1)* *Breeze Enclave, Ulloor* *Thiruvananthapuram*	*Member*
Dr. V. Nandakumar *Scientist-F, Crustal Processes (CrP)* *National Centre for Earth Science Studies* *Akkulam, Thiruvananthapuram*	*Member Secretary*

11.2 Internal Committees

11.2.1 Group Heads

Director, NCESS	*Chairman*
Dr. T. Radhakrishna *Crustal Processes*	*Member*
Dr. T. N. Prakash *Coastal Processes*	*Member*
Dr. M. Samsudhin *Atmospheric Processes*	*Member*
Dr. R. Ajayakumar Varma *Natural Resources & Environmental Management*	*Member* *(till February 2016)*
Dr. D. Padmalal	*Member* *(since March 2016)*
Shri. P. Sudeep *Chief Manager*	*Member*
Dr. D. S. Suresh Babu *Head, Project, Training & Documentation*	*Convenor*

11.2.2 Material Purchase

Shri. John Mathai	*Chairman*
Dr. T. N. Prakash	*Member*
Shri. P. Sudeep	*Member*

11.2.3 Library Management

Director	*Chairman*
All Group Heads	*Members*
Manager, Accounts	*Member*
Head, PT&D	*Member*
Librarian (i/c)	*Convenor*

11.2.4 Canteen

Dr. D. S. Suresh Babu	*Chairman*
Shri. R. Haridas	*Member*
Shri. P. H. Shinaj	*Member*
Shri. K. Eldhose	*Member*
Smt. Nita Sukumar	*Member*

11.2.5 Campus Development and Green Committee

Dr. V. Nandakumar	*Chairman*
Shri. G. Sankar	*Member*
Dr. L. Sheela Nair	*Member*
Dr. Tomson J. Kallukalam	*Member*
Shri. D. Raju	*Member*
Shri. M. Ramesh Kumar	*Member*
Shri. N. Nishanth	*Member*
Smt. K. V. Padmaja Kumari	*Member*
Smt. Indu Janardanan	*Member*
Shri. S. Krishnakumar	*Convenor*

11.2.6 Complaints Committee to combat Sexual harasment at work place

Dr. L. Sheela Nair	*Chairperson*
Smt. G. Lavanya	*Member*
Smt. K. Reshma	*Member*
Dr. Tomson J. Kallukalam	*Member*
Dr. S. Anitha	*External Member*

11.2.7 Website Management

Dr. D. S. Suresh Babu	*Chairman*
Shri. N. Nishanth	*Member*
Shri. S. S. Salaj	*Member*

11.2.8 Official Language Committee

Dr. M. Samsudhin	*Chairman*
Dr. T. Radhakrishna	*Member*
Dr. T. N. Prakash	*Member*
Smt. G. Lavanya	*Member*
Smt. K. Reshma	*Member*
Shri. P. Sudheep	*Member Secretary*

11.2.9 CRZ Projects Vetting Committee

Dr. K. K. Ramachandran	*Chairman*
Shri. D. Raju	*Convenor*
Shri. M. Ramesh Kumar	*Member*
Shri. S. Mohanan	*Member*

11.2.10 CRZ Projects Monitoring Committee

Dr. T. N. Prakash	*Chairman*
Dr. K. K. Ramachandran	*Convenor*
Dr. D. S. Suresh Babu	*Member*

Staff Details

12.1 Directors office

Dr. Virendra M. Tiwari	*Director (since August 2015)*
Dr. M. Sudhakar	*Director (till August 2015)*
Dr. M. Samsuddin	*Director (till July 2015)*
Dr. D. S. Suresh Babu	*Scientist-E & Head PT&D*
Smt. T. Remani	*Helper (Gr. 1)*

12.2 Crustal Processes (CrP)

Dr. T. Radhakrishna	*Scientist-G & Head*
Shri. John Mathai	*Scientist-G*
Dr. C. P. Rajendran	*Scientist-G (till May 2015)*
Shri. G. Sankar	*Scientist-G*
Dr. V. Nandakumar	*Scientist-F*
Smt. Sreekumari Kesavan	*Scientist-D*
Dr. Tomson J. Kallukalam	*Scientist-C*
Shri. Thatikonda Suresh Kumar	*Scientist B (since February 2016)*
Shri. Arka Roy	*Scientist B (since February 2016)*
Shri. N. Nishanth	*Scientific Asst. (Gr. B)*
Shri. K. Eldhose	*Technician (Gr. B)*

12.3 Coastal Processes (CoP)

Dr. T. N. Prakash	*Scientist-G & Head*
Shri. P. John Paul	*Scientist-E & Librarian (i/c)*
Dr. L. Sheela Nair	*Scientist-E*
Dr. D. S. Suresh Babu	*Scientist-E*
Dr. K. Raju	*Scientist-E (till October 2015)*
Dr. Reji Srinivas	*Scientist-C*
Shri. D. Raju	*Scientific Officer (Gr. 3)*
Shri. S. Mohanan	*Scientific Officer (Gr. 2)*
Shri. M. Ajith Kumar	*Scientific Officer (Gr. 2)*
Shri. M. Ramesh Kumar	*Scientific Officer (Gr. 2)*
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. K. Surendran	*Co-ordinator Gr. 4*
Shri. Louis William	*MTS*

12.4 Atmospheric Processes (AtP)

Dr. M. Samsuddin	*Scientist G & Head (since August 2015)*
Dr. R. Ajayakumar Varma	*Scientist-G & Head (till August 2015)*
Dr. E. A. Resmi	*Scientist C (since January 2016)*
Shri. Dharmadas Jash	*Scientist B (since February 2016)*
Shri. Mohammed Ismail	*Technical Officer (Gr. 4)*
Smt. Nita Sukumar	*Scientific Asst. (Gr. B)*

12.5 Natural Resources and Environmental Management (NREM)

Dr. D. Padmalal	*Scientist F & Head (since March 2016)*
Dr. R. Ajayakumar Varma	*Scientist-G & Head (August 2015 - february 2016)*
Dr. M. Samsuddin	*Scientist-G & Head (on deputation) (till August 2015)*
Dr. K. K. Ramachandran	*Scientist-F (on deputation)*
Dr. D. Padmalal	*Scientist-F*
Dr. Ansom Sebastian	*Scientist-E*
Dr. K. Maya	*Scientist-E*
Shri. B. K. Jayaprasad	*Scientist-E*
Dr. K. Anoop Krishnan	*Scientist-C*
Dr. A. Krishnakumar	*Scientist-C*
Dr. Archana M . Nair	*Scientist-C (till July 2015)*
Shri. Badimela Upendra	*Scientist B (since february 2016)*
Shri. Prasenjit Das	*Scientist B (since February 2016)*
Shri. Rajat Kumar Sharma	*Scientist B (since February 2016)*
Smt. C. Sakunthala	*Scientific Officer (Gr. 5)*
Smt. T. M. Liji	*Scientific Asst. (Gr. B)*
Shri. P. B. Vibin	*Scientific Asst. (Gr. B)*

12.6 Projects, Training & Documentation (PT&D)

Dr. D. S. Suresh Babu	*Scientist-E & Head*
Dr. K. Raju	*Scientist-E (till October 2015)*
Shri. S. S. Salaj	*Scientific Asst. (Gr. B)*
Smt. K. Reshma	*Scientific Asst. (Gr. B)*
Shri. P. M. Gopakumar	*Junior Executive (till November 2015)*

12.7 Administration

Shri. P. Sudeep	*Chief Manager*
Shri. M. A. K. H. Rasheed	*Manger (Finance)*
Shri. M. Philip	*Internal Auditor*
(on deputation from AG's office) (till August 2015)	
Smt. Mariamma Mathew	*Internal Auditor*
(on deputation from AG's office) (since August 2015)	
Smt. K. V. Padmaja Kumari	*Joint Manager*
Shri. T. D. Bashardeen	*Co-rdinator (Gr. 5)*
Shri. R. Haridas	*Deputy Manager*
Smt. K. Viswabharathy	*Deputy Manager*
(on long leave) (till November 2015)	
Shri. C. M. Youseph	*Deputy Manager*
	(on deputation)
Shri. M. Madhu Madhavan	*Deputy Manager*
Smt. R. Jaya	*Deputy Manager*
Smt. G. Lavanya	*Deputy Manager*
Shri. S. Krishnakumar	*Assistant Manager*
Smt. Femi R. Sreenivasan	*Executive*
Shri. P. Rajesh	*Executive*
Smt. P. C. Rasi	*Executive*
Shri. N. Jayapal	*Executive*
Smt. Smitha Vijayan	*Junior Executive*
Smt. K. S. Anju	*Junior Executive*
Shri. P. H. Shinaj	*Junior Executive*
Smt. D. Shimla	*Junior Executive*
Smt. V. Sajitha Kumari	*Junior Executive*
Smt. Seeja Vijayan	*Junior Executive*
Smt. Indu Janardanan	*Scientif Asst. (Gr. B)*
Smt. P. Prabhavathy	*Co-ordinator (Gr.4)*
	(till November 2015)
Smt. N. J. Saramma	*Senior Executive*
	(till December 2015)
Smt. K. Prasanna	*Senior Executive*
Shri. M. Parameswaran Nair	*Technician (Gr. E)*
Shri. N. Unni	*MTS*
Shri. P. S. Anoop	*MTS*
Smt. P. S. Divya	*MTS*
Shri. B. Rajendran Nair	*MTS*
Shri. P. Saseendran Nair	*MTS*
Shri P. Rajendra Babu	*MTS*
Shri. K. Sudeerkumar	*MTS (Driver)*

12.8 Retirements / Resignation

Dr. R. Ajayakumar Varma
Scientist-G & Head
Natural Resources and Environmental Managemnet
Superannuated on
29th February 2016

Dr. C. P. Rajendran
Scientist G
Crustal Processes
Superannuated on
31st May 2015

Dr. K. Raju
Scientist-E
Coastal Processes
Superannuated on
31st October 2015

Dr. Archana M. Nair
Scientist-C
Natural Resources and Environmental Management
Relieved on
08th June 2015

Smt. K. Viswabharathi
Deputy Manager
Finance & Accounts
Superannuated on
23rd November 2015

Smt. P. Prabhavathy
Co-ordinator Gr. 4
Personal & General - Administration
Superannuated on
23rd November 2015

Smt. N. J. Saramma
Senior Executive
Superannuated on
31st December 2015

Shri. P. M. Gopakumar
Junior Executive
Library
Superannuated on
30th November 2015

12.9 New Appointments

Dr. E. A. Resmi
Scientist C
Atmospheric Processes

Shri. Badimela Upendra
Scientist B
Natural Resources and Environmental Management

Shri. Dharmadas Jash
Scientist B
Atmospheric Processes

Shri. Thatikonda Suresh Kumar
Scientist B
Crustal Processes

Shri. Arka Roy
Scientist B
Crustal Processes

Shri. Prasenjit Das
Scientist B
Natural Resources and Environmental Management

Shri. Rajat Kumar Sharma
Scientist B
Natural Resources and Environmental Management

Manoj & Sajeev
CHARTERED ACCOUNTANTS

UTILISATION CERTIFICATE

This is to certify that The National Centre For Earth Science Studies (NCESS), Akkulam, Thiruvananthapuram has received total grant of Rs. 24,91,22,928/- (Rupees Twenty Four Crore Ninety One Lakh Twenty Two Thousand Nine Hundred and Twenty Eight Only) from The Ministry of Earth Sciences, Government of India for the financial year 2015-16 as detailed below:

A. GRANT-IN-AID RECEIVED FROM MINISTRY OF EARTH SCIENCES, GOVERNMENT OF INDIA

Sl No.	Order No. & Date	R&D Programmes ₹	Operations & Maintenance ₹	Major Works ₹	Total ₹
1.	MoES/41/CESS/2012-PC-11 DT: 19.06.2015		8,00,00,000.00		8,00,00,000.00
2.	MoES/P.O (NCESS)/3/2015 DT: 16/12/2015		2,00,00,000.00		2,00,00,000.00
3.	MoES/P.O (NCESS)/3/2015 DT: 08/02/2016		2,00,00,000.00		2,00,00,000.00
4.	MoES/P.O (NCESS)/2/2015 DT: 29/03/2016			1,91,22,928.00	1,91,22,928.00
5.	MoES/P.O (NCESS)/3/2015 DT: 16/09/2015	3,00,00,000.00			3,00,00,000.00
6.	MoES/P.O (NCESS)/3/2015 DT: 08/02/2016	8,00,00,000.00			8,00,00,000.00
	TOTAL GRANT RECEIVED	11,00,00,000.00	12,00,00,000.00	1,91,22,928.00	24,91,22,928.00
7.	Interest from Bank				27,86,304.00
	GRAND TOTAL (A)	**11,00,00,000.00**	**12,00,00,000.00**	**1,91,22,928.00**	**25,19,09,232.00**

(Rupees Twenty Five Crore Nineteen Lakh Nine Thousand Two Hundred and Thirty Two Only)

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

T C 9/1444 (2), TRRAW D 188, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

	R & D Programmes ₹	Operations & Maintenance ₹	Total ₹
B. Revenue Expenses	2,96,82,293.00	11,65,21,447.00	14,62,03,740.00
C. Library Books & Others		2,48,483.00	2,48,483.00
D. Capital Expenditure	5,47,45,982.00		5,47,45,982.00
GRAND TOTAL (B+C+D)	**8,44,28,275.00**	**11,67,69,930.00**	**20,11,98,205.00**

(Rupees Twenty Crore Eleven Lakh Ninety Eight Thousand Two Hundred and Five Only)

It is further certified that the above sum has been utilized during the period for the purpose of which it is received.

For National Centre for Earth Science Studies
Akkulam, Thiruvananthapuram

Manager (F&A) Chief Manager Director

Manoj & Sajeev
Chartered Accountants
FRN. 008024 S

Sajeev .R, FCA
(Partner)
M.No. 206626

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * TRIVANDRUM

Thiruvananthapuram
Dated: 09.09.2016

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

AUDITORS' REPORT

To,

The Director
National Centre for Earth Science Studies,
Thiruvananthapuram

REPORT ON THE FINANCIAL STATEMENTS

We have audited the accompanying financial statements of **National Centre for Earth Science Studies, Thiruvananthapuram** which comprise the Balance Sheet as at 31st March 2016, and the Income and Expenditure Account for the year ended, and a summary of significant accounting policies and other explanatory information.

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.

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.

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

T C 9/1444 (2), TRRAW D 188, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

Manoj & Sajeev
CHARTERED ACCOUNTANTS

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

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 2016;

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

For Manoj & Sajeev
Chartered Accountants
FRN. 008024 S

R. Sajeev, FCA
(Partner)
M.No. 206626

Place : Trivandrum
Date : 09.09.2016

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

T C 9/1444 (2), TRRAW D 18B, Moolayil Lane, Sasthamangalam, Trivandrum - 695 010
Tel: 0471 2721444, 91 90615 77668, E-mail: manojandsajeev@gmail.com

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India

Balance Sheet as on 31st March, 2016

Particulars	Sch No.	2015-16	2014-15
		Rs.	Rs.
Liabilities			
Capital Reserve	1	12,87,55,659.00	10,64,56,544.00
General Reserve	2	(2,06,66,195.00)	(1,91,56,822.00)
Unspent Balance GOI - MoES	3	13,67,54,716.00	8,58,79,874.00
Unspent Balance of Projects	4	8,07,13,948.00	7,17,50,149.00
Corpus Fund	5	8,81,10,152.00	7,16,42,995.00
Current Liabilities	6	38,42,520.00	28,03,204.00
Total		**41,75,10,800.00**	**31,93,75,944.00**
Assets			
Fixed Assets	7	12,87,55,659.00	10,64,56,544.00
Current Assets, Loans & Advances	8	28,87,55,141.00	21,29,19,400.00
Total		**41,75,10,800.00**	**31,93,75,944.00**
Notes forming part of Accounts	15		

AUDITOR'S REPORT
As per our report of even date attached

Manoj & Sajeev
Chartered Accountants
(FRN. 008024 S)

R. Sajeev, FCA
Partner
M No. 206626

Thiruvananthapuram
09.09.2016

MANOJ & SAJEEV CHARTERED ACCOUNTANTS TRIVANDRUM

Manager (F&A) **Chief Manager** **Director**

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India

Income & Expenditure for the year ended 31st March, 2016

Particulars		Sch No.	2015-16	2014-15
			Rs.	Rs.
Income				
Operation and Maintenance Grant				
Grant Received	12,00,00,000.00	9	11,97,51,517.00	9,43,46,695.00
Less: Capital Expenditure	2,48,483.00			
Interest from Bank		10	1,30,974.00	5,33,027.00
Other Income				10,31,778.00
Depreciation Written Back			3,38,38,919.00	2,11,19,207.00
Total - A			**15,37,21,410.00**	**11,70,30,707.00**
Expenditure				
Staff Salary & Benefits		11	9,68,40,406.00	9,49,59,211.00
Other Institutional Expenses		12	1,96,81,041.00	1,77,21,267.00
Total of Other Institutional Expenses	1,99,29,524.00			
Less: Capital Expenditure	2,48,483.00			
Depreciation			3,38,38,919.00	2,11,19,207.00
Total - B			**15,03,60,366.00**	**13,37,99,685.00**
Excess of Income over expenditure (A-B)			33,61,044.00	(1,67,68,978.00)
Excess of Income over expenditure of Prev. Year			(37,02,613.00)	1,30,66,365.00
Total			**(3,41,569.00)**	**(37,02,613.00)**
Notes forming part of Accounts		15		

AUDITOR'S REPORT
As per our report of even date attached

Manoj & Sajeev
Chartered Accountants
(FRN. 008024 S)

R. Sajeev, FCA
Partner
M No. 206626

Thiruvananthapuram
09.09.2016

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Manager (F&A) **Chief Manager** **Director**

National Centre for Earth Science Studies
Ministry of Earth Science, Government of India
Receipts & Payments Account for the year ended 31st March, 2016

Receipts	Amount	Amount	Payments	Amount	Amount
Opening Balance:			**Staff Salary & Benefits:**		
State Bank of Travancore	7,25,01,050.00		Staff Salary	7,11,79,861.00	
SBT-E-tax	4,34,136.00	7,29,35,186.00	Bonus & Festival Allowance	1,24,344.00	
Previous Year Advances			Contribution to EPF/EPFIF/EPS	52,55,389.00	
Advance Payments for purchases	12,70,351.00		LIC GG Scheme for Staff	1,50,00,000.00	
Advance Payments to Staff	1,06,150.00		Children Education Allowance	4,18,998.00	
EPF to Staff	10.00		EPF/IF Administrative Charges	4,10,794.00	
Service Tax Receivable	63,036.00		Previous Year Salary	23,66,526.00	
TDS Receivable	10,31,778.00		Medical Expenses Reimbursement	3,37,047.00	
Margin Money On LC	1,21,47,000.00	1,46,18,325.00	LTC	10,45,533.00	
			Leave Salary & Pension Contribution	7,16,282.00	
			NPS	15,618.00	9,68,70,392.00
Grant Received during the year:					
Operations & Maintenance	12,00,00,000.00		**Other Institutional Expenses:**		
R&D Programes (Project A To D)	11,00,00,000.00		Advertisement	95,935.00	
a) Major Works (Project E)	1,91,22,928.00	24,91,22,928.00	Audit Fee/ legal Charges	1,49,685.00	
			Electricity Charges	23,12,408.00	
Other Receipts:			Water Charges	45,505.00	
Interest from Bank	27,86,304.00	27,86,304.00	Hospitality Expenses	1,57,662.00	
			Printing & Stationery	3,95,869.00	
Other Receipts- Payable:			Postage & Communication	5,76,545.00	
TDS- Staff	3,32,500.00		Repairs & Maintenance	10,06,083.00	
EPF Staff	6,74,668.00		Consumables	4,42,224.00	
Subscription to NCESS Recreation club	1,475.00		Remuneration to Project Staff	24,99,552.00	
License Fee payable	28,356.00	10,36,999.00	Books & Journals	26,059.00	
			Furniture	58,062.00	
Transfer From CESS:			Computer System & Accessories	91,962.00	
Imprest RC			Electrical /UPS Installations	4,800.00	
Leave Salary Receivable	25,583.00	25,583.00	Office Equipments	67,600.00	
			Sitting Fee/Honor - Visiting Expenses	68,000.00	
			Travelling Expences	10,03,611.00	
			Vehicle Hire Charges	5,38,396.00	
			Research Council Expenses/ Honorarium	1,62,087.00	
			Contingency	51,14,061.00	
			Taxes & Insurance - Vehicles	21,942.00	
			Petrol, Diesel & Oil	1,51,936.00	
			Rent - Director	1,19,275.00	
			Seminar/Conference	48,50,904.00	
			Advance Payments	86,59,323.00	
			EMD	12,30,500.00	
			Security Deposits	10,000.00	2,98,59,986.00
			Payment against R & D Funds:		
			A. Crustal Processes		

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Equipments	40,04,113.00	
Manpower	22,33,111.00	
Travel & Field DA	8,93,561.00	
Consumables	25,39,085.00	
Vehicle Hire Charges	3,68,247.00	
Repairs & Maintenance	1,87,375.00	
Contingency	12,47,957.00	
Margin Money on LC	60,16,000.00	
Advance Payments	52,48,751.00	2,27,38,200.00
B. Coastal Processes		
Capital/Equipments/Softwares	1,81,60,109.00	
Manpower	7,66,642.00	
Travel	33,23,596.00	
Consumables	19,70,928.00	
Boat Hire Charges	1,54,000.00	
Vehicle Hire Charges	3,53,169.00	
Repairs, Maintenance, Amc, Insurance	10,20,875.00	
Contingency	21,63,561.00	
Margin Money on LC	1,54,77,000.00	
Advance Payments	2,45,37,999.00	6,79,27,879.00
C. Atmospheric Processes		
Equipments/Softwares	37,05,186.00	
Manpower	6,89,319.00	
Travelling Expenses	2,12,838.00	
Consumables	1,05,527.00	
Vehicle Hire Charges	59,887.00	
Repairs & Maintenance	6,56,138.00	
Contingency	7,04,028.00	
Advance Payments	11,39,735.00	72,72,658.00
D. Natural Resources & Environmental Management		
Equipments	2,88,76,574.00	
Manpower	7,06,949.00	
Travel	8,83,920.00	
Consumables	30,73,005.00	
Vehicle Hire Charges	3,03,144.00	
Repairs & Maintenance	17,68,344.00	
Contingency	32,97,087.00	
Margin Money on LC	1,27,04,000.00	
Advance Payments	1,69,12,495.00	6,85,25,518.00
Other Payments/ Receivables		
Deposit for House Rent	57,000.00	
Festival Advance	27,000.00	
Other Advance	1,36,347.00	
Rolling Contingent Advance	56,549.00	
Tour Advance	4,63,502.00	

MANOJ & SAJEEV TRIVANDRUM CHARTERED ACCOUNTANTS

			TDS Receivable	10,31,778.00	
			IT Staff	3,95,500.00	
			IT Contractors	37,636.00	22,05,312.00
			Closing Balance		
			SBT-E-tax	1,000.00	
			State Bank of Travancore	4,51,24,380.00	4,51,25,380.00
Total	**34,05,25,325.00**	**34,05,25,325.00**	**Total**	**34,05,25,325.00**	**34,05,25,325.00**

Manager (F&A) **Chief Manager** **Director**

For **Manoj & Sajeev**
Chartered Accountants
(FRN. 008024 S)

R. Sajeev, FCA
Partner
M No. 206626

MANOJ & SAJEEV ★ CHARTERED ACCOUNTANTS ★ TRIVANDRUM

Thiruvananthapuram
09.09.2016

Schedule 1 - Capital Reserve

Particulars		As at 31.03.2016	As at 31.03.2015
		Rs.	Rs.
Opening Balance		10,64,56,544.00	7,98,02,697.00
Add: Addition to Capital Asset		5,50,73,979.00	3,04,29,419.00
Add: Transfer from External Projects		10,64,055.00	1,73,83,592.00
Less: Depreciation		3,38,38,919.00	2,11,19,207.00
Less: Loss on Sale of Fixed Assets		-	39,957.00
Closing balance		**12,87,55,659.00**	**10,64,56,544.00**

Schedule 2 - General Reserve

Particulars		As at 31.03.2016	As at 31.03.2015
		Rs.	Rs.
Plan fund from GOK			
Opening Balance		74,85,131.00	1,72,52,325.00
Add: Receipts for R&D from operations and maintenance fund			5,38,500.00
Less: Plan Revenue Expenditure for the year	Note 7(a)	12,74,597.00	5,88,753.00
Less: Plan Capital Expenditure for the year	Note 7(b)	2,43,329.00	1,31,58,244.00
Add: Interest Received and other income			3,50,836.00
Add: Previous Year Adjustments			30,90,467.00
Closing Balance		**59,67,205.00**	**74,85,131.00**
Non Plan Fund from GOK			
Opening Balance		(2,66,41,953.00)	(2,68,78,796.00)
Add: Receipts during the year	Note 7(c)	28,438.00	2,64,008.00
Less: Non Plan Revenue Expenditure for the year	Note 7(d)	19,885.00	27,165.00
Closing Balance		**(2,66,33,400.00)**	**(2,66,41,953.00)**
Total		**(2,06,66,195.00)**	**(1,91,56,822.00)**

Schedule 3 - Unspent Balance GOI - MoES

Particulars	Sch.No		As at 31.03.2016	As at 31.03.2015
Operation and Maintenance Fund			Rs.	Rs.
Opening Balance			(37,02,613.00)	1,30,66,365.00
Add: Grant Received during the year	9		12,00,00,000.00	10,15,34,000.00
Less: Revenue Expenditure	11 & 12		11,65,21,447.00	10,95,90,011.00
Less: Capital Expenditure	11 & 12		2,48,483.00	71,87,305.00
Less: Previous Year Adjustments			-	30,90,467.00
Add: Income from Interest & Other Income	10		1,30,974.00	15,64,805.00
Closing Unspent Balance of Grant			**(3,41,569.00)**	**(37,02,613.00)**
Research Program Fund				
Opening Balance			8,95,82,487.00	
Add: Grant Received during the year			11,00,00,000.00	11,00,00,000.00
Less: Revenue Expenditure	13		2,96,82,293.00	1,04,02,729.00
Less: Capital Expenditure	14	5,47,45,982.00		1,00,43,913.00
Less: Income from Sale of Assets		1,63,815.00	5,45,82,167.00	
Add: Income from Interest & Other Income			26,55,330.00	29,129.00
Closing Unspent Balance of Grant			**11,79,73,357.00**	**8,95,82,487.00**

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

Major Works Fund				
Grant Received during the year			1,91,22,928.00	-
Closing Unspent Balance of Grant			**1,91,22,928.00**	-
Closing Unspent Balance			**13,67,54,716.00**	**8,58,79,874.00**

Schedule 4 - Unspent Balance of Projects

Particulars	Sub Sch No.		As at 31.03.2016	As at 31.03.2015
			Rs.	Rs.
Research Projects	A		1,06,15,059.00	1,24,85,037.00
Divisional Core Research Projects	A		87,82,219.00	92,07,252.00
Service Component Projects	A		72,74,439.00	54,41,261.00
Consultancy Projects	B		5,40,42,231.00	4,46,16,599.00
Total			**8,07,13,948.00**	**7,17,50,149.00**

Schedule 5 - Corpus Fund

Particulars		As at 31.03.2016	As at 31.03.2015
		Rs.	Rs.
Opening Balance		7,16,42,995.00	5,84,21,083.00
Add: Interest Received Fixed Deposit		65,82,547.00	52,91,598.00
Add: Income from Consultancy Projects		14,43,520.00	22,76,049.00
Add: Overhead Charges		44,95,592.00	6,54,022.00
Add: Other Receipts		39,45,498.00	50,00,243.00
Closing Unspent		**8,81,10,152.00**	**7,16,42,995.00**

Schedule 6 - Current Liabilities

Particulars		As at 31.03.2016	As at 31.03.2015
		Rs.	Rs.
Common Fund		35,668.00	35,668.00
EMD		17,64,000.00	12,32,500.00
License Fee Payable		28,356.00	
Tax Deducted at Source Payable Contractors		6,90,324.00	37,636.00
Tax Deducted at Source Payable Staff		3,32,500.00	3,95,500.00
Security Deposit		3,15,519.00	1,01,900.00
EPF Staff		6,74,678.00	-
Subscription to NCESS Rec- Club		1,475.00	
Discharge of Gratuity Insurance		-	10,00,000.00
Total		**38,42,520.00**	**28,03,204.00**

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * TRIVANDRUM

Schedule 7- Fixed Assets

Sl No.	Particulars	Gross Block						Depreciation				Net Block	
			Addition		Deletion / Adjustments	As at March 31, 2015	Rate %	As at April 01, 2014	Provided during the year	Deletions Adjustments	As at March 31, 2016	As at March 31, 2016	As at March 31, 2015
		As at April 01, 2014	More than 180 days	Less than 180 days									
		Rs.	Rs.	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
1	Buildings	2,76,28,823.00	-	-	-	2,76,28,823.00	10	30,87,348.00	24,54,147.00	-	55,41,495.00	2,20,87,328.00	2,45,41,475.00
2	Library Books	1,34,41,694.00	4,620.00	3,64,568.00	-	1,38,10,882.00	25	36,99,306.00	24,82,323.00	-	61,81,629.00	76,29,253.00	97,42,388.00
3	Computers	45,11,233.00	28,60,127.00	1,69,88,772.00	18,71,986.00	2,24,88,146.00	60	29,36,947.00	76,96,313.00	17,70,376.00	88,62,884.00	1,36,25,262.00	15,74,286.00
4	Furnitures & Fixtures	42,61,531.00	8,243.00	58,062.00	1,03,372.00	42,24,464.00	10	5,62,763.00	3,72,886.00	96,192.00	8,39,457.00	33,85,007.00	36,98,768.00
5	Laboratory Equipments	6,19,16,033.00	32,00,168.00	1,71,56,870.00	15,87,821.00	8,06,85,250.00	15	98,13,168.00	95,75,301.00	15,41,696.00	1,78,46,773.00	6,28,38,477.00	5,21,02,865.00
6	Office Equipments	24,83,933.00	68,900.00	79,849.00	69,865.00	25,62,817.00	15	4,49,136.00	3,20,208.00	60,965.00	7,08,379.00	18,54,438.00	20,34,797.00
7	Plant & Machinery	68,923.00	-	-	-	68,923.00	15	13,252.00	8,351.00	-	21,603.00	47,320.00	55,671.00
8	Electrical Installations	82,30,042.00	60,315.00	2,98,329.00	-	85,88,686.00	15	15,42,830.00	10,34,503.00	-	25,77,333.00	60,11,353.00	66,87,212.00
9	Vehicles	13,76,408.00	-	-	-	13,76,408.00	15	2,64,619.00	1,66,768.00	-	4,31,387.00	9,45,021.00	11,11,789.00
10	Research Boats	6,074.00	-	-	-	6,074.00	20	1,572.00	900.00	-	2,472.00	3,602.00	4,502.00
11	Softwares	82,93,002.00	74,65,454.00	76,87,572.00	-	2,34,46,028.00	60	33,90,211.00	97,27,219.00	-	1,31,17,430.00	1,03,28,598.00	49,02,791.00
	Total	**13,22,17,696.00**	**1,36,67,827.00**	**4,26,34,022.00**	**36,33,044.00**	**18,48,86,501.00**		**2,57,61,152.00**	**3,38,38,919.00**	**34,69,229.00**	**5,61,30,842.00**	**12,87,55,659.00**	**10,64,56,544.00**

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

Schedule 8 - Current Assets, Loans & Advances

Particulars		As at 31.03.2016	As at 31.03.2015
		Rs.	Rs.
A. Current Assets			
1. Stock - in - hand		10,30,098.00	10,10,975.00
2. Cash & Bank Balance			
Cash in Hand	-		
Bank Balance -MoES Fund			
Bank Balance - Consultancy Projects (6493)	2,75,53,710.00		
SBT Akkulam -External (7168)	2,50,20,778.00		
SBT- NCESS - (7168)	4,90,15,577.00		
SBT - Corpus Fund SB Account	728.00		
Treasury SB Accounts (GOK)	11,000.00		
NCESS E-TAX SBT Akkulam	6,91,324.00		
Term Deposits	7,63,10,291.00		
Imprest Balances	32,705.00	17,86,36,113.00	17,51,31,798.00
Total A (1+2)		**17,96,66,211.00**	**17,61,42,773.00**
B. Loans, Advances & Other Assets			
1.Deposits			
Deposit with EPF	55,80,486.00		
Deposit with KSEB	4,33,020.00		
Deposit for House Rent	57,000.00		
Deposit with Others	12,300.00	60,82,806.00	60,64,091.00
2. Advances & other amount recoverable in cash or in kind or for value to be recovered			
Tour Advance	4,63,502.00		
Other Advance	1,26,347.00		
Festival Advance	27,000.00		
Rolling Contingent Advance	56,549.00		
Margin Money on LC NCESS	3,41,97,000.00		
Advance to staff - External/Consultancy Projects	1,84,890.00		
Advance to Suppliers - External Projects	59,596.00		
Advance to Suppliers - NCESS	5,67,57,130.00		
LC - Projects	2,94,000.00		
Leave Salary Receivable	68,840.00		
Salary Receivable	6,40,079.00		
TDS Receivable	99,01,066.00		
Service Tax Interest Receivable	10,163.00		
Service Tax Receivable	2,19,962.00	10,30,06,124.00	3,07,12,536.00
Total B (1+2)		**10,90,88,930.00**	**3,67,76,627.00**
Total (A+B)		**28,87,55,141.00**	**21,29,19,400.00**

MANOJ & SAJEEV TRIVANDRUM CHARTERED ACCOUNTANTS

Schedule 9 - Grant Received

Particulars	As at 31.03.2016	As at 31.03.2015
Operation and Maintenance Fund	**Rs.**	**Rs.**
Add: Grant Received During the Year	12,00,00,000.00	10,15,34,000.00
Total	**12,00,00,000.00**	**10,15,34,000.00**

Schedule 10 - Interest & Other Income

Particulars	As at 31.03.2016	As at 31.03.2015
	Rs.	**Rs.**
Receipt From Other Projects		4,79,453.00
Miscellaneous Receipts		5,52,325.00
Sale of Tender Forms		-
Application Fee (Right to Information Act)		-
Interest From Bank	1,30,974.00	5,33,027.00
Total	**1,30,974.00**	**15,64,805.00**

Schedule 11 - Staff Salary & Benefits

Particulars	As at 31.03.2016	As at 31.03.2015
	Rs.	**Rs.**
Bonus & Festival Allowance	1,24,344.00	1,62,338.00
Contribution to NPS	15,618.00	
Contribution to EPF	52,05,589.00	53,55,475.00
Children Education Allowance	4,18,998.00	3,52,136.00
Contribution to EPF If	49,800.00	44,029.00
Leave Salary & Pension Contribution	7,16,282.00	4,98,587.00
Leave Travel Concession	10,45,533.00	4,39,924.00
IF Administration Charges	2,489.00	892.00
Incentives to Staff		10,000.00
LIC GG Scheme for Staff	1,50,00,000.00	1,00,72,926.00
Medical Allowance		72,181.00
Medical Expenses Reimbursement	3,37,047.00	2,02,414.00
EPF Administrative Charges	4,08,305.00	5,25,665.00
Previous Year Salary	23,66,526.00	37,22,578.00
Professional Update Allowance		27,774.00
Salary Director	8,92,806.00	21,28,435.00
Salaries Others	7,02,57,069.00	7,13,43,857.00
Total	**9,68,40,406.00**	**9,49,59,211.00**

MANOJ & SAJEEV * CHARTERED ACCOUNTANTS * THIVANDRUM

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 01/04/2015 to 31/03/2016

	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							
1	COMAPS4	7,84,029.00	53,01,581.00		53,01,581.00	60,85,610.00	43,31,413.00	17,54,197.00
2	CSIR24	37,158.00	1,42,833.00	17,185.00	1,25,648.00	1,62,806.00	1,62,806.00	-
3	DBT1	51,216.00	-	-	-	51,216.00	-	51,216.00
4	DMD1	22,86,765.00	90,771.00		90,771.00	23,77,536.00	-	23,77,536.00
5	DST79	958.00	8,00,000.00		8,00,000.00	8,00,958.00	7,86,420.00	14,538.00
6	DST80	30,53,976.00	1,66,111.00		1,66,111.00	32,20,087.00	28,86,367.00	3,33,720.00
7	DST82	40,742.00	4,29,232.00	-	4,29,232.00	4,69,974.00	41,557.00	4,28,417.00
8	DST83	-	3,50,000.00	-	3,50,000.00	3,50,000.00	2,06,691.00	1,43,309.00
9	FC	1.00	-	-	-	1.00	-	1.00
10	KESS1	1,30,290.00	-	893.00	- 893.00	1,29,397.00	1,29,397.00	-
11	KSCS16	16.00	-	16.00	- 16.00	-	-	-
12	KSCS17	12,508.00	-	12,508.00	- 12,508.00	-	-	-
13	KSCS19	6,85,018.00	-	6,85,018.00	- 6,85,018.00	-	-	-
14	KSCS20	3,08,924.00	-	3,08,924.00	- 3,08,924.00	-		-
15	KSCS21	37,37,001.00	-	36,15,133.00	- 36,15,133.00	1,21,868.00	1,21,868.00	-
16	KSCS24	2,81,662.00	-	2,81,662.00	- 2,81,662.00	-	-	-
17	KSCS26	4,711.00	-	2,197.00	- 2,197.00	2,514.00	2,514.00	-
18	KSCS28	4,03,330.00	7,095.00	-	7,095.00	4,10,425.00	-	4,10,425.00
19	KSCS29	- 9,15,924.00	50,34,674.00	-	50,34,674.00	41,18,750.00	17,49,252.00	23,69,498.00
20	KSCS30	37,698.00	2,15,051.00	-	2,15,051.00	2,52,749.00	2,15,295.00	37,454.00
21	KSCS31	9,36,200.00	15,303.00	-	15,303.00	9,51,503.00	5,25,227.00	4,26,276.00
22	KSCS32	-	2,31,479.00		2,31,479.00	2,31,479.00	2,28,817.00	2,662.00
23	KSCS33	-	6,65,268.00	-	6,65,268.00	6,65,268.00	85,807.00	5,79,461.00
24	KSCS34	-	2,31,971.00	-	2,31,971.00	2,31,971.00	74,868.00	1,57,103.00
25	MAPAN	3,22,950.00	6,405.00	-	6,405.00	3,29,355.00	2,55,359.00	73,996.00
26	MOES10	- 3,70,511.00	20,63,919.00	-	20,63,919.00	16,93,408.00	11,49,554.00	5,43,854.00
27	MOES11	4,23,279.00	4,31,758.00	-	4,31,758.00	8,55,037.00	5,31,082.00	3,23,955.00
28	MOES12	3,15,439.00	2,56,879.00	-	2,56,879.00	5,72,318.00	2,64,280.00	3,08,038.00
29	MOES9	26,371.00	22,86,656.00	-	22,86,656.00	23,13,027.00	21,14,941.00	1,98,086.00
30	NDMA1	- 1,45,806.00	138.00	-	138.00	- 1,45,668.00	10,651.00	- 1,56,319.00
31	UGC4	9,474.00	-	-	-	9,474.00	-	9,474.00
32	UGC5	17,562.00	2,96,581.00	-	2,96,581.00	3,14,143.00	3,13,630.00	513.00
33	UGC6	10,000.00	2,33,400.00	-	2,33,400.00	2,43,400.00	15,751.00	2,27,649.00
	Total	**1,24,85,037.00**	**1,92,57,105.00**	**49,23,536.00**	**1,43,33,569.00**	**2,68,18,606.00**	**1,62,03,547.00**	**1,06,15,059.00**

MANOJ & SAJEEV ★ TRIVANDRUM ★ CHARTERED ACCOUNTANTS

	Project	Opening Balance Rs.	Amount Received Rs.	Amount Refunded Rs.	Net Amount Received Rs.	Net Amount Available Rs.	Amount Utilised Rs.	Closing Balance Rs.
	Divisional Core Research Projects							
1	ENDF	8,60,264.00	53,276.00	-	53,276.00	9,13,540.00	-	9,13,540.00
2	GEOMAT	43,80,411.00	-	-	-	43,80,411.00	1,19,526.00	42,60,885.00
3	MACIS	39,66,577.00	13,20,000.00	-	13,20,000.00	52,86,577.00	16,78,783.00	36,07,794.00
	Total	**92,07,252.00**	**13,73,276.00**	-	**13,73,276.00**	**1,05,80,528.00**	**17,98,309.00**	**87,82,219.00**
	Service Component Projects							
1	AAS	23,398.00	74,263.00	-	74,263.00	97,661.00	96,764.00	897.00
2	AGRI4	15,542.00	-	15,542.00	- 15,542.00	-	-	-
3	CPT3	3,61,632.00	2,29,895.00	-	2,29,895.00	5,91,527.00	4,65,759.00	1,25,768.00
4	DECC2	18,79,804.00	15,75,294.00	-	15,75,294.00	34,55,098.00	9,44,106.00	25,10,992.00
5	HVRA	1,71,401.00	-	-	-	1,71,401.00	154.00	1,71,247.00
6	KSUDP2	35,559.00	46,000.00	-	46,000.00	81,559.00	13,213.00	68,346.00
7	PSA	17,407.00	-	-	-	17,407.00	17,000.00	407.00
8	RBM1	88,823.00	-	-	-	88,823.00	88,823.00	-
9	RSA3	1,27,453.00	-	-	-	1,27,453.00	-	1,27,453.00
10	SDMA 1	-	21,83,406.00	-	21,83,406.00	21,83,406.00	3,55,621.00	18,27,785.00
11	TKH1	1,34,391.00	-	-	-	1,34,391.00	-	1,34,391.00
12	UTL6	25,05,585.00	-	-	-	25,05,585.00	2,25,685.00	22,79,900.00
13	XRF	80,266.00	4,56,987.00	-	4,56,987.00	5,37,253.00	5,10,000.00	27,253.00
	Total	**54,41,261.00**	**45,65,845.00**	**15,542.00**	**45,50,303.00**	**99,91,564.00**	**27,17,125.00**	**72,74,439.00**
	Grand Total	**2,71,33,550.00**	**2,51,96,226.00**	**49,39,078.00**	**2,02,57,148.00**	**4,73,90,698.00**	**2,07,18,981.00**	**2,66,71,717.00**

MANOJ & SAJEEV * TRIVANDRUM * CHARTERED ACCOUNTANTS

Sub Schedule B

Statement of Unspent Balance of Consultancy Projects for the year 2015-16

	Project	Opening Balance Rs.	Consultancy Fee Received Rs.	Consultancy Expenses Rs.	Incentive Money to Staff Rs.	Transferred to Corpus Fund Rs.	Transferred to CESS Fund Rs.	Transferred to Common Fund Rs.	Total Expense Rs.	Closing Balance Rs.
1	CONY	-	6,67,270.00	-	-	6,67,270.00	-	-	6,67,270.00	-
2	CONY196	13,78,327.00	-	-	-	-	-	-	-	13,78,327.00
3	CONY201	14,89,911.00	-	-	-	-	-	-	-	14,89,911.00
4	CONY281	5,76,159.00	-	-	-	-	-	-	-	5,76,159.00
5	CONY293	39,204.00	-	-	-	-	-	-	-	39,204.00
6	CONY308	25,500.00	-	-	-	-	-	-	-	25,500.00
7	CONY309	2,70,933.00	-	-	-	-	-	-	-	2,70,933.00
8	CONY312	1,13,604.00	-	-	-	-	-	-	-	1,13,604.00
9	CONY315	1,86,145.00	-	-	-	-	-	-	-	1,86,145.00
10	CONY317	7,62,858.00	-	-	-	-	-	-	-	7,62,858.00
11	CONY329	8,41,832.00	-	-	-	-	-	-	-	8,41,832.00
12	CONY330	6,08,916.00	-	-	-	-	-	-	-	6,08,916.00
13	CONY334	18,06,278.00	-	-	-	-	-	-	-	18,06,278.00
14	CONY343	9,00,955.00	-	-	-	-	-	-	-	9,00,955.00
15	CONY344	11,89,994.00	-	-	-	-	-	-	-	11,89,994.00
16	CONY345	3,48,227.00	-	-	-	-	-	-	-	3,48,227.00
17	CONY346	2,91,911.00	-	-	-	-	-	-	-	2,91,911.00
18	CONY349	5,53,429.00	-	-	-	-	-	-	-	5,53,429.00
19	CONY355	2,64,732.00	-	-	-	-	-	-	-	2,64,732.00
20	CONY356	6,69,288.00	-	-	-	-	-	-	-	6,69,288.00
21	CONY360	2,20,206.00	-	-	-	-	-	-	-	2,20,206.00
22	CONY361	56,06,823.00	86,50,877.00	19,78,479.00	-	-	-	-	19,78,479.00	1,22,79,218.00
23	CONY363	3,87,953.00	-	-	-	-	-	-	-	3,87,953.00
24	CONY365	2,64,559.00	-	-	-	-	-	-	-	2,64,559.00
25	CONY369	12,89,931.00	-	613.00	-	-	-	-	613.00	12,89,318.00
26	CONY370	10,57,072.00	-	-	-	-	-	-	-	10,57,072.00
27	CONY371	2,59,535.00	-	-	-	-	-	-	-	2,59,536.00
28	CONY372	2,39,635.00	-	-	-	-	-	-	-	2,39,635.00
29	CONY374	2,10,000.00	-	-	-	-	-	-	-	2,10,000.00
30	CONY375	93,500.00	-	-	-	-	-	-	-	93,500.00
31	CONY378	91,00,942.00	26,20,087.00	5,09,256.00	-	-	-	-	5,09,256.00	1,12,11,773.00
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	[illegible]	-	-	-	-	-	-	-	2,80,099.00
38	CONY386	[illegible]	-	-	-	-	-	-	-	11,88,390.00
39	CONY391	7,13,993.00	-	50,000.00	-	-	-	-	50,000.00	6,63,993.00
40	CONY392	12,99,994.00	-	-	-	-	-	-	-	12,99,994.00
41	CONY393	1,74,223.00	2,17,500.00	51,750.00	-	-	-	-	51,750.00	3,39,973.00

	Project	Opening Balance Rs.	Consultancy Fee Received Rs.	Consultancy Expenses Rs.	Incentive Money to Staff Rs.	Transferred to Corpus Fund Rs.	Transferred to CESS Fund Rs.	Transferred to Common Fund Rs.	Total Expense Rs.	Closing Balance Rs.
42	CONY400	2,95,593.00	-	1,90,450.00	-	1,05,143.00	-	-	2,95,593.00	-
43	CONY401	12,90,525.00	-	1,00,000.00	-	-	-	-	1,00,000.00	11,90,525.00
44	CONY402	7,13,060.00	-	-	-	-	-	-	-	7,13,060.00
45	CONY403	17,84,252.00	-	-	-	-	-	-	-	17,84,252.00
46	CONY406	6,75,000.00	-	3,00,000.00	-	3,75,000.00	-	-	6,75,000.00	-
47	CONY407	2,85,000.00	-	-	-	-	-	-	-	2,85,000.00
48	CONY409	75,000.00	-	25,000.00	-	50,000.00	-	-	75,000.00	-
49	CONY410	1,65,015.00	1,35,526.00	23,582.00	-	-	-	-	23,582.00	2,76,959.00
50	CONY411	2,63,805.00	-	1,45,000.00	-	1,18,805.00	-	-	2,63,805.00	-
51	CONY412	71,880.00	-	35,500.00	-	36,380.00	-	-	71,880.00	-
52	CONY413	2,70,000.00	-	1,45,000.00	-	1,25,000.00	-	-	2,70,000.00	-
53	CONY414	3,30,000.00	-	1,20,000.00	-	2,10,000.00	-	-	3,30,000.00	-
54	CONY415	2,65,475.00	-	1,76,500.00	-	88,975.00	-	-	2,65,475.00	-
55	CONY416	2,69,217.00	-	1,45,000.00	-	1,24,217.00	-	-	2,69,217.00	-
56	CONY417	3,30,000.00	-	1,20,000.00	-	2,10,000.00	-	-	3,30,000.00	-
57	CONY418	2,68,284.00	-	-	-	-	-	-	-	2,68,284.00
58	CONY419	16,500.00	-	-	-	-	-	-	-	16,500.00
59	CONY420	2,70,000.00	-	-	-	-	-	-	-	2,70,000.00
60	CONY421	3,95,377.00	-	84,323.00	-	-	-	-	84,323.00	3,11,054.00
61	CONY422	2,70,000.00	-		-	-	-	-	-	2,70,000.00
62	CONY423	2,70,000.00	-	14,122.00	-	-	-	-	14,122.00	2,55,878.00
63	CONY424	51,750.00	-	10,190.00	-	-	-	-	10,190.00	41,560.00
64	CONY425	3,15,000.00	-	88,433.00	-	-	-	-	88,433.00	2,26,567.00
65	CONY426	-	50,000.00	15,000.00	-	-	-	-	15,000.00	35,000.00
66	CONY427	-	1,05,000.00	31,000.00	-	-	-	-	31,000.00	74,000.00
67	CONY428	-	3,15,000.00	45,000.00	-	-	-	-	45,000.00	2,70,000.00
68	CONY429	-	3,15,000.00	49,095.00	-	-	-	-	49,095.00	2,65,905.00
69	CONY430	-	60,000.00	15,100.00	-	-	-	-	15,100.00	44,900.00
70	CONY431	-	5,25,000.00	75,000.00	-	-	-	-	75,000.00	4,50,000.00
71	CONY432	-	8,00,000.00	1,21,281.00	-	-	-	-	1,21,281.00	6,78,719.00
72	CONY433	-	1,05,000.00	31,106.00	-	-	-	-	31,106.00	73,894.00
73	CONY434	-	3,15,000.00	50,306.00	-	-	-	-	50,306.00	2,64,694.00
74	CONY435	-	3,15,000.00	45,000.00	-	-	-	-	45,000.00	2,70,000.00
75	CONY436	-	50,000.00	15,000.00	-	-	-	-	15,000.00	35,000.00
76	CONY437	-	3,15,000.00	50,004.00	-	-	-	-	50,004.00	2,64,996.00
77	CONY438	-	50,000.00	15,000.00	-	-	-	-	15,000.00	35,000.00
78	CONY439	-	2,17,500.00	51,750.00	-	-	-	-	51,750.00	1,65,750.00
79	CONY440	-	3,15,000.00	1,25,500.00	-	-	-	-	1,25,500.00	1,89,500.00
80	CONY441	-	3,15,002.00	94,500.00	-	-	-	-	94,500.00	2,20,502.00
81	CONY442	-	3,15,000.00	94,500.00	-	-	-	-	94,500.00	2,20,500.00
	Total	**[illegible]**	**1,67,73,762.00**	**52,37,340.00**	**-**	**21,10,790.00**	**-**	**-**	**73,48,130.00**	**5,40,42,231.00**

MANOJ & [illegible] CHARTERED ACCOUNTANTS TRIVANDRUM

Schedule 15:

Notes on Financial Statements for the financial year ended 31st March 2016

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.

Significant Accounting Policies:

1. **Basis of Accounting:**

   The Society had followed mercantile system of accounting till the conclusion of financial year 2013-14. Financial year 2014-15 onwards, Society has changed their accounting system to cash basis. So it recognizes income and expenditure on cash basis.

   The effect of change in Accounting Policy for the financial year (From 01.01.2014 to 31.03.2014) is negligible.

2. **Income Recognition**

   The Grant-in-aid is received by the Society from the Ministry of Earth Sciences as Research Program Grant and Operations and Maintenance Grant.

   In addition, the society also undertakes other R&D Projects sponsored by Ministries/ Department of GOI/ GOK, Consolidated Service Projects and Consultancy Projects which amounts to Rs 370.31 Lakhs. The Grant-in-aid unutilized at the end of the period is as disclosed in Schedule 4.

3. **Fixed Assets and Depreciation:**

   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

MANOJ & SAJEEV * TRIVANDRUM * CHARTERED ACCOUNTANTS

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 projects on closure of the projects or on receipt of permission from concerned Government Departments/ Ministry.

4. 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 bank balances, term deposits and margin money in letter of credit are as per the confirmations provided.

5. Loans and Advances

Advances to staff represent the balance with them for meeting the expenses in connection with the conduct of research projects and are considered good and secured.

Advances and deposits with the suppliers and creditors are as certified by the management and are considered good.

6. 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.

7. General Reserve

The unspent/ overspent balance of the grant received from the Government of Kerala has been stated under general reserve which will be closed once the projects stated

under the schemes of CESS is completed or overspent balance amount is received from the Kerala State Council for Science Technology and Environment. The detail of the said workings is as stated in Schedule No 2.

a) CPWD advance of Rs. 12,92,480/- was paid on 24.02.2010 for the purpose of Leak proofing & Terrace of Administrative block and the advance settled on 31.03.2016. It was shown as CPWD Advance under Current assets on 24.02.2010. For the financial year 2014-15, the advance was included in general reserve since the centre was undertaken by the Ministry of Earth Science. On settlement of advance during the financial year 2015-16, an amount of Rs.12,92,480/- is debited to General reserve and credited to CPWD advance. Actual expenditure incurred is Rs. 12,74,597/- and balance amount of Rs. 17,883/- refunded.

b) CPWD advance of Rs. 3,45,100/- was paid in the financial year 2012-13 for the purpose of providing Internal Electrical Installations and Fans in the record room and providing electrical connection in the parking shelter. Advance settled on 31.03.2016. It was shown as CPWD Advance under Current assets. For the financial year 2014-15, the advance was included in general reserve since the centre was undertaken by the Ministry of Earth Science. On settlement of advance during the financial year 2015-16, an amount of Rs.3,45,100/- is debited to General reserve and credited to CPWD advance. Actual expenditure incurred is Rs. 2,43,329/- and balance amount of Rs. 1,01,771/- refunded.

c) Interest income of Rs. 28,438 is received from Fixed Deposit of Rs. 10,00,000 created for the purpose of discharge of gratuity from CESS fund. During the current year, Fixed Deposit closed for payment. Interest received from the above fixed deposit is used to create a Fixed Deposit. Interest income is debited to Term deposit and credited to General reserve.

d) An amount of Rs.19,885/- was deposited to various parties when the Centre managed under Government of Kerala. The centre has decided to written off the irrecoverable deposits and the deposits of Rs.19,885/- credited to Advance to suppliers and debited to General Reserve.

8. 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.1100 lakhs funds towards Research Program Grant from the Ministry of Earth Sciences (MoES). Unspent balance as on 31st March, 2016 is 1179.73 lakhs.

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9. 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 amount Rs.370.31 lakhs and unspent balance as at the end of the period amounts to Rs.807.14 lakhs. Detailed list of project wise unspent balance is as in Sub-Schedule A& B.

10. Operations and Maintenance Fund

Unspent balance of Grant received from the Ministry of Earth Sciences (MoES) for operational and maintenance expenditure and other income of NCESS is stated as the balance of Operations and Maintenance Fund. The excess of income over expenditure or deficit of income over expenditure in the Statement of Income and Expenditure is credited or debited in the account. Overspent balance as on 31st March,2016 Rs.3.41 lakhs.

11. 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. Balance of unutilized grant in aid and other receipts as on the date of Balance Sheet has been shown as Schedule 4. The unspent amount on the completion of consultancy projects is transferred to NCESS.

12. Retirement Benefits

Liability towards Gratuity is provided through a Group Gratuity Scheme of LIC. The gratuity amount is limited to Rs.10,00,000/-.

Leave Encashment is accounted on cash basis. No provision for leave encashment is made in the accounts. The terminal encashment is limited to 300 days and the amount paid is considered as the expense in the year of payment itself.

13. Income and Expenditure Account

Income and expenses of the Society are accounted on cash basis.

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14. Interest Received

The Society parks funds in Short Term Deposit with bank and also in Savings Bank accounts. 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.

15. Other Income

Other income and Miscellaneous Receipts were credited to Income & Expenditure Account till 31.03.2015. The Society decided to change the accounting policy with respect to Miscellaneous Receipts and other income. Therefore the Society decided to credit the Miscellaneous receipts and other income to the Corpus Fund of the Society with effect from 01.04.2015. The amount of Miscellaneous Income and other income so far credited to Income and Expenditure Account till 31.03.2015 is Rs. 34,29,106/-.

Manager (F&A) **Chief Manager** **Director**

For Manoj & Sajeev
Chartered Accountants
FRN. 008024 S

R. Sajeev, FCA
(Partner)
M.No. 206626

MANOJ & SAJEEV * TRIVANDRUM * CHARTERED ACCOUNTANTS

Place : Trivandrum
Date : 09.09.2016