Proceedings

KERALA ENVIRONMENT CONGRESS 2017

6th to 8th December, 2017
Thiruvananthapuram

Focal Theme

Science, Technology and Innovation
for Environment and Development

Organised by

CED

Centre for Environment and Development

In association with

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Energy Management Centre-Kerala

Sponsored by

Kerala State Council For Science, Technology & Environment
Kerala State Biodiversity Board
Agency For Non-Conventional Energy and Rural Technology
GJ Nature Care & Energy

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Government of India

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Resource Agency Urjakiran
EMC, Kerala

PROCEEDINGS OF

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FOREWORD

Debates on how best to promote sustainable and inclusive development are incomplete without a full consideration of issues of science, technology and innovation (STI). Access to new and appropriate technologies promote steady improvements in living conditions, which can be lifesaving for the most vulnerable populations, and drive productivity gains which ensure rising incomes.

There are two essential science, technology and innovation issues that need to be tackled simultaneously in the post-2015 development agenda. Firstly, innovation driven growth is no longer the prerogative of high income countries alone, some developing countries have achieved significant economic growth through the creation and deployment of science, technology and innovation. Science, technology and innovation policy has often been pursued independently of the broader developmental agenda; it is important that STI be integrated into public policy goals, giving particular focus to the link between STI, culture, education and development. Secondly, in addressing these issues, science, technology and innovation will need to be made more participatory and inclusive so that there is public engagement in the scientific endeavor from the full spectrum of social actors, including women, young people and indigenous communities. A well-functioning STI ecosystem needs to include, inter alia, political stability, well-functioning institutions and educated workforce; sound research and education infrastructure and linkages between public and private innovation actors; enterprises committed to research and development, as well as balanced intellectual property rights (IPRs) framework.

India is one of the major countries where we have excelled in many areas of science, technology and innovation. The space science and technology, nuclear sciences, biotechnology, medical sciences, information and communication technology are some of the areas where India has showcased its major achievements. India has also developed a mechanism in utilizing its achievements in the area of science and technology for the development of the society and also to find viable solutions to the upliftment of the toiling masses.

Kerala has also many things to claim in the science, technology and innovation and also utilizing the science and technology for the development of the society.

The efforts of many scientific movements and social organizations in Kerala have supported the policy decision makers to utilize the science and technology to solve the major issues affecting the society especially the poor and underprivileged people.

The topic science, technology and innovation for environment and development is considered as very important in view of the sustainable development of the society. The innovations in science and technology can be utilized in a positive way leading to sustainable development. At times, it is used in a negative way also leading to unsustainable way of development. This has to be clearly understood and wise and informed decisions have to be taken by all concerned people.

It is in this context that the 13th Kerala Environment Congress (KEC) organized by Centre for Environment and Development in association with Energy Management Centre from 6th to 8th December, 2017 on the focal theme 'Science, Technology and Innovation for Environment and Development' assumes great importance. The KEC seeks to spearhead the message of importance of scientific and technological innovations in various sectors of environment and development such as climate change mitigation and adaptation, agriculture and food security, water and sanitation, energy management, health care services, transportation planning, marine and ocean management, education, information and communication technology, space science and technology, biodiversity, urban planning, etc.

The presentations and panel discussions during the event and the papers published in this Proceedings Volume will go a long way to bring into focus the need for utilizing the benefits of science and technology for finding solutions for issues affecting the life of the people and also to suggest viable options for sustainable development of the society.

We hope that, like the earlier Congresses, this year too this collection of research papers and articles will inspire scientists, academicians, policy-decision makers, environmentalists and the enlightened citizens contribute their might to the application and utilization of science and technology for environmental conservation and development in the country, particularly the State of Kerala.

Padma Mahati

Padma Mahati

KERALA ENVIRONMENT CONGRESS 2017

The Kerala Environment Congress(KEC) was initiated by the Centre for Environment and Development (CED) with the objective of creating a platform for bringing together scientists and technologists, policy-decision makers, development managers and research students for sharing of knowledge, expertise and experience in subjects of high relevance to the sustainable development of the country. CED organized the Indian Environment Congress in 2004 and the success of this program and the request from several corners prompted us to initiate the Kerala Environment Congress (KEC) in 2005. CED initiated the Odisha Environment Congress jointly with Human Development Foundation and Regional Museum of Natural History in 2010 and has completed six Congresses. CED has initiated activities to organize Telangana Environment Congress(TEC) during February,2018 at Hyderabad

The Centre for Environment and Development(CED) established in 1993 at Thiruvananthapuram, Kerala, is an autonomous R&D, Consultancy and Training institution recognized as a Scientific and Industrial Research Organisation(SIRO) by Department of Scientific and Industrial Research, Government of India.

The Centre has now expanded its coverage into twelve states in the country and has wide network and collaboration with many state, national and international agencies. CED has been focusing both on environment and development related sectors bringing complementarities, leading to sustainable development. CED is working with 6 Program Areas viz., (i) Natural Resources and Environment Management, (ii) Water, Sanitation and Health,Climate Change Studies, (iv) Urban and Rural Studies, (v) Energy and Environment and (vi) Information and Knowledge Management. CED is the Centre of Excellence of Ministry of Housing and Urban Development, Government of India on Solid Waste and Waste Water Management; National Key Resource Centre on Water and Sanitation of Ministry of Drinking Water and Sanitation, Government of India and Regional Resource Agency of Ministry of Environment and Forests and Climate Change, Government of India. CED is also the Training Institute of Ministry of Housing and Urban Development, Government of India. CED has its Eastern Regional Centre at Bhubaneswar, Odisha, Regional Centre at Hyderabad and a new Regional Centre initiated at Jaipur. The Centre has at present its activities spread over the states of Odisha, Andhra Pradesh, Telangana, Rajasthan,Himachal Pradesh, Gujarat, Lakshadweep islands apart from Kerala.

CED has been providing technical support to many local self government institutions in the country for Water Supply Engineering, Solid Waste Management, Wastewater Management, Preparation of GIS based Maps and GIS based Master Planning, Biodiversity Conservation, Urban Development, Energy and Environment Auditing, Policy studies and reforms,etc. During the last 24 years, CED has completed nearly 150 research, consultancy and training projects supported by different national and international agencies like the World Bank, UNDP, JICA, ADB, RNE, IDRC, Ministry of Housing and Urban Development, Ministry of Science and Technology, Ministry of Environment, Forests and Climate Change,etc and many State governments agencies. All the twelve Congresses had been organized on different focal themes which had

high relevance in the context of environmental conservation, management and sustainable development.

The first Kerala Environment Congress was organised in 2005 at Kochi with the focal theme 'Coastal and Marine Environment'. The second Congress was held at Kozhikode in 2006 with the focal theme 'Forest Resources of Kerala' and the third KEC was organized in 2007 with 'Wetlands of Kerala' as the focal theme. The fourth Congress focused on the theme 'Environmental Sanitation, Health and Hygiene' and the next one was held in 2009 with the focal theme 'Water Resources of Kerala'. The sixth, seventh and eighth Congresses were held in 2010, 2011 and 2012 with the focal themes 'Solid and Liquid Waste Management', Energy and Environment and Agriculture and Environment respectively. The nineth Congress was held at Thiruvananthapuram with the focal theme "Culture, Heritage and Environment". The tenth KEC was organized at Kochi with the focal theme "Water and Energy SecurityIssues, Challenges and Potentials" which was inaugurated by Dr A.P.J. Abdul Kalam, Hon'ble Former President of India and the last KEC was organized at Kottayam on the focal theme "Climate Change and Sustainable Development". The twelth KEC was organized at Thiruvananthapuram with focal theme-"Urbanization and Environment".

This year's Kerala Environment Congress (13th KEC) is being organized from 6th to 8th December,2017 in association with the Energy Management Centre, Kerala at EMC Conference Hall, with the focal theme " Science,Technology and Innovations for Environment and Development". CED gratefully acknowledges the support of the Kerala State Council for Science, Technology and Environment, Government of Kerala, Kerala State Biodiversity Board, Agency for Non-Conventional Energy and Rural Technology(ANERT) and G J Eco Power LTD for co-sponsoring the KEC.CED is also partnering with professional bodies such as Kerala State Remote Sensing and Environment Centre,Indian Society of Remote Sensing, Indian Meteorological Society,Indian Society of Geomatics and Indian Society of systems for Science and Engineering.

The Congress include Key Note Address, 17 Invited Presentations and 15 Presentations and Posters by young researchers to be considered for Young Scientist Award. The Young Scientist Award is instituted by CED in the name of our former friend and colleague (Late) Dr R. Satheesh, who had contributed immensely in the environmental research. We expect nearly 250 researchers, policy experts, decision makers, students and development thinkers to actively participate and contribute in the Congress. This Proceedings Volume contains full papers of invited presentations,and abstracts of students for Young Scientist Award. CED takes this opportunity to place our heartfelt gratitude to all the distinguished personalities, important institutions, organizations and government agencies for supporting us these years to organize the Kerala Environment Congress successfully. We hope that the deliberations in the Congress and the papers published in the Proceedings Volume will help to evolve a strategy for use of science and technology for sustainable Environment Management and development in the Country the State of Kerala in particular..

Dr Babu Ambat
Executive Director, CED

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INVITED PAPERS

Role of Science, Technology and Innovation in Agriculture for Ensuring Food Security

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INTRODUCTION

India had launched a Science and Technology (S & T) Policy in 2003. Considering the importance of innovation in development, an improved version of S & T policy renamed as Science, Technology and Innovation Policy (STIP) was announced by the Government at the centenary session of the Indian Science Congress held at Kolkata during January, 2013. With the announcement of STIP, the Government aimed at creating a robust national innovation system and to enhance the role of private sector in the national science, technology and innovation system through the PPP mode.

Innovation serves as a catalyst for development by identifying and supporting new ways of 'doings different things' and 'doing things differently'. It also helps to manage an array of competitions and challenges in development. In this context, there is also the need to effectively link innovations and stakeholders /user communities (farmers, entrepreneurs, consumers) in relation to food security. The focus on demand side of innovation is warranted to make development process more inclusive by building upon creative and innovative practices pursued by the community.

Challenges of food security

Seventy percent of world's food supply comes from just three grains- rice, wheat and maize (corn). Eighty percent of our plant based food intake comes from just 12 plant species – 8 grains (rice, wheat, maize, barley, oats, sorghum, millets, and buckwheat) and 4 tubers (potato, tapioca, sweet potato and yams). As markets fluctuate, climate change takes hold and the global population continues to grow, we need to find a solution for increasing the diversity of food crops and adding more crops as staple crops for ensuring food security. While all crops are vulnerable to risks, it is found that vegetables tend to be more dependable than the staple crops, because they have shorter cycles, grow faster and require less space. Indigenous vegetables are more hardy and climate resilient. In this respect, small scale farmers must diversify the crops they grow to cushion themselves against market failures as well as climate related crop failures. Also, linking farmers more directly to local markets and ensuring local consumption will help ensure that demand meets supply.

Food is a basic human right. Food sovereignty entails the sustainable care and use of natural resources, especially land, water and seeds. Food is first and foremost a source of nutrition and secondarily only an item of trade. It is to be ensured that food sovereignty of a country be achieved by developing their own domestic farm and food policies that respond to the true needs of farmers and all consumers, especially the poor. Many national and international policies directly or indirectly give priority to large TNCs for food production and trade. While farmers work hard to ensure the sustainability of seeds and food, the violation of farmer's rights undermines the world's capacity to feed itself.

Innovation in the farm sector is crucial to meeting key challenges, as under:

- Climate change: This has already begun to affect crop yields. It is also restricting the means by which production can be enhanced. Production gains usually come largely from intensification of existing lands rather than the expansion into new areas. This necessitates innovation along almost the entire agriculture value chain.
- Soil quality: The process of intensification is aggravated by soil quality issues such as soil and water loss, soil pollution, soil salinity, etc in critical production and consumption regions.
- Water depletion: Climate change is directly affecting water availability in numerous ways. Regions that are currently subject to dry conditions are getting drier and those with already high levels of rainfall are getting wetter. Underground water pollution is also a significant issue
- Yield plateaus: It is possible that key production regions have reached yield plateaus, which will require investments in new techniques to either increase yields in those regions, or improve yields in regions that have more potential

Dimensions of Food security

Food security is framed in four dimensions- availability, access, utilization and use and food stability.

Availability refers to supply side of food security, wherein biotic and abiotic stresses, lack of water availability and soil health problems pose challenges and determine the production and productivity. S & T interventions to address the challenges include disease and pest resistant crops, climate resilient crops, improved agronomic practices, advanced genetic engineering, etc. Application of science and technology for increased food production is aimed at ensuring increased availability of food through genetic modification of plant varieties for nutritional fortification, and tolerance to biotic and abiotic stresses. Harvest Plus, based at IFPRI has pioneered bio-fortification as a global plant breeding strategy for a variety of food crops.

Pulses are part of a healthy, balanced diet and have been shown to have an important role in preventing illnesses such as cancer, diabetes and heart diseases. Encouraging awareness of the nutritional value of pulses can help consumers adopt healthier diets. Pulses are locally adapted and can be grown by local farmers for their own nutrition as well as for sale, which is important to improve food security. They are highly accepted crops, which can keep well in storage. Pulses, because of their

role in improving sustainability, notably through soil management, also impact food security. Soil degradation is a major threat to food security in many areas. By improving the crop patterns using pulses, farmers can improve their yields and limit the long-term threat to food security that soil degradation represents.

Access to sufficient, safe and nutritious food is a major dimension of food security Food access is directly related to income, expenditure and buying capacity of households and individuals. A key aspect of food access is that food should be within the reach of every person and every individual should have enough money (purchasing power) to buy sufficient and safe food. Another aspect of accessing food is also minimizing food losses during production, storage and transportation and waste of food by retailers and consumers.

The National Food Security Act, 2013 (Right to Food Act) aims to provide subsidised food grains to the poor and needy persons. NFSA converts into legal entitlements for existing food security programmes of Government of India, which includes Midday Meal Scheme, ICDS scheme and Public Distribution System (PDS). Many innovative delivery mechanisms like e-PDS and e-POS and supply chain management and vehicle tracking system implemented in Telangana, m-PDS implemented in Odisha covering four modules, viz, procurement, delivery, lifting and closing balance and fair price shop automation done in Jharkhand have been tried in India for better access by the people.

Food utilization is often used interchangeably with nutrition, though it also includes food processing and storage and health and sanitation services. Value chains have attempted to improve food utilization and achieve nutritional gains, mostly by targeting agricultural value chains. The issues of income-nutrition linkages, value chain selection, food safety, gender and household nutrition practices, post harvest handling, complementary interventions, and nutritionally sensitive groups are concerns to be addressed when working to improve food utilization.

Food stability refers to measures taken for protection of food from external chemical, physical and microbial injuries, which can profoundly modify the nutritional and sensory properties of food. Innovations in food packaging ensure food stability. Besides the traditional thermal treatments for food preservation, thermal and non thermal processing techniques have been developed recently, which include irradiation, high pressure processes, pulsed electric fields, UV treatments, anti microbial packaging, etc. The globalisation of food industry requires adhering to international standards and compliance with multiple regulations. New technologies, especially nano technologies have to be examined for their effect on product quality and public health.

Two significant trends in food processing technology today are convenience and safety. Convenience parameters may be related to product, processability, warehousing, traceability, display qualities, tamper resistance, ease of opening and cooking preparation. Safety relates to public health and security against bioterrorism. Food packaging also should be natural and environment friendly.

Besides the four dimensions of food security, related two dimensions of food security are- food safety and food sovereignty.

Food safety involves a much broader range of public health issues related to food production. Food safety concerns begin from on-farm production of food commodities. It is the key entry point for the introduction of production and management practices that allow minimizing potential contamination with excessive residues of harmful chemicals in food, water and the introduction in food of harmful biological agents. In developing countries with predominance of small holder farming, proactive and preventive approaches offer the most cost effective option of ensuring food safety. Adoption of Good Agricultural Practices (GAP) is one such preventive food safety approach. Nutrition and food security must be considered in developing food safety guidelines and standards. Gains in agricultural productivity and ingenuity in devising superior storage and post harvest processing have directly contributed to enhanced food security around the globe.

Food sovereignty is the right and freedom to grow diverse and nutritious food and the right to have access to save healthy adequate and affordable food. Food sovereignty grows from household, to the community, the regional and the national level. It is critical because our current food and farm system is very much broken. Food sovereignty is essential to guarantee the human rights of communities to choose where and how their food is produced and what food they consume. The International Human Rights framework which includes thematic instruments that address the rights to food, water and health, as well as human rights is to be considered here.

Innovations for ensuring food security

- **Precision Agriculture or Satellite farming or Site specific crop management (SSCM)** is a farm management concept based on observing, measuring and responding to inter and intra field variability in crops. The goal is to define a decision support system (DSS) for whole farm management with the objective of optimising returns on inputs while preserving resources. The practice of precision agriculture has been enabled by the advent of GPS and GNSS. Precision agriculture is an application of breakthrough digital farming technologies such as High Precision Positioning system (like GPS), Automated steering systems, Geomapping, Sensors and remote sensing, Variable role technology and Integrated electronic communication.
- Commercial agriculture increasingly occurs in a context where private entrepreneurs coordinate extensive value chains linking producers to consumers, sometimes across vast distances. A growing number of entrepreneurial smallholders are organizing to enter these value chains, but others struggle with the economic marginalization that comes from being excluded from such opportunities. In this context, markets, urbanization, globalization, and a changing environment not only influence patterns of consumption, competition, and trade but also drive agricultural development and innovation far more than before.

Agricultural Production Value chain is a game changer for small holders, which increase both food security and income of small holder farmers. A ‘value chain’ in agriculture describes the range of activities and set of actors that bring agricultural

product from production in the field to final consumption, wherein at each stage value is added to the product. Value chain analysis is a tool which analyses the factors influencing performance, including access to and requirements of end markets; the legal, regulatory and policy environment; co-ordination between firms in the industry; and the level and quality of support services. **Farmer Producer Companies can be considered as organisational innovations for creating value chains in agriculture.**

Urban farming- This is a process of innovative scientific farming techniques to produce more yield and high quality fresh organic food in very limited urban areas like terraces, balconies, etc all the year round. Urban farming can be sustainable if it has environmental integrity, economic resilience, promotion of social well-being and is backed with supportive governmental policies. As more people aggregate in megacities, urban farming is now emerging as a sustainable way to produce and supply locally grown fresh food produce to the city dwellers. Start up companies and small corporate firms are now catering to the needs of eco-conscious and organic friendly urbanites. Roof top farming/terrace farming, vertical farming, hydroponics and aquaponics are emerging as sustainable technologies. Hydroponics is a method of growing crops based on use of mineral enriched water, whereas aquaponics takes matters a step further, bringing together fish and crop farming in one recirculatory system.

Grassroots innovation- It is defined as innovative product or process created at the bottom of the pyramid, usually due to necessity, hardships and challenges. Grassroots innovations (GRIs) emerge when existing systems and practices fail to serve the needs of the people. Normally, the term innovation at farmers' level has been used to refer to farmer's adoption of new technology coming from outside, rather than the new technologies, management practices and institutions that farmers and their communities have developed themselves. Many local innovations need not be of a technical nature, rather they can be socio-economic and institutional innovations, such as new ways of gaining access to resources or new ways of organising marketing activities.

Grassroots innovations are community-led solutions for sustainability. They can offer promising new ideas and practices, but often struggle to scale up and spread beyond small niches. Honey Bee Network was set up in the first stage to scout and document grassroots innovations, followed by the Grassroots Innovation Augmentation Network to scale up and convert grassroots innovations into viable products, and the National Innovation Foundation (NIF) in 2000 to provide institutional support to grassroots innovators and traditional knowledge holders from the unorganized sector. In agriculture, GTIAF (Grassroots Technological Innovation Acquisition Fund) was established under NIF. GTIAF was envisioned to allow NIF to acquire the rights of technologies (including seeds) from the innovators generating public goods, which NIF can then make open source. Also, in future if the technology gets commercialized, a fair share of benefit will go back to the original knowledge provider.

Innovations for adaptation and mitigation of climate change- STI for climate change mitigation and adaptation focus on information provision and knowledge

transfer and include social as well as technical innovations. Many practices deliver both and many of the effective adaptation, resilience and mitigation approaches to a changing climate which offers important ecological, agronomic, economic and social co-benefits.

National Innovations on Climate Resilient Agriculture (NICRA) is a network project of the Indian Council of Agricultural Research (ICAR) launched in 2011, which aims to enhance resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. The research on adaptation and mitigation covers crops, livestock, fisheries and natural resource management. Adaptation to climate variability and climate change requires long term strategic research in the area of Natural Resource Management, Crops, Pests and disease dynamics, Livestock, Fisheries & Energy Efficiency. The strategic research is being carried out involving 21 Institutes of the ICAR out of which seven are core institutes where state of the art research infrastructure and equipments will be installed for climate change research on irrigated crops, rainfed crops, horticulture, livestock, fisheries and energy efficiency.

The Technology Demonstration Component (TDC) of NICRA has been implemented in 151 vulnerable districts to address several issues related to climate vulnerabilities such as droughts, floods, salinity, frost, cyclone, heat and cold waves. These demonstrations have helped in enhancing the adaptive capacity of the farmers and also to cope with climate vulnerabilities related to crop production, livestock and poultry and fisheries, which is essential to achieve climate resilience.

Convergence of new and emerging technologies- Artificial intelligence (AI), tissue engineering, drones and robotics may have profound impacts on the future of food production and food security. Such technologies have the potential to reshape the future of food production, either individually or as a part of converged application. Start up companies are developing animal free egg whites that use less water and land inputs while preserving the taste and nutritional value of hen borne egg whites.

Post harvest innovation is a critical area related to food security that could support the poor in many ways through production, employment, value addition, and cheaper and safe food. Post harvest R & D offers the potential to support the livelihoods of the poor people in developing countries as farmers, small scale agro processing entrepreneurs, off farm labourers and consumers of food and agricultural products.

Governance for Food Security

Consumption and production of food are governed by social values that are just and equitable as well as moral and ethical. A number of factors impinge on the efficiency of governance in a national innovation system in general and an Agricultural Innovation System (AIS) in particular, which reflects on the extent to which policy processes have the greatest effect with a given use of resources. The evidence indicates that efficient governance depends on certain qualities, which include the following:

- **Legitimacy-** The policy actors and approaches adopted in policy processes related to food security have to be appropriate and widely accepted for the tasks at hand.

- **Coherence -** The strands of innovation policy and associated policy instruments of food security must fit together.
- **Stability -** Innovation requires sufficiently stable framework conditions, institutions, and implementable policy.
- **Adaptive ability**- As the environment for innovation and innovation itself keeps evolving, governance actors need to be able to adapt to the changing circumstances
- **Ability to steer and give direction**- A related capability is the governance system's ability to provide direction to actors and steer the innovation system as a whole. This capacity requires commitment and leadership by policy makers at the highest level.

Innovation system is defined as a network of organisations, enterprises and individuals focused on bringing new products, new processes, and new forms of organising into economic use, together with the institutions and policies that affect their behaviour and performance. In relation to food security, it is suggested that the AIS system may adopt a **4 E Strategy** to foster innovation culture in the farm sector. This includes:

- **Encouraging** use of indigenous innovative products/practices
  - Developing niche markets for food and food products
  - Promoting sustainable eco-friendly practices as part of GAP
  - Upscaling time tested and validated indigenous innovations
- **Enabling** access to new generation technologies
  - Application of IT, BT, Nanotechnology, GIS, Remote Sensing
  - Cautious approach in borrowing outside technologies and GM technologies
  - Promoting only need based, sustainable and culturally compatible innovations
- **Enriching** traditional knowledge by blending with sustainable scientific technologies
  - R & D for technology adaptation and refinement for production and post production activities
  - Technologies for effective utilization of food
  - Development of sustainable products/services ensuring food safety
- **Empowering** farmers and entrepreneurs to emerge as innovators
  - Developing innovation portfolio for different segments - trademarks, branding
  - Ensuring protection of IP (patents, GI registration)
  - Benefit sharing to the community

Food systems include a wide range of actors and activities from production to consumption. Thus, governance processes include a wide range of stakeholders and parallel decision making processes related to food. These processes comprise of regulatory environments, infrastructure provisions, support mechanisms and education and awareness creation. The effective implementation of NFSA with its various components needs a vibrant and cohesive governance mechanism. The

links between 'conventional food sources' and 'alternative food initiatives' have to be identified and the multiple functions of private and public spaces should be addressed. Similarly, there are campaigns and movements against 'food miles; which advocate eating only locally grown foods. 'Food miles' is a term which refers to the distance food is transported from the place of its production until it reaches the consumer. It is one major factor considered in assessing the environmental impact of food, particularly impact on global warming. The arguments in favour of food miles are- reduces carbon dioxide emissions of food's freight, strengthen local economies by protecting small farmers, local jobs and local shops, and increases national food security.

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Recent Advances in Biodiversity Conservation through Modern Technology

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INTRODUCTION

India is one of the 17 mega biodiversity countries in the world with its diverse habitats and ecosystems (World Bank, 1996). Country with 2.4% of the world's geographical area and about 1% of forests, has over 8% of the world's total biodiversity. This status is based on the species richness and levels of endemism recorded in a wide range of taxa of both plants and animals. This diversity can be attributed to the vast variety of landforms and climates, resulting in habitats ranging from tropical to temperate and from alpine to desert. Adding to this is a very high diversity of human influenced ecosystems, including agricultural and pasture lands, and a diversity of domesticated plants and animals.. India is also considered one of the world's eight centres of origin of cultivated plants. Being a predominantly agricultural country, India also has a mix of wild and cultivated habitats, giving rise to a very specialised biodiversity, which is specific to the confluence of two or more habitats (Kalpvrikh 2004 and MoEFCC 2009).

For in-situ conservation currently 4.93% of country's geographic area has been set aside under Protected Area (PA) Network; with 103 National Parks, 543 Wildlife Sanctuaries, 73 Conservation Reserves and 45 Community Reserves (WII Database, November 2017). Kerala with its 24% of total geographical area under forests has a network of 23 PAs (28.41% of its forest area). This includes 5 National Parks, 17 Wildlife Sanctuaries and one community Reserve. Kerala also has two Tiger Reserves, four Elephant Reserves and two Biosphere Reserves (ENVIS 2016; KFD Database 2017). Entire PA network of Kerala is a life line of the state as these form the catchments of the major rivers. As a part of inclusive management approach, state has implemented Ecodevelopment programs in Periyar Tiger Reserve, Parambikulam Tiger Reserve and Eravikulam National Park. These initiatives have not only secured these areas from protection and habitat degradation problems but have also provided important lessons for participatory PA management. These successful conservation initiatives reveal that if the larger objective of conservation has to be achieved, such programs need to be extended beyond the boundaries of PAs, covering large landscapes (Bhardwaj, 2008; WII, 1999a; World Bank 2004). Conservation of biodiversity at landscape level requires a comprehensive and multi-scale approach

that includes both, the PAs and biodiversity rich areas and the surrounding matrix (Uniyal et al., 2014; WII 2015, World Bank, 2014). Managing large landscapes has new challenges in terms of protection, baseline information and scientific monitoring. It is here that Kerala Forest and Wildlife Department is trying to explore new strategies using modern technology.

BIODIVERSITY CONSERVATION THROUGH WILDLIFE MONITORING

The conservation of elusive and cryptic species of wildlife had been a challenge through the years. The application of modern technology in biodiversity conservation has gained pace over the years. Certain wildlife species are cryptic and difficult to study or estimate the population. The technology advancement in wildlife conservation not only assisted in studying these species but also to estimate their population and distribution which otherwise would be impossible. The camera trapping method aids in overall monitoring both flora and fauna (NTCA 2011). During the camera trap exercise, the parameters related to habitat quality such as trees, shrubs and grasses are recorded which help in monitoring the vegetation every year. The conservation of flagship species such as tiger is exceedingly dependent on precise estimation of minimum number of individuals that is achieved by camera trapping. The camera traps not only help in identifying the individual tiger, but also in monitoring the movement of individuals across habitats. The wildlife monitoring through camera trap method of endangered species like tiger and leopard reflects on the healthy population of herbivores which in turn is availability of good habitat quality. The camera trap exercise is an effective tool in the context of biodiversity conservation. The camera traps deployed in vayal (marshy grassland) and grasslands are a vital source of information on herbivore distribution and utilization across these unique habitat type. The availability of sufficient herbivores ensures the long term survival of the predators and also maintains the habitat quality.

The habitat quality richness is ensured due to the effective conservation of water source in that habitat. The wildlife monitoring also shows the strength of level of water conservation that is done indirectly. The water conservation in such wildlife habitats are the lifeline for the communities that reside in the fringe of the Park. The continuous monitoring of wildlife ensures protection to the habitat and the water which receives its major source from these habitats. The communities in the immediate vicinity are benefited by the water conservation that is achieved through effective monitoring of wildlife and its habitat. Human wildlife interface is a challenging task which involves both administrative and ecological approach. The species richness of herbivores which is evident from monitoring ensures the predators to avoid human habitation in search of prey and are highly less prone to be in interface. The habitat quality richness sustains the carrying capacity of prey species in that habitat and attracts predators which form territory within the vicinity of the prey. The habitat quality, ample prey and water restrict the predators within the forest areas and reduce the ranging areas closer to human habitation.

Camera trapping is a method used to identify individual species of wildlife which have permanent identification on their body such as stripes, rosettes and other patterns. The first phase of camera trap deployment involves identification of potential sites for deployment. A thorough sign survey is done to identify the

potential location for deploying camera traps. The indirect evidences (pugmark/scat/scratch/scrape) of predators such as tiger, leopard are recorded in the entire area. The area is then divided into grids of 4 km^2. A pair of automated cameras are deployed in each grid. Camera traps are deployed in potential locations. The animals with unique identity marking on body differ on both sides. The cameras are deployed on both sides in each grid. The camera traps are equipped with motion sensor which is activated when the animal passes in the detection range. Photographs of both sides of the individual are triggered. After identifying both sides of each individual tiger, a database can be developed and maintained for the long term monitoring.

CAMERA TRAPPING BEYOND BORDER:

The concept of landscape conservation of wildlife is a major long term vision of Periyar Tiger Reserve. Periyar Tiger Reserve has been identified as a source population of tigers in the landscape. The flagship species such as tigers move at a larger extent between habitats and this area of operation may be outside Protected Area. The All Kerala Tiger monitoring exercise of Periyar –Agasthyamala part was done by Periyar Tiger Reserve. To ensure the protection outside Protected Area, a wildlife monitoring protocol is essential which is also aimed at long term conservation. Periyar Agasthyamala landscape is a vital source of tiger population in Western Ghats. The Divisions falling in the Periyar-Agasthyamala landscape was divided into 4 landscapes by combining forest divisions.

Thiruvananthapuram Landscape: This landscape consists of Neyyar, Peppara and Shendurney Wildlife Sanctuaries and Thiruvananthapuram Forest Division.

Periyar Landscape 1: Periyar Tiger Reserve and territorial forest divisions such as Ranni, Konni & Kottayam are included under this landscape.

Periyar Landscape 2: Forest areas under the territorial forest divisions such as Achencoil, Punalur and Thenmala are considered under this landscape.

Munnar Landscape: Forest Divisions such as Munnar, Munnar Wildlife, Idukki Wildlife, Marayoor, Mankulam and Kothamangalam are included in this landscape.

The entire area of these landscapes were extensively surveyed for tiger and co-predators presence/absence based on sign survey. The locations were identified based on scale of high, medium and low. Prey density was estimated using line transects laid in each block all Forest Division. Automated cameras were laid in all the grids with potential locations identified during the survey. Habitat quality was assessed using plots in each 400m in all the transects throughout the landscape. The parameters of prey abundance, prey density and distribution were worked out for all forest division and a baseline map of prey distribution was achieved through this camera trapping exercise. The information will help in understanding movement of tigers between habitats and outside protected Area to adjoining forest divisions in entire landscape.

REAL TIME MONITORING (RTM)

The monitoring of wildlife using camera traps is being done meticulously every year. The requirement to study the behaviour and the habitat utilization of wildlife throughout the year was a field of interest during the years. A real time monitoring

(RTM) system for wildlife, which can be termed as new generation of camera traps, was decided to be devised and installed at certain hotspots initially. To meet this requirement initial discussions and field visits were done to identify the locations suitable for camera installation. The line of sight needs to be ascertained to facilitate the sender and receiver communication, which was done using Google earth. As a first step identification of strategic locations (hill tops) was done from where maximum field area is visible. Wireless connections were established from the field to those locations using microwave antennas and it was again connected to the network which is already being used in our Division office. Completely in-house technology utilizing suitable equipments that were available readily from the market was used for accomplishing this. The cameras can be controlled real time from anywhere in the world.

RTM helps the ecologists and conservation biologists to study the behaviour of wildlife in their natural conditions, without any physical intervention of human, which at many times may alter the behaviour. The interaction between herbivores such as gaur, sambar, and elephants can be studied and interesting observations can be recorded as snapshot and a video. The habitat utilization of herbivores at different season can be assessed using RTM. The night life of the denizens of the forest can be studied with minimum or no impact. Vayal in which camera installed can also be a tool to monitor the habitat over the years. In addition to wildlife monitoring, RTM is one of the best tool that is used to monitor any illegal intrusions. The illegal activities can be immediately recorded through the 24x7 monitoring system. This allows the mobilization of staff at the earliest to the spot. The cameras when installed at interstate boundary and vulnerable entry points can be a strong protection strategy to curb any intrusions or possible illegal activities.

RTM system has a wide range of uses in addition to wildlife monitoring. PA managers can have video conferencing from his base camp with all the field staff. Internet can be routed to those camp sheds, which will help researchers to clarify any doubts while in field. Officer with user credentials can login to the network from anywhere from the world and see the cameras setup in the field. Camera Trap Images can be transmitted directly from field to office, without the physical transportation of the camera trap from the field to office. Daily Mstripes data can be uploaded to the network and managers can evaluate the perambulation patterns. RTM Can be used to track radio collared animal also.

TECHNOLOGY IN CONFLICT MITIGATION

As part of conflict mitigation management in Sabarimala pilgrim route, this year, the forest department have taken a step which includes mobile phone technology. Wildwatch system consists of mobile app and control room. When Forest officials detect a wildlife movement in any particular area, he can send alert to the system using the mobile application. This alert will appear instantly in the control room and on mobile phones of registered officials including elephant squad. Forest control room staff can view this alert on his screen with latitude and longitude of the alert with maps. This enables the rapid action to the conflict location without any delay. Also, admin receives an image uploaded by officials to verify the alert. Once control room staff approves the alert, the *Early warning lights* installed at various control

rooms switches ON automatically, and an alert is sent as SMS to registered users. As of now, the application has been distributed to Motor Vehicle Department patrolling team, Forest Department Officials and elephant squad. This system has been installed at Forest Control Room, Pampa since 16th November 2017 and in this initial phase 15 alerts have been received in the system. Similar SMS alert systems have also been installed in areas where human wildlife conflict is intense and it has helped effective functioning of Rapid Response Teams (RRTs) in these areas.

The process of innovation using technology has been initiated in few PAs and Non PA areas of the state. Steps are proposed to be taken to expand these initiatives on large landscapes. More such innovations in terms of modern technology are also being planned and we hope the this will help us to manage our forests much more scientifically and efficiently with overall objective conservation, water security and community well-being.

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Issues, Challenges and Potentials for Integrating Science, Technology and Innovation in Marine and Ocean Resources Management, Kerala

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INTRODUCTION

The sustainable development goals set by the United Nations warrants concerted efforts towards building an inclusive, sustainable and resilient future for people and planet primarily by harmonizing three core elements - economic growth, social inclusion and environmental protection. The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly, and agreed upon by the nations across the world, suggest an ambitious set of universal goals and targets to tackle the developmental challenges of humanity. In the recent past the concept of blue economy and blue growth are gaining more visibility and importance within the framework of the 17 United Nations Sustainable Development Goals (SDGs). In particular, Goal 2 (end hunger, achieve food security and improved nutrition, and promote sustainable agriculture) and Goal 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development) are connected to the oceans.

Healthy marine and coastal ecosystems provide many valuable services - from food security, resources for economic growth and recreation alongside tourism and coastline protection, not to speak of the innumerable ecosystem services which often sustain life in the planet. They are also recognized as crucial reservoirs of biodiversity at a time when the loss of species on both land and in the sea is an increasing cause for concern. Moreover, in states like Kerala, the health of the coastal and marine ecosystems are intricately related to the health of other ecosystems such as forests, rivers, backwaters, estuaries and mangroves. Further, coastal and marine resources are essential to human well-being and social and economic development of the state.

Traditionally, Kerala is a marine fish producing and consuming state and the state, by virtue of its geographical setting with rich and varied coastal and marine resources in the form of extensive 39,139 sq km continental shelf area, 2,18,536 ha Exclusive Economic Zone (EEZ), 53 interconnected backwaters (Kayals), numerous wetlands and with a 590 km long coastline, has a strong resource base for coastal and marine resources. Fisheries is a major sector in Kerala's economy. Therefore conservation and sustainable use of marine resources and use of science, technology and innovation for achieving these objectives are all the more important. Moreover, the

future development and economic growth of the state may also be linked with sectors related to marine and oceanic resources, including tourism, aquaculture, exploitation of energy resources, sustainable exploitation of offshore marine and other resources, and promotion of blue biotechnology especially though the development of novel compounds and marine nutraceuticals.

CURRENT STATUS OF RESOURCES

Coastal and marine ecosystems are among the most productive, yet threatened, ecosystems in Kerala; they include backwaters, lagoons, estuaries, mangroves, mudflats, sand dunes, seaweed ecosystems and the extensive coastal waters which cover terrestrial ecosystems, areas where freshwater and saltwater mix (estuaries and brackishwater lakes, Kayals), near shore coastal areas (backwaters in Kerala, including Kuttanad Wetland), and open ocean marine areas. The Coastal Zone in Kerala is the low land fringing the sea extending over 590 km (about 10 per cent of the coastline of India), with a height of less than 8 m from the Mean Sea Level (MSL), covering about 15 % of the State's total area of 38,863 sq km.

The coastal zone of Kerala is not only an important physiographic unit of the State, but also important in terms of economic activity and demographic distribution. As per the population census 2011, the fisher folk population in Kerala is 10.02 lakh covering 7.71 lakh in coastal area (Economic Review, 2013). Kerala is home to 2.76% of India's population (total population as per 2011 census is 33.3 million), with high population density (859 persons per sq km.); the population density in the coastal zone is almost three times that in midland and highland areas and about 30% of the population in Kerala inhabits coastal region (www.censusindia.gov.in). Coastal zone of Kerala harbours most of the industries in the State, ports, air ports, water ways, thermal power plants and is the hub for the present and appears to be the future development of tourism. Thanks to upwelling and formation of mud banks (*Chakara*), the coastal waters of Kerala are one of the leading States in marine capture fisheries and also rich in coastal/marine biodiversity. Commercially valuable mineral base is also found along the coastline, including thorium and titanium.

Healthy marine and coastal ecosystems provide many valuable services - from food security, resources for economic growth and recreation alongside tourism and coastline protection. They are also recognized as crucial reservoirs of biodiversity at a time when the loss of species on both land and in the sea is an increasing cause for concern. Moreover, in the maritime State like Kerala, the health of the coastal and marine ecosystems are intricately related to the health of other ecosystems such as forests, rivers, backwaters, estuaries and mangroves. However, the conservation of coastal and marine ecosystems did not receive proper attention compared to the terrestrial ecosystems.

Drivers of Change and Impacts

Healthy marine and coastal ecosystems provide many valuable services - from food security, resources for economic growth and recreation alongside tourism and coastline protection. They are also recognized as crucial reservoirs of biodiversity at a time when the loss of species on both land and in the sea is an increasing cause for concern. Moreover, in the maritime State like Kerala, the health of the coastal

and marine ecosystems are intricately related to the health of other ecosystems such as forests, rivers, backwaters, estuaries and mangroves. Most services derived from marine and coastal ecosystems are used unsustainably and therefore getting deteriorated faster than other ecosystems. Unsustainable use of services can result in threatening food security of coastal communities, besides debilitating their means of survival. Important drivers of marine and coastal ecosystems include: population growth, land use change and habitat loss, overexploitation (overfishing) and increased demand for marine food, climate change, eutrophication, pollution, globalization, and invasive species.

a. Population Growth

Under the physiographic conditions of Kerala, the population density has tended to increase towards the coastal region. Considering the large number of people (about 30% of population) in the coastal zone, the high concentration of industries, the existence of small and large ports, and the enormous fishing potential, the question of limiting development or putting in place a regime of regulatory measures for human activities on the coast is much more challenging than any other geographical area in the State.

Marine fishing communities live close to the shoreline. The latest fish census of Kerala published by Central Marine Fisheries Research Institute (CMFRI) shows that there are 1,18,937 fishermen families in Kerala with a population of 6,10,165; 98% belonged to traditional fishermen (CMFRI, 2011). Among these 65,459 (55%) families are below poverty line. The sustainable management of coastal and marine ecosystems and the resources therein are therefore crucial when sustainable development programmes are envisaged in Kerala and poverty eradication programmes are planned in coastal zones.

b. Coastal development, land use change, and habitat loss

Coastal zone in Kerala is one of the major centers of economic development in the State, with establishment of industries, hotels and residential establishments, stadiums, IT firms, theme parks, and the like. The records of Kerala State Pollution Control Board indicate that most of the industrial and commercial establishments in Kerala are concentrated in the coastal zone. Eloor- Edayar- Ambalamugal area is the major industrial area located in the coastal zone in the city of Kochi in Ernakulam District along the banks of the Cochin backwaters (KSCSTE¸ 2005).

Coastal wetlands, mangroves, mud flats, sand dunes, backwaters, beaches and estuaries and coastal habitats along Kerala coast are in various stages of degradation. Over the years there are frequent report of ever increasing violation of Coastal Management Zones of the state, especially for developmental activities. Undoubtedly, one the ecosystems that witnessed greatest impact of anthropogenic intervention in the State is the mangrove forests. In Kerala, a few decades ago there were about 70,000 ha of mangroves; however, in recent years it has been reduced to less than 4,200 ha (Mohanan, 1997) though field observations reveal that the condition of mangrove ecosystems in Kerala is still pathetic, with a few healthy patches restricted to the northern districts. The destruction of mangroves for the development activities

and construction of aquaculture ponds has not only started affecting the productivity and biodiversity of coastal waters, but also in destabilisation of shorelines.

Unstinted reclamation activities have drastically reduced the extent and functioning of brackishwater lakes in the State. According to Kurian *et al.* (1995), the brackish water coverage of the State has come down from 2.51akh ha in the 1950s to 61,200 ha in 1990. The biggest backwater system of the State and the second biggest in the country, Vembanad lake, which occupied an area of about 36,500 ha in 1983 (Gopalan *et al*., 1983) has shrunken to 13,000 ha currently. Coastal wetlands, mangroves and backwaters have been destroyed considerably for the development and expansion of the urban settlements, transportation, industries, and other projects. The unscientific coastal development activities have complicated the issue of siltation of water bodies.

Dredging for the maintenance of harbours and the disposal of dredged materials offshore have changed the shoreline morphology, especially along the Kochi Port. The uninhibited sand mining in most of the backwaters of Kerala not only affected the ecology of the system but also started affecting the fishery resources. Similarly sand mining from beaches poses grave environmental as well as livelihood problems. Mining of beach sand, especially from the foreshore, would lead to coastal erosion. This has already surfaced along the Neendakara-Alappad coast (KSCSTE, 2005).

The construction of Thottapally spillway has turned out to be an ecological disaster in Kuttanad and its adjoining area, resulting in checking natural downstream migration of the giant freshwater prawn and fishes and upstream migration of marine or estuarine shrimps and fishes for feeding and breeding, besides altering the hydrological regime and ecological profile of Vembanad lake; limitations in natural flushing resulted in accumulation of pollutants and intensifying disease outbreaks in aquatic organisms (Kurup *et al*., 2000; Padmakumar *et al*., 2002). The breakwaters constructed across the shoreline interfered with the littoral transport processes and caused coastal erosion on the down drift side and some accretion on the up drift side of these breakwaters (KSCSTE, 2005).

A series of coastal regulation zone violations have been reported from the State due to the unplanned development plans, unauthorised constructions and encroachments.

c. Over exploitation of resources

Kerala is one of the leading marine fish producing States of India, contributing up to 25% of the marine fish landings of the country. Marine fisheries and fisheries from the backwaters of Kerala ensure food and nutritional security, livelihood options and generate foreign exchange through export. Such a highly productive inshore area is being exploited intensively by more than 21,781 crafts, of which 4,722 were mechanized (CMFRI, 2011). Excessive number of trawlers in Kerala also increases the landing of bycatch including eggs and juveniles of commercial species which would in the long run affect the delicate ecological fabric of the ecosystem. Continued use of illegal nets and unscientific fishing practices also put great pressure on resources, besides issues related to ghost fishing (fishes and other marine organisms caught in nylon nets thrown back at the oceans).

The fisheries of brackishwater systems are also seriously affected as a result of ecosystem changes due to habitat loss/modification, pollution, invasive species, and

pollution. The black clam (*Villorita cyprinoides*) fishery of Vembanad is currently unsustainable as a result of exploitation of juvenile clams (below Minimum Legal Size) using nets of very small mesh size. The economic loss due to exploitation of the juvenile clams during 15 years has been estimated at Rs. 51.3 crores by CMFRI (Kripa *et al.,* 2004). Similarly unsustainable exploitation of sub-fossil deposits of clam shells in brackishwater lakes such as Vembanad and Ashtamudi also create rampant ecological changes. However, of late, the availability of clams has improved in the Ashtamudi lake as a result of regulations imposed on fishing and certification of fishery.

The total marine fish production in Kerala during 2016 was 5.23 lakh tonnes (FRAD, CMFRI, 2017), however, decadal landing over the last 65 years shows a gradual decline in total marine fish landings in the state (Fig. 1.).

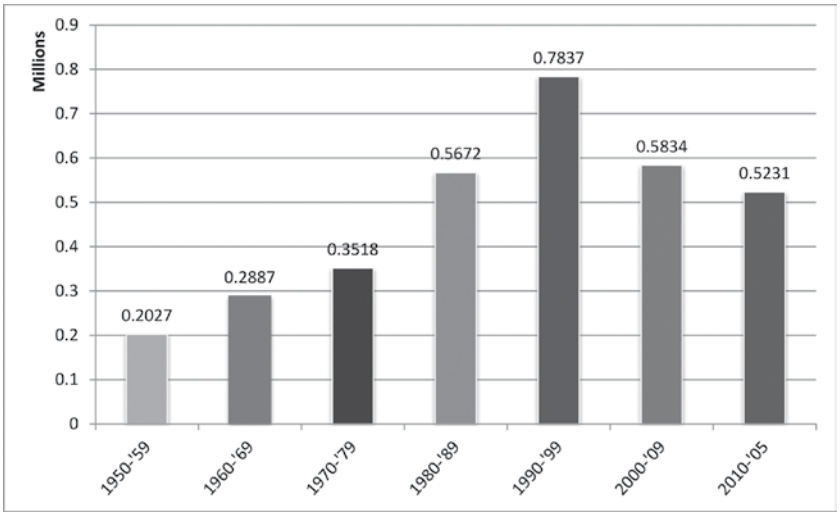

Fig.1.
Decadal variations in marine fisheries landings in Kerala

The excessive fishing pressure and open access nature of the ocean continue to exert pressure on inshore waters, often leading to heavy competition leading to inter- and intra-sectoral conflicts. Further, increasing capital investments in the sector coupled with pressure from market as a result of globalisation further aggravate the problem; the plight of the traditional fishermen in the State continues to be miserable than any other section of the society.

d. Tourism

The main focal areas of tourism development in Kerala are coasts and backwaters, and therefore the support systems including hotels, beach resorts, backwater resorts and other tourist accommodation facilities are mainly situated in the coastal belt. There are about 200 motorised house boats plying in the Vembanad lake exclusively for tourism purpose. As the State is one of the hot destinations of both domestic

and foreign tourists, this sector is recording fastest growth rate compared to other industries, the pressure on coastal ecosystems would continue to increase. The deterioration of environmental quality, including erosion of coasts and beach would further hamper the sustainable development of the tourism industry.

e. Coastal Erosion

According to Ahana *et al.* (2012) Kerala – which has 80% of its coast as sandy beaches and reportedly the maximum extent of erosion – was found to have 215.9 km of seawalls. Reports of the National Centre for Sustainable Coastal Management (NCSCM) indicate that 63% of Kerala coast is subjected to erosion, out of which around 53% can be classified as "Artificial Coast", managed by artificial structures such as sea walls and/or riprap revetments/groynes. Out of the remaining 37%, only 8% is stable. This situation also warrants careful interventions in the coastal front, and rethinking on construction of artificial walls along the vulnerable coastal stretches of Kerala (NCSCM, 2013). Most of the seawall constructions in India have been initiated without detailed background studies on the geology and environmental settings of the individual beaches and therefore these structures promote erosion in the remaining sea-wall free areas. However, with careful planning and designing, the shoreline armouring structures could be used to support local marine biodiversity by providing them with adequate habitat to settle and survive (Bijukumar and Ravinesh, 2011).

The few ideal beaches for the nesting of endangered marine turtles left in Kozhikkode (Payyoli) and Kasargod (Neeleswaram) are also severely impacted by the issue of coastal erosion and sand mining. The impacts of coastal erosion on human settlements and traditional livelihood activities are also rampant. The expenses incurred by the Government towards protection of coast from erosion are also huge, costing about rupees 4 crores per kilometer of the coast. The State's economy is getting strained in this process.

f. Climate Change

The potential impacts of climate change are reflected on shorelines, estuaries, coastal wetlands and ecosystems bordering ocean, and the impacts in Kerala coast may be due to several key drivers including increase in sea level change, alterations in precipitation patterns and subsequent delivery of freshwater, nutrients, and sediment, increased sea surface temperature, increase in ocean acidity alterations in circulation patterns and increased levels of atmospheric CO_2. Estuarine productivity could change in response to alteration in the timing and amount of freshwater, nutrients, and sediment delivery. The coastal areas, especially the low lying areas in the state such as Kuttanad, may experience adverse impacts such as submergence, coastal flooding and coastal erosion due to relative sea level rise. This will further impact the water security and food production in the coastal habitats. The highly productive ecosystems along Kerala coast, including mangroves and sea weed ecosystems would also be impacted by the climate change. The available modelling studies project shift in marine fish populations and coastal impacts due to sea level rise in cities such as Cochin. The monsoon vagaries, presently more frequent could also be correlated with climate change and El Nino.

The sea level rise recorded in Indian seas during 1970-2010 was more than 8cm (Unnikrishnan and Shankar, 2007) and the projection for 2050 and 2100 are more than 20 to 40 and 50 to 70 cm respectively. Under the influence of climate change, beaches, sand dunes and cliffs currently eroding will continue to do so under increasing sea level. The human settlements (especially those of the fisher folks), transportation and tourism infrastructure at or near the coast is vulnerable to more frequent flooding, rising sea levels and possible increase in the magnitude and frequency of tropical storms and other natural calamities due to climate change. Main threats could be salinity ingress in water bodies and inundation of low lying areas, with resultant loss of fertile agricultural lands in coastal areas. However, aquatic biodiversity like fisheries resources may provide opportunity for adaptive livelihood measures for food security in the coastal area (Anon., 2010).

Analysing the data on Sea Surface Temperature (SST) obtained from International Comprehensive Ocean – Atmosphere Data Set (ICOADS) (www.cdc.noaa.gov) and 9-km resolution monthly SST obtained from Advanced Very High Resolution Radiometers (AVHRR) satellite data (provided by the NOAA/NASA at http://podaac.jpl.nasa.gov/), it has been found that the SST increased in the Indian seas, by 0.2^{0}C along the northwest (NW), southwest (SW) and northeast (NE) coasts, and by 0.3^{0}C along the southeast (SE) coast during the 45 year period from 1961 to 2005 (Vivekanandan, 2013). Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C- 2°C for various scenarios (IPCC, 2013). The SST showed peaks at an interval of about ten years (1969-70, 1980, 1987-88, 1997-98) during 1961-2005, and the decadal number of SST anomalous (+ 1 or – 1 deviation from the 45-year mean) months increased. Off Kerala, for example, only 16% of the months were SST anomalous during 1961-1970, but 44% during 2001-2005 (Vivekanandan *et al*., 2009), while the predictions for 2050 consider it as more than 1.5^{0}C and for 2100 as 2.0-2.5^{0}C.

Besides the changes in mean sea level, changes in extreme sea level occur through storm surges, which is less frequent along the west coast of India. The vagaries shown by monsoon and frequent flash floods further aggravate the issues. Kerala coast is reported to show a small increase in annual precipitation in the 2030s, with respect to the baseline, that is, 1961– 1990s (or 1970s); projections for the western coast indicate a variation from 935±185.33mm to 1794±247mm, which is an increase 6%–8% with respect to the1970s (Anon., 2010). Inundation maps prepared for a 1m and 2m sea-level rise indicated that Cochin region of Kerala is highly vulnerable to sea-level rise and extreme events (Anon., 2010). Of the 9 coastal districts of Kerala Alappuzha was found to be most vulnerable to the coastal erosion and flooding; the three taluks such as Karthikapally, Ambalappuzha and Cherthala were found to be most affected ones in the district (CMFRI, 2013).

Studies by CMFRI has already showed shifts in the occurrence of commercial fishes such as oil sardine and mackerel along Kerala coast (Vivekanandan *et al.,* 2009). Prsannakumar *et al.* (2009) recorded increase in phytoplankton biomass and oil sardine in the last two decades in the Arabian Sea. According to Mohamed *et al.* (2013) the increase in catch of puffer fish *Lagacephalus inermis* biomass along Kerala coast in the recent decades may be related to the decline of predators. The

examples recorded from Kerala coast shows that differential physiological effects of temperature on individual species are key to understanding and projecting climate-induced changes in species interactions and in community composition. Occurrence, increase in frequency, intensity and spatial coverage of harmful algal blooms during the past decade in the EEZ of India indicated a sharp increase, with the frequent contribution of toxic species such as *Alexandrium* spp.,*Gymnodinium* spp., *Dinophysis* spp., *Coolia monotis, Prorocentrum lima,* and *Pseudonitzschia* spp. (Padmakumar *et al.,* 2012).

The impact of the rising sea levels would be variable depending upon the characteristics of the coast such as geomorphology and slope and the variability of marine processes such as waves and tides along the coast. Mapping of coastal landforms, slopes, and the recent changes that occur, therefore assumes greater significance in understanding the coastal response to sea-level rise (Anonymous, 2012). Although these potential impacts of climate change and variability will vary from region to region, in-depth studies are needed to surmise the potential impacts on coastal and marine ecosystems of Kerala. The available modelling studies project shift in marine fish populations and coastal impacts due to sea level rise in cities such as Cochin.

MANAGEMENT REQUIREMENTS

a. Protection of coastal zone

- Although existing Coastal Regulation Zone Act is effective in controlling many of the impacts in the coastal zone, increasing number of violations have been reported from the State. The State Coastal Zone Management Authority should take stringent actions against the violators and has to take effective mechanisms to monitor and check violations. Use of modern technologies including historical coastal zone maps (including those available in open access platforms such as Google earth maps) should be used to book cases of violations.
- A Costal Zone Monitoring Network should be established involving all coastal local bodies, with the participation of Civil Society Groups and environmentalists to monitor violation of CRZ act and to ensure the progress of implementation of the act. The functioning of the State Coastal Zone Management Authority has to be decentralized by establishing District level Authorities with adequate legislative and financial powers to monitor and to implement the act.
- Ecosystem services of the critical coastal and marine habitats have to be analysed specifically through integrated inclusive research so as to prepare Integrated Coastal Zone Management Plans and for identifying hotspots for conservation and sustainable management.
- The reclamation of lakes and coastal wetlands should be banned totally and the existing boundaries are to be identified and fixed using advanced technologies including satellite mapping to prevent further encroachment.
- Strict guidelines shall be formulated to control mining of strategically important heavy minerals, namely black sand (such as ilmanite, monazite and rutile) and industrially important minerals, namely glass sand (white sand – silicates) and,

the same may be enforced strictly. Mining heavy mineral deposits should be done only after determining the sustainable limits of resources through sediment budgeting and mining should be limited to public sector agencies, with proper monitoring done by a body involving civil society representatives.

- In order to prevent human settlement in CRZ, separate fishing townships with all facilities required for the fishing communities should be developed outside the No Development Zone of the Coastal Regulation Zone (CRZ).
- Since the Coastal Regulation Zone (CRZ) notification of February 1991 and Coastal Management Zone (CMZ) notification of 2011 are in vogue, 200 meter width of coastal areas are to be statutorily earmarked as undeveloped zones, except for utilizing it for fishery related activities of the coastal fisherfolk.
- Mudflats, coastal wetlands, reefs, mangroves, sand dunes and shoals should be categorised as ecologically sensitive CRZ I areas. All heritage sites and reserved forests should be categorised as CRZ I.
- No reclamation or constructions after 1991 should be regularised. This has particular relevance where industrial clearances are sought from the MoEF.
- Though periodic dredging is a necessity in ports and harbours, it has to be ensured that the dredged materials should not get back to the harbours and used for reclamation in or near the entrance of harbours leading to choking of inlet mouths. Further, dumping sites have to be fixed only after EIA studies, including modelling.
- No sand excavation, mining or shell/shale/stone extraction be allowed from CRZ areas. Effective enforcement mechanisms have to be set up for implementing the ban, particularly in sensitive areas such as turtle nesting sites.
- Ground water exploitation has to be regulated in the coastal zone to specified wells and specified quantities based on scientific assessment. Necessary technology should be adopted so that the saline water lenses are not disturbed.
- Considering the fact that construction of sea wall for shoreline protection is a threat to the existing beaches and the colossal expenses involved, the whole process has to be reviewed critically. Restoration of beaches and protection of sea shore through natural shields such as mangroves and typical coastal vegetation have to be promoted with the participation of coastal communities. In addition to mangroves, cultivation of economically valuable plants such as *Calophyllum inophyllum* (beach touriga/ Indian doomba oiltree Punna/Avanakku) and *Morinda citrifolia* (Indian mulberry/noni) can be promoted in the coastal areas of the state.

Pollution Control

- Industrial effluent disposal in the coastal water bodies has been regulated through the Environment (Prevention and control) and CRZ rules, but not effectively implemented. Judicial intervention has recently pressurized the regulatory authorities to take action. The treatment plants shall be made mandatory for the industries which generate effluents. Effluents conforming to the prescribed standards shall only be allowed to be disposed in the water bodies.

- Following the principle of "Polluter pays", industries may be levied the cost of environmental damages and the amount so generated shall be fully utilized for environmental management programmes.
- There is no proper or adequate facility for collection, treatment and disposal of sewage in the coastal cities and towns of the State. As the population increases and urbanisation intensifies, a long term planning for the sewage collection, treatment and disposal should be initiated and implemented.
- Sewage collection and treatment mechanisms have to be made mandatory for house boats operating in the backwaters.
- There are no effective mechanisms to control the generation of solid wastes in large quantities in urban centres and tourism destinations in the coastal area. Local bodies should take urgent measures to control the solid waste generation and take eco-friendly measures for proper recycling or disposal of the wastes. Segregation at source and using the organic waste for biogas and fertilisers are the best options.
- Specific standards for cleanliness should be adopted and monitoring mechanisms implemented in ports and harbours. Fisheries harbours have to be upgraded with sanitation facilities, boat fuelling area and better drainage systems.
- Efforts should be made to reduce its ill effects of coconut husk retting by adopting modern environment–friendly retting methods. The present practice of discharging waste pith into the water should not be allowed.
- The impact of marine debris or marine litter (human-created waste that has deliberately or accidentally been released into the coastal and marine environment) should be studied in detail in Kerala coast and their use should be strictly regulated. Beach Cleanup programs should be initiated with the help of civil society organisations and coastal communities.
- Coastal tree shied with indigenous coastal vegetation of a minimum of 10 m width should be promoted in areas of human settlements, with the participation of local communities. Planting of vegetation and deriving benefits from these resources should also be promoted as an alternate employment opportunity to the local population.

Biodiversity Conservation and Sustainable Use

- One of the pre-requisites for conservation is a strong quantitative and qualitative data base on the living marine resources of Kerala coast in order to frame conservation and management plans.
- The maximum sustainable yield of the commercially exploited species should be determined in coastal and brackishwater habitats and harvesting should be regulated accordingly.
- Sustainable harvesting of resources should be ensured by strictly adhering to the existing rules such as Kerala Marine Fishing Regulation Act and by assessing the maximum permissible limit of mechanised fishing vessels.
- Mandatory registration and licensing of all motorized and mechanized boats, review of licensing every five years, cancellation of registration of vessels

violating fishing regulations, and temporary moratorium for further sanction of mechanized vessels for inshore waters would also be considered to reduce fishing pressure.

- Restriction of multiday fishing by fixing upper limit and fixing and capping the size and power of the boats in each sector by imposing upper limits for the length and horsepower, especially the large ring seines (Mainly for controlling mass destruction of juveniles).
- Bycatch reduction methods should be made mandatory in trawl nets to reduce the loss of biodiversity, especially the destruction of RET species.
- Monsoon trawl ban has helped in better fishery production and, therefore, this should be continued in the forthcoming years as well. Only non-motorised and low horse powered (up to 10 HP) OBM/IBM vessels should be allowed to operate during the closed season.
- Stake nets are found to be highly destructive in the sustenance of brackishwater fishery resources of the State and therefore, they may be removed in a phased manner as per the recommendations submitted by the Stake Net Committee appointed by the Govt. of Kerala.
- Appropriate areas in the estuarine and sea coast of the State for mangrove afforestation should be identified and mangrove planting through community participation implemented. Science clubs in educational institutions should be given training and funding for adopting mangrove plantations for its maintenance.
- Promote alternate livelihood options to the fisher folk and involving them in ancillary industries would not only reduce pressure on resources but also provide better living conditions for them.
- Empower fisher women by organizing Self Help Groups (SHGs) in coastal panchayaths for conservation and sustainable use of biodiversity.
- The higher diversity of fish and shellfish resources available in Kerala coast offers better prospects for diversification, especially with regard to development of new products and value addition.
- Better and effective transfer of technology from the research and academic institutions to the stakeholders by winning their confidence and working with and for them.
- The mariculture activities, particularly fish culture, are at its infancy in India, even now, without any commercial production systems. More attention has to be given to develop suitable eco-friendly low cost technologies for marine pisciculture along Kerala coast.
- Declaration of certain coastal areas closed for trawling would also help in reducing overexploitation of resources as well as conservation of marine organisms. Establishment of community-owned systems of marine protected areas that are consistent with the social, economic, political and cultural characteristics of the region, with active community participation supported by local NGOs and government agencies.
- Implementation of an integrated national conservation strategy involving *in situ* and *ex situ* and *in vitro* and *in vivo* methods for all marine Rare, Endangered

and Threatened (RET) species has also become imperative. The sea ranching programmes needs to be strengthened in India in order to replenish stocks, especially that of exploited and RET species.

- At present there is no concerted effort to make the coastal communities aware of the present ecological status of the ocean ecosystem and impacts due to the depletion of biodiversity. Fishery co-operatives, self-help groups in coastal areas, NGOs and religious institutions should be networked along with government systems for this purpose. Similarly, conservation efforts should be strengthened taking clues from the rich traditional knowledge of the local fishing communities. The rich traditional and technological knowledge of the local fisher folk remains to be documented.
- Protect all the remaining pokkali fields for sustainable integrated farming, as these are the areas used for eco-friendly rice fish culture.
- Steps should be taken to avoid Illegal, unreported and unregulated (IUU) fishing in Indian coast. In this context, ban introduction of foreign trawlers into the EEZ of India, including in the name of 'joint' ventures.
- Principles of Ecosystem Approach to Fisheries (EAF) and Code of Conduct for Responsible Fisheries (CCRF) should be adopted to manage marine fisheries of Kerala coast to sustain the productivity.
- The use of certification or catch document schemes should be encouraged to make fishing more ecofriendly.
- The trend of developing Special Economic Zones in certain potential fishing areas and fishermen hamlets for complementing high-tech projects should not be encouraged. Paradigm shift is needed to pursue the concept of development in these areas.

Combating climate change

- Microlevel studies are required to develop models to assess and predict the impact of climate change in various coastal ecosystems and to assess erosion prone areas in the coast with the Digital Elevation model. Further, vulnerability assessment should also be done at microlevels. There is also a need for flood mapping, flood forecasting, developing hydrological framework and downscaled climate change projections modeling.
- At present the local communities in Kerala coast are least adapted for facing the climate vagaries. Considering the fact that the coastal zone is the population dense area in the state, with lot of developmental activities in progress, there is an urgent need for strengthening coastal protection methods with the participation of local communities, especially by promoting coastal bioshields wherever ecologically feasible. Further, a techno-legal regime for construction of disaster resilient housing and public infrastructure and construction of multipurpose flood shelters in the coastal areas are required in vulnerable areas, besides improving measures for flash flood management.
- The adaptation methods would become effective only through integrating climate change risk in the state's disaster management policy. There is also a

need for setting up an integrated training and capacity building protocol. Energy audit should be done to identify how to reduce the use of fuel for routine fishing operations, followed by energy efficiency programmes to implement these savings.

- The global focus on the Kuttanad unique system of farming will be reinforced by the setting up of proposed international-level institute for below sea-level farming in Kuttanad. The traditional method of integrated farming system practiced in Kuttanad, with salt and flood tolerant rice varieties at below sea level would serve as a model to plan adaptation strategies elsewhere.
- Integrated coastal area development programme covers activities of improvement of socio-economic conditions of fisherfolks in coastal areas. Adaptation measures for the communities reliant on fisheries for food and income should also consider options such as education, entrepreneurial training, and training in tourism and aquaculture to prevent potential deterioration of social conditions in fisher communities associated with climate change. Value-adding to current catches and improved market access through eco-certification and other mechanisms should also support fisheries adaptation. The fish processing sector in Kerala is managed predominantly by the women workforce and the efficiency and productivity are likely to be improved by ensuring that the rights and responsibilities of women are recognised in their employment conditions and their sustainable income is ensured.
- In the marine fisheries sector there is a need to develop a database on the impact of climate change and marine fisheries. Projections should be made on the biodiversity changes in marine ecosystem under the influence of climate change through appropriate modelling studies. Capture fisheries also faces multiple pressures as a result of overfishing, habitat modification and pollution. To build resilience to the effects of climate change and derive sustainable benefits, fisheries and aquaculture managers needs to adopt and adhere to best practices such as those described in the FAO Code of Conduct for Responsible Fisheries. These practices need to be integrated more effectively with the management of river basins, watersheds and coastal zones partnerships and collaboration are of prime importance in addressing the complex and cross-cutting challenges of climate change.
- Considering the impending sea level rise, adaptation strategies including a proper rehabilitation programme for those who will be displaced shall be worked out and put in place sufficiently in advance.
- Knowledge base has to be strengthened for better understanding of the impact of climate changes on fish stocks in our coastal waters with proper modelling studies as the first step towards planning and framing better management strategies.

Responsible Tourism

- The responsible tourism guidelines should be followed for all the tourism initiatives in the coastal and marine areas.
- The number of houseboats in backwaters should be strictly limited, based on carrying capacity studies and strict rules and regulations for waste management,

especially in backwater tourism using house boats, shall be formulated and enforced. All house boats shall run on non-conventional energy sources such as solar and be fitted with green toilets/safe disposal of the wastes.

SCIENCE, TECHNOLOGY AND INNOVATION

Science, technology, and human resource development are the major pillars for achieving the goals as well as for implementation of programmes for the same. The Scientific Advisory Board of United Nations Secretary General "calls upon scientists and policy-makers to recognize science as a universal public good, to acknowledge basic science as a principle requirement for innovation, to enhance diversity in science for sustainable development, to strengthen science education, to raise investments in science as well as to promote an integrated scientific approach." Main recommendations include integrating the Sustainable Development Goals into research agendas, so that sustainability becomes the corner-stone for future research both in fundamental and applied science, creating effective mechanisms to allow the scientific community to contribute to the national and global follow-up and review processes of the 2030 Agenda, and establishing independent scientific monitoring mechanisms to allow science to play a role as a constructive corrective for achieving the SDGs.

Diversification and popularization of Science, Technology and Innovation (STI) also play a critical role in achieving SDGs besides recognition, protection and promotion of indigenous and local knowledge. Moreover, it demands for more partnership amongst science and technology communities and indigenous peoples and local communities. It also increases the responsibilities of scientists to take up research in order to meet the demands of the society for achieving SDGs.

With regard to marine and oceanic resources the for countries like India, the priority goals should remain as poverty alleviation and maintenance of better environmental conditions in coastal oceans for ensuring the consistent supply of resources in order to achieve environmental, economic and social sustainably. Further, there is lesser utilization of resources from the oceans towards sustainable development, which include trapping the energy potentials of oceans, maximising the tourism potential of coastal areas for yielding better benefits through responsible tourism, promotion of sustainable aquaculture practices in both coastal and brackishwater areas, promoting transportation through coastal water ways and seas (especially with lesser scope for expanding land-based infrastructure for transportation in the state), better exploitation of deep sea and offshore resources through the application of modern technology and promotion of 'blue biotechnology', for the development of novel molecules.

Further scientists can provide information in characterising the challenges (eg: meta data, models, innovative research, etc), providing solutions (eg: information on climate resilient species, technologies for sustainable coastal or below sea level farming, processing, value added products, etc) and strengthening institutions (eg: reorienting existing curricula by incorporating SD principles, reorienting research for achieving SDGs, human resource development in S & T sector, etc). Some of the key points in this sector are outlined below:

- Science and technologies can help build tools for adapting to climate change and enhancing disasters awareness, preparedness and education (Eg. Early warning systems for Tsunami, cyclones and other natural hazards).
- Science and policy can benefit greatly from local and indigenous knowledge, which are understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. Such knowledge and practices can be an important asset in reducing risk to disasters, and to devise locally-appropriate climate change adaptation strategies.
- The transition towards a 'blue economy' requires that we educate and train the human resources and prepare society at large for such sustainable future. This requires a revised curriculum in maritime state like Kerala, where the importance of oceans in sustaining economy and development are highlighted, highlighting the role of science, technology and innovation.
- Social Inclusiveness and adoption of right-based approaches is a must in order to avoid the digital and technological divide in environmental protection. This also needs to bring on board indigenous rights while formulating regional plans for adaptation to climate change in agriculture and forests and restoration coastal areas.
- Most ocean pollution starts on land and therefore there is a need to mitigate the effects from land-based pollution by monitoring the biggest culprits of marine pollution, plastics and agricultural and industrial runoff.
- Over the years, the marine protected areas (MPAs) have made great contribution to protecting and enhancing biodiversity and contributed to local socio-economic development. In Kerala coast establishing community reserves and heritage sites along the mangrove areas could help using them as open laboratories for sustainable development, besides achieving true sustainability and a genuine community participation. Further, this will be a step-by-step approach toward 'ecosystem-based management' which has now become the international standard towards achieving sustainability.
- S&T can help guide investments in renewable energy technologies such as solar, wind, tidal energy and biomass, using the resources in the coastal and marine habitats of the state.
- S&T innovations can play a role in filling gaps in fisheries data, enhancing the coordination of fisheries management efforts, and implementing and operationalizing an ecosystem approach to fisheries management (EAFM). A few examples of this include use of acoustic technologies such as fish finding and monitoring devices, oceanographic remote sensing data to exploit and conserve resources, mobile phone and crowd-sourcing apps, next generation sequencing techniques to identify and document biodiversity, sea food standard quality testing, testing the quality of marine products through PCR technologies, climate prediction models, marine spatial planning model development using GIS, etc.
- Relying on new technologies will promote blue economy. For example, tides, waves and wind can provide green energy; aquaculture (possibly including new applications onshore and in open waters offshore) can potentially provide

sustainably produced, high-quality food to supplement capture fisheries. New technologies can be used to exploit previously inaccessible resources such as hydrocarbons and minerals in the deep sea environments; and advances in shipping technology can greatly increase the efficiency and safety of marine transport while reducing emissions and pollution, including unwanted transport of invasive species in ballast water.

- Marine bio-resources hold untapped potential as a source of new products and processes, and may help to address the national and regional challenges of food, energy and health, as well as contribute to green growth and sustainable industries. Therefore promotion of blue or marine biotechnology is key to realising this potential, especially for the development of new potent drugs and nutraceuticals and cosmeceuticals from marine resources.
- Science–Policy interface is essential for informed decision-making. Therefore scientific knowledge, up-to-date data, statistics and information on natural resources and related trends are of paramount importance for the management and sustainable use of marine resources. New technologies and survey methods should be employed for generation of special data on resources. The availability of internationally comparative data and statistics is of utmost importance for decision-makers and other stakeholders. Better knowledge about the state of resources and the impacts of decisions can also reduce uncertainty.
- Marine spatial planning is still at its infancy and this is essential for the management of coastal zones as well as resources.

CONCLUSIONS

The coastal waters of Kerala involve a mix of nature and human activities, with multiple users often having conflicting objectives. Therefore, simple, inflexible, one-solution management options are no longer appropriate. Integrated management approaches have been developed to help people understand the complexities of connections among ocean ecosystems and human uses, and what cumulative impacts might result from multiple human uses.

Integrated management is the best means of dealing with the complex and interconnected nature of Kerala coast. Integrated management ideally requires knowledge of all parts of the coastal and marine ecosystem, including climate, food webs and habitats, human uses, economic and social values, and governance. However, many of the decisions made on coastal resource use and coastal area development in the state are based on our limited knowledge and associated uncertainty. This brings out the need for the development of science and evidence-based tools, which may help support integrated decision making, synthesising the available information and explicitly incorporating patchy and imperfect understanding, resource limitations and multiple competing priorities. Above all this also necessitates considering ocean science as a multidisciplinary subject, which demands more and more inputs from science, technology and innovations from multiple fields, if we really wish to reap the benefits of blue economy and blue growth, besides conservation of marine and ocean resources.

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Appropriate Scientific Technologies and Innovations for Solid Waste Management for Kerala

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INTRODUCTION

Efficient delivery of public services and infrastructure are pressing issues for Urban Local Bodies (ULBs) in most developing countries. It is the responsibility of Local self-government institutions to provide all the amenities to its citizens and fulfill the basic needs of infrastructure- water supply, sewage system and management of municipal solid waste and in many countries, solid waste management has become a top priority. Different types of interventions are essential to improve the quality of our cities and reducing the adverse health and environmental effects. Improper and unscientific SWM measures usually adopted in many countries not only has its local significance but pose much wider global implications. Climate change and effects of greenhouse gas emissions have made SWM, one of the most pressing environmental challenges globally as well as locally.

The total Indian urban population amounts to approximately 285 million (World Bank, 2008). There are 4,378 cities and towns in India. Of those cities, according to the 2001census, 423 are considered class I, with a population exceeding100,000(one lakh).The class I cities alone contribute to more than72 percent of the total municipal solid waste (MSW) generated in urban areas. This includes 7 mega cities (which have a population of more than 4 million), 28 metro cities (which have a population of more than 1 million), and 388 other towns (which have a population of more than1lakh) (NEERI,1996).The Central Public Health and Environmental Engineering Organization (CPHEEO) estimated a per capita waste generation in Indian cities and towns in the range of 0.2 to 0.6 kilograms per day. According to Central Pollution Control Board (CPCB), average collection coverage ranges from 50 to 90 percent. Of the collected waste, 94 percent is disposed of without any scientific management practices. Hence, there is severe pollution of ground water and surface water through leachate, as well as air through uncontrolled burning of waste.

There are different types of solid waste which need to be dealt with. The first is recyclable waste, which can be recycled. Solid waste management includes the construction of facilities to recycle these goods, which include scrap metal,

glass, cans, paper, plastics, wood, and similar materials. Another category is toxic waste, which could potentially contaminate the environment, meaning that it needs to be handled with care. This category includes electronic waste, a growing problem in many industrialized nations. Next is organic waste which can be composted and returned to the earth.

The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and producing energy from solid waste. Municipal solid waste management (MSWM) involves the application of principle of Integrated Solid Waste Management (ISWM) and it is the application of suitable techniques, technologies and management options dealing with all types of solid wastes from all sources to achieve the twin objectives of (a) waste reduction and (b) effective management of waste still produced after waste reduction (Cointreau,2001).

CLASSIFICATION OF SOLID WASTE

Municipal Solid Waste (MSW) is the trash or garbage that is discarded day to day in a human settlement. According to the Municipal Solid Waste Management Rules, 2016: "solid waste" means and includes solid or semi-solid domestic waste including sanitary waste, commercial waste, institutional waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste, construction and demolition waste and treated bio-medical waste excluding industrial hazardous waste, bio-medical waste and e-waste generated in an area under urban local body.

Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is essential for the design and operation of the functional elements associated with the management of solid wastes. Solid wastes are generally classified in to two, based on source of generation and type.

1. Classification based on Source

Based on the source of generation, solid waste can be classified into residential, commercial, institutional, industrial, agricultural etc. (Table 1).

2. Classification based on Type

There are mainly two categories of wastes based on the type-biodegradable and non-biodegradable wastes. This classification is based on physical, chemical and biological characteristics of wastes. Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetables and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. Non- biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc.

Table: 1
Classification of Solid Wastes

Type	Description	Source
Garbage	Wastes from the preparation, cooking and serving of food, market refuse, waste from the handling, storage, and sale of produce and meat.	**Households** institutions and commercial concerns such as hotels, stores, restaurants, market, etc
Combustible and non-combustible	Combustible (primarily organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings etc.	
Ashes	Residue from fires used for cooking and for heating building cinders	
Bulky wastes	Large auto parts, tyres, stoves, refrigerators, other large appliances, furniture, large crates, trees branches, stumps etc	Streets, sidewalks, alleys, vacant plots etc.
Street wastes	Street sweepings, dirt, leaves etc.	
Dead animals	Dogs, cats, rats, donkeys etc.	
Abandoned vehicles	Automobiles and spare parts	
Construction and demolition wastes	Roofing and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation etc	Streets, sidewalks, alleys, vacant plots etc.
Industrial wastes	Solid wastes resulting from industrial processes and manufacturing operations, such as food processing wastes, boiler house cinders, wood, plastic and metal craps, shaving etc.	Factories, power plants etc
Hazardous wastes	Pathological wastes, explosives, radioactive materials etc.	Households, hospitals, institutions, stores, industry etc.
Animals and agricultural wastes	Manure, crop residues etc.	Livestock, farms, feedlots and agriculture
Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

Source: Phelps et al., 1995

Table: 2
Degeneration Time for Biodegradable and Non-biodegradable Wastes

Category	Type of waste	Approximate time taken to degenerate
Biodegradable	Organic waste such as vegetable and fruit peels, leftover foodstuff, etc	A week or two
	Paper	10-30 days
	Cotton cloth	2-5 months
	Woollen items	1 year
	Wood	10-15 years
Non-biode-gradable	Tin, aluminum, and other metal items such as cans	100-500 years
	Plastic bags	One million years
	Glass bottles	Undetermined

Source: Phelps et al, 1995

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on scientific principles. This includes all technological, financial, institutional and legal aspects involved for solving the whole spectrum of issues related to solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes. Typical SWM system with its functional elements and linkages are shown in the Fig:.

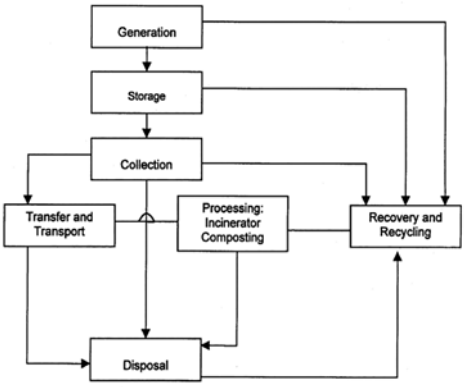

Fig: 1
Typical SWM System: Functional Elements

WASTE GENERATION AND CHARACTERISTICS

Information on waste quantity and composition is important in evaluating alternatives in terms of equipment system, plans and management programmes. For example, if wastes generated at a commercial facility consist of only paper products, the appropriate equipments are shredders and balers. Similarly, on the basis of quantity generated, we can plan appropriate means for separation, collection and recycling programmes for wastes.

The characteristics of the wastes can be divided into physical characteristics and chemical characteristics. The analysis of characteristics of waste is very important in determining the appropriate processing options and identification of technology.

i. Physical Characteristics

Density of waste: Mass per unit volume (kg/m3) is a key factor in the design of a SWM system. Compaction of wastes to optimum density is one of the key factors in sanitary land fill operation

Moisture content: Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total weight of the wet waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour.

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are also seen in states like Kerala where the state is getting around six month's rainfall in a year.

Size: Measurement of size distribution of particles in waste stream is important because of its significance in the design of mechanical separators and shredders. Generally, the results of size distribution analysis are expressed in the manner used for soil particle analysis.

ii. Chemical Characteristics

The products of decomposition and heating values are two examples of chemical characteristics. The knowledge on chemical characteristics is essential if solid wastes are to be used as fuel, or are used for any other purpose. The major components to be assessed are lipids, carbohydrates, proteins, natural fibres, synthetic organic materials (plastics), non-combustibles, heating value etc. When evaluating incineration as a means of disposal or energy recovery, we need to consider the heating values of respective constituents.

Characterization of waste is necessary to know the changing trends in composition of waste. Based on composition/ characterization of waste, appropriate selection of waste processing technologies could be selected.

Table: 3
Typical Waste Composition

Characteristics	Low income population	High income population	Comments
Paper	1-4%	20-50%	Low paper content indicates low caloric value.
Plastics	1-6%	5-10%	Plastic is low as compared to high-income areas though the use of plastic has increased in recent years
Ash and Fines	17-62%	3-10%	Ash and fines do not contribute to combustion process
Moisture Content	30-40%	15-30%	Moisture content depends largely on the nature of the waste, climate and collection frequency. Waste can dry out while awaiting collection
Bulk Density	300-400 kg/ m^3	150 kg/m^3	Heavier waste may cost more to handle and difficult to burn

Source: Ali et al.,1999

Table: 4
Waste characterization in Indian cities

S. No	Name of City	Compostable (%)	Recycla-bles (%)	C/N Ratio	HCV* (Kcal/ Kg)	Moisture (%)
1	Kavarati	46.01	27.20	18.04	2242	25
2	Gangtok	46.52	16.48	25.61	1234	44
3	Itanagar	52.02	20.57	17.68	3414	50
4	Daman	29.60	22.02	22.34	2588	53
5	Silvassa	71.67	13.97	35.24	1281	42
6	Panjim	61.75	17.44	23.77	2211	47
7	Kohima	57.48	22.67	30.87	2844	65
8	Port Blair	48.25	27.66	35.88	1474	63
9	Shillong	62.54	17.27	28.86	2736	63
10	Simla	43.02	36.64	23.76	2572	60

11	Agartala	58.57	13.68	30.02	2427	60
12	Gandhinagar	34.30	13.20	36.05	698	24
13	Dhanbad	46.93	16.16	18.22	591	50
14	Pondicherry	49.96	24.29	36.86	1846	54
15	Imphal	60.00	18.51	22.34	3766	40
16	Aizwal	54.24	20.97	27.45	3766	43
17	Jammu	51.51	21.08	26.79	1782	40
18	Dehradun	51.37	19.58	25.90	2445	60
19	Asansol	50.33	14.21	14.08	1156	54
20	Kochi	57.34	19.36	18.22	591	50
21	Raipur	51.40	16.31	223.50	1273	29
22	Bhubaneswar	49.81	12.69	20.57	742	59
23	Tiruvanan-thapuram	72.96	14.36	35.19	2378	60
24	Chandigarh	57.18	10.91	20.52	1408	64
25	Guwahati	53.69	23.28	17.71	1519	61
26	Ranchi	51.49	9.86	20.23	1060	49
27	Vijaywada	59.43	17.40	33.90	1910	46
28	Srinagar	6177	17.76	22.46	1264	61
29	Madurai	55.32	17.25	32.69	1813	46
30	Coimbatore	50.06	15.52	45.83	2381	54
31	Jabalpur	58.07	16.61	28.22	2051	35
32	Amritsar	65.02	13.94	30.69	1836	61
33	Rajkot	41.50	11.20	52.56	687	17
34	Allahabad	35.49	19.22	19.00	1180	18
35	Visakhapatnam	45.96	24.20	41.70	1602	53
36	Faridabad	42.06	23.31	18.58	1319	34
37	Meerut	54.54	10.96	19.24	1089	32
38	Nasik	39.52	25.11	37.20	2762	62
39	Varanasi	45.18	17.23	19.40	804	44
40	Jamshedpur	43.36	15.69	19.69	1009	48
41	Agra	46.38	15.79	21.56	520	28
42	Vadodara	47.43	14.50	40.34	1781	25
43	Patna	51.96	12.57	18.62	819	36
44	Ludhiana	49.80	19.32	52.17	2559	65

45	Bhopal	52.44	22.33	21.58	1421	43
46	Indore	48.97	12.57	29.30	1437	31
47	Nagpur	47.41	15.53	26.37	2632	41
48	Lucknow	47.41	15.53	21.41	1557	60
49	Jaipur	45.50	12.10	43.29	834	21
50	Surat	56.87	11.21	42.16	990	51
51	Pune	62.44	16.66	35.54	2531	63

Source: CPCB, 2004-05

MSW in India has approximate 40–60% compostable, 30–50% inert waste and 10% to 30% recyclable. Analysis carried out by NEERI reveals that in totality, Indian waste consists of Nitrogen content (0.64 ± 0.8) %, Phosphorus (0.67 ± 0.15)%, Potassium (0.68 ± 0.15)%, and C/N ration (26 ± 5) %. Change in the physical and chemical composition of Indian MSW with time is shown in Table 3.

Table: 5
Change in composition of municipal solid waste with time (in %)

Year	Biode-gradables	Paper	Plastic/ rubber	Metal	Glass	Rags	Others	Inert
1996	42.21	3.63	0.60	0.49	0.60	-	-	45.13
2005	47.43	8.13	9.22	0.50	1.01	4.49	4.02	25.16
2011	42.51	9.63	10.11	0.63	0.96	-	-	17.00

MSW GENERATION IN KERALA

Kerala Sustainable Urban Development Project (KSUDP) generated data on the quantum of MSW generated from different source in four Municipal Corporations by engaging consultants with specific terms of references based on standard protocols. Estimates based on direct sampling for the four corporations is given in Table 6 to get an idea about waste generation in Kerala

Table 6
Estimated MSW Generation in the Municipal Corporations in Kerala

Sl. No	Sources of MSW Generation	Quantity MSW Generation(tones/day)			
		Kollam	Kochi	Thrissur	Kozhikkode
1	Domestic sources	95	135.00	75.75	100.12
2	Commercial establishments	17	33.00	13.02	28.16
3	Marriage & community halls	1	4.75	2.12	1.56
4	Hotel & Restaurants	19	30.00	14.57	24.07

5	Markets	6	20.00	11.01	12.08
6	Institutions/ schools, offices	7	15.00	5.51	10.62
7	Street sweepings	14	31.00	13.87	19.28
8	Hospitals(Non-infectious)	2	4.22	3.6	6.64
9	Slaughter house	2	5.26	2.25	-
10	Construction & Demolition	7	17.00	13.6	11.0
	Total	170	295.00	154.70	213.53
	Per capita generation (g/day/ head)	434	482	476	477

Source: AjayakumarVarma, 2007

The chemical composition revealed high moisture content, low calorific value and high nutrient content indicating the suitability of organic fraction of waste for composting. Considering the chemical properties of typical MSW from the state, it is found that moisture content of MSW for the state is very high approximately about 70% (AjayakumarVarma,2007). Unofficial estimates indicate that the quantity of solid waste generated in Kerala is nearly 8000 MT/day.

Based on the source of generation, the solid waste generated in Kerala can be categorized as given below:

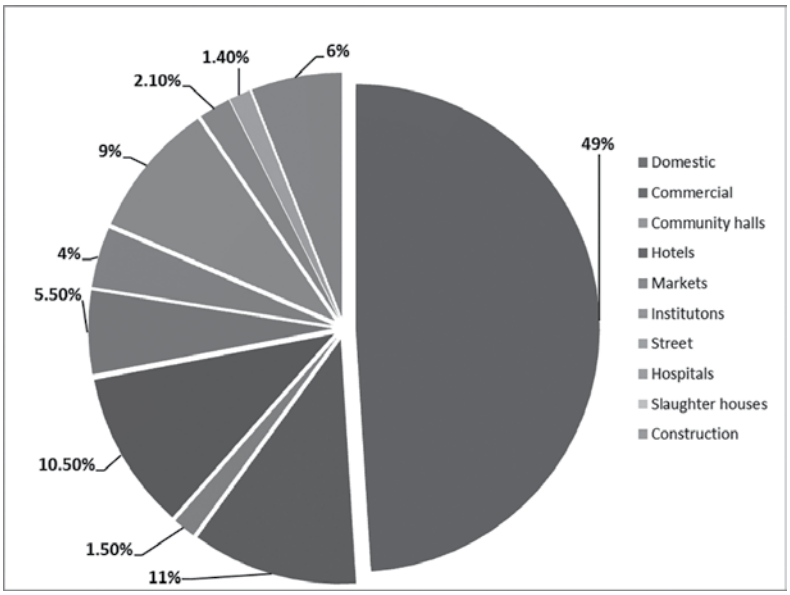

Fig: 2
Sources of Solid Waste and Rate of Generation

Table: 7
Composition of solid waste

Sl. No.	Component	Percentage of total
1	Biodegradable	71-83
2	Paper	3.5-5
3	Plastic, rubber, glass metal	5-9
4	Inert, earth, domestic hazardous	4.9-11.5

Source: Malinya Muktha Keralam Action Plan(2007)

LEGAL FRAMEWORK FOR SWM IN INDIA

In India, SWM is the primary responsibility and duty of the local body authorities. State legislation and the local acts that govern municipal authorities include special provisions for collection, transport, and disposal of waste. Most state legislations does not cover the necessary technical or organizational details of SWM. Laws talk about sweeping streets, providing receptacles in various parts of the city for putting waste, and transporting waste to disposal sites in general terms, but they do not clarify how this cleaning shall or can be done. The municipal acts in many states do not specify in clear terms which responsibilities belong to the citizens. Most state legislations, with the exception of that of Kerala, does not fulfil the requirements for an efficient SWM service. A public interest litigation was filed in the Supreme Court in 1996 (Special Civil Application No. 888 of 1996) against the Government of India, state governments, and municipal authorities for their failure to perform their duty of managing MSW adequately.

The Supreme Court then appointed an Expert Committee to look into all aspects of SWM and to make recommendations to improve the situation. After consulting around 300 municipal authorities, as well as other stakeholders, the Committee submitted the report to the Supreme Court in March 1999. The report included detailed recommendations regarding the actions to be taken by class 1 cities, by the state governments, and by the central government to address all issues of MSWM effectively. On the basis of the report, the Supreme Court directed the Government of India, state governments, and municipal authorities to take necessary actions. The Ministry of Environment and Forests was directed to expeditiously issue rules regarding MSW Management and Handling. Thus, in September 2000, the Ministry issued the Municipal Solid Waste (Management and Handling) Rules 2000 under the Environment Protection Act, 1986.

Recently in 2016 the following Rules on waste management are formulated in supersession of the existing rules.

1. Solid Waste Management Rules, 2016 - Ministry of Environment, Forests and Climate Change, 8th April, 2016
2. The Plastic Waste Rules, 2016- Ministry of Environment, Forests and Climate Change, 18th March, 2016

3. The Bio-Medical Waste Management Rules, 2016 - Ministry of Environment, Forests and Climate Change, 28th March, 2016
4. The E-Waste (Management) Rules, 2016, Ministry of Environment, Forests and Climate Change, 23rd March 2016
5. The Hazardous and other Waste (Management and Transboundary Movement) Rules 2016- Ministry of Environment, Forests and Climate Change, 4th April, 2016
6. Construction and Demolition Waste Management Rules, 2016, Ministry of Environment, Forests and Climate Change,29th March, 2016

As detailed above, even though MSW Rules 2000 was issued in the year 2000 and considering the stipulations therein, even after sixteen years, the progress achieved in waste management is meager and no ULB in India complied with the MSW Rules 2000. Open dumping, open burning and landfill/dumpsite fires are common. A more comprehensive set of rules, viz., Solid Waste Management Rules, 2016 have been issued by MoEFCC in 2016 replacing the MSW Rules,2000.The rules lay down the steps to be taken by all municipal authorities to ensure management of solid waste according to best practices. They are responsible for implementing provisions of the 2016 rules and also to provide the infrastructure and services with regard to collection, storage, segregation, transport, treatment and disposal of MSW. The State Pollution Control Boards are directed to process the application of municipal authorities and to issue authorization to the municipalities.The CPCB is responsible for coordinating the implementation of the rules among the state boards.

These rules are applicable to every local body and stipulate that all municipal authorities to scientifically manage the solid waste generated in their respective jurisdictions.

A major change that is visible in the new Rule from the MSW Rule 2000 is the focus on the processing of biodegradable portion of waste at source.

The rule says that the biodegradable waste shall be processed, treated and disposed of through composting or biomethanation within the premises as far as possible.

The residual waste shall be given to the waste collectors or agency as directed by the local body. Waste generators are not to litter i.e. throw or dispose of any waste such as paper, water bottles, liquor bottles, soft drink cans, tetra packs, fruit peel, wrappers, etc., or burn or burry waste on streets, open public spaces, drains, water bodies.

Timeframe for Creation of Infrastructure

The SWM Rules lay down the steps to be taken by central and state departments and all municipal authorities to ensure management of solid waste according to best practices. Municipal authorities are responsible for implementing provisions of the 2016 Rules. They must provide the infrastructure and services with regard to collection, storage, segregation, transport, treatment, and disposal of MSW. The Rule provides the timeframe for creation of necessary infrastructure for implementation of these Rules. The infrastructure shall be created by the local bodies and other concerned authorities on their own, by directly or engaging agencies within the time frame specified. Infrastructure includes suitable sites for setting up solid waste processing facilities, and common regional sanitary landfill facilities.

Table: 8
Timeframe for Creation Infrastructure

Sl. No	Activity	Time limit from the date of notification of Rules (8th April, 2016)
1	Identification of suitable sites for processing facilities	1 year
2	Identification of suitable sites for setting up common regional sanitary landfill facilitiesfor suitable clusters of local authorities under 0.5 million population	1 year
3	Identification of suitable sites for settingup common regional sanitary landfill facilities or standalone sanitary landfill facilities byall local authorities having a population of 0.5 million or more	1 year
4	Procurement of suitable sites for setting up solid waste processing facility and sanitarylandfill facilities	2 year
5	Enforcing waste generators to practice segregation waste at source	2 year
6	Ensure door to door collection of segregated waste and its transportation incovered vehicles	2 year
7	Ensure separate storage, collection and transportation of construction and demolitionwastes	2 year
8	Setting up solid waste processing facilities by all local bodies having 1lakh or morepopulation	2 year
9	Setting up solid waste processing facilities by local bodies and census towns below 1lakh population	3 years
10	Setting up common or standalone sanitary landfills by or for all local bodies having 0.5million or more population	3 years
11	Setting up common or regional sanitary landfills by all local bodies and census townsunder 0.5 million population	3 years
12	Bio-remediation or capping of old and abandoned dump sites	5 years
13	Prepare a state policy and solid waste management strategy for the state or the union territory	1 year

Clause 15(a) of Solid Waste Management (SWM) Rules, 2016 stipulates that the local authorities shall "prepare a solid waste management plan as per state policy and strategy on solid waste management within six months from the date of notification of state policy and strategy and submit a copy to respective departments of State Government or Union Territory Administration or agency authorized by the State Government or Union Territory Administration"

TECHNOLOGY OPTIONS FOR WASTE MANAGEMENT

The process of solid waste management has two important streams of activities such as the social engineering and technology applications. The major element of social engineering is the participation of the community in the process and their involvement in the proper management of the wastes as well as adopting the 4R concept to the maximum extent possible. The technology application deals with the use of appropriate technology for processing and disposal of solid wastes to improve the supportive capacity of the environment.

The technology options available for processing the municipal solid waste are based on either bioconversion or thermal conversion (Diaz et al., 2002; Benedict et al., 1998; Corey,1969; Tchobanoglous, 2003; UNEP, 2005; Salvato,1992).The bio- conversion method is applicable to the organic fraction of wastes, to form compost or to generate biogas such as methane (waste to energy) and residual sludge (manure). Various technologies are available for composting such as aerobic, anaerobic and vermi composting. The thermal conversion technologies are incineration with or without heat recovery, pyrolysis and gasification, plasma pyrolysis and pelletization or production of Refuse Derived Fuel (RDF)

COMPOSTING

Microorganisms such as bacteria, fungi and actinomycetes as well as larger organisms such as insects and earthworms play an active role in decomposing the organic materials. As microorganisms begin to decompose the organic material, they break down organic matter and produce carbon dioxide, water, heat and humus (the relatively stable organic end product). This humus end product is compost.

Different communities of microorganisms predominate during the various composting phases. Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds. The heat they produce causes the compost temperature to rise rapidly. As the temperature rises above 40°C, the mesophilic microorganisms become less competitive and are replaced by thermophilic (heat loving) ones. At temperatures of 55°C and above, many microorganisms that are pathogenic to humans or plants are destroyed. Temperatures above 65°C kill many forms of microbes and limit the rate of decomposition. In composting process usually aeration and mixing is done to keep the temperature below this point. During the thermophilic phase, high temperatures accelerate the breakdown of proteins, fats and complex carbohydrates like cellulose and hemicellulose, the major structural molecules in plants. As the supply of these high-energy compounds become exhausted, the compost temperature gradually decreases and mesophilic microorganisms once again take over the final phase of curing or maturation of the remaining organic matter (EPA,1989 and 1995).

There are three basic steps involved in all composting practices such as preprocessing (size reduction, nutrient addition etc), decomposition and stabilization of organic materials and post-processing (grinding, screening etc). The decomposition and stabilization phase happens when the bacteria and other

organisms act on organic fraction of MSW that essentially consists of proteins, aminoacids, lipids, carbohydrates, cellulose, lignin and ash in presence of oxygen. The commonly used composting technologies are windrow, aerated static pile, in-vessel composting, anaerobic composting , vermin composting and Aero bin composting.

Windrow Ccomposting

The Windrow System is the least expensive and most common method adopted. Windrows are defined as regularly turned elongated piles, trapezoidal in cross section and upto a hundred meters or more in length. The cross-sectional dimensions vary with feedstock and turning equipment, but most municipal solid waste (MSW) windrows are 1.5 to 2 meters high and 3 to 6 meters wide.Windrows composed of MSW are usually required to be located on an impermeable surface. The optimum size and shape of the windrow depends on particle size, moisture content, pore space and decomposition rate - all of which affect the movement of oxygen towards the centre of the pile.

Turning the pile re-introduces air into the pile and increases porosity so that efficient passive aeration from atmospheric air continues at all times. The windrow dimensions should allow conservation of the heat generated during the composting process and also allow air to diffuse to the deeper portions of the pile. They may be turned as frequently as once per week, but more frequent turning may be necessary, if high proportions of bio-solids are present in the feedstock.

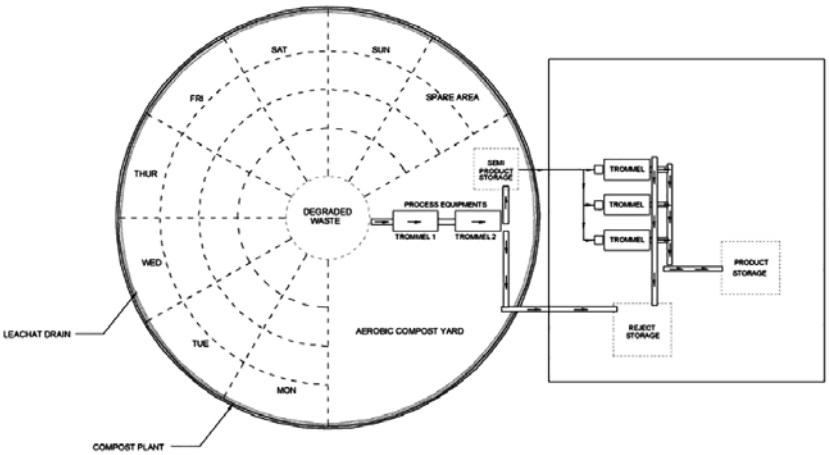

Fig: 3
Layout of a Windrow composting Plant

Aerated Static Pile Composting

Aerated static pile composting is a non-proprietary technology that requires the composting mixture (i.e., a mixture of pre-processed materials and liquids) to

be placed in piles that are mechanically aerated. The piles are placed over a network of pipes connected to a blower, which supplies the air for composting.

Air circulation in the compost piles provides the needed oxygen for the composting microbes and prevents excessive heat build-up in the pile. Removing excess heat and water vapour cools the pile to maintain optimum temperature for microbial activity. A controlled air supply enables construction of large piles, which decreases the need for land. Odours from the exhaust air could be substantial, but traps or filters can be used to control them. The temperatures in the inner portion of a pile are usually adequate to destroy a significant number of the pathogens and weed seeds present. The surface of piles, however, may not reach the desired temperatures for destruction of pathogens because piles are not turned in the aerated static pile technology. This problem can be overcome by placing a layer of finished compost of 15 to 30cm thick over the compost pile. The outer layer or finished compost acts as an insulating blanket and helps maintain the desired temperature for destruction of pathogens and weed seeds throughout the entire pile. When the composting process is nearly complete, the piles are broken up for the first time since their construction. The compost is then taken through a series of post-processing steps. Producing compost using this technology usually takes about 6 to 12 weeks.

In-vessel composting system

In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing, aeration and moisture. Drums, digester bins and tunnels are some of the common in-vessel type systems. In some cases, the vessel rotates, and in others, it is stationary and a mixing/agitating mechanism moves the material around. Most in-vessel systems are continuous-feed systems, although some operate in a batch mode. A major advantage of in-vessel systems is that all environmental conditions can be carefully controlled to allow rapid composting.

Vermi composting

Vermi composting is a modified and specialised method of composting and it is the end product of the breakdown of organic matter by some species of earthworm. Vermi compost is a nutrient- rich, natural fertilizer and soil conditioner. The earthworm species most commonly used are Eudrillus eugineae, Eisenia foetida or Lumbricus rubellus. Small scale vermi composting is done in bins of varying sizes and style and three different types of practices, such as Non-continuous, Continuous, Continuous vertical flow and Continuous horizontal flow are adopted. The methods for large scale vermi composting are windrow and raised-bed or flow - through systems. Flow through systems is well suited to indoor facilities, making them the preferred choice for operations in colder climates. Kitchen wastes except oily and spicy items are suitable for worms. But too much kitchen waste leads to putrification before worms can process it and becomes harmful to the worms. Similarly, material sprayed with pesticides, high water content materials like water melon, woody part of garden wastes etc., may prevent

the composting process. Regular removal of composted material, adding holes to bins or using continuous-flow bin, etc., improve oxygen supply to worms. An important point to note in case of vermicomposting but widely ignored, is to carry out proper sieving of the compost before applying it in the fields. In the usual way vermicomposting is practiced now in Kerala is both labour-intensive and requires some infrastructure. As a result, most vermi compost units set up in the local bodies are not functioning now. However, at household level it is found very effective.

The following aspects have to be taken into consideration while planning a Vermi composting programme.

i. The Vermi composting plant should be protected from flies, ants etc., by providing a metal net covering.
ii. Extreme wet and dry conditions will harm the worms and care should be taken to control extreme temperature by sprinkling water or putting a wet gunny bag above the plant especially during summer.
iii. The Composting plant will not cause any smell, odour, or any unhygienic atmosphere, so it can be placed inside the house or work place.

Aero bin composting

The Thumboormuzhi model Aerobic Composting units are efficient system for decentralized waste management. It is an aerobic composting technique for the biodegradable portion by using aerobic bacteria. The perforated bins of 1.20m x1.20m x 1.20 m are used, the bins are filled up to optimum level with biodegradable waste and dry leaves in layers, cow dung is used as source of carbon and inoculum, the solid waste and dry leaves are added alternatively in layers of 15 cm. Dry leaves are used for moisture absorption and aeration facilitation in to the bin. In each bin 1 to 1.5 ton of waste can be fed, the required time of composting is 90 days to obtain mature compost. The filled bin will be kept for 90 days without turning as required in windrow composting. The leachate from the bin is very minimal as it is absorbed by the dry leaves and can be disposed through a soak pit and hence no leachate treatment plant is required. On the four sides of the bin wire mesh is provided to prevent entry of rats. After filling the bin, close the top of the bins with wire mesh. The mature compost after sieving can be used as manure.

The proposed RCC model can be easily erected and dismantled as it consists of four pillars with grooves on lateral and medial sides. The side bars (4 cm wide) can be locked in position through the grooves on the four corner stands. The four feet diameter is ideal for Kerala Agro climatic conditions having average ambient temperature (28-32oc), relative humidity (70-80 %), and wind speed (4-5 km/hr) as the aeration through the layering to reach the core of the installation worked up to 2 ft. from sides. Aerobic composting process in Thumburmuzhy model is made possible by oxygen aerating the whole layer from periphery to core in a 4ft x 4ft x 4ft dimension.

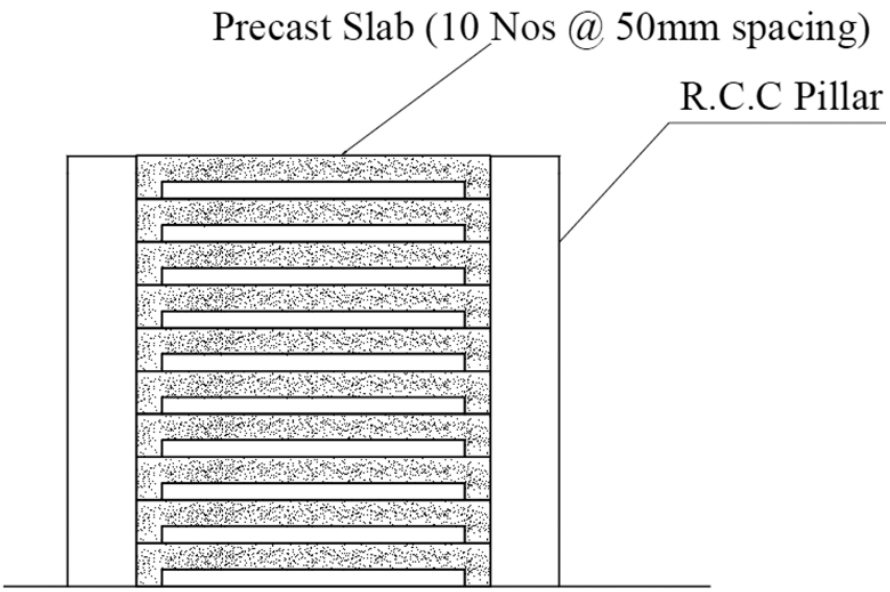

Fig: 4
Aerobic composting bin

Anaerobic Ccomposting

In anaerobic processes, facultative bacteria break down the organic materials in the absence of oxygen and produce methane and carbon dioxide. Anaerobic systems, if conFig:d efficiently, will generate sufficient energy in the form of methane to operate the processes and have enough surpluses to either market as gas or convert to electricity. Conventional composting systems, on the other hand, need significant electrical or mechanical energy inputs to aerate or turn the piles. There are mainly two approaches such as Single-stage digesters and two-stage digestion.

Biomethanation

In this process, methanogenic bacteria breakdown the organic material under anaerobic condition and produce methane and carbon dioxide rich biogas, suitable for energy production. The effluent after digestion is a rich source of nutrients and can be used as a fertilizer.

Anaerobic processing of organic material is a two-stage process, where large organic polymers are fermented into short-chain volatile fatty acids. These acids are then converted into methane and carbon dioxide. The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia and organic acids. Further, the acidogenic

bacteria convert the resultant organic acids into acetic acid, along with additional ammonia, hydrogen and carbon dioxide. Finally, the methanogenic bacteria convert these products to methane and carbon dioxide (waste.nl, 2007). The major problem with the single stage process is that the different reactions in the process cannot be separately optimized. The acidogenic microorganisms grow fast and lower the pH of the reaction mixture, whereas the methanogens, which grow slowly, have a pH optimum around 7.0. The development of the two-stage digestion process solves this problem as hydrolysis and acidification occur in the first reactor vessel, kept at a pH of around 6.0 and methanogenesis occurs in the second vessel, operated at a pH of 7.5 - 8.2. The whole process can run with a retention time of 5 to 8 days.

The main feature of anaerobic treatment is the concurrent waste stabilization and production of methane gas, which is an energy source. The retention time for solid material in an anaerobic process can range from a few days to several weeks, depending upon the chemical characteristics of solid material and the design of the biogasification system (e.g., single stage, two-stage, multi-stage, wet or dry, temperature and pH control).

In the absence of oxygen, anaerobic bacteria decompose organic matter as follows:

Organic matter + anaerobic bacteria = CH_4 + CO_2 + H_2S+ NH_3 + other end products + energy

The conditions for bio gasification need to be anaerobic, for which a totally enclosed process vessel is required. When compared to composting, it requires less area. The microbiology of anaerobic digestion and the optimum environmental considerations for the microorganisms can be achieved by selecting the proper type of digester. There are three types of digesters viz., Standard rate single-stage digester, High rate single-stage digester and High rate two-stage (called High Performance) digester.

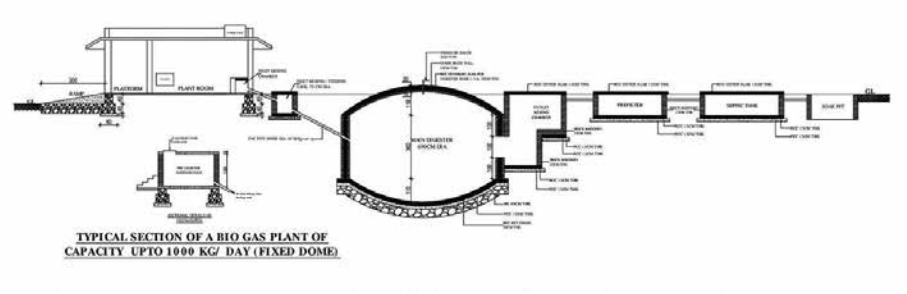

Fig: 5
Typical biogas plant for MSW (1000 kg/day)

PELLETIZATION/REFUSE DERIVED FUEL(RDF) SYSTEM

Pelletisation of MSW involves the processes of ssegregating, crushing, mixing high and low heat value organic waste material and solidifying it to produce fuel

pellets, also referred to as Refuse Derived Fuel (RDF). The process is essentially a method that condenses the waste or changes its physical form and enriches its organic content through removal of inorganic materials and moisture. The calorific value of RDF pellets can be around 4000 KCal/Kg depending upon the percentage of organic matter in the waste, additives and binder materials used in the process. RDF consists largely of organic components of municipal waste such as plastics and biodegradable waste compressed in to pellets, brickets or logs. RDF systems have two basic components: RDF production and RDF incineration (Chantland, 2006).

RDF production plants characteristically have an indoor tipping floor. The waste in an RDF plant is typically fed onto a conveyor, which is either below grade or hopper fed. In some plants, the loader doing the feeding will separate corrugated and bulky items like carpets. On the conveyor, the waste travels through a number of processing stages, usually beginning with magnetic separation. The processing steps are tailored to the desired products, and typically include one or more screening stages, using trommel or vibrating screens, shredding or hammer milling of waste with additional screening steps, pelletizing or baling of burnable wastes and depending on the local recycling markets and the design of the facility, a manual separation line.

Depending on the type of combustor to be used, a significant degree of separation can be achieved to produce a high-quality RDF (i.e., low ash), which typically results in the loss of a higher percentage of combustibles when compared to systems that can produce a low-quality fuel (i.e., slightly higher ash content) for firing in a specially designed combustor. These types of systems recover over 95% of the combustibles in the fuel fraction.The RDF can be used alongside traditional sources of fuel in coal power plants, cement kiln industry, plasma arc gasification modules, pyrolysis plants etc. RDF is capable of being combusted cleanly and can provide a funding source where unused carbon credits are sold on the open market via a carbon exchange. The RDF burning technology includes spreader stroker fired boiler, suspension fired boiler, fluidized bed units and cyclone furnace units (Bjeldanes and Beard,1996)

ENERGY RECOVERY FROM THE COMBUSTION OF MSW

Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion and landfill gas recovery. This process is often called waste to energy.Energy recovery from the combustion of municipal solid waste is a key part of the waste management hierarchy, which ranks various management strategies from most to least environmentally preferred. Energy recovery ranks below source reduction and recycling/reuse but above treatment and disposal. Confined and controlled burning, known as combustion, can not only decrease the volume of solid waste destined for landfills, but can also recover energy from the waste burning process. This generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills.

Incineration

Incineration is a chemical reaction in which carbon, hydrogen and other elements in the waste mix with oxygen in the combustion zone and generates heat. The major aims of incineration of solid wastes are (i) Volume reduction (ii) Stabilization of waste (iii) Recovery of energy from waste and (iv) Sterilization of waste.

About 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilized either for direct thermal applications, or for producing power via steam turbine generators (Bhide and Sundaresan,1983). Some modern incinerators utilise higher temperatures up to 1650°C using supplementary fuel. These reduce waste volume by 97% and convert metal and glass to ash. Incinerator systems are designed to maximize waste burn out and heat output, while minimizing emissions by balancing the oxygen, time, temperature and turbulence. Complete incineration of solid wastes produces virtually an inert residue, which constitutes about 10% of the initial weight and this residue is generally land filled.The incineration facility along with combustion of waste emits air pollutants. Other concerns relating to incineration include the disposal of the liquid wastes from floor drainage; quench water, scrubber effluents and the problem of ash disposal in landfills because of heavy metal residues.

The major incineration technologies commonly used are Mass Burning System, Modular Incineration and Fluidized Bed Incineration. The two most widely used and technically proven incineration technologies are Mass-Burning Incineration and Modular Incineration.

Mass burn units burn MSW in a single combustion chamber under conditions of excess air. In combustion systems, excess air promotes mixing and turbulence to ensure that air can reach all parts of the waste. This is necessary because of the inconsistent nature of solid waste. Most mass-burn facilities burn MSW on a sloping, moving grate that vibrates or otherwise moves to agitate the waste and mix it with air. The waste used to fuel the mass burn facility may or may not be sorted before it enters the combustion chamber. Many advanced municipalities separate the waste on the front end to save recyclable products.

At an MSW combustion facility, MSW is unloaded from collection trucks and placed in a trash storage bunker. An overhead crane sorts the waste and then lifts it into a combustion chamber to be burned. The heat released from burning converts water to steam, which is then sent to a turbine generator to produce electricity. The remaining ash is collected and taken to a landfill where a high-efficiency baghouse filtering system captures particulates. As the gas stream travels through these filters, more than 99 percent of particulate matter is removed. Captured fly ash particles fall into hoppers (funnel-shaped receptacles) and are transported by an enclosed conveyor system to the ash discharger. They are then wetted to prevent dust and mixed with the bottom ash from the grate. The facility transports the ash residue to an enclosed building where it is loaded into covered, leak-proof trucks and taken to a landfill designed to protect against groundwater contamination. Ash residue from the furnace can be processed for removal of recyclable scrap metals.

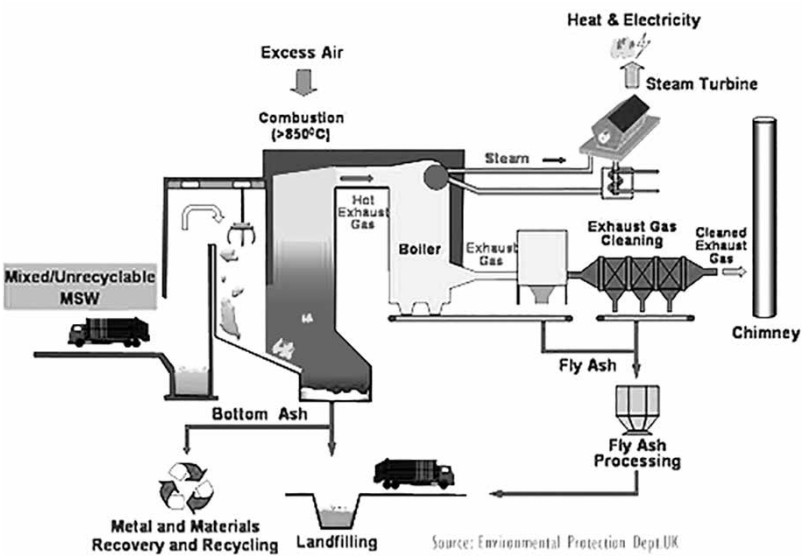

Fig: 6
MSW Incineration Plant

The operation of the combustion process plays an important role in the formation of pollutants, which are carbon monoxide, NOx (oxides of nitrogen), hydrocarbons and other volatile organic compounds. It also produces gaseous stream containing dust, acid gases (HCI, SOx, HF), heavy metals and traces of dioxins. The majority of modern incinerators, however, produce less particulate and gaseous pollutants than their predecessors. The various gaseous pollutants formed due to incineration processes are Carbon dioxide (CO2),Carbon monoxide (CO), Sulphur oxides (SOx), Nitrogen oxides (NOx), Particulates, Hydrochloric acid (HCI), Hydrogen fluoride (HF), Heavy metals (Hg, Cd, Pb, Zn, Cu, Ni, Cr), Dioxins and furans. There many technologies employed to carry out the necessary flue gas cleaning such as (i) Electrostatic precipitators (ESP) (ii) Fabric filters and (iii) Scrubbers. Apart from air pollution, there are other environmental concerns related to incineration like Water pollution, Land-retained pollution, Residue disposal, Noise pollution, Aesthetic impact, etc.

Pyrolysis and Gasification

'Pyrolysis and Gasification, like Incineration are options for recovering value from waste by thermal treatment. It is a process that converts carbonaceous materials, such as biomass into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen (Middleton, 2005; Marshall & Morris, 2006; Varma, 2008) The resulting gas mixture is called synthesis gas or syngas and is a good fuel. Gasification is a method for extracting energy from different types of organic materials. The advantage of gasification is that using the syngas is more efficient than direct combustion of the original fuel.

Gasification can also be done with materials that are not otherwise useful fuel, such as biomass or organic waste. It is an important technology for renewable energy.

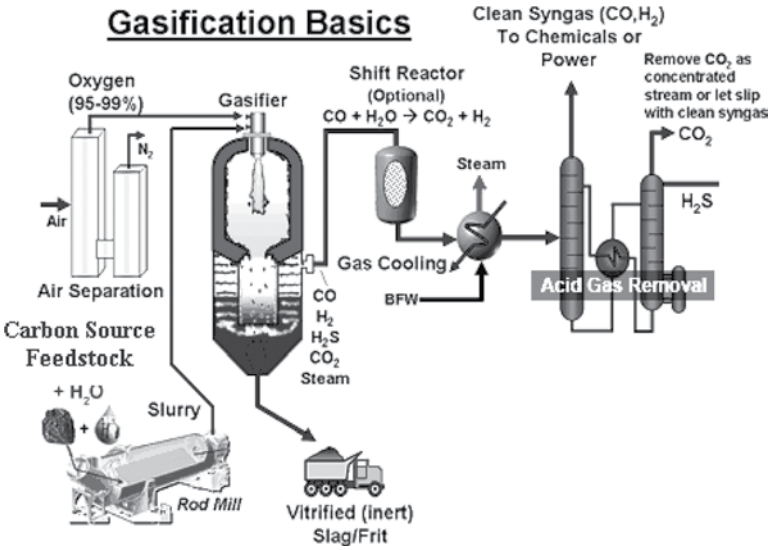

Fig: 7
MSW Gasification plant

Plasma Pyrolysis

Plasma pyrolysis or Plasma gasification is a waste treatment technology that gasifies matter in an oxygen-starved environment to decompose waste materials in to its basic molecular structure (Williams & Nguyen, 2003; Varma, 2008). It uses high electrical energy and high temperature created by an electric arc gasifier and does not combust the waste as incinerators do. This arc breaks down waste primarily into elemental gas and solid waste (slag) in a device called plasma converter. The process has been intended to be a net generator of electricity, depending upon composition of input wastes, and to reduce the volume of wastes being sent to landfill sites. High voltage and high current electricity is passed between two electrodes placed apart, creating an electrical arc where temperatures as high as 10000 ^{o}C are quite easily reached. At this temperature most types of waste are broken into basic elemental components in a gaseous form and complex molecules are separated into individual atoms. Depending on the input waste (plastics tend to be high in hydrogen and carbon), gas from the plasma containment can be removed as Syngas, and may be refined into various fuels at a later stage. Dioxin emissions are possible from plasma arcs when chlorine is present although the extremely high temperature at which plasma gasification operates minimizes the possibility. Process gas clean up can be necessary when gasifying waste streams such as municipal waste streams known to contain heavy metals, chlorine/fluorine, sulfur, etc.

Waste to Energy Plants in India

Municipal Solid Wastes (MSW) to Energy Plants with a cumulative installed capacity of 66.5 MW are currently operational/under trial run in the country.

Table: 9
Waste to energy plants currently operational/under trial run in the country

Sl. No.	State	Name of the City/ Town	Capacity (MW)
1	Maharashtra	Solapur	3.0
2	Delhi	Okhla	12.0
3	Delhi	Ghazipur	16.0
4	Delhi	Narela-Bhawana	24.0
5	Madhya Pradesh	Jabalpur	11.5
	Total		66.5

The Ministry of Housing and Urban Development (MoUD) has received 53 proposals from 22 states with potential to generate 405.3 MW of electricity under Swachh Bharat Mission (SBM) which are currently under various stages of construction or tendering. The details of such tenders are:

Table: 10
Waste to Energy Plants under various stages of Construction or Tendering

S. No.	State	No. of Plants	Total Proposed capacity (MW)
1	Andhra Pradesh	11	85
2	Assam	1	5
3	Bihar	1	12
4	Chhattisgarh	2	10
5	Delhi	1	1.6
6	Gujarat	3	30.5
7	Haryana	3	18.5
8	Himachal Pradesh	1	1.7
9	J&K	1	6.5
10	Jharkhand	2	23
11	Karnataka	2	20
12	Kerala*	1	10
13	Madhya Pradesh	5	32

14	Maharashtra	3	28.5
15	Manipur	1	1
16	Odisha	1	11.5
17	Punjab	2	16
18	Rajasthan	3	26
19	Tamil Nadu	1	8
20	Telangana	1	11
21	Uttar Pradesh	5	25
22	West Bengal	1	22.5
Total		53	405.3

*The Kerala Government have already sanctioned a waste to energy plant at Cochin (Brahmapuram) for treating 300 tons of waste/ day to a private company called M/S Eco Power PVT Ltd using British technology.

RECYCLING PROGRAM

Recycling is one of the fundamental parts of the waste management plan. Recycling has a lot of direct significance for the society such as (i) Economic significance which includes cost reduction, employment generation, energy saving, reduced health care costs etc.(ii) Environmental and health significance such as improved environment, natural resources conservation etc., and (iii) Social significance. The recycling of waste will increase the economic value of the waste and will reduce quantum of waste to be disposed.

Table: 11
Important Recycling Materials: Advantages and Drawbacks

Material	Advantage	Drawbacks
Aluminum	• Aluminum has a high market value. • It can be easily recycled by shredding and melting. • It can be recycled indefinitely because it does not deteriorate from reprocessing. • Aluminum recycling requires significantly less energy than producing aluminum from ore.	• Separate collection is important. • Recycling is suitable only if a processing plant is available.
Batteries	• Recycling recovers valuable metals. • Recycling protects the environment from heavy metals such as lead, cadmium and mercury.	• Large variation in type and size of batteries requires specific recycling processes. • Older batteries have high heavy metal content

Concrete and demolition waste	• Demolition waste can be crushed to gravel and reused in road construction and landscaping.	• Machinery required for crushing is maintenance intensive. • Recycled waste is valuable only if there is a lack of other construction material.
Glass	• Glass has a moderate market value • It can be sorted into colours and melted. • Use of recycled glass saves energy compared with processing raw material. • Glass can be recycled indefinitely because it does not deteriorate from reprocessing.	• Broken glass can contaminate and eliminate opportunities for recycling.
Organic waste	• Most commonly recycled by composting or anaerobic digestion.	• Though compost is very beneficial to depleted soils, it still has a low market value.
Other metal	• Scrap metal has a high market value (especially steel, copper, silver and platinum) • It can be recycled indefinitely because it does not deteriorate from reprocessing.	• High-value metals (such as copper and silver) are incorporated in electronic devices, but extraction can cause severe environmental impacts.
Paper	• Paper can be easily recycled; however, quality deteriorates with each cycle. • Paper or cardboard from recycled paper requires less energy to produce and protects forests.	• Appropriate technologies with circular processes are required to protect the environment.
Polyethylene terephthalate (PET)	• PET can be recycled if segregated from other waste. • Reprocessing into granulate is very easy. • PET has a high market value if processing plants are available.	• More 'downcyling' than recycling occurs because quality decreases with every processing cycle.
Other plastic	• Other plastic, such as polyethylene or polyvinyl chloride, can be recycled but has less value on the market than PET; the value depends on recycling and manufacturing options in the vicinity.	• Recycling requires specific machinery
Electronic waste	• Electronic waste (such as computers or mobile phones) contains high value metals. • Electronic items can be dismantled, reused or recycled.	• Metals are often covered with polyvinyl chloride or resins, which are often smelted or burned, causing toxic emissions.

Source: World Bank, 2008

Table: 12
Common Types of Plastics that may be recycled

Sl. No	Chemical Name	Abbreviation	Typical uses
1	Polyethylene terephthalate	PETE	Soft drink bottles
2	High-density polyethylene	HDPE	Milk cartons
3	Polyvinyl Chloride	PVC	Food packaging, wire insulation and pipe
4	Low-density polyethylene	LDPE	Plastic film used for food wrapping, trash bags, grocery bags, and baby diapers
5	Polypropylene	PP	Automobile battery casings and bottle caps
6	Polystyrene	PS	Food packaging, foam cups and plates, and eating utensils
7	Mixed plastic		Fence posts, benches and pallets

Source: Aarne vesilind, et al,2004

Source separation is an important activity in any recycling programme and it refers to the segregation of the recyclable and reusable materials at the source of generation. This requires separation of different components in different containers. In some places, a well planned programme for collection of recyclable materials is in place like Drop-off programme and Buy-back programme. A drop- off programme requires resident to separate the recyclable materials and bring them to a specified drop off or collection. Buy- back refers to a drop- off programme that provides monetary incentives to participants. In this type of programme, the residents are paid back for their recyclable material directly or indirectly through the reduction in collection and disposal fees. Collection vehicles that are designed specifically for collecting recyclables have several storage bins, which can be easily loaded and often equipped with automatic container-tipping devices.

MATERIAL RECOVERY FACILITY(MRF)

Dry segregated material is received in a mixed form consisting of a combination of fibres (paper, card board, mixedpaper, magazines, etc.) and containers (plastic, glass, metal, etc.), among other materials. The first stage of waste management is the segregation of the materials in to different categories (fiber, paper, plastic, containers, etc.). These recyclables are also sorted by using automated machines when quantities to be handled are large.

In Kerala, the Material Recovery Facility (MRF) has been established in many of the urban local bodies and panchayats to collect the non-degradable wastes separately,which can be easily transferred to recycling units. CED has also designed MRF considering the various aspects such as quantity, type of materials, etc

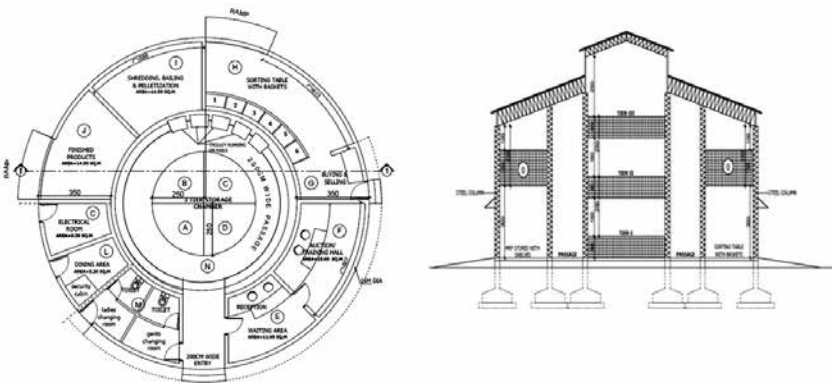

Fig: 8
MRF designed by CED (2017)

TECHNOLOGIES FOR DISPOSAL OF PLASTIC WASTE

Utilization of Plastic Waste in Bitumen Road

Plastic waste is collected and segregated (except chlorinated/brominated plastic waste) from mixed MSW. The segregated plastic waste is cleaned from impurities and dried. The dried plastic waste is shredded to 2-4 mm size and added to heated stone aggregate followed by mixing. Further, the coated aggregate is mixed with hot bitumen, which is used for laying and compaction. The use of plastic waste in road construction shall follow the IRC: SP:98- 2013, titled as "Guidelines for the use of waste plastic in hot bituminous mix (dry mixing) in wearing courses". Presently, several roads have been constructed using plastic waste with bitumen in many of the States/UTs, such as: Tamil Nadu, Himachal Pradesh, Nagaland, West Bengal, Pondicherry etc.

Co-processing of Plastic Waste in Cement Kilns

Co-processing refers to the use of waste materials in industrial processes as alternative fuels and raw material (AFR) to recover energy and material from them. Due to the high temperature and long residence time in cement kiln, all types of wastes can be effectively disposed without any harmful emissions. As per the Basal Convention, variety of wastes including hazardous wastes, get disposed in an environmentally safe and sound manner through the technology of co-processing in cement kiln. In cement plants, plastic waste is used as Alternate Fuel and Raw-material (AFR), subjected to higher temperature around 1400^{0}C-1500^{0}C. During the process, energy is recovered while burning of plastic waste and its inorganic content get fixed with clinker. It requires an automatic feeding mechanism for feeding plastic waste to cement kilns. This technology is used successfully in some of the States where cement plants (have facility for co-processing of waste) are present, such as: Gujarat, Tamil Nadu, Karnataka, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Andra Pradesh,Odisha etc. Flow diagram for co-processing of plastic waste in cement kilns is shown in Fig:.

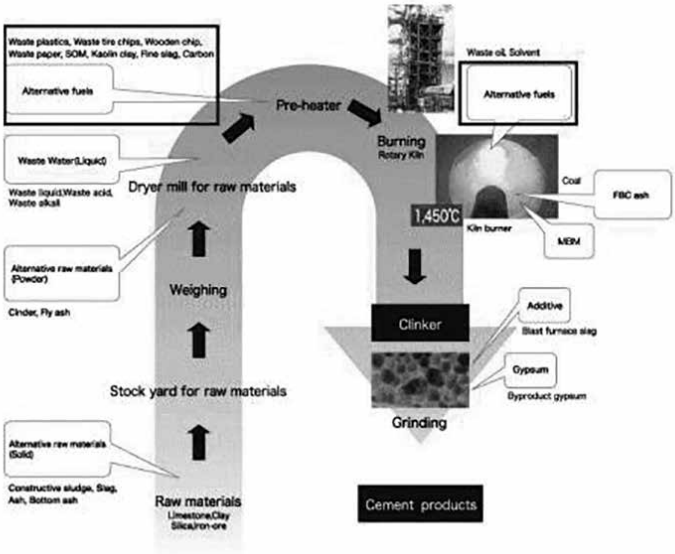

Fig: 9
Flow diagram for co-processing of plastic waste in cement kilns

Conversion of Plastic Waste into Fuel-oil

For converting plastic waste into fuel-oil (RDF), plastic waste is collected and segregated. The segregated plastic waste is then fed into multi fractionalization, where the unwanted material is rejected for better handling and processing. The segregated plastic waste (only HD, LD, PP and multilayer packaging except PVC) is then fed into in-vessel for de-polymerisation system. The Catalytic Gasolysis in-vessel is designed to handle polymers. The selection of catalyst depends on the type of raw material used. The reactor operates at high temperature and in absence on Air. At high temperature, the polymers are Gasolysied to small chain hydro carbon linkage. The vapors produced are condensed in the Condensers and collected as crude oil. There are three types of condensing takes place where first cut gives fuel oil (FO), second cut gives light diesel oil (LDO) and third constitutes of highest grade diesel oil. The total percentage of this is generally at 40% to 50% of input depending on the input quality of plastics and contaminations. The non-condensable remains are then passed through scrubber for removal of gases like Chlorine, Gas-Fuel etc. This Gas-Fuel is used in process for heating.

Plasma Pyrolysis Technology (PPT) for Plastic Waste

Plasma pyrolysis technology is the disintegration of organic/inorganic compounds into gases and non- leachable solid residues in an oxygen-starved environment. Plasma pyrolysis utilizes large fraction of electrons, ions and excited molecules together with the high energy radiation for decomposing chemicals. In this process the fourth state of matter i.e. plasmas (core temperature is around 20,000°K) is used for dissociating molecular bonds. Different types of plastic waste such as polyethylene

bags, soiled plastic, metalized plastic, multi-layer plastic and PVC plastic can be disposed through PPT. In Plasma Pyrolysis, firstly the plastics waste is fed into the primary chamber at 850°C through a feeder. The waste material dissociates into carbon monoxide, hydrogen, methane, higher hydrocarbons etc. Induced draft fan drains the pyrolysis gases as well as plastics waste into the secondary chamber where these gases are combusted in the presence of excess air. The inflammable gases are ignited with high voltage spark. The secondary chamber temperature is maintained at 1050°C. The hydrocarbon, CO and hydrogen are combusted into safe carbon dioxide and water. The process conditions are maintained such that it eliminates the possibility of formation of toxic dioxins and furans molecules (in case of chlorinated waste). The process flow diagram of plasma pyrolysis for disposal of plastic waste is shown in Fig:.

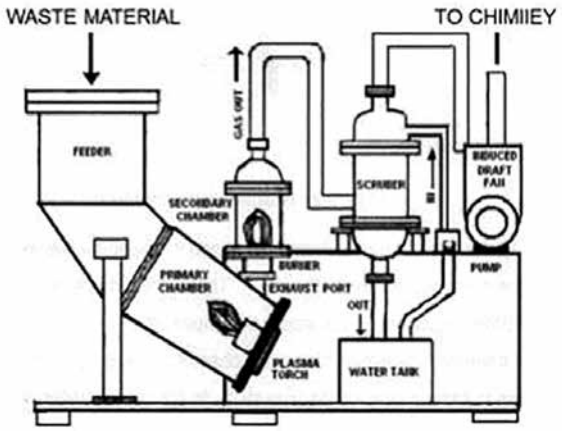

Fig: 10
Flow Diagram of Plasma Pyrolysis for Plastic Waste

SANITARY ENGINEERED LANDFILL

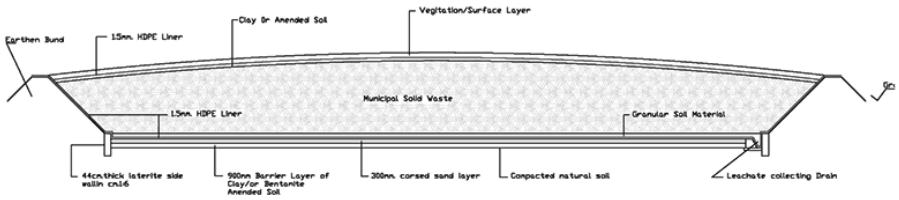

Fig: 11
Cross Section of Landfill

The term 'landfill' is used to describe a unit operation for final disposal of 'Municipal Solid Waste' on land, designed and constructed with the objective of minimum impact to the environment. Sanitary land fill is a systematic disposal

technique especially for the rejects after processing. This term encompasses other terms such as 'secured landfill' and 'engineered landfills' which are also sometimes applied to municipal solid waste (MSW) disposal units.

Essential Components

(a) A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil.

(b) A leachate collection and control facility which collects and extracts leachate from within and from the base of the landfill and then treats the leachate.

(c) A gas collection and control facility (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery.

(d) A final cover system at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation.

(e) A surface water drainage system which collects and removes all surface runoff from the landfill site.

(f) An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site.

(g) A closure and post-closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.

Landfill gas can be toxic and can lead to global warming as well as to explosion leading to human calamity. It contains a high percentage of methane due to the anaerobic decomposition of organic matter, which can be utilized as a source of energy. A typical landfill gas contains a number of components such as methane (typically making up 50-60% of the landfill gas), carbon dioxide (30-40%), oxygen and nitrogen.

STATUS OF SWM IN KERALA

There is a serious crisis in urban waste management that has manifested itself in the form of deadlocked garbage disposal plans in all the Municipalities and Corporations in the State and also in urbanized grama panchayats. With an urban population share of nearly 48 per cent, Kerala comes close to the global rate. The trend of urbanisation in the state is also different from that in the rest of the country. There is an urban-rural continuum which is further complicated by a ribbon like sprawl along major roads. Even the rural areas are displaying distinct urban characteristics like high density of population and composite primary and tertiary occupation structures. The hotspots of garbage management crisis in the State are a reflection of the collective failure to devise an appropriate strategy and technology.

Solid waste management has been the mandate of the Local Authorities. However, most local authorities did not prioritize the establishment of proper waste management systems and hence allocated meager resources for its management.

Further the councils lacked technical and institutional capacities to manage waste. This has led to the current poor state of waste management which includes indiscriminate dumping, uncollected waste and lack of waste segregation across the state. The citizens as well as the authorities do not fully recognize the importance of waste management and hence place least priority for proper management and feels it convenient to dump the waste. Despite the existence of national and state laws for waste management, weak implementation and poor practices have led to cities, towns, and even villages being overwhelmed by their own waste, consequently affecting public health and the environment.

Key Challenges for Solid Waste Management in Kerala

Inadequate State Policy or Strategy

There is no well-defined state policy or strategy for waste management. The international hierarchy of waste management is advocated aiming to Reduce, Reuse and Recycle. But no concerted effort from the national government is visible for practicing the same. For example, process and product change to reduce waste is not under the control of the state; hence if the first principle of reduction of waste is to be achieved, national level intervention is needed. It has been observed that in spite of a stringent legislation in place, open dumping is the most widespread form of waste disposal.

Conventional Approaches

Most of the current approach to waste management system is conventional considering it as a technical issue which can be solved through some engineering interventions. The stress is on collection and disposal and not on reuse, reduction, recycling and recovery. The culture of dumping and the general attitude that waste management is a municipal responsibility had been cultivated among the community by this approach over a long period. Authorities are yet to recognize widely that solid waste management needs social, fiscal and administrative solutions as well.

The local bodies are either ignorant or averse to modern technologies. They are waiting for successful models from other parts of the country and raising it as an excuse not to invest in waste management. As Kerala conditions are different from other parts of the country technologies suitable for Kerala is to be evolved here and it is high time to investment in this direction by implementing projects on experimental as well as on research basis.

Lack of Public Cooperation

The public carries a negative perception of the role played by the local body mainly because of the huge quantities of waste lying uncollected and the unscientific disposal practices followed by it. At the same time, there is widespread resistance against developing sites for treatment plants and effective IEC has to be planned and implemented to create behavioural change

Non-recognition of the Role of Informal Service Sector

The informal sector consisting of the waste collectors remove a considerable quantum of waste from households and the streets. The scrap dealers who buy these

materials are also integral part of the waste management chain. Majority of the waste collectors suffer an 'invisible status' as they are not seen as legitimate stakeholders by the society. Positive steps from the Suchitwa Mission to recognize the informal sector is expected to bring good results.

Lack of Infrastructure

Lack of database and record keeping

None of the local bodies have a functional recordkeeping method to assess the ward-wise volumes of waste handled. Without adequate record keeping and realistic databases it is difficult to improve the quality of planning and delivery of SWM service in the LSGs.

Lack of processing facilities and recycling units

Acute shortage of land is faced by the state and as adequate land is not available, treatment facilities could not be established in local bodies. Even in panchayats close habitations are found near the dumpsites. The facilities once established are not running due to public protest. Another major issue faced by the state is the lack of recycling units for plastic, paper, glass and metal and the state is depending on the neighboring states for recycling.The lack of recycling facility has to be addressed so that all the recyclable items are effectively recycled.

Lack of Sanitary Engineered Landfill Site

Local government bodies have been struggling to find suitable land for sanitary land fill. Due to high population density in a rapidly urbanizing state, finding large extents of land away from main habitations is difficult. Not even a single landfill site is developed in the state. At present, there is no secured landfill site available in state for disposal of refuse.

Inadequate technical capability of local bodies

In the last few years the Suchitwa Mission and Kerala Government were trying to strengthen LSGIs for preparing DPRs for SWM. The functionaries and engineers were given extensive trainings for the preparation of DPRs. Provided them with model Detailed Project Reports (DPRs) and even facilitated preparation of the same but the technical capability of local bodies are still inadequate. The SM was supposed to fill the gaps in the DPRs who lacked technical hands both at the District and state level. The local body engineers are also not able to do the task because they are not trained adequately. Undoubtedly, a human resource issue is affecting the efficiency and effectiveness of the waste management. Under the present circumstances, they have had very little opportunity to expand their knowledge horizons and enhance the technical know-how.

STRATEGIES AND FRAMEWORK FOR SWM

A three-tiered approach shall be adopted to achieve sustainable MSW management. The first priority - avoidance and minimization - is to address the problem at source and to encourage people to reduce waste generation as much as possible. If it is not feasible to avoid generating waste in the first place, the waste generated should be

minimized as much as possible, through avenues such as appropriate product design or minimal packaging. The next priority is to maximize the reuse, recovery and recycling of suitable recyclable materials. To make recycling work efficiently, robust sorting, collection and distribution systems must be in place. Equally important are the market outlets for the recycled materials. Once the possibilities of waste avoidance, minimization and recycling have been exhausted, we must properly treat and reduce the volume of residual waste through appropriate treatment technologies. It is a commonly accepted principle that all waste should be properly treated prior to disposal at landfills to prevent long-term liabilities. The direct disposal of untreated MSW causes leachate and landfill gas (LFG) emission, and would result in long-term environmental burden. In economic terms, waste avoidance, reduction and recovery generate high return with relatively less investment.

MSW management strategy places top priority on waste avoidance and minimization. In order to achieve this, it is required to significantly increase the recovery of our domestic waste and hence a state-wide waste recovery programmes to facilitate source segregation of waste. To make proper use of the recyclables recovered, we must have a robust recycling industry locally and market for the recycled products. While these measures would have substantial impact on waste reduction and recycling, one must face up to the reality that there will still be unavoidable waste that must be handled.

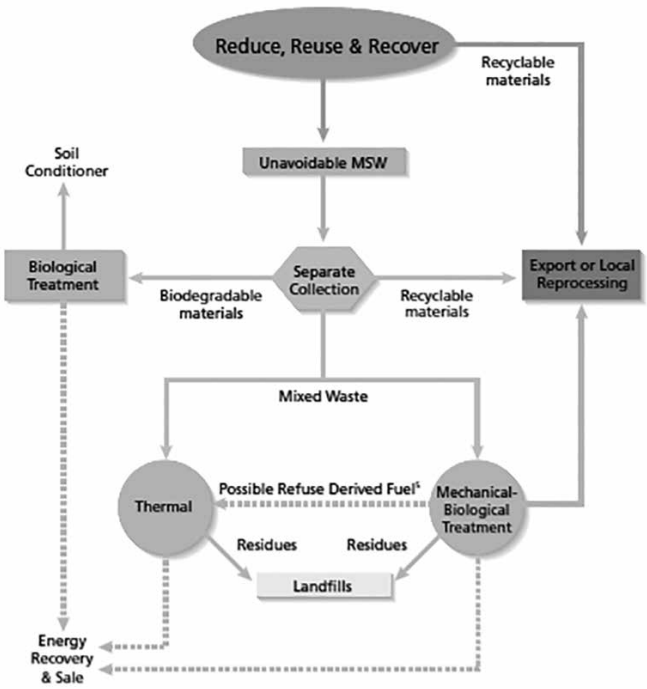

Fig: 12
Process flow MSW generation and management

WASTE AVOIDANCE AND MINIMISATION

Variable charging based on volume

Waste charging is the key policy tool in waste avoidance and minimisation. By putting a price on generating waste, we can induce change in people's wasteful habits and behaviour. A variable charge by the amount of waste generated is more appropriate for the state. The charge shall be imposed only on mixed waste, which is the remainder after reusable and recyclable materials are taken out. A variable charging system can encourage both the reduction of MSW and the recycling of useful materials whereas a flat fee can induce neither.

Volume-based systems that involve pre-paid waste disposal bags in different sizes shall be considered as an option for waste collection. The prices of the bags should be set at a rate high enough to recover the cost of treatment and encourage a change in behaviour. These pre-paid bags will be the only ones accepted by waste collectors. As a major initiative that has state-wide implications, the public shall be fully consulted on this specific proposal and sufficient time shall be allowed to build public consensus. Subject to public consultation, legislation specifying how MSW will be charged and suitable sanctions on non-compliance shall be framed.

Source Separation of Waste

The success of reuse, recovery and recycling depends on the sorting of waste at source. There is a distinction between 'clean' sorted waste (like paper, plastics, and metals) and 'dirty' waste (contaminated materials, such as food packaging, used tissues and soiled diapers). Dirty waste is commonly known as mixed waste and has little recycling value. On the other hand, clean sorted waste holds high value for the recycling industry.Publicity, awareness creation and education are important to support waste sorting and separation. A website dedicated to source separation can be set up to provide regular recovery data. The website can provide technical advice on how best to separate and where to store the separated materials.

Supporting the Recycling Industry

Waste recycling is a key element in the MSW strategy. Reuse, recovery and recycling, as integral elements in the waste hierarchy, encourage repeated uses of resources or materials.The policy of the Government shall be to promote the local recycling industry to attain a "circular economy". The Government shall formulate a comprehensive policy to support the recycling industry. This includes allocating suitable land resources, encouraging research and development, introducing environmental legislation and providing effective support measures.

The Government shall:

i. Improve the collection network through programmes on segregation of waste at source;

ii. Adopt Producer Responsibility Schemes (PRSs) as a major measure to enhance the recovery of recyclable materials;

iii. Adopt Green Protocol to reduce the quantum of waste generated and also to completely avoid some specific wastes;

iv. Establish Eco Parks to provide long-term land for the environmental and recycling business;

v. Adopt a green procurement policy to enhance market demand for recycled products;

vi. Support and encourage research and development of new recycling technologies through funding; and

vii. Continue to organise educational programmes at the community level to increase the public awareness of waste recycling.

Reduction of Waste to Landfill Disposal

A landfill (when one is established) disposal ban on biodegradable MSW will facilitate a sustainable waste management strategy. Relying on landfills for waste disposal is clearly not sustainable. Everywhere in the world existing landfills are running out of capacity, and the countries are facing increasing difficulty in identifying suitable sites for new landfills. The cost of constructing and operating landfills as well as to maintain after their closure is a huge burden. We must conserve the landfill capacity only for the disposal of unavoidable and inert waste.

In Kerala, as appropriate technologies such as composting or anaerobic digestion can be suitably employed, landfill disposal bans should be introduced to cover biodegradable waste, such as food waste. We still need treatment technologies to further reduce the volume of waste before final disposal. Through MSW separation at source, recyclable materials will be recovered for recycling. Biodegradable materials such as food waste from commercial and industrial establishments can be separately collected at source for biological treatment such as composting and anaerobic digestion. Composting requires stringent control on the composting conditions and on the emissions to reduce odour problem. The volume of biodegradable waste which could be treated by biological methods also depends on the available outlets for the by-products, which are becoming limited in the state.

The remaining mixed MSW will then be treated by mechanical-biological treatment (MBT) and waste to energy technologies. The MBT process mainly recovers recyclable materials and a biodegradable fraction from mixed waste. A series of mechanical operations take out recyclable materials such as metals, glass and plastics. The biodegradable fraction is treated and stabilised by a biological process such as composting or anaerobic digestion before being applied to land. While it can only reduce the waste volume by about 50%, MBT requires 2-3 times more land than other technologies. Experience in Europe suggests that 50 - 60% of the residues will still need to be disposed of at landfills if MBT technology alone is adopted. Hence, MBT cannot be the sole method used in Kerala to treat mixed MSW.

The portion of the mixed waste not treated by MBT will be incinerated or subjected to gasification. Incineration is a technologically well-proven method adopted by many advanced countries in Europe and Asia. Through incineration, waste is combusted to reduce its volume and hazardous properties. Either heat or electricity can be generated in the process. Modern incinerators adopt advanced process control measures to optimise the combustion process. Such measures include

controlled burning at temperatures typically over 850° C, long residence time and high turbulence to ensure complete combustion of MSW to destroy all organic pollutants and prevent the production of new pollutants. Incinerators can meet the most stringent international emission standards by using advanced gas-cleaning and pollution abatement equipment such as fabric filters, scrubbers and activated carbon-powder injection systems. Incineration is considered the most cost-effective technology of the options being considered to divert waste from the landfills. Furthermore, incinerators need far less land than biological treatment options.

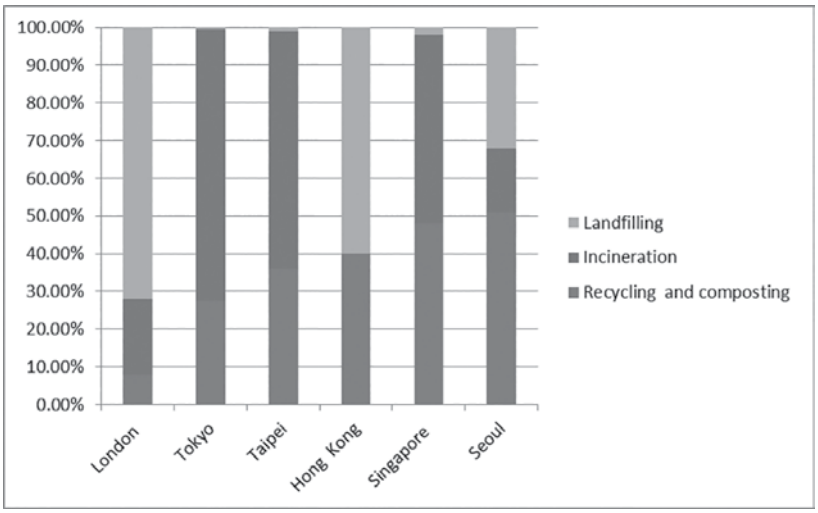

Fig: 13
MSW Management in few cities across the world

Strategy for Management of Biodegradable Waste

For the biodegradable fraction, the general approach and strategy to be followed is decentralized waste processing including source level treatment as much as possible. The centralized systems are to be provided as complementary to the decentralized systems especially in highly urbanized and large cities. In decentralized system, the biodegradable wastes can be collected and processed locally either at the source itself by the generator or at community / residents association level.

Household waste can contain 60 or 70 percent organic matter. Waste from urban fruit and vegetable markets contain even higher amounts of organic materials. Because organic waste causes major hygienic and environmental problems in cities and at landfills, the 2016 rules mandate improved management and treatment of this fraction before final disposal. The strategy for processing the biodegradable waste is based on the proximity principle that waste shall be processed and treated as close as possible to the place of their origin. For the compostable fraction of the MSW decentralized and centralized options are required for the state. Common centralized treatment plant, common decentralized treatment plants and source level treatment for the compostable fraction is necessary to overcome the problem of solid

waste management. Required numbers of decentralized facilities and a centralized treatment facility with a landfill have to be established at each LSG or a cluster of LSGs together to cater to waste streams from streets, from markets, public places, etc

Source level management of biodegradable waste

The point of waste treatment at source has been advocated as a means to substantially decrease the burden of waste disposal and to contribute to the zero waste. Wet organic kitchen wastes can be used to generate compost, which is rich in plant nutrients. Waste treatment by composting, biogas and vermin compost suggest that these will reduce the domestic waste disposal problem by 30-40%. Households, large hotels, function halls, institutions and offices having sufficient land shall adopt processing at source. Kerala has presently focusing on this approach which is successful to certain extent. But some of the technologies adopted is not found to be sustainable in the long run unless give sufficient care.

Decentralized facilities for biodegradable waste

The other option is decentralized treatment at different locations in a ward. Those households or bulk generators having no sufficient land to offer processing at their respective premises shall be brought under the decentralized/centralized systems. In the case of small hotels also this method is required.

Decentralized waste management will help to reduce the transportation of wastes, reduce the quantum of wastes reaching the centralized processing plant thus reducing the extent of land required, infrastructure, equipment and manpower and also major environmental issues related to handling of large quantity of wastes in a single location.

Centralized facility for biodegradable waste

A common centralized plant is required for meeting the total requirement of the city to manage part of the biodegradable wastes which cannot be managed at source or by decentralized systems. As number of decentralized plants is in place a small size centralized waste management system with a capacity of not more than 25 to 50 tons is required for the corporations. In the case of municipalities, the capacity of the centralized plant can be upto 15 to 20 tons. The decentralized plants can be of varying capacity ranging from 1 ton to 5 tons depending on waste to be processed. Decentralized composting/bio methanation plants can be established in each ward or where there is sufficient land availability.

A centralized treatment facility with a landfill to be established at each LSG or for a group of LSGs to cater to waste streams from streets, from markets, public places and in exigencies. Composting would be the preferred method of treatment for biodegradable waste.

Strategy for Non-Biodegradable Wastes

In the case of non- biodegradable waste and hazardous waste, the local body can arrange for collection on pre-informed dates. It can be either collected from households and other establishments based on collection of user charges or drop-

in facilities to be arranged. The collection schedule may be fixed by the local body during the planning stage and through stake holder consultation. The local body has to establish Material Recovery Facility (MRF) at suitable locations for storing non compostable waste / dry waste. Plastic waste, glass, metal and paper will be sent to reprocessing plants and these plants can be established at Regional level for a cluster of districts managed by government or private entrepreneurs. Hazardous waste shall be collected through drop-in facilities and shall be disposed through authorized collecting agents till recycling facilities and designated landfills are established for the purpose. Government shall consider establishing common Treatment, Storage and Disposal Facilities (TSDF) for the disposal of domestic hazardous waste on a regional basis. Similarly in the case of electrical and electronic waste also, recycling is yet to start in Kerala and the only option is to send to recycling units in neighbouring states till sufficient facilities are established.

The waste shall be stored in separate containers at the source by the generators. From the generators, waste shall be transported to MRF. The waste reaching the MRF need to be further sorted into recyclable and non- recyclable. It shall be sorted into various fractions so that it can be transferred to the recycler as per demand. The recyclable portion shall reach the recyclers either through scrap dealers or directly to the recyclers.

Final Disposal by Constructing Sanitary Engineered Landfills

The SWM Rules mandate treatment of the organic fraction of solid wastes before final disposal of rejects and inerts in scientifically engineered landfills. Landfill is a vital component of any well designed SWM system. Environmentally safe landfill shall be a part of long-term disposal strategy but the landfill should be restricted to waste that cannot be recycled, treated or recovered. This mechanism will cater to the remediation of already accumulated waste and confinement of subsequent rejects. The landfill can be operated directly by the LSG or through competent agencies in the public or private sector, adopting the procedures and specifications defined in the 2016 SWM Rules as well as SPCB / CPCB norms.

Kerala is faced with acute shortage of land and hence construction of landfills in each local body is not at all possible and a possible option is for going for regional landfills for a group of local bodies. State government shall facilitate the construction of a few regional landfills for a group of local bodies. For this purpose Kerala can be divided into different zones.

Zone 1 – Thiruvananthapuram, Kollam, Pathanamthitta Districts

Zone 2 – Allapuzha, Kottayam, Idukki and Ernakulam Districts

Zone 3 – Thrissur, Palakkad and Malappuram Districts

Zone 4 – Kozhikode , Kannur ,WaynadandKasragod Districts

Standalone separate sanitary engineered landfills with at least 50 acres of land shall be developed in suitable locations for these zones. The state government shall initiate discussion with the respective local bodies and identify locations. Along with these facilities, TSDF for domestic hazardous waste shall also be setup.

The urban solid waste management involves two integral elements, viz, (i) the ultimate disposal of waste adopting any of the approved methods appropriate for the type of waste generated and (ii) the community action that leads to the proper handling of the waste from its source to the disposal point. In solid waste management, the primary measures are collection, segregation, storage and transportation of waste while disposal of the waste constitutes the secondary measures. The primary measures generally involve social aspects that necessitate community action whereas the secondary measures are by and large technical. It is essential that, the solid waste management system should encompass an effective and systematic mechanism for the collection, segregation, storage and transportation of the waste generated at these places. Since people's participation is vital for sustenance of the system, participatory methods should be adopted to the extent possible. A typical sequential action and strategies for implementing a solid waste management system in any urban local body is given below:

Table: 13
Strategy for SWM

Component	Strategy	Target	Responsibility
Segregation and Storage	Segregation (biodegradable, non-biodegradable) and separate storage at source. Three separate bins will be kept for biodegradable (Green color), non-bio degradable (white color) other waste (black color) generated in all premises	Cover all premises through a continued and organized awareness creation, motivation and subsequent enforcement	Those who generate waste
Primary Collection	Door step collection / block of segregated and stored waste Direct collection from non domestic bulk generators.	100% door step collection	ULB, through agencies like Kudumbasree, other NGOs, residents' association
Street Sweeping	Cover all roads/ streets and open spaces; and cleaning of drains (below 60 cm depth) by the sanitary workers in the afternoon.	Daily coverage of dense commercial areas; Sweeping on all days including Sundays in city centre and market area; alternate day coverage of medium density and dense housing area; and weekly coverage (twice/ once) in other areas.	ULB, through CLR workers

Secondary Collection	Abolition of all open collection points by placing containers – separate for organic and inorganic; and Direct transfer of waste from primary collection vehicle to containers	100% coverage with provision for 30% additional storage capacity to prevent overflow; and Paving all container stations.	ULB, through collection vehicles
Direct Collection	Direct collection of waste from large hotels and restaurants, marriage and function halls, hospitals, construction waste, slaughterhouse, etc. by deploying exclusive vehicles for the purpose.	100% coverage; and Bi-weekly collection of bulk waste /garden waste from domestic area on pre-fixed days.	ULB, through collection vehicles
Transportation	'Container Exchange System of Transport' that transports organic and inorganic waste in dumper bins to compost plant and landfill site respectively by using dumper placer vehicles	100% removal of organic waste daily; Need based removal of inorganic/ inert waste without allowing overflow	ULB- Daily collection in transportation vehicle (covered tipping truck) of premises under direct collection system and direct transportation to disposal site.
Treatment	Treatment of organic fraction	Centralized compost plant Localized decentralized compost plants Source level compost plants Bio-gas units	ULB- Directly or through competent agencies
Landfill	Engineered landfill for inerts and compost rejects	Remediation of all ready accumulated waste; and Development of sanitary landfill	ULB- Directly or through competent agencies

Waste Processing and Disposal

- Development of centralized waste processing plant where there is ample space
- Development of localized decentralized waste processing plants where there is scarcity of space for waste disposal. This can be a viable option even if there is sufficient space for centralized plant since this is in line with the proximity theory of waste management. Setting up of bio-gas plants at the markets and slaughterhouses.
- Recycling of waste in formal recycling plants
- Waste to energy from the mixed waste stream
- The waste processing plants will process the organic waste through aerobic composting process, recycling units reprocess the recyclable portion, waste to energy process for the mixed dirty waste and the landfill receive the inert matter or unavoidable portion of the waste stream. compost plant and decentralized plants.
- Prevention of ground water contamination, with adequate leachate treatment.

GREEN PROTOCOL IN MSW MANAGEMENT

Having identified the long term havocs created by the excessive use of plastic, GREEN PROTOCOL movement is gaining momentum irrespective of continental boundaries. By observing the protocol, the damaging effects of unhealthy environmental practices can be minimized to a great extent. The overall things can be summarized as to resort to scientific waste management, saving energy by promoting non- conventional sources of energy, promote green surroundings, and discourage the use of non-degradable materials like plastic and replace plastic as far as possible with natural or reusable product or utensils.

A deep analysis into the problem of Solid Waste Management will light the fact that waste becoming an unmanageable problem is mainly due to the "Disposables". By disposables what is meant here is that the use of one time use and throw products has increased drastically in the past ten to fifteen years and with it the magnitude of the problem of its disposal. Disposable water bottles, disposable paper, Styrofoam and plastic cups, disposable paper, plastic and Styrofoam plates, disposable food packaging including aluminium and Styrofoam packaging, plastic bags, etc. Therefore Green protocol is essentially a set of measures which when implemented results in significant reduction of waste with primary focus on prevention of use of disposables and using reusable alternatives like glass/stainless/porcelain cutleries.

When Green Protocol is implemented in any event, non-biodegradable waste generation becomes close to zero. Therefore, the question of waste management post the event becomes virtually non- existent. It was tried for the first time in National Games conducted at Thiruvananthapuram and now it has become a people's movement with many functions including weddings implementing Green Protocol.

Though many initiatives have been taken in the sector of waste management, Green Protocol is the first of its kind initiative, that gave life to the first R "Reduce" of the Solid Waste management hierarchy, the importance and significance of which is felt all across the society and hence taken up people belonging to different religions and backgrounds.

A disposable free event has never been thought of in the country before, and it was the first ever National Games that implemented a Zero Waste concept and this makes it the only mega sports event in the world that implemented Zero waste concept. Using events like that of sports, elections, etc to spread consciousness on environment protection and sustainable waste management behavior is another first.

Green protocol as of today has truly become a movement in Kerala. It has definitely taken the form of an enviro-cultural revolution that the mission strongly believes is going to change the way we live in this Country and on this planet. Wedding ceremonies in Kerala are all set to become 'green', with the state government coming out with a green protocol to make auspicious occasions more nature-friendly. With the implementation of the protocol, plastic and other non-biodegradable articles including disposable glasses and plates and thermocol decorations will be kept at bay from marriage functions. Instead of this, people would be persuaded to use tumblers, plates and other utensils made of glass and environment-friendly metals.

A green school project has already started in the schools. One of the aims of the scheme is elimination of plastic from educational institutions. Accordingly, efforts will be taken to encourage school children to make use of environment-friendly containers in place of plastic water bottles. Flex and plastic glasses will not be used at school functions. Care will be taken to avoid paper glasses and minimise wastage of food.

The main prerequisite for the success of this scheme is the positive behavioral alteration rather than legislation. Effective awareness programs based on systematic IEC will be helpful to change the conventional mindset of the people. A set of creative proposals associated with Green Protocol has already been initiated by the State Government and the LSGs to ensure clean and safe environment. Legislations have also brought to ban the use of plastic products as far as possible.

MICRO LEVEL PLAN FOR SOLID WASTE MANAGEMENT

Traditionally the planning for door to door collection and transportation of waste was done on a zonal basis. The municipality area is divided into different zones for administrative purpose of waste management. Due to the large number of households and shops in each zone, the approach was proved inefficient for ensuring segregation of waste. To make the system of cleaning the whole city on a regular basis, the residential as well as commercial waste collection method had to be implemented based on the micro plan. The intention is to strengthen the Municipal Solid Waste (MSW) collection system and decentralized waste management within the area of urban local body. In the context of decentralized waste treatment this approach can bring very good results.

A Micro Plan is a process of creating a solid waste management plan for the smallest unit of management, by splitting the ward into clusters. (Say a group of households, commercial and institutional waste generators amounting to 500 to 750). Thus a ward can be split into a number of smaller units. Separate clusters under wards, zones and the ULB shall be decided upon to make the effective collection of waste from all areas systematically. The objective is to improve the environment by timely collection of waste from every residence / shop on daily basis. This will also ensure easy identification of households or hotels that are ready for in-situ waste management like home composting or biogas generation. No open dumping and reduction in the number of placing big containers at certain spots will eventually help to reduce air and water pollution due to filthy smell and overflowing of semi-liquid waste.

The micro plan shall also provide for selection of type of vehicle based on the width of existing road, coverage of number of residences and commercial establishments on each route - between 500 and 750, time of collection for example both in the morning and evening hours, will strengthen the system of garbage collection.

Stages in developing a Micro Plan

(i). Creating ward level plan

The ward level plan required the data collection at the ward and cluster level for the planning process. To facilitate this following activities are needed:-

Ward Template: This involves the creation of database for data collection at ward level

Concept of Cluster: The size of the cluster, (say 500 HHs+ 200-300 commercial establishments) is designed and is to be generated through the field survey.

Cluster Template: This involves the creation of database for data collection at cluster level

Ward maps: creation of GIS maps of the ward

Cluster maps: Creating GIS maps of the designated clusters.

Location of secondary transfer points: GPS locations of secondary transfer points on the cluster and other maps.

Centralized and decentralized facilities: To obtain this data, forms to be created which contain data about facilities, agencies, infrastructure, equipment, manpower and the geo-location of each of the facilities as well as secondary collection points.

Vehicle details: Formats to collect information about existing vehicles deployed per ward and additional vehicles required to obtain complete data for planning.

Vehicle allotment: The allotment of vehicles to be planned for the collection of dry waste and wet waste per cluster

(ii). Data base and transparency

SWM Website: A solid waste management website to be developed either by the ULBs to create a platform for data entry, dissemination and management. Data regarding the ward and cluster levels will be available to public. The website to be designed to enable its use for data uploading as well as generation of daily reports. The website can be designed to input other data such as route information, vehicle movement, complaint registration and providing other information. This will ensure transparency of the activities of the ULB.

Centralized complaint management system at ward level: Centralized complaint management system is to be set up at the ward level with modern communication facilities

Organizational details: details of the officer in charge of each cluster, workers employed in waste collection, AEES, HIs etc to be provided in the website.

Capacity Building Plan: For the entire SWM cell to function in accordance with the micro plan, training sessions for all categories of staff is essential and is part of the micro plan

Benefits of implementing the micro plan - Decentralized Planning, Operations and Management

Implanting segregation at source: Close monitoring is possible as the planning unit is clusters Awareness campaigns can be carried out to one on one more effectively thus increasing the degree of segregation.

Segregated waste to Processing units: By formalizing the normative for collection and transportation, rigorous data collection of all units, it will be able to improve the segregated waste to processing units.

Uniform system: By creating one uniform system that is understood by all the citizens as well officials, the model has a higher likelihood of being followed

Optimize decentralized infrastructure: The data driven approach with multiple sources of data enable to capture gaps and issues in the system, therefore guiding the process of planning for optimizing land, infrastructure and manpower.

Creating impact in the attitude: The overall rise in accountability due to decentralization of responsibilities and management will result in improved adherence to the system which will bring positive altitudinal change among the citizens.

The micro plan is a fast-track implementation strategy to scale down the system of waste management, and monitoring from a ward level (5,000 HHs) to a cluster (500 HHs). The primary reasons for the shift towards decentralizationis

- Facilitating segregation at source
- Increasing accountability on ground
- Improving planning and governance

Sustainability

Uniformity: A uniform system is created through the micro plan and which is followed across the ULB will be helpful for everyone to adapt to the system faster and easier.

Documentation: Specific data collection formats for reporting across the city at different stages of the waste chain will increase transparency and accountability within the system. This system will also help in understanding, comparing and evaluating the progress across the city in SWM with regard to waste generation, processing and disposal.

Scope to revise: The data collection is happening at every scale and hence the system offers the scope to revise the planning or management. The micro scalar data and planning allows for contextualization and adaptability.

Transferability

Since the micro plan is a strategy / approach it has the potential to be adopted by other cities and towns. Within the approach, the normatives, the management structure etc is flexible to the context it is designed for.

The concept of the Cluster level planning and waste management is an innovative approach which will help in streamline the process. The infrastructure and management structure complement each other to create a seamless SWM system for the city. In effect, Micro plans need to be developed for each ward at the ward and sub-ward levels if the overall solid waste management effort of the city was to be secured sustainably.

DPR for SWM of Nenmara Grama Panchayat - Micro planning process

CED employed micro planning for developing the DPR for SWM of Nenmara grama panchayat. The GIS maps of the entire panchayat, the town area where SW generation is an issue, route map for collection of waste were prepared. Identified the locations where waste collection bins are to be placed and the GPS points of location of bins also incorporated. Detailed data from 20 wards were collected for planning for waste management. The present disposal methods adopted by each HH and other generators were collected. Data on HHs with less than 5 cents of land where source level treatment may be impracticable were also collected and incorporated during the planning process. Based on the data methods to be employed by each HH and institutions were proposed. Separate plans were developed for the rural areas and the town in the panchayat.

The Nenmara grama panchayat comprises two towns Vallanghy and Nenmara which are geographically contiguous. Major part of the town is covered by the 7 wards (wards 1,2,3,4, 6, 18 and 19) of the town areas. Data on the households and other major waste generators to be covered are collected for planning. Exclusion of generators who can afford waste management by their own are identified during the planning process. In the DPR thus proposals were made for addressing the waste management for the town area through the proposed centralized processing plant for the biodegradable wastes, remedial capping of the openly dumped waste at the existing dumpsite and providing sanitary engineered landfill for the inert waste.

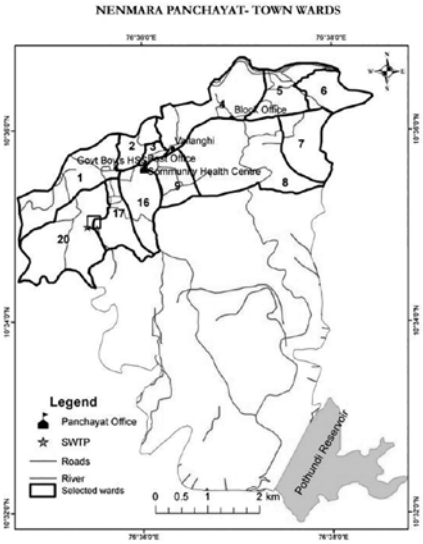

Fig: 14
Town profile of Nenmara grama panchayat

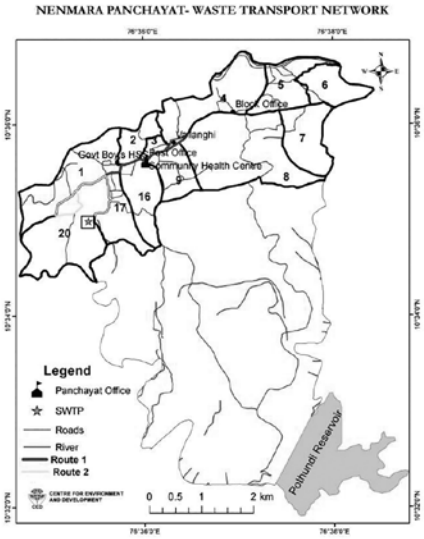

Fig: 15
Waste transport network for Nenmara grama panchayat

THE WAY FORWARD

Acute land scarcity coupled with high density of population is the main feature which hinders progress in developing a sustainable system to manage MSW in Kerala. As land is scarce the available land must be used wisely. The approach to MSW management will be based on i) avoidance and minimization; ii) reuse, recovery and recycling; and iii) bulk reduction and disposal. While all efforts would be made in reducing and recycling waste, the reality is that there will still be unavoidable waste that needs proper treatment before disposal at the landfills. Kerala should adopt state-of-the-art technology to treat unavoidable waste in a cost-effective, yet environmentally sustainable, manner. To catch up with international trends, waste to energy either using mass burn incineration, which has been widely adopted overseas, or gasification as the core technology for final waste treatment, while, of course, adopting stringent emission standards that command public confidence. Micro level planning at each level of value chain is essential in obtaining best results. Appropriate legislation for enforcing the plan along with proper IEC is also part of the strategy.

A key driver to waste avoidance and minimization is public education and partnership. Environmental education plays an important role in inducing behavioral change and gaining public support. Publicity and education on waste avoidance and reduction, as well as separation and recycling, are to be stepped up to reflect the high priority of MSW management in public policy. A series of activities and education programmes intended for people from all walks of life will place emphasis

on turning awareness into real action and empowering them to be agents of change in achieving a more sustainable lifestyle. It is also essential to help the community build capacity so that it can sustain its participation. The Government cannot solve the MSW problem alone. The public must recognize the problem and work together to achieve a sustainable way of life. The Government must take the lead, while the public must take ownership.

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Kochi Waste to Energy Project – Technology and Benefits

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India is facing one of its most difficult challenges like any other rapidly developing country with large quantities of waste being produced because of a fast-economic growth and urbanisation. The growing population combined with the economic migration into the cities not only generates an ever-increasing amount of waste, but also requires an increase in electrical power to meet the extra demand. The current situation in cities of Kerala is that, the existing waste disposal process is limited to basic collection and surface dumping of the waste into uncontrolled sites.

The state of Kerala has six municipal corporations and a population of 34.8 million within their designated zones. Typical surveys suggest the average waste generated per capita per day to be around 0.3 to 0.5 Kg which equates around 1400 tonnes of Municipal Solid Waste (MSW) produced per day. As waste management techniques rarely tend to be a single-solution scenario, we recommend multiple solutions depending on the waste characteristics.

The proposed Waste to Energy plant being set by GJ Nature Care & Energy Private Limited (GJNCE), in Brahmapuram, Kochi will be able to process 1.75 lakh tonnes of waste and generate 78 million units of renewable power annually.

The MSW in Kerala possess several technical and practical challenges when conversion to effective energy generation source. The higher moisture content, seasonal variations in waste profile and low calorific value are some of the key challenges. However a detailed waste analysis and characterisation study over extended period has enable GJNCE to provide a sustainable and a robust technological solution.

The proposed project utilise well established technologies of **Bio-drying** and **Gasification** to convert Municipal Solid Waste (MSW) to an energy source. A brief details of these technology is given below.

Bio-drying process

Bio-drying (biological drying) is the bioconversion process in mechanical–biological treatment (MBT) plant. The bio-drying reactor within an MBT plant receives shredded unsorted MSW and produces a bio-dried output. Within the bio-drying

bioreactor the thermal energy released during aerobic decomposition of readily degradable organic matter is combined with excess aeration to dry the waste.

The Bio-Drying technology selected is able to use the latest in natural biological drying processes. The system works by using the power of naturally occurring bacterial activity. The waste is stored in specially designed areas and covered with a special membrane material that only allows water vapour to pass through it.

Bio drying has many advantages over other methods of treating raw MSW;

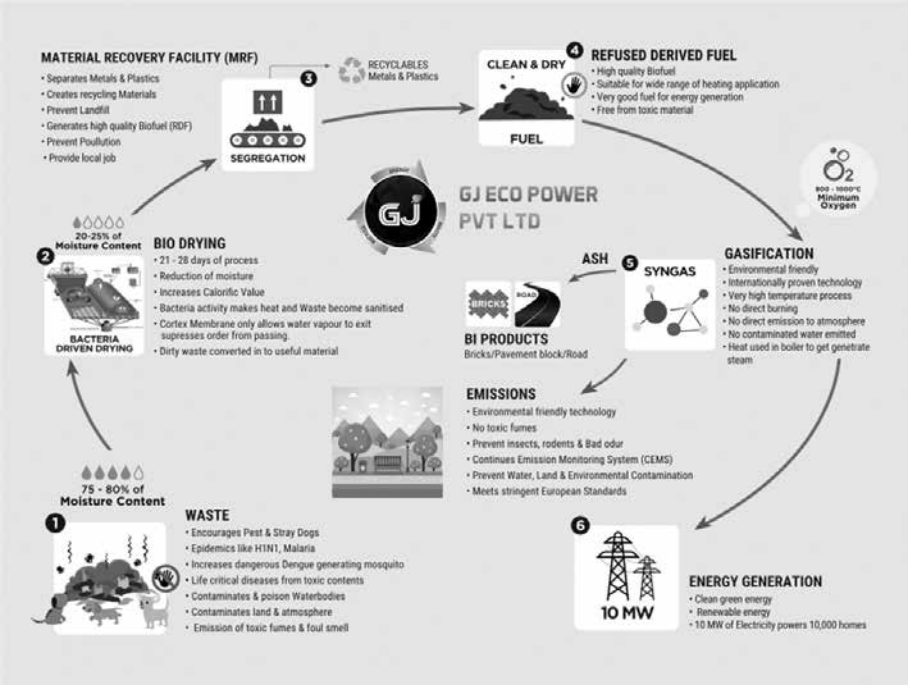
- There is a very low electrical requirement with bio drying technologies, as the mesophilic and thermophilic bacteria's present in the municipal organic waste stream generates high exothermic heat when excited in an oxygen rich atmosphere. A small fan controls the oxygen levels injected into the MSW heaps through an aerated channel floor.
- Control of the temperature inside the membrane allows for heat levels to increase, allowing rapid gaseous exchange of moisture laden air, which can pass freely through the membrane, whereas odours, bio-aerosols and viruses are retained within the mass beneath the membrane.
- Bio dried materials are stabilized and virus free following elevated temperature stabilization and pass a 3 day culture test to show the material is totally biologically inactive.
- The MSW mass is dried down over a period of time, with negligible organic mass loss –the main losses being water, which passes through the membrane as a gaseous vapour or steam.
- Typically, this technology can remove large amounts of water (over a controlled period of time) from the MSW mass, delivering a dried, friable material that lends itself to far more effective mechanical separation.

Gasification Technology

Gasification is a unique process that transforms a carbon-based material, such as MSW or biomass, into other forms of energy without actually burning it. Instead, gasification converts the solid and liquid waste materials into a gas through a chemical reaction at very high temperature.

This reaction combines those carbon-based materials (known as feedstocks) with small amounts of air or oxygen (but not enough to burn the materials), breaking them down into simple molecules, primarily a mixture of carbon monoxide and hydrogen.

The output of gasification is known as 'Syngas' that can be converted into electricity and valuable products. The non-recycled plastics are excellent fuel source for Gasification and removes our cities from plastic contamination. There are significant environmental benefits of MSW gasification, including reducing the need for landfill space, decreasing methane emissions from the decomposition of organic materials in the landfill, and reducing the risk of surface water and groundwater contamination from landfills and prevents environmental pollutions.



The Key Benefits of the Projects

Reduction in Green House Emissions

Generation of CO2 when processing MSW is 0.38T/MW and 1.02T/MW while processing coal thermally. It clearly mentions, the generation of CO2 is 3 times when we use coal for generating the same power.

The power generated will be Green energy preventing significant amount of methane and CO2 generation. Studies have proven that methane is the third largest contributing factor towards hazardous GHG and is emitted out of untreated waste dump yards/ landfills in India. MSW waste if dumped, without proper waste management can produce and release Methane in huge quantities. Methane is 20 times more harmful than CO2. A waste dump of 100000 tons can release 10 tons of methane which is equivalent to 200 tons of CO2. According to Climate Change Congress, Methane emissions contribute 28 times more to global warming when compared to the same quantity of CO2.

Carbon Footprint:

Implementing a waste to energy project of this sort, we can gain around 200 Carbon credits which is equivalent to emitting 200 tons of CO2 otherwise back to the atmosphere. At Brahmapuram, the size of dump yard is estimated to 300000 tons. To produce 10 MW of electricity from coal, it generates 10.2 tons of CO2. But producing 10 MW of electricity from waste, CO2 emissions comes down to 3.8 tons. It means

the CO2 emission from a coal based plant is 2.7 times more than a waste to energy plant.

Benefits to adjoining municipalities – HUB concept

The Brahmapuram waste processing facility can act as a hub for the adjoining 11 Municipalities around Cochin City for the treatment of waste generated in each locality. Thus, the economies of scale achieved in processing the waste by reducing the cost of processing per ton benefits both the stakeholders. The added advantage of the centralised waste processing facility reduces the liability of each municipality to have a separate plant and in effect benefits the society as a whole with a cleaner city and adjoining areas.

Reduction in Land fill

The advanced Gasification technology combined with the sophisticated Bio Drying technology and Material Recovery Facilities creates very limited quantity of potentially hazardous fly ash for landfill (0.5 tonnes per day) compared to other waste processing technologies. This project will prevent the requirements of further landfills in Kochi. Over the years the plant will be able to utilise the existing landfill quality of waste and can support reclaim of the current precious land for KMC.

Health benefits

Currently there is public outrage due to the odour, insects, stray dogs, contagious diseases and rodent proliferation. Rodent and stray dog proliferation through unmanaged waste has a direct health hazard impact. These factors contribute immensely to the outbreak of epidemics like, waterborne illness, Dengue, Malaria, H1N1 and Hepatitis.

The hidden danger of accumulated MSW can trigger Cancer and life changing respiratory illnesses. The pollution through ground water, contaminated rivers & water bodies, air pollution and burnt plastic will directly affect human health. The cost of adverse human health due to the pollution from MSW is exorbitantly high. On an average, up to 2% of the general population in Kochi if impacted by MSW driven life changing illness, considering the average treatment cost of Rs. 1 to 2 lacks per year, this is costing the public over 150 crores per annum. Then considering the over 10-15% public get infected by contagious diseases, waterborne illness and insect driven illness driven by MSW will indicate over 500 crores worth of productivity loss from human resource and 100 of crores of medication and treatment. Furthermore a small percentage of unfortunate infected public will reach to terminal illness or end up into full medical dependency.

Reduction in Air/Soil/Water Contamination

The collection and removal of plastics from the streets and dumping grounds will prevent public incineration of plastic material. The dioxins and other toxic fume generations will be prevented from minimising such activities.

The leachates and exposed organic waste act as a source of contagious bacterial infections. These contaminants can be exposed to public through infectious aerosols

and cross contamination through manual handling. The leachates can seep into the ground and contaminate the soil and also crops in the surrounding areas.

Contamination from waterbodies and underwater table will be minimised through the project. The hidden danger of heavy metals and microbial contamination into the water supply can be reduced by appropriate waste management system.

Kochi selected a SMART city by the Central Government

The central government has handpicked Kochi as a city to be developed under their ambitious SMART city programme. For this, one of the main criterions for any city is scientific waste management of MSW generated.

The cleanliness of the city will be a step change in its profile outlook and leverage significant boost in investments and tourism. One of the key criteria enable a city's fortune change will be its cleanliness and this project will enable Kochi to achieve this. The value stream improvement of business facilities and properties will be enhanced through a clean city initiate.

The industrial scale recycled material generation, commercially valuable aggregates and the value adding ash produced from the facility will enable employment and entrepreneurial options for local communities.

Employment

The facility will provide up to 150 local employment. The employees will be trained to international standards and the skills and competency development programme will ensure security and empowerment of employees. This project will provide apprentice programme to the local educational institutions and will generate budding professionals for the future.

Water and Wastewater Treatment Technologies: Present Status and Future Challenges

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INTRODUCTION

The need for new technologies in water treatment has been driven by three major factors: the discovery of new and rarer contaminants, zest for stringent water quality standards, and cost element. The municipal water treatment system for a long time confined to conventional chemical clarification, granular media filtration, and chlorination. However, dramatic changes are observed recently in the water treatment industry, in which alternative treatment technologies have emerged to replace traditional filtration/chlorination treatment approach. For a new technology to be adopted, it must have advantages over traditional treatment processes. Some of the advantages of these new technologies in comparison to the traditional ones perhaps are: lower capital and operations and maintenance costs, higher efficiency, easier operation, better effluent water quality, and lower waste production. Before adopting these technologies, there is a need to demonstrate its applicability in different stages; the stages identified by experts are: (i) successful demonstration in another field; (ii) testing and development at bench- and pilot-scale levels (1 to 50 gpm); (iii) verification at demonstration-scale level (>100 gpm); (iv) multiple successful installations and operations at small/full-scale level (0.5 to 5 MGD); (v) implementation at a large-scale municipal water treatment plant. In addition, regulatory approvals are to be obtained and the cost levels should be competitive. A few emerging technologies relevant in the context of municipal water treatment are discussed in the paper.

Residences, institutions, hospitals, commercial and industrial establishments create sewage. Sewage treatment by resorting to different physical, chemical and biological processes removes the contaminants from wastewater and household sewage. The purpose of such treatments is to produce a waste stream or treated effluent and a solid waste or sludge suitable for discharge or reuse. This can be achieved either by 'stand-alone' treatment units to cater to the location-specific needs or a sewage system network with pipes and pumping stations to collect and covey the sewage to the municipal/panchayat treatment plants. Industrial effluents often call for specialized treatment facilities. The technologies which are in vogue for municipal wastewater treatment are highlighted. New trends in the primary, secondary and

tertiary treatment stages are discussed. Also, the developments in disinfection technology are highlighted apart from topics of interest like package plants and reactors and methods of sludge disposal and treatment of receiving environment.

The status of water and wastewater treatment in India including Kerala State is not often compatible to the standards specified by the national and international agencies. Coverage of water supply and sewage treatment is also not often satisfactory. Conventional technologies are adopted for water and wastewater treatment in most of the cities and towns in the country. The paper is intended to provide an overview of the emerging ideas and technologies in the area.

EMERGING TECHNOLOGIES FOR DRINKING WATER TREATMENT

GENERAL

A wide range of water treatment technologies have been developed recently or are currently in development. A few of the modern technologies that have application in municipal water treatment plants are discussed in this paper (NRC 1999). However, most of the water treatment plants in India are still the conventional ones with chemical clarification, granular media filtration, and chlorination. A typical diagram of such a plant is given in Figure 1.

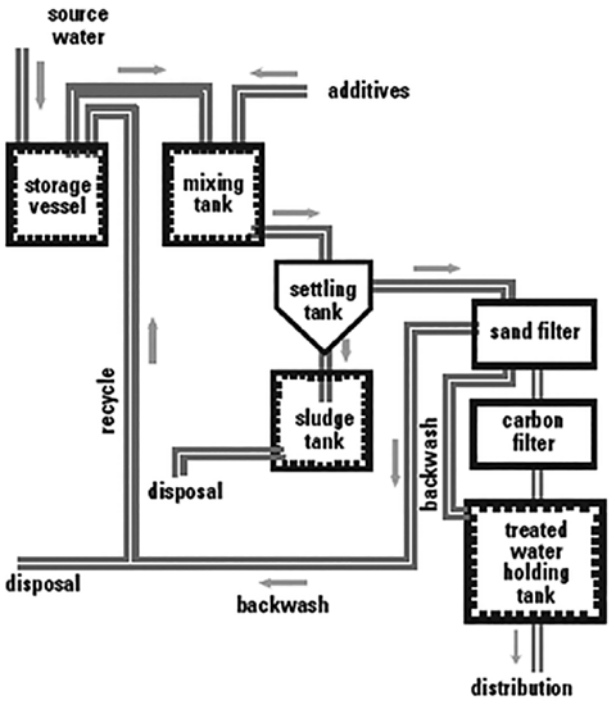

Figure 1
Typical process diagram of a conventional water treatment plant

MEMBRANE FILTRATION TECHNOLOGY

The two types of membrane treatment systems in vogue are: low-pressure membrane systems (such as microfiltration and ultrafiltration) and high-pressure membrane systems (such as nano-filtration and reverse osmosis). Low-pressure membranes, including microfiltration (MF) and ultrafiltration (UF), are operated at pressures ranging from 10 to 30 psi, whereas high-pressure membranes including nanofiltration (NF) and reverse osmosis (RO) are operated at pressures ranging from 75 to 250 psi. Figure 2 shows a schematic diagram of the pore size of each membrane system as compared to the size of common water contaminants.

Low-Pressure Membranes

The idea of low-pressure membrane filtration for surface water treatment was born in the early 1980s. The low-pressure membranes were initially used in the food-processing industry as nonchemical disinfectants. During the latter half of the 1980s, several research projects were initiated by West Coast Water Utilities, the American Water Works Association (AWWA) Research Foundation, and other organizations to evaluate MF and UF for municipal surface water treatment. The studies clearly showed that both MF membranes (with a nominal pore size of 0.2 mm) and UF membranes (with a nominal pore size of 0.01 mm) are highly capable of removing particulate matter (turbidity) and microorganisms. It was realized that membrane-treated water was of much better quality than that produced by the best conventional filtration plants. The majority of treated water samples had a turbidity level near the limit of the on-line turibidimeter (less than 0.05 Nephelometric Turbidity Units - NTU). In addition, the particular UF membranes tested by Jacangelo et al. (1995) were also proven to act as absolute barriers to viruses because of their nominal pore size of 0.01 mm.

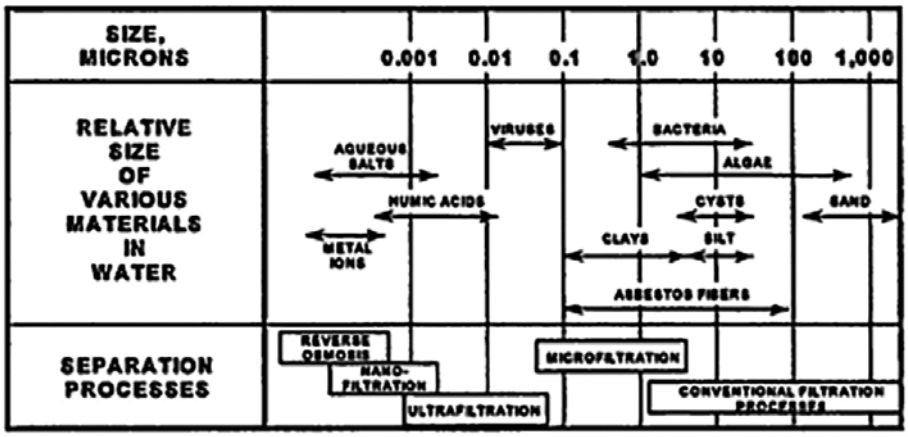

Figure 2
Pore size ranges of various membranes

The advantages of low-pressure membrane filtration include: smaller waste stream, lower chemical usage, smaller footprint, greater pathogen reduction, no disinfection

byproduct formation, and more automation and all the more, low-pressure membranes can treat turbidity excursions as high as several hundred NTUs with manageable impacts on process operation and efficiency (Yoo et al., 1995).

On the other hand, because of their porous structure, low-pressure membranes are ineffective for the removal of dissolved organic matter. Therefore, color-causing organic matter, taste-and-odor-causing compounds can pass through the membranes into treated water. This limits the applicability of low-pressure membrane filtration to surface water sources where the removal of organic matter is not required. However, UF membrane system has overcome this limitation by introducing powdered activated carbon (PAC) as part of the system.

There were several limitations for low-pressure membrane filtration, which it had to overcome. For several years, the cost of membrane filtration systems at 'municipal' scale (i.e., greater than 1 MGD) was prohibitively high. The membrane filtration did not have regulatory acceptance and required extensive evaluation on a case-by-case basis. The information on its reliability in large-scale municipal applications was not available. Now, membrane system construction costs are believed to be comparable to conventional plant construction costs up to a capacity of 20 MGD. This upper ceiling is rapidly rising; there are membrane plants being considered in the United States with capacities ranging from 30 to 60 MGD.

High-Pressure Membranes

Nanofiltration (NF) and reverse osmosis (RO) membranes are also included under high pressure membranes. NF membranes are actually thin-film composite Re membranes that were developed specifically to cover the pore size between Re membranes (<1 nm) and UF membranes (>2 nm) (Matsuura, 1993), hence the name nanofiltration. The result was a type of membrane that operates at higher flux and lower pressure than traditional cellulose acetate (CA) RO membranes. In fact, NF membranes are sometimes referred to as 'loose' RO membranes and are typically used when high sodium rejection, which is achieved by RO membranes, is not required; but divalent ions (such as calcium and magnesium) are to be removed (Scott, 1995). Nevertheless, NF membranes are viewed by the water industry as a separate class of membranes than RO membranes; NF membranes are commonly operated at pressures ranging from 75 to 150 psi (Lozier et al., 1997). NF membranes have been used successfully for groundwater softening since they achieve greater than 90 percent rejection of divalent ions such as calcium and magnesium. Several NF membrane-softening plants are currently in operation in the United States. Because most commercially available NF membranes have molecular weight cutoff values ranging from 200 to 500 daltons (Bergman, 1992; Scott, 1995), they are also capable of removing greater than 90 percent of natural organic matter present in the water. Therefore, they are also excellent candidates for the removal of color and, more importantly, disinfection byproduct (DBP) precursor material (Taylor et el., 19870.

Currently, NF membranes are being considered as a total organic carbon (TOC) removal technology in surface water treatment. The idea is to install NF membranes downstream of media filtration in order to maintain a very low solids-loading rate on the membranes. Although NF membranes have been designated by the U. S.

Environmental Protection Agency (EPA) as one of two best available technologies for meeting stage 2 of the Disinfectants/Disinfection Byproducts Rule of the US; they have not been applied for surface water treatment at full scale.

RO membranes have long been used for desalination of seawater around the world. These membranes can consistently remove about 99 percent of the total dissolved solids (TDSs) present in the water, including monovalent ions such as chloride, bromide, and sodium. However, for a long time these membranes were predominantly made from CA and required operating pressures at or greater than 250 psi. Recent innovations in Re membrane manufacturing have developed a new class of Re membranes, called TFC membranes that can achieve higher rejection of inorganic and organic contaminants than CA Re membranes, while operating at substantially lower pressures (100 to 150 psi). In addition, CA Re membranes commonly require acid addition to lower the pH of the water to a range of 5.5 to 6.0 to avoid hydrolysis of the membrane material. It should be noted that the need for pH depression for preventing the precipitation of salts on the membrane surface (such as $CaCO_3$) may still be necessary in some cases depending on the quality of the water being treated and the availability of suitable antiscalents.

TFC RO membranes are currently being evaluated for water reclamation. Results from ongoing pilot studies show that TFC RO membranes can achieve greater than 90 to 95 percent rejection of nitrate and nitrite, compared to 50 to 70 percent removal with CA Re membranes. The same pilot studies also show that the TOC concentration in the effluent of TFC Re membranes can be as low as 25 to 50 g/l.

Because of their existing applications for water softening and seawater desalination, high-pressure membrane treatment is currently accepted by the regulatory community and the water industry as a reliable technology. The main obstacle to increased application of high-pressure membranes in municipal water treatment is their high cost.

Two-Stage Membrane Filtration

From the above discussion, it is apparent that low-pressure membranes are highly effective for particulate removal, while high-pressure membranes are effective for dissolved matter removal (both organic and inorganic). Conceptually, combination of the two membrane systems in series (MF or UF followed by NF or RO) would provide a comprehensive treatment process train that is capable of removing the vast majority of dissolved and suspended material present in water. Such a treatment train is commonly termed ‘two-stage membrane filtration’. Other names include ‘integrated membrane systems’ or ‘dual-stage membrane filtration’. The only material that is believed to pass through such a treatment train includes low-molecular-weight organic chemicals. However, compared to existing treatment, a two-stage membrane filtration process (possibly coupled with PAC addition) would produce far superior water quality. The main concern about such highly treated water is that it may be more corrosive. Special corrosion inhibition measures for low-TDS waters of this kind require further development.

Several studies have been conducted to evaluate two-stage membrane systems for surface water treatment (Vickers et al., 1997). The results of these studies have

clearly shown that MF or UF membranes are excellent pretreatment processes to NF or RO membranes and that the combined particulate removal and organic removal capabilities of this treatment scheme produce excellent water quality that complies with existing and forthcoming regulatory requirements.

The primary obstacle that a two-stage membrane treatment system needs to overcome is its cost. Lozier et al. (1997) estimated the capital cost of a 40-gpm, two-membrane system at $4/gpd. The capital unit cost of a large-scale, two-stage membrane system may range from $2 to $3/gpd of capacity. This is still substantially higher than the cost of conventional treatment, which is estimated at $1 to $1.5/gpd.

Summary on Membrane Filtration Technology

Membrane filtration technology is rapidly becoming accepted in the water treatment industry. Low-pressure membrane filtration (MF and UF) is now replacing conventional filtration for surface water treatment at several locations in the United States and elsewhere. High-pressure membrane filtration (both NF and RO) is used primarily for softening and TDS reduction but is being evaluated for the removal of natural organic matter in water treatment. The main obstacle to large-scale implementation of membrane filtration is its capital cost. Ongoing innovations in the design of large-scale membrane systems are continually lowering their capital cost and making them increasingly cost competitive with conventional treatment processes.

ULTRAVIOLET IRRADIATION TECHNOLOGY

Ultraviolet (UV) irradiation technology is primarily used in the water and wastewater treatment industry as a disinfection process that capitalizes on the germicidal effect of UV light in the wavelength range of 250 to 270 nm (EPA, 1996). The process is commonly designed such that water flows in a narrow region around a series of UV lamps. The microorganisms in the water are inactivated through exposure to the UV light. The process is compact since the time of exposure (which translates into hydraulic retention time) is commonly measured in seconds. UV irradiation technology has been used since the 1950s at approximately 500 drinking water facilities in the United States, and more than 1,500 facilities in Europe (Parrotta and Bekdash 1998). Most of the facilities are either transient-noncommunity groundwater systems or non-transient and non-community groundwater systems serving less than 3,000 people each. These facilities provide water to restaurants, highway rest areas, airports, schools, camps, factories, rest homes, and hospitals. In fact, UV disinfection technology in drinking water treatment is currently only promoted for small-scale groundwater systems. However, the process can certainly be scaled up to large-scale applications since it is currently applied at large-scale wastewater treatment plants for final effluent disinfection. One of the largest wastewater treatment UV system in the world is located in Edmonton, Alberta, Canada, with a peak design capacity of 265 MGD (Reed, 1998).

There are four types of UV technologies of interest to the water industry: low-pressure, low-intensity (LP-LI) UV technology; low-pressure, medium-intensity (LP-MI) UV technology; medium-pressure, high-intensity (MP-HI) UV technology;

and pulsed-UV (PUV) technology. Approximately 90 percent of the UV installations in North America have LP-LI UV technology, with some dating back to the 1970s. The power output of LP-LI UV lamps commonly varies from 40 to 85 W. Another unique characteristic of low-pressure lamps is that they emit a monochromatic light at a wavelength of 254 nm. EPA's design manual is specifically based on and tailored to LP-LI UV technology. The primary advantage of LP-LI UV lamps is their high efficiency. The primary disadvantage is their low power, which results in the need for a large number of lamps for a small plant. Considering that a significant labor effort is required to clean and maintain UV lamps, the application of LP-LI UV technology at large scale is not desirable.

LP-MI UV lamps are identical to LP-LI UV lamps with the exception of a higher power output--170 W compared to 40 to 85 W. Therefore, a typical secondary wastewater effluent would now require only 20 to 24 lamps per MGD of capacity. This makes LP-MI UV technology more applicable for medium-size water treatment facilities than LP-LI UV technology.

MP-HI UV lamps operate at substantially higher gas pressure inside the lamps compared to low-pressure UV lamps and are characterized by a power output that varies from 5 to 30 KW. Contrary to low-pressure lamps that produce all of their light at approximately 254 nm, medium-pressure lamps produce a polychromatic light, of which only 25 percent is in the germicidal wavelength range of 200 to 300 nm. Currently, more than 270 MP-HI UV systems are in operation, with 70 of them operating at municipal wastewater treatment plants. One drawback of MP-LI UV technology is its low power efficiency compared to low-pressure technology. Another drawback is its high capital cost.

Low- and medium-pressure UV technologies are past the research stage and have been accepted as reliable disinfection technologies. In fact, specific LP-LI UV doses are listed in the Surface Water Treatment Rule (SWTR) *Guidance Manual* of EPA for the inactivation of viruses in water. The cost of UV systems is also not prohibitive since the technology is less expensive than ozone and many other disinfection processes.

The new UV technology under development is pulsed UV technology. In this process the energy is stored in a capacitor and then released to the lamp in a short, high-intensity pulse. However, questions remain about the ability to accurately measure the UV dose emitted by a pulsed UV system.

ADVANCED OXIDATION TECHNOLOGY

The term 'advanced oxidation processes' (AOPs) was first used to describe a process that produces hydroxyl radicals (OH) for the oxidation of organic and inorganic water impurities. AOPs include a number of processes. However, three main AOPs are discussed herein: ozone, ozone with hydrogen peroxide addition, and UV irradiation with hydrogen peroxide addition. AOPs can have multiple uses in water treatment. Examples include oxidation of synthetic organic chemicals, color, taste-and-odor-causing compounds, sulfide, iron, and manganese and destruction of DBP precursors prior to the addition of chlorine. The system is not considered to be cost-effective.

Ozone

There are numerous published books, peer-reviewed articles, and proceedings papers on the application of ozonation in drinking water treatment. Since the early 1980s the application of ozone in water treatment has increased, especially for color removal, taste-and-odor control, and/or disinfection. With the increased pressure to reduce chlorination byproduct formation and the need to inactivate increasingly resistant pathogens, many utilities are looking to ozone as their primary disinfection process. Ozone also has unique benefits over most other disinfectants including taste-and-odor control and the ability to inactivate of *Cryptosporidium*. In 1990 approximately 40 ozone water treatment plants were in operation in the US. In 1998, the number of ozone plants having greater than 1-MGD capacity was estimated at 114.

It is fair to assume that ozone is no longer considered an 'emerging' water treatment technology since it has been applied in large municipal treatment plants. Quenching of the residual ozone before the water exits the contactor is necessary in order to minimize operator exposure to unhealthy levels of ozone in the atmosphere. This task appears to be more challenging than earlier thought. Options to quench the ozone residual include air stripping the ozone in the last chamber of the ozone contactor and quenching the ozone residual with a reducing agent to the last chamber of the contactor (these include hydrogen peroxide, thiosulfate, and bisulfite).

It should be noted that one of the main obstacles to wider use of ozonation in municipal drinking water treatment is the potential formation of bromate (BrO_3-), a possible human carcinogen, when the water being treated contains bromide. In general, bromide concentrations greater than 50 g/l may result in bromate formation at levels greater than the maximum contaminant level (MCL) of 10 g/l. At this time, the only demonstrated bromate formation control strategy is to depress the water pH in the ozone contactor to less than 6.5 to 7. Additional work is needed to control bromate formation during ozonation of bromide-containing waters.

Rule-of-thumb costs for ozone systems are currently estimated at $2,000 to $3,000 per pound per day of ozone capacity. Therefore, for a 12-MGD treatment plant requiring an ozone dose of 5 mg/l, the capital cost of the ozone treatment system is estimated at $1 million to $1.5 million. This includes the ozone equipment and the concrete ozone contactor.

Ozone with Hydrogen Peroxide Addition

When hydrogen peroxide (H_2O_2) is added to ozonated water, it reacts with the molecular ozone, which accelerates the formation of hydroxyl radicals. Therefore, in an ozone-H_2O_2 process the goal is to increase the concentration of hydroxyl radicals, which is a stronger oxidizer than molecular ozone, and consequently rapidly reduce the concentration of molecular ozone. Therefore, hydrogen peroxide is added to an ozone process if it is used as an oxidation process but not as a disinfection process, which relies on the prevalence of a high concentration of molecular ozone.

The ozone-H_2O_2 process is used for the destruction of taste-and-odor-causing compounds, color removal, and destruction of micropollutants, such as volatile organic compounds, pesticides, and herbicides. Stoichiometric analysis suggests that the optimum H_2O_2-to-ozone ratio is approximately 0.3:1 (mg/mg). However,

pilot-and full-scale studies have shown that the optimum ratio is more on the order of 0.5:1 to 0.6:1 mg/mg .

Currently, the conventional design of an ozone-H_2O_2 treatment process is one in which hydrogen peroxide is fed as a liquid to the influent water and an ozone-rich gas is fed through fine-bubble diffusers at the bottom of a contactor.

Considering the complexity of the reaction chemistry between ozone, hydrogen peroxide, natural organic matter, and other water constituents, it is not clear whether such a conventional design is the optimum design for an ozone-H_2O_2 treatment system. Innovations in engineering design may be able to improve the efficiency of the process at lower ozone and/or hydrogen peroxide doses.

UV IRRADIATION WITH HYDROGEN PEROXIDE ADDITION

In the presence of UV light, hydrogen peroxide decomposes to form hydroxyl radicals. Addition of hydrogen peroxide to the influent of a UV irradiation process is currently being used for the destruction of micropollutants from groundwater, but it can also be used for the same purposes as other AOPs, which include the destruction of taste-and-odor-causing compounds and the removal of color. The reaction between UV and hydrogen peroxide to form hydroxyl radicals is substantially slower than that between ozone and hydrogen peroxide. However, in many groundwater remediation efforts, the simplicity of a UV irradiation system has been favored over the complexity of an ozone generation and feed system. However, owing to the slow hydroxyl-radical formation reaction in UV-H_2O_2 systems, the process must be operated with an excess of high concentration of hydrogen peroxide (5 to 20 mg/l hydrogen peroxide residual). Therefore, for this process to be used in drinking water treatment, either the process should be modified to utilize less hydrogen peroxide or a treatment process should be installed downstream to quench the hydrogen peroxide residual to acceptable levels (<0.5 mg/l) before the water is put into the distribution system. The various options available for quenching the hydrogen peroxide residual include chlorine, thiosulfate, sulfite, or granular-activated carbon.

ION EXCHANGE TECHNOLOGY

Ion exchange (IX) technology has been used in the chemical and environmental engineering fields for a long time. However, its use has been mostly limited to water softening (Ca^2+ and Mg^2+ removal), either at the water treatment plant or as a point-of-use treatment process and for industrial applications, such as the production of fully demineralized water. However, with new limits being set on several inorganic chemicals, IX technology is finding new applications in water treatment. Some of the primary candidates for removal with IX include nitrate, arsenic, selenium, barium, radium, lead, fluoride, and chromate. A new contaminant recently discovered in groundwater is perchlorate ($C1O_4$-), which is a component of solid-rocket fuel. The California Department of Health Services has adopted a perchlorate action level of 18 g/l. IX technology is ideal for the removal of perchlorate ion from contaminated groundwater. The technology is commonly designed as a fixed-bed process in which a synthetic resin is packed. As water passes through the resin bed, contaminant ions present in the water are exchanged with ions on the resin surface, thus removing

the contaminant ions from the water and concentrating them on the resin. The resin is frequently regenerated to remove the contaminant from the resin surface and replenish it with the original exchange ion. There are four primary types of IX resins: strong acid cationic (SAC) resin, weak acid cationic (WAC) resin, strong base anionic (SBA) resin, and weak base anionic (WBA) resin.

The cost of IX technology is competitive with that of other inorganics removal processes, such as lime softening, high-pH precipitation, and high-pressure membranes (e.g., RO membranes). For example, the capital cost of IX treatment for nitrate removal from groundwater is estimated at $0.4 to $0.5/gpd. However, application of IX technology large-scale is problematic because of the waste stream produced by the process. The volume of the waste stream is not large and can amount to only 2 to 5 percent of the water volume treated; however, the waste stream contains a high concentration of acid (HCl), base (NaOH), or salt (NaCl), ranging from 1 to 3 M. In addition, the waste stream contains a high concentration of the contaminant removed from the water (e.g., NO_3^-, $HAsO_4^{2-}$, Pb^{2+}, etc.). The disposal of a waste stream containing these components is the primary obstacle to widespread implementation of IX technology at large-scale water treatment plants. Plants in coastal areas may have the option of disposing of this stream into the ocean. However, no cost-effective disposal options exist for inland plants.

BIOLOGICAL FILTRATION

All of the technologies discussed above are physical and/or chemical processes. In fact, the water treatment industry depends solely on physical and/or chemical processes to meet water quality goals. Utilization of biological processes in water treatment has been frowned on by the industry because of concern about the introduction of microorganisms to water. However, this barrier has been broken by the introduction of biological filtration as the most effective process for the production of biologically stable water. This was specifically driven by concern about the increase in the concentration of biodegradable organic matter (BOM) as a result of ozonating natural waters. There is concern that higher BOM levels may result in increased potential for biological regrowth in the distribution system. Therefore, implementing biological filtration in the water treatment plant reduces BOM concentrations in the water before it is introduced into the distribution system. There are several unanswered questions about the design and operation of biological filtration, such as what filter media type and size to use and what minimum empty bed contact time (EBCT) can be used while maintaining satisfactory BOM removal. Pilot studies conducted by various researchers have concluded that either granular-activated carbon (GAC) or anthracite, compared to sand, is required as the attachment medium for the biofilm. Clearly, anthracite is substantially less expensive than GAC. Anthracite has been shown to be equivalent to GAC as a biological filtration medium when used in warm climate. However, it may not be satisfactory in cold climates, as studies have shown that a higher GAC surface area, compared to that of anthracite, is required to maintain an active biofilm when treating cold water. The concentration of biomass on the surface of biologically active GAC filters was approximately three to eight times greater than that on the surface of biologically active anthracite filters.

The use of biofiltration in drinking water treatment opens the door to new and innovative applications of this process. Biofiltration can be used for the biological reduction of various inorganic contaminants such as nitrate, bromate, perchlorate, chlorate, and selenate. However, its use for these applications still requires a substantial amount of research and engineering and is far from being ready for implementation at large municipal scale.

SUMMING UP ON WATER TREATMENT TECHNOLOGIES

Historically, the water industry has adapted to new technologies at a slow, incremental pace. In the past 20 years, there has been a rapid entry of new technologies that continue to be developed, tested, demonstrated, and introduced into the municipal water treatment market. Some of these technologies are membrane filtration, UV irradiation, advanced oxidation, ion exchange, and biological filtration. These are certainly not the only technologies being considered by the water treatment industry. However, they have come a long way toward demonstrating their reliability and applicability to large-scale municipal water treatment plants. As the cost of these technologies continues to decrease, their applicability will steadily increase.

There is almost no contaminant that cannot be removed from water. The question becomes that of cost. As alternative water resources become increasingly less available, the need for innovative and cost-effective treatment technologies will rise steadily.

SEWAGE TREATMENT

GENERAL

The major stages of sewage treatment are classified in to *primary*, *secondary*, and *tertiary* treatment. Initially, the solids are separated from the wastewater stream. Then, the dissolved biological matter is often converted into a solid mass by using preferably indigenous, water-borne micro-organisms. In the final stage, the biological solids are neutralized and the treated water is disposed of or re-used. The treated water may be disinfected chemically or physically using lagoons or resorting to micro-filtration. The final effluent can be discharged into a natural water course or it can be used for the purpose of irrigation of lawns or garden. Depending on its level of purification, it can also be used for groundwater recharge or agricultural purposes.

Sewage includes the household wastewater from toilets, bath rooms, showers, kitchens and sinks disposed of through sewers. In some areas, sewage also includes wastewater from industry and commerce.

The household wastewater is often segregated into greywater and blackwater. Greywater with treatment or without, depending on the condition, is used in developing countries for watering plants or is recycled for flushing toilets. Considerable quantum of sewage in towns often includes rainwater from the roof and stormwater runoff. Those sewage systems capable of handling stormwater come under combined systems. Such systems bring down the efficiency of sewage treatment plants due to variability in flow. Combined systems are more expensive due to the larger quantum of water to be treated and these systems also may spill during the periods of heavy rainfall. It is always preferable to have a separate storm

drain system for stormwater. Rainwater picks up some contaminants including soil particles, heavy metals, organic compounds, animal waste, and oil and grease. In some regions, it is mandatory to carry out some level of treatment before discharging into the waterways. The treatment processes for stormwater include sedimentation basins, wetlands, buried concrete vaults with filters, and vortex separators to remove coarse solids.

The mechanical, chemical and biological systems used in wastewater treatment plant as also their sequential order of use and types are typically the same in most of the countries (New World Encyclopaedia, Article on Sewage Treatment). The details of typical systems in vogue are given below:

- *Mechanical treatment*
  - Influx (Influent)
  - Removal of large objects
  - Removal of sand and grit
  - Pre-precipitation
- *Biological treatment*
  - Oxidation bed (oxidizing bed) or aeration system
  - Post precipitation
- *Chemical treatment*
  - Usually combined with settling and other processes to remove solids, such as filtration - the combination is referred to in the United States as physical chemical treatment.

The typical materials that are removed during the primary treatment include fats, oil, and grease (referred to as FOG), sand, gravels and rocks (referred to as grit), larger settling solids and floating materials including rags and used sanitary napkins - this step being done generally using machinery. The Process flow diagram of a typical sewage treatment plant is given in Figure 3.

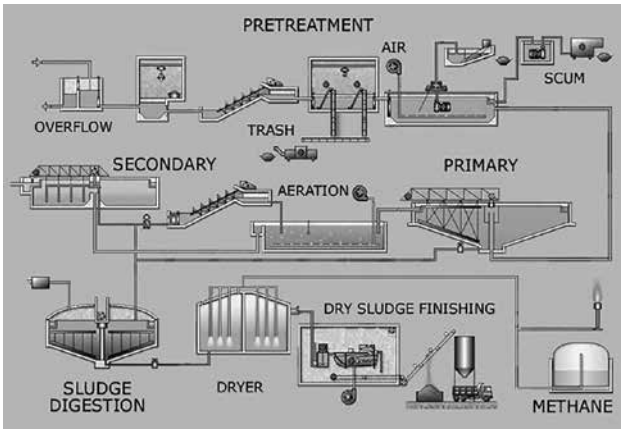

Figure 3
Process flow diagram for a typical treatment plant (After New World Encyclopaedia)

PRIMARY TREATMENT - REMOVAL OF LARGER PARTICLES

The influent sewage water is strained during the primary treatment to remove all large objects that are deposited in the sewer system, which may consist of rags, sticks, cans, etc. This is most generally done by manual or using automated mechanically raked bar screen. The solids are collected in a dumpster and disposed of as landfill.

Primary treatment system often includes a sand or grit channel or chamber, which helps in controlling the velocity of incoming wastewater, thereby allowing sand, grit and stones to settle. The majority of the suspended organic material remains in the water column. This device is popularly known as 'degritter' or sand catcher, which removes sand, grit, and stones in the early stages so as to avoid damage to pumps and other equipment used in the latter stages of treatment. The sand washer (grit classifier) along with a conveyor is also used in certain plants to transfer sand to a container for disposal. The contents from the sand catcher may be fed into the incinerator in a sludge processing plant, but generally it is used as a landfill.

Sedimentation

A sedimentation stage is often recommended, in which the sewage is allowed to slowly move through large tanks, known as 'primary clarifiers' or 'primary sedimentation tanks'. These large tanks permit the sludge to settle and floating materials such as grease and oils rise to the surface, from where they are skimmed off. The primary clarification stage helps in obtaining a homogeneous liquid fit for biological treatment; the sludge can be separately treated or processed. Primary settling tanks usually have mechanically driven scrapers that continually move the collected sludge towards a hopper at the base of the tank, from where it can be pumped out.

SECONDARY TREATMENT

Secondary treatment is mainly intended to degrade the biological content of the sewage substantially. These are derived from human waste, food waste, soaps and detergent. The majority of municipal plants in developed countries treat the settled sewage using aerobic biological processes. For the effective treatment at this stage, the biota requires oxygen for the process and a substrata for its survival. These conditions can be fulfilled by several methods. In all these, the bacteria and protozoa consume biodegradable soluble organic contaminants, such as sugars, fats, organic short-chain carbon molecules, etc. and bind much of the less soluble fractions into the floc. The secondary treatment systems are classified as fixed film or suspended growth. The fixed film treatment process include trickling filter and rotating biological contactors, in which the biomass grows in the media and the sewage passes over its surface. In suspended growth systems, such as activated sludge, the biomass mixes well with the sewage and can be operated in a smaller space than fixed film systems that can treat the same amount of wastewater. However, fixed film systems have more capability to cope with the drastic changes in the quantum of biological material and have higher removal rates for organic material and suspended solids than suspended growth systems.

Roughing filters are meant to treat very strong or variable organic loads, particularly of industries, to enable them then to be treated by the conventional secondary

treatment processes. Typical characteristics include tall, circular filters filled with open synthetic filter media to which wastewater is applied at a relatively high rate. They are designed to allow high hydraulic loading and a high flow-through of air. In larger installations, air is forced through the media using blowers. The resultant wastewater is usually within the normal range for conventional treatment processes.

Activated Sludge

Activated sludge plants encompass a variety of mechanisms and processes that use dissolved oxygen to promote the growth of biological floc that substantially removes the organic material. In the process particulate material is trapped and under ideal conditions, ammonia is converted to nitrite and nitrate and ultimately to nitrogen gas. Most of the biological oxidation processes for treating industrial wastewaters generally make use of oxygen or air and microbial action. It is seen that surface-aerated basins achieve 80 to 90 percent removal of Biochemical Oxygen Demand with retention times ranging from 1 to 10 days (Committee on US-Iranian Workshop 2005). The basins may range in depth from 1.5 to 5.0 meters and use motor-driven aerators floating on the surface of the wastewater. In an aerated basin system, the aerators provide two functions: they transfer air into the basins required by the biological oxidation reactions, and they provide the mixing required for dispersing the air and for contacting the reactants (oxygen, wastewater and microbes). Typically, the floating surface aerators are rated to deliver the amount of air equivalent to 1.8 - 2.7 kg O_2/kwh. However, good mixing is not possible in this, as is normally achieved in activated sludge systems. Therefore, aerated basins do not achieve the same performance level as activated sludge units.

Biological oxidation processes are sensitive to temperature and, between 0 °C and 40 °C, the rate of biological reactions increase with temperature. Surface aerated vessels generally operate between 4 °C and 32 °C.

Fluidized Bed Reactors

The carbon absorption followed by biological treatment is recommended for effectively bringing down the BOD and COD levels. The fluidized bed reactor combines the most commonly used stirred tank packed bed and continuous flow reactors. In such reactors, the substrate is moved upward through the immobilized enzyme bed at a high velocity to lift the particles. However, the velocity should not be high enough so that the enzymes are entirely swept away from the reactor. These types of reactors are suitable for exothermic reactions; it has its application in immobilized enzyme catalysis.

Filter Beds or Oxidizing Beds

In plants which are old or receiving more variable loads, trickling filter beds are used where the settled sewage is spread onto the surface of a deep bed made up of coke - carbonized coal-limestone chips or specially fabricated plastic media. Such media with high surface areas support the biofilms that are formed. The liquor is distributed through perforated rotating arms radiating from a central pivot. The distributed liquor trickles through this bed and is collected in drains at the base. These drains also provide a source of air which percolates up through the bed, keeping it aerobic.

Biological films of bacteria, protozoa and fungi form on the media's surfaces and eat or otherwise reduce the organic content. This biofilm is grazed by insect larvae and worms which help maintain an optimal thickness. Overloading of beds increases the thickness of the film leading to clogging of the filter media and ponding on the surface.

Biological Aerated Filters

Biological Aerated Filter (BAF) or Anoxic Filter (BAF)/Biofilter combines in it the functions of filtration with biological carbon reduction, nitrification or denitrification. The BAF usually includes a reactor filled with filter media. The media is either in suspension or supported by a gravel layer at the foot of the filter. The dual function of this media is to support active biomass that is adherd to it and to filter the suspended solids. Both carbon reduction and ammonia conversion take place in aerobic mode and sometimes both these are achieved in a single reactor while nitrate conversion occurs in anoxic mode. BAF is operated either in up-flow or down-flow configuration depending on the design specified by the manufacturer.

Membrane Bioreactors

Membrane Bioreactor (MBR) has activated sludge treatment combined with a membrane liquid-solid separation process. The membrane is either low pressure microfiltration one or ultra filtration membranes and it eliminates the need for clarification and tertiary filtration. The membranes are generally immersed in the aeration tank; however, in some cases, a separate membrane tank is used. A membrane bioreactor system effectively overcomes the limitations associated with poor settling of sludge in Conventional Activated Sludge (CAS) processes. The technology has the advantage of the bioreactor operation with considerably higher mixed liquor suspended solid (MLSS) concentration than CAS systems, which have limited sludge settling capability. The process is generally operated at MLSS in the range of 8,000–12,000 mg/l, while CAS is operated in the range of 2,000–3,000 mg/l. The elevated biomass concentration in the membrane bioreactor process permits effective removal of both soluble and particulate biodegradable materials at higher loading rates. It is observed that increased Sludge Retention Times (SRT) - exceeding 15 days - ensure complete nitrification even under extremely cold weather conditions.

The construction and operation of MBR is often higher than the conventional wastewater treatment systems. However, this technology has become very popular and is widely accepted. The life-cycle cost has been reducing over the years. The small footprint of MBR systems, and the high quality effluent produced, makes them particularly useful for water reuse applications.

Secondary Sedimentation

The secondary treatment stage is complete with the settlement of the biological floc or filter material. At this stage, sewage water containing very low levels of organic material and suspended matter is achieved.

Rotating Biological Contactors

Rotating Biological Contactor (RBC) is a mechanical secondary treatment system, which is capable of withstanding fluctuating organic load. RBCs were first installed

in Germany in 1960. Thereafter, it was modified and refined time and again till a reliable operating unit was developed. The rotating discs support the growth of bacteria and micro-organisms present in the sewage are supported by the rotating disc, which breaks down and stabilize the organic pollutants. Micro-organisms need both oxygen to live and food to grow; oxygen is obtained from the atmosphere as the discs rotate. As the micro-organisms grow, they live on the media till they are sloughed off due to shear forces caused by the rotating discs. Effluents from the RBC is then passed through the clarifiers in which the micro-organisms in suspension settle down as sludge. The sludge is removed from the clarifier and further treated.

A functionally similar biological filtering system has become popular as part of home aquarium filtration and purification. The aquarium water is drawn up out of the tank and then cascaded over a freely spinning corrugated fiber-mesh wheel before passing through a media filter and back into the aquarium. The spinning mesh wheel develops a biofilm coating of microorganisms that feed on the suspended wastes in the aquarium and are also exposed to the atmosphere as the wheel rotates. This is especially good at removing waste urea and ammonia in the aquarium water.

TERTIARY TREATMENT

The tertiary treatment is the final stage in which the quality of wastewater is enhanced before discharging to the receiving environment - sea, river, lake, ground, etc. More than one tertiary treatment process may be applied at the treatment plant. If disinfection is done, it is always the final stage of treatment, popularly known as 'effluent polishing'.

Filtration

Sand filtration is often practised to remove the residual suspended matter and filtration over activated carbon removes residual toxins.

Lagooning

Lagooning in ponds or wetlands permits settlement and further biological improvement. These lagoons are highly aerobic and colonization by native macrophytes, especially reeds, is often encouraged. Small filter feeding invertebrates such as Daphnia and species of Rotifera assist in the treatment considerably by removing the fine particulates.

Constructed Wetlands

Constructed wetlands include engineered reed-beds and similar other methodologies, all of which provide a high degree of aerobic biological improvement. They are also often used as a substitute to secondary treatment for small communities.

Nutrient Removal

Wastewater often contains high levels of the nutrients - nitrogen and phosphorus. Excessive release to the environment can lead to a build-up of nutrients, leading to eutrophication, which contribute to the overgrowth of weeds, algae, and cyanobacteria - blue-green algae. This may cause an algal bloom, a rapid growth in the population of algae. The decomposition of the algae by bacteria takes up so

much of oxygen in the water that most or all of the animals die. This produces more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies. It is recognized that different treatment processes are necessary to remove nitrogen and phosphorus.

Nitrogen Removal

The nitrogen removal is effected through the biological oxidation of nitrogen from ammonia –nitrification- to nitrate, followed by denitrification - the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from water.

Nitrification itself is a two-step aerobic process, each step is caused by a different type of bacteria. The oxidation of ammonia (NH_3) to nitrite (NO_2^-) is most often caused by *Nitrosomonas* spp. (nitroso referring to the formation of a nitroso functional group). It is now understood that nitrite oxidation to nitrate (NO_3^-), is facilitated in the environment almost exclusively by *Nitrospira* spp.

Denitrification requires anoxic conditions for appropriate biological communities to form; it is facilitated by diverse bacteria. Sand filters, lagooning and reed beds can all help in reducing nitrogen, but well-designed activated sludge process is the most suitable. Tertiary treatment at times refers to only the conversion of toxic ammonia to nitrate.

Phosphorus Removal

Phosphorus removal is important since it is a limiting nutrient for algae growth in many fresh water systems. It is also particularly important for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as reverse osmosis. Phospherous is removed biologically by resorting to a process called enhanced biological phosphorus removal. In this process, a specific bacteria, known as polyphosphate accumulating organisms (PAOs) are selectively enriched and large quantities of phosphorus accumulate within their cells (up to 20 percent of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids have a great fertilizer value. Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride), aluminum (e.g. alum), or lime; this is often more reliable than biological phosphorus removal. The phosphate rich sludge can be used for land filling, or if in suitable condition, can be used as fertilizer.

DISINFECTION

The role of disinfection in the treatment of wastewater is to substantially bring down the number of microorganisms in the water to be discharged back into the environment. The effectiveness of disinfection depends on the quality of the water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Common methods of disinfection include ozone, chlorine, or ultraviolet light. Chloramine, which is used for drinking water, is not used in wastewater treatment because of its persistence.

Chlorination remains the most common form of wastewater disinfection due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

Ultraviolet (UV) light can also be used instead of chlorine, iodine, or other chemicals. Since no chemicals are used, the treated water has no adverse effect on organisms that later consume it, as may be the case with other methods. UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent maintenance and replacement of parts and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation.

Ozone is very unstable and reactive and oxidizes most of the organic materials it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine. Ozonation also produces fewer disinfection by-products when compared to chlorination. The disadvantage of ozone disinfection is the high cost of the equipment and the requirements for special operators.

PACKAGE PLANTS AND BATCH REACTORS

In order to use less space, treat difficult waste, deal with intermittent flow or achieve higher environmental standards, a number of designs of hybrid treatment plants have been produced. Such plants often combine all or at least two stages of the three main treatment stages into one combined stage. Package plants are common in UK to cater to small clusters of population since it is a viable alternative to building discrete structures for each process stage.

One type of system that combines secondary treatment and settlement is the Sequencing Batch Reactor (SBR). Typically, activated sludge is mixed with raw incoming sewage and mixed and aerated. The resultant mixture is then allowed to settle producing a high quality effluent. The settled sludge is run off and re-aerated before a proportion is returned to the head of the works. SBR plants are now being deployed in many parts of the world.

The disadvantage of such processes is that precise control of timing, mixing and aeration is required. This precision is usually achieved by computer controls linked to many sensors in the plant. Such a complex, fragile system is unsuited to places where such controls may be unreliable, or poorly maintained, or where the power supply may be intermittent.

Package plants may be referred to as *high charged* or *low charged*. This refers to the way the biological load is processed. In high charged systems, the biological stage is presented with a high organic load and the combined floc and organic material is then oxygenated for a few hours before being charged again with a new load. In the low charged system, the biological stage contains a low organic load and is combined with flocculate for a relatively long time.

SLUDGE TREATMENT AND DISPOSAL

The sludge accumulated in a wastewater treatment process must be treated and disposed of in a safe and effective manner. The purpose of digestion is to reduce the amount of organic matter and the number of disease-causing microorganisms present in the solids. The most common treatment options include anaerobic digestion, aerobic digestion, and composting.

The choice of a wastewater solid treatment method depends on the amount of solids generated and other site-specific conditions. However, in general, composting is most often applied to smaller-scale applications followed by aerobic digestion and then lastly anaerobic digestion for the larger-scale municipal applications.

ANAEROBIC DIGESTION

Anaerobic digestion is a bacterial process that is carried out in the absence of oxygen. The process can either be *thermophilic* digestion, in which sludge is fermented in tanks at a temperature of 55°C, or *mesophilic*, at a temperature of around 36°C. By allowing shorter retention time (and thus smaller tanks), thermophilic digestion is more expensive in terms of energy consumption for heating the sludge.

One major feature of anaerobic digestion is the production of biogas, which can be used in generators for electricity production and/or in boilers for heating purposes.

AEROBIC DIGESTION

Aerobic digestion is a bacterial process occurring in the presence of oxygen. Under aerobic conditions, bacteria rapidly consume organic matter and convert it into carbon dioxide. The operating costs used to be characteristically much greater for aerobic digestion because of the energy used by the blowers, pumps, and motors needed to add oxygen to the process. However, recent technological advances include non-electric aerated filter systems that use natural air currents for the aeration instead of electrically operated machinery. Aerobic digestion can also be achieved by using diffuser systems or jet aerators to oxidize the sludge.

COMPOSTING

Composting is also an aerobic process that involves mixing the sludge with sources of carbon such as sawdust, straw or wood chips. In the presence of oxygen, bacteria digest both the wastewater solids and the added carbon source and, in doing so, produce a large amount of heat.

SLUDGE DISPOSAL

When a liquid sludge is produced, further treatment may be required to make it suitable for final disposal. Typically, sludges are thickened (dewatered) to reduce the volumes transported off-site for disposal. There is no process which completely eliminates the need to dispose of biosolids. There is, however, an additional step some cities are taking to superheat the wastewater sludge and convert it into small pelletized granules that are high in nitrogen and other organic materials. In New York City, for example, several sewage treatment plants have dewatering facilities that use large centrifuges along with the addition of chemicals such as polymer to further remove liquid from the sludge. The removed fluid, called centrate, is typically

reintroduced into the wastewater process. The product which is left is called 'cake' and that is picked up by companies which turn it into fertilizer pellets. This product is then sold to local farmers and turf farms as a soil amendment or fertilizer, reducing the amount of space required to dispose of sludge in landfills (Drinan 2000).

TREATMENT IN THE RECEIVING ENVIRONMENT

Many processes in a wastewater treatment plant are designed to mimic the natural treatment processes that occur in the environment, whether that environment is a natural water body or the ground. If not overloaded, bacteria in the environment will consume organic contaminants, although this will reduce the levels of oxygen in the water and may significantly change the overall ecology of the receiving water. Native bacterial populations feed on the organic contaminants, and the numbers of disease-causing microorganisms are reduced by natural environmental conditions such as predation exposure to ultraviolet radiation, for example. Consequently, in cases where the receiving environment provides a high level of dilution, a high degree of wastewater treatment may not be required. However, recent evidence has demonstrated that very low levels of certain contaminants in wastewater, including hormones (from animal husbandry and residue from human hormonal contraception methods) and synthetic materials such as phthalates that mimic hormones in their action, can have an unpredictable adverse impact on the natural biota and potentially on humans if the water is re-used for drinking water. In the United States and EU, uncontrolled discharges of wastewater to the environment are not permitted under law, and strict water quality requirements are to be met. A significant threat in the coming decades will be the increasing uncontrolled discharges of wastewater within rapidly developing countries.

SEWAGE TREATMENT IN DEVELOPING COUNTRIES

There are a few reliable figures on the share of the wastewater collected in sewers that is being treated in the world. In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment or after primary treatment only. In Latin America about 15 percent of collected wastewater passes through treatment plants (with varying levels of actual treatment). In Venezuela, a below average country in South America with respect to wastewater treatment, 97 percent of the country's sewage is discharged raw into the environment (Droste 1997).

In a relatively developed Middle Eastern country such as Iran, Tehran's majority of population has totally untreated sewage injected to the city's groundwater (Spellman 2009). Israel has also aggressively pursued the use of treated sewer water for irrigation. In 2008, agriculture in Israel consumed 500 million cubic meters of potable water and an equal amount of treated sewer water. The country plans to provide a further 200 million cubic meters of recycled sewer water and build more desalination plants to supply even more water.

Most of sub-Saharan Africa is without wastewater treatment

Water utilities in developing countries are chronically underfunded because of low water tariffs, the nonexistence of sanitation tariffs in many cases, low billing

efficiency (i.e. many users that are billed do not pay) and poor operational efficiency (i.e. there are overly high levels of staff, there are high physical losses, and many users have illegal connections and are thus not being billed). In addition, wastewater treatment typically is the process within the utility that receives the least attention, partly because enforcement of environmental standards is poor. As a result of all these factors, operation and maintenance of many wastewater treatment plants is poor. This is evidenced by the frequent breakdown of equipment, shutdown of electrically operated equipment due to power outages or to reduce costs, and sedimentation due to lack of sludge removal.

Developing countries as diverse as Egypt, Algeria, China or Colombia have invested substantial sums in wastewater treatment without achieving a significant impact in terms of environmental improvement. Even if wastewater treatment plants are properly operating, it can be argued that the environmental impact is limited in cases where the assimilative capacity of the receiving waters (ocean with strong currents or large rivers) is high, as it is often the case.

BENEFITS OF WASTEWATER TREATMENT COMPARED TO BENEFITS OF SEWAGE COLLECTION IN DEVELOPING COUNTRIES

Waterborne diseases that are prevalent in developing countries, such as typhus and cholera, are caused primarily by poor hygiene practices and the absence of improved household sanitation facilities. The public health impact of the discharge of untreated wastewater is comparatively much lower. Hygiene promotion, on-site sanitation and low-cost sanitation are thus likely to have a much greater impact on public health than wastewater treatment.

CONCLUSIONS

The emerging technologies in water treatment have been highlighted along with their advantages and disadvantages. The traditional and modern technologies available for wastewater treatment has been brought to light with other peripheral aspects of disposing of the sludge, land-filling, composting and finally the management of receiving environment.

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Disaster Management in an 'Internet of Things' Enabled Society

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INTRODUCTION

Right from the early days of human civilization, spanning the prehistory and recorded history, archeologists and historians have unearthed rudimentary and/or compelling evidences of communities and societies that perished and/or vanished by the brutal hit of natural disasters like, volcanic ash falls (Mt. Vesuvius un AD79 and remains at Pompeii), earthquakes, tsunamis, river floods, and on drought. In contrast to the historic past, modern disasters are human induced while some others are qualify to be designated as technological disasters. Presumably all the natural disasters are manifestations of some aspect of the earth system processes. Agung volcanic activity in Bali in this past week, is a living example a volcanic eruption disrupts normal life of the citizens and civil aviation of that country.

The onslaught of all sorts of disasters has cumulatively taken a huge toll of human life, property and disruption of safe living of families. Among the nations of the world, disasters of sorts and sizes have been infrequently striking communities in towns and villages and taking large or small tolls of human life and property resulting in disruption of peace and security life of people and families. Disaster management covers all the processes, preparations and speedy delivery of emergency services to the affected and needy before, during and after the disaster. These days in developing and emerging countries like India disaster management (DM) boils down to rescue and rebuilding or rehabilitation. Truly, avoidance of disasters by preventive measures and preparedness are far more or as important as rescue and rebuilding.

Ground Reality in India

Interestingly average Indian is fairly unaware of the facts that 57% of India is vulnerable to earthquakes and 12% of the same has been categorized as highly vulnerable. Further 68% of the Indian lands are drought prone; 12% is prone to floods and another 8% under cyclones. For example, in Kerala, during the annual 'Sabarimala' pilgrimage season nearly 30 million people visit the 'Ayyappa shrine' set in the deep forest in the high mountains and far away from the society and communities. The level of risk and preparedness are still very 'crude' and modest, with the exception of mobile/internet connectivity. The potential risk of stampedes,

animal attacks, and accidental fires looms large but the pilgrim visitors are oblivious of the former. Poor transport infrastructure, better sanitation and emergency shelters are still inappropriate in the environs of this pilgrim center.

The global climate change phenomenon, due to CO_2 build in the lower troposphere (currently at 407 ppm) whose consequences to human society are now playing out in different parts of the globe, and manifests as unheard of and unseasonal weather phenomena in different parts of the nation disrupting the otherwise relatively normal life and calm of the societies. Our ability and capacity as a nation to cope up with the consequences are in doubt especially with incidence of more severe and prolonged floods, continuous spells of drought years or both and concomitant secondary consequences affecting human well being and social behavior due to the changed natural environment.

National Disaster Management Authority - NDMA

The NDMA and its subsidiaries in the states are the nodal agencies in the Nationally and provincially mandated to design and implement region and location specific programs for managing disasters of sorts by identification of potential candidates, preparedness plans, rescue mechanisms and route plans and rehabilitation plans and programs. The level of technology adaption by the state agencies in respect of DM program remains a terra incognita for the public – the primary stakeholder.

For e.g., though the Kerala state DM agency is to deal with a relatively smaller geographic area (=38830 km^2), the relatively high population density warrants a larger momentum and input in the areas of public awareness – especially through their web portal.

Disaster – Definition

One definition in Wikipedia for example states “Disaster as a serious disruption of functioning of a community or society spanning over a relatively short time, involving widespread human, material, economic or environmental loss and impacts, but exceeding the abilities of the community or society to cope with own resources”. However, the academia considers disaster as the consequences of an inappropriately managed risk.

As mentioned in the foregoing, disaster in general fall into two broad types, viz., the natural disasters and man made disasters. However, after the 9/11 terrorist bombing of the twin towers of World Trade Center, terrorism found a place in the list man made disasters. At least, the citizens in the Kashmir valley, India, are exposed daily to acts of terrorism disrupting the calm (an important input for progress in all facets of life) in the day-to-day life of the citizens.

Manmade disasters (including technological ones) that are frequenting parts of the nation are large and small train accidents, fires affecting factory/warehouse/commercial/residential buildings, building collapses, and acts of terrorism etc.

What happens when disaster strikes is solely dependent on where you are? In a hot, crowded and ‘poorly’ disciplined country like India, at the time of a disaster everything goes out of control. India abounds in natural disasters and the commonest are earthquakes, floods, droughts, coastal flooding due to cyclones, landslides and

land slips, and once-a-century Tsunami. Unlike the Himalayan states (e.g., such as the NE states, Bihar, northern UP, NCR, Uttarakand, Kashmir, Himachal Pradesh), in Kerala devastating earthquakes are rare but not earth tremors.

Kerala vis-à-vis disasters

The SW monsoon rains in Kerala is both an enabler and a trigger of scores of landslips especially along state highways where the road bed/pavement is perched along hill slopes. Kerala earned a first, in respect of landslide awareness, by publication of a 'Land Slide Atlas of Kerala' (Sajinkumar and Oommen, 2017), through the Geological Society of India. Monsoon is an enabler by steadily supplying water to seep down and fill the porous substrate to the extent of sharply increasing the pore pressure and leading to failure.

Other natural disasters of the state are mostly monsoon rains induced over bank flood flows in rivers in parts of midland and coastal land, backshore floods and erosion of beaches, and occasional ferry boat tragedies. The coastal communities are constantly under threat of loss of property and damage to homes during the on set of SW monsoon season when the monsoon waves erode off a few hundred thousand tons of beach material. This annual show of beach erosion and loss to the people are partially neutralized by injection funds in rebuilding the dwellings and relocating the affected in temporarily in schools in coastal villages. Perhaps, relocating the backshore dwellers in safe zones to the east following the CRZ notification seems to be the only permanent solution.

Display of pyrotechnics in places of worship, at the conclusion of festivities of one kind or other, occasionally ends up in disasters taking a toll of life disrupting human life and destruction of property. The Tsunami of 2004 December 26th, though was a national disaster at a huge loss of life in the known history of the nation, had a share in Kerala's coastal population in the Kollam district.

Table 1.
IOT- Areas of applications in developing and emerging countries

USING SENSORS FOR GOOD Health care, Agriculture, Enhancing smallholder productivity Disaster Management –huge potential before, during and after disaster to minimize disruption of life in all its facets.

Disaster Management and IOT – Internet of Things

The phrase, Internet of Things or IOT, was coined by Mr. Kevin Ashton, in 1999, of Proctor and Gamble, and later in MIT Auto ID Center. IOT is an extraordinary mix of hardware, software, data (Table 1) and services. Data collected with various devices and technologies then automatically flow the data between other devices. Moreover, IOT allows more direct integration of physical world into computer-based systems for better efficiency, accuracy and economic benefit, notwithstanding reduced human intervention. When IOT is augmented with sensors and actuators, the technology becomes an instance cyber-physical systems. A case in point is many of the INCOIS delivered services (detailed details below)

IOT has the potential for a paradigm shift from the conventional model of relief and recovery in DM to the one basing risk and vulnerability assessment enabling to focus on key issues and challenges relating to natural or man made disasters.

Disaster Emergency Response is a critical input for saving human lives when struck by a disaster. The UN Outer Space Affairs division has brought out a knowledge product or a set of guidelines to meet the disaster emergency in the member nations and especially in the ASEAN countries. This knowledge product would amplify and enhance skills, capacity and institutional development in the member countries using space-based technologies in disaster risk management.

Geospatial input for data analytics in DM

These days satellite based geospatial information is often used for better situational awareness and activities there of, in the post disaster phase However, despite free availability of satellite data for emergency responses, many disaster managers or end users are mostly unaware of such global or regional initiatives. This is true in the Indian national scene. Currently the agencies of the government involved in DM, work in a compartmentalized style as one might infer from the absence of links in the web sites of the NDMA or SDMA to the DM programs, plans or activities of the participating agencies.

However, the Sendai frame-work for disaster reduction (2015-30) underscored the critical role of space based technologies in disaster risk reduction. The chief objective of SBI is to deliver the right information to the right person at the right time.

In most emergencies, the NDMA or their functionaries coordinate the emergency responses. This seven-step-procedure (i.e., evaluate, identify, Asses, Request, Share, Integrate and Reflect), or work flow and decision making uses SBI for emergency response.

UNOSAT (a 24x7 agency) is the operational satellite applications program with a mission to leverage satellite technology enabling geospatial data to create integrated solutions for human security, safety, and socio-economic development not only to the member nations but to those outside. The service covers products such as maps, GIS-ready-data, statistics etc.. Also, UNOSAT is linked to companies like Airbus, Digital Globe, and Radarsat to produce commercial images rather quickly and even reprogramming of satellites to make the data flow faster. SEM, International Working Group SEM or satellite based emergency mapping creates maps, geoinformation products and spatial analysis enabling creation of situation awareness for emergency management and crisis information to prevent and manage crisis

The INCOIS – a near IOT Service Enterprise

INCOIS or the Indian National Centre for Ocean Information Services, an agency of GoI, is a part of the ESSO (Earth System Science Organization) mandated to offer the best possible ocean information and advisories to the public, government agencies, industry and other stake holders. Services of the INCOIS are available through a portal and various other devices positioned in various parts of the country and especially along the 5800 km long mainland coast.

The INCOIS is involved in collecting primary data as well as aggregating secondary data from international providers, relating to the status and anomalies of ocean and coastal waters. After data processing and analysis, advisories are offered regarding aspects of business, security and safety to the various stakeholders through a variety of near real time basis on a wireless or non-terrestrial network. Data gathering by sensors and processing with appropriate algorithms followed by analysis and transmitting the inferences back to public is a form of IOT in action in the INCOIS.

The service offered under the Potential Fishing Zones (PFZ) of the country is perhaps the inaugural service of INCOIS. The data offered by OCEANSAT through NOAA (National Oceanic and Atmospheric Administration) on ocean colour and sea surface temperature (SST) is at the back bone of PFZ The fishers of the nation took the full advantage of the PFZ advisories in practicing their trade efficiently, safely and profitably. Further, the Tuna Fish Forecasting Service added a great impetus to the Tuna fisheries.

In addition, data streamed from a network of 17 tide gages and bouys allow identification and validation of tsunami wave arrivals. To this is added, data from 17 seismometers of the IMD and the 10 stations of the Wadia Institute of Himalayan Geology along with data from a network of 300 monitoring stations in the international network.

The Indian Ocean Forecasting System or INDOFOS is capable of predicting the surface and subsurface attributes of the Indian Ocean. The forecast is passed on to various stakeholders through a network of village information centers AIR, FM radio, digital bulletin boards as well as NGO websites. The language TV network is also used for broadcasting important information to the public.

CONCLUSIONS

The disasters and human civilization are two unequal sides of the same coin- smaller of the two represents disasters. The annual human toll of disasters of all categories is huge and keeps rising. A UN agency estimates that India is the country occupying the third slot from the top in respect of lives lost due to disaster strikes. As world marches ahead, the loss of lives due to disasters keep going up.

One of the solutions for disaster risk reduction is the readiness or preparedness of societies and communities or indirectly of the nations in facing up the challenges with adaptation of modern technologies such as IOT and Geospatial mapping.

Sensors and actuators streaming data from the elements or components of the physical and made systems and linked to computers, software, artificial intelligence based algorithms to generate possible actionable solutions, are the backbone of IOT.

The sensing of changes taking place in lower atmosphere, pedosphere, hydrological systems, and linking the reported data to geospatial data bases and maps shall be the gold standard for the future DM strategies.

Such DM strategies shall be the future action plan in preparedness preparations and risk analysis in stead of rescue and rehabilitation is obviously at a huge human and national cost. The INCOIS is an example of an IOT application in Disaster Mangement.

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Latest Development in Technologies for Meteorology and Climatology

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INTRODUCTION

Ministry of Earth Sciences (MoES) is mandated to provide the nation with the best possible services in forecasting the monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems, for the Public Safety and socio-economic benefits. The Ministry also deals with science and technology for exploration and exploitation of ocean resources (living and non-living), and play nodal role for Antarctic/Arctic/Himalayas and Southern Ocean research. India Meteorological Department (IMD) is the national agency for Meteorology and Hydrology services. MoES is launched two Mobile Apps (i) 'India Quake' for dissemination of earthquake parameters and (ii) 'Sagar Vani' to disseminate ocean information and alerts to the user community in timely manner.

The introduction of NWP in IMD operational forecasting has been a major shift in practice, which has enhanced forecast capabilities across different time scales ranging from a few hours to a month. Extensive use of web-based dissemination has evoked tremendous public response and has proved to be very effective. Priority has been given to supply the required information to the targeted user and to streamline connectivity with disaster management authorities.

IMD is carrying out 24x7 weather surveillance including DWR and latest satellite products and employing dedicated telecom systems in a fail-safe mode for issuing warnings of hazardous weather. Drishti and DCWIS are the latest technologies used for Aviation services for IMD. AWS and ARG are added and maintained along with the Manual IMD observatory networks, which helped in augmenting digital met data for decision supporting systems. Specialized Meteorological information to various sectors as per the requirement and need is also being issued. Weather capsules for Doordarshan and other TV channels are being prepared and disseminated as per the adapted operational procedures and protocols. IMD Thiruvananthapuram is in collaboration with Kerala state government has generated an app mKeralam for dissemination of weather information and warning/alerts to the registered/user community, will be launched shortly.

1.1 General Forecasting Services:

Due to its unique geo-climatic conditions the Indian subcontinent experiences a variety of weather systems with two monsoons and cyclone seasons. It is also exposed to a number of natural hazards like floods, droughts, heat waves, cold waves, thunderstorms, cloud burst, landslides, avalanches, cyclones etc. The challenges lie in improving forecast skill in face of such extreme variability so as to prevent/ minimize loss of life and damages to property. The number of user agencies and diversified demands from various sectors of economy on rendering weather based services are continuously increasing. Besides the traditional users, such as disaster managers; air traffic services and maritime transportation operators, other sectors like energy, agriculture, environment, tourism or leisure sports, require reliable and most representative information on current and future weather. In addition, the forecasters have to cope with ever increasing data volume, notably emanating from NWP models; meteorological satellites and radars, etc. They have also to process them faster while supplying more customized information in a quantitative manner

1.2 Agro-Meteorological Advisory Services (AAS):

Based on the weekly forecast of weather comprising maximum and minimum temperature, rainfall, cloud cover and surface humidity, advisories for farmers have been developed in association with State Agricultural Universities and ICARs Krishi Vignan Kendras (KVKs). These services are available in 539 districts of the country currently. Through this service, farmers receive crop-specific advisories with regard to the time of sowing of weather-sensitive high yield variety of seeds, need-based application of fertilizer, pesticides, insecticides, efficient irrigation and harvest. The services are made available through web, radio, TV, newspaper, and mobile. Currently over 25.0 lakhs farmers have subscribed for receiving this information through mobile in vernacular languages.

1.3 Aviation services:

The needs of aviation services are catered through a network of four Meteorological Watch Offices (MWO) functioning at the four major international airports at Chennai, Kolkata, Mumbai and New Delhi, 18 Aerodrome Meteorological Offices (AMO) (inclusive of the four MWOs) and 51 Aeronautical Meteorological Stations (AMS). The responsibility of the four MWOs is to maintain a continuous watch of meteorological conditions over their respective Flight Information Regions (FIR) and prepare SIGMETs (Significant Meteorological Charts) for hazardous en-route weather phenomena, such as, thunderstorms, tropical cyclones, turbulence, volcanic ash, etc., which may affect the safety of aircraft operations. AMOs maintains watch over their aerodromes; prepare forecasts, warnings, current weather observations and other relevant information for flights operating from their aerodromes and their associated aeronautical meteorological stations. AMSs mainly supply current weather observations. Their forecasting needs are met by the associated AMO. Monitoring system of the weather and visibility conditions within the airport area (especially visibility over runways) has been taken up through the commissioning of state-of-the-art Automatic Weather Observation Systems (AWOSs) with a continuous monitoring

of Runway Visibility Range (RVR). The real time RVR conditions, measured at Delhi airport, are uploaded to the IMDs web portal in Delhi during the winter months along with the crucial fog forecast products. The accuracy of fog forecasting was 94% and 86% for December and January months during 2009-10, respectively. A frame work of dynamical-statistical models for forecasting the changing visibility conditions for the airports of north India has been firmed up.

1.4 Hydrological service:

Based on real time daily rainfall data, weekly district-wise, sub-division wise and state wise/season wise rainfall distribution summaries are prepared in the form of rainfall tables and maps. District-wise and subdivision-wise rainfall statistics provide important information useful to the agricultural scientists, planners and decision makers. The inputs on rainfall to the Central Water Commission (CWC) through ten Flood Meteorological Offices (FMOs) established in different parts of India for operation Flood Forecasting. Flood, QPF (Quantitative Precipitation Forecast) were issued by FMOs and supplied to the Central Water Commission for flood forecasting purposes. A MOS technique is being developed for QPF in a pilot mode on the Mahanadi basin. Design storm studies were conducted to evaluate intense storm estimates (rainfall magnitude and time distribution) for various river catchments/ projects in the country, for use as main input for design engineers in finalising design flood for hydraulic structures, irrigation projects, dams, etc. on various rivers.

1.5 Environmental Service:

The network for Air Pollution Monitoring stations have been set up at Allahabad, Jodhpur, Kodaikanal, Minicoy, Mohanbari, Nagpur, Port Blair, Pune, Srinagar and Visakhapatnam to collect rain samples for chemical analyses and measurement of atmospheric turbidity with the objective of documenting the long-term changes in composition of trace gases of the atmosphere. These observations provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve understanding of atmospheric chemistry. Specific services pertaining to environment are rendered to the Ministry of Environment and Forests and other Government agencies in the assessment of likely air pollution impacts arising from thermal power generation, industries and mining activities. Atmospheric diffusion models developed for carrying out air quality impacts of multiple sources located in different climatic and geographical conditions are being utilized for setting up of industries, environmental impact assessment and adoption of air pollution control strategies.

1.6 Metropolitan Weather and Air Quality Forecast System:

Site-specific weather and air-quality forecast system, was put in place in a record time with indigenous capability for the National Capital Region during CWG 2010. 35 Automatic weather stations (11 of which were equipped with air quality measurements) were installed in the NCR of Delhi including those at the Games venues. Hourly updates to different air quality and weather parameters at the venues and other locations were provided to the organizers. A set of NWP models from global to very high-resolution sub-regional models was used for the forecasts. An

uniquely designed nowcast system were made operational for the first time in India for providing the site specific forecasts for next three hours. Considering the success of the project, the facility would be extended to other Metro cities of India.

1.7 Data Services:

Observational data of past and present are provided to researchers, Government agencies and private parties on demand in accordance with a stated policy. Real-time data, which is of vital importance to aviation and transport sector, is made available through dedicated channels and web-based systems. The data is also shared freely with the international weather services through WMO. During this plan period the electronic dissemination modes have been utilized more predominantly with experiments being done with utilizing mobile SMS services.

2. ATMOSPHERIC OBSERVATIONAL NETWORKS

Details of the augmentation of atmospheric observation network under Modernization of IMD Phase-I are shown in Table-1. DWRs have been commissioned, each at Hyderabad, New Delhi, Nagpur, Patna and Mumbai etc.., and the products are regularly available to the users on Web. The Delhi DWR has also been demonstratively used for building now-casting system in support of the Common Wealth Games (CWG 10) through generating site specific weather forecasts on hourly scale. The GPS sonde has improved the quality of upper air observations over India. At the same time, a new variant of indigenously developed upper air sounding system based on GPS has been successfully tested by IMD. Action is underway to produce the same for operational induction in a limited scale facilitating for robust performance evaluation.

Table 1
Augmentation of atmospheric observation network under Modernization of IMD Phase-I

Sensor	Target	Up to July 2011	Existing prior to modernization	Total	Data receipt
AWS	550	411	125	522	503
ARG	1350	364	-	364	314
GPS-S	10	10	1	11	11
DWR	13	2	5	7	7
Pilot Balloon	70	65	-	-	65

2.1 Status of Atmospheric Observation Network

An instrumented air-craft was chartered during monsoon period to conduct cloud aerosol-interaction experiment during 2009-11. A Web-interfaced National Satellite Data Centre was established for archiving all satellite data available till date and serving near real time value added products. The new satellite INSAT 3D is to be launched in the near future. The ground segment required to process its data has already been established and is being currently tested for the existing Indian satellites, Kalpana-1/INSAT-3A. The new system will substantially augment Indian capability to foreshadow high impact weather occurrences.

Satellite product broadcast services were upgraded with Digital Meteorological Data Dissemination (DMDD) systems being installed at 37 locations in India and neighbouring SAARC countries of Nepal, Male and Sri Lanka. 353 coastal Digital Cyclone Warning Disssemination Stations (DCWDS) continued to operate with the support of fail-safe satellite communication. Its migration to DTH mode has already been prototyped for deployment.

A significant development was a bilateral agreement between EUMETSAT and IMD to receive data of all European satellites. Other areas of development during this period included Integrated Precipitable Water Vapour using GPS satellites data and installation of data receiving systems from NOAA/MODIS/Metop polar orbiting satellites.

The climate particularly temperature and precipitation are responsible for the biotic pattern. vegetation has often been employed as basis for climatic classification. The pattern of plant changes progressively from low land to the high ranges in conformity with climatic regime terrain and soil type. The low flat land are fertile farmlands mainly of rice, bananas and coconut plantations, while the middle land have plantations of rubber, pepper, cashews, jack and mango trees. Papaya, tapioca and pineapple are also grown here. While the high land having verdant slopes have plantations of cardamom, pepper, coffee and tea.

3. ATMOSPHERIC MODELING & RESEARCH

3.1 Data Integration and Computing Facilities:

A complete end-to-end forecasting system that includes acquisition of data from various observing systems, linkage to a central data processing system, their utilization in the numerical models, providing a state-of-the-art IT based environment to all forecasters across the country has been installed. This involves integration of all observations and overlaying them on model outputs and synoptic charts along with proper visualization and customized dissemination of weather forecast to the end users.

During the first phase of the modernization of IMD, along with the commissioning of state-of-the-art observing systems, application module “SYNERGIEe” has been installed at 34 forecasting offices all over India. These have the capability to visualize multiple layers of observation and forecast overlayed on each other, thus providing to the forecaster the capability to assimilate terabytes of information before issuing weather forecast. A Public Weather Service System(PWS) ‘METEOFACTORY ’ enables the forecaster to generate required customized presentation for the automatic delivery of products to the visual and print media viz. newspaper, TV, farmers, shipping, etc. The Central Information Processing System (CIPS) with a super-computer at the back-end has given a paradigm shift from Observation Network Management towards integrated information processing systems providing fully customized services to the user community. It is equipped with state-of-the-art hardware and software to handle, manage, store, process and archive all data and forecast products used in operational weather forecasting. It consists of seven sub-systems comprising data

acquisition, data policy management, data centre, tpolicy management, task centre, backup policy management . The CIPS Data Centre provides flexibility to ingest any kind of meteorological data like satellite, radar, etc. with regard to the assessment of current weather and prognosis for the future.

A set of four High Performance Computing systems (HPCS), one each at INCOIS, IITM, IMD, and NCMRWF have been installed for global data processing, assimilation and numerical weather prediction (NWP) for weather and ocean state forecasting services. The combined strength of HPCS in ESSO is about 125 TeraFlops, which has significantly improved coupled atmospheric–ocean modelling capability. High End Servers at 10 centres namely, RMC Delhi, Kolkata, Chennai, Mumbai, MC Chandigarh, Ahmedabad, Nagpur, Bhubaneswar, Bangalore and Hyderabad were commissioned.

3.2 Weather Modeling Framework:

With the commissioning of HPCs, Global Forecast System (GFS T382/L64) having spatial resolution of 35 km was made operational at IMD, incorporating Grid Point Statistical Interpolation (GSI) scheme for global data assimilation for the generation of global scale forecasts up to 7 days in advance. At NCMRWF, continuous efforts are on to enhance the accuracy and reliability of the forecasts by increasing resolution, improving physical processes, data assimilation, optimizing use of satellite and DWR data , coupling land, ocean and atmosphere, ensemble forecasting along with extensive verification and validation. The horizontal resolution of the Global Forecast System (GFS) was increased from T254L64 (50km) to T382L64 (~35km) along with assimilation of direct satellite radiances which was subsequently made operational at IMD. Experimental runs with higher resolution (T574L64(22km) GFS and unified model (N512L70(25Km) with 4D VAR assimilation) models are underway. It is planned to make the high resolution system operational after extensive evaluation and verification studies.

Meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km, 9 km and 3 km horizontal resolutions for the forecast up to 3 days in advance using initial and boundary conditions from the GFS T382/L64 system. At regional centres as mentioned above, very-high-resolution mesoscale models (WRF at 3 km resolution) are made operational to generate high resolution regional scale forecasts. Typical customization of NWP-based forecast products is carried out in support improving cyclone warning service. Doppler weather and mesoscale WRF-model-based Nowcast system was exclusively for the national Capital of Delhi to generate site specific hourly scale weather forecasts. Global model assimilation utilizing 4D VAR is being done on experimental basis for WRF model for generating regional scale data assimilation.

In an effort o take care of the uncertainties in the initial conditions, model dynamics and model physics, Multi Model Ensemble (MME) forecasting project for providing rainfall forecasts during the monsoon season has been developed. Rainfall forecast data from 4 global models of India and outside India, i.e. NCMRWF, NCEP,USA, UKMO,UK and JMA, Japan for the summer monsoon period were used to train the

MME algorithm coefficients. MME forecasts of rainfall in short and medium range were made available for operational real time use for the Indian region. District Level Quantitative five-days weather forecasts based on MME system are being generated in support of rendering district scale Agro-Meteorological Advisory Service (AAS) of India during the current five year plan.

Polar WRF is implemented to provide day-to-day short range (48 hours) weather forecast for the Maitri region in the Antarctica. All these NWP products are routinely made available on the IMD web site (www.imd.gov.in) in support of Antarctic Expedition. NCMRWF was regularly providing NWP guidance from its global and regional analysis and forecast products in support of first ever South Pole Expedition.

A new state-of-the-art Climate Forecast System (CFS) based on coupled ocean-land-atmosphere model, was setup at IITM and numerous sensitivity experiments were carried out to test the model skill in predicting the Indian Summer monsoon rainfall on seasonal time Further, the model horizontal resolution is increased from T62 (~ 200km) to T126 (~ 110 km) that resulted in better reproduction of spatial distribution of monsoon rainfall over India. This effort led to the utilization of coupled model framework to provide experimental forecast assessment of the Indian Summer monsoon seasonal mean rainfall and its distribution since March 2010. Similarly, prediction of active/break spells of the Indian summer monsoon is implemented in IMD through collaboration with IITM

The Numerical Weather Prediction (NWP) products from mesoscale model WRF were supplied to BARC at 9km resolution for the four nuclear sites namely Trombay, Kalpakkam, Kaiga and Narorafor their Indian Real time Online Decision Support System for Offsite Nuclear Emergency (IRODOS).

4. MODERNISATION OF IMD (PHASE-II)

4.1 Proposed Modernization of atmospheric observation network in IMD Phase-II

The Cabinet Committee on Economic Affairs had approved the program on `Modernization of Observation & Forecast of India Meteorological Department (IMD) to be implemented in a phased manner. The Phase-I of the program got implemented during the XI plan. This resulted in commissioning of state of art observing systems throughout the country with their networking and integration, utilizing them in high resolution numerical models in high performance computing facility, their visualization, archival and dissemination to the user community in a skilful manner. The second phase of the modernization is aimed towards augmentation and enhancement of various observation systems as per requirement over different parts of the country. The first phase has established a fully integrated system and the second phase will enhance the existing system with optimal augmentation of observing systems. Augmentation of Observing Systems and Forecast Facilities of the India Meteorological Department (IMD)

The modernization phase II shall enhance the coverage and density of observations for the entire country with a centrally connected digital observational data acquisition, processing and visualization systems. It will render the full benefit of

the modernization in terms of automation and improved quality of service. In order to achieve the envisaged objectives, the following facilities/observing systems are required to be commissioned. The framework of the observing systems is originally recommended by the Sikka Committee constituted by the MoES. The observing systems proposed for modernization phase-II are on the basis of Sikka Committee recommendations (Table 2).

Table 2
Proposed Modernization of atmospheric observation network in IMD Phase-II

S.N.	Item	Number Ph-II
1	Synoptic AWS	400
2	ARG	2000
3	Upper Air	14
4	Wind Profiler	52
5	Doppler Weather Radar	34
6	Public weather systems	5
7	Forecasting System	100
8	Information Processing System (Mirror for DRC at Pune)	1

4.2. Atmospheric Observation Systems

Atmospheric observation system forms the backbone of any meteorological service. Reliable and accurate measurement of upper air and surface Meteorological data is a basic requirement for defining current weather, weather forecasting, NWP and disaster management. Radiosonde provides the vertical profile of temperature and humidity at a place and this data is used for calibrating the satellite observations as well. High resolution data from improved radiosonde, wind profilers, wind Lidars as well as measurements from aircraft through dropsondes lead to improved initial conditions of vertical profiles which in turn improve the forecast. The high quality upper air data and its sustenance is thus essential for improved performance not only at National level but at the International level as well since it provides input for global model. The long series of archived observational data also forms an integral part of the climate studies. The radiation measurements are undertaken to get the atmospheric radiation profile. This data along with ozone measurement data collected from all the stations are used for environmental monitoring and in the air pollution studies. Radars have an essential role in detection of storms and for detection and tracking of cyclones. Radar observations and lightning detection systems are used for Aviation services and also used for Now-casting (up to 6 hours in advance) of severe weather systems. Radar data is also used for undertaking research on the understanding of the dynamics and micro physics of convective weather phenomena which are crucial for tropical region like India. Similarly the data from automatic weather systems as well as Automatic rain gauges distributed

over the country provide information over various regions capturing the variability of surface parameters over different locations including remote areas.

The measurement of various atmospheric parameters through surface, upper air, aircraft and satellite-based platforms is a prime requirement for weather forecasting. The current observations need to be continued. The augmentation of observation system through Doppler Weather Radars (DWRs), AWSs, ARGs is also proposed. In addition, in order to understand specific atmospheric processes, there is a need to continuously undertake observations pertaining to cloud microphysics, radiation budget, aerosol physics etc that are required to be established, sustained and augmented. Observations/field campaigns related to air-sea interaction would support the objectives of monsoon mission. The main objectives are

- Sustenance of observational etworks covering DWRs, ARGs & AWSs, Upper air, surface and environmental observatories etc on 24x7 basis.
- Provision of adequate communication system for data and product transmission.
- Maintenance of operational forecast system, delivery system for forecast and other services. Conduct of special campaigns for improving Cyclone, Thunderstorm and Fog forecasting, etc.
- Planning of new observations and augmentation of existing observation system.
- Planning and sustenance of specific process related observing systems over India

4.3. Satellite meteorology (including aircraft-based) (Continuing):

Weather forecast is an initial value problem indicating the need for accurate initial condition that is achieved through data assimilation. As conventional data coverage is spatially and temporally limited, satellite data provides much better coverage in both space and time. About 90% of the data that goes into the assimilation of any analysis-forecast system comprise of data from satellite and rest from in situ platforms. Satellite Meteorological services involve receiving satellite data from Indian and International satellites, its processing for generation of images in all channels, derivation of operational products their archival and their real time utilization for weather forecasting. The various products include cloud top temperature, vertical profiles of temperature, humidity, fog, sea surface temperature, atmospheric motion vectors, outgoing long-wave radiation, total precipitable water etc.The main objectives are

- To acquire, process satellite data and generate products for operational needs as per the needs from time to time.
- To establish a dedicated dissemination system of satellite data and products using INSAT transponders.
- To set up a countrywide network of GPS Stations for measurement of integrated precipitable water vapour for use in nowcasting and NWP models.
- To augment and enhance Satellite Data Centre

4. 4. Numerical Modeling of Weather & Climate

The objective of this programme is to improve the accuracy, reliability and range of weather forecasts. through (i) better understanding of atmospheric processes and

their representation in numerical model, (ii) assimilation of data from all available platforms including satellites/radars and (iii) use of ensemble and multi-model ensemble techniques.These can be implemented by adopting the following points.

- Increase temporal range and spatial resolution of the Global Forecast System: This will be achieved by developing and improving data assimilation techniques (especially 4D VAR and Ensemble Data Assimilation) to make use of data from Indian Observation Systems (both land and space based), particularly high resolution data from the DWR and AWS, and improving physical parameterization schemes with particular reference to cloud resolving schemes and radiation processes with respect to aerosols.
- Observation System Experiments (OSE) / Observation Simulation System Experiments: The experiments will be carried out for evaluation of an existing observing system, and to design new observing systems which would have an impact on model forecast. These activities are required to optimize the deployment of observation systems (land based and space based) and maximize the information extracted from the observations.
- Implementation of a dynamical Global Ensemble Forecasting system:The short and medium range weather forecasts are very sensitive to the initial state of atmosphere from which the models begin their computations. Hence, many of the leading international centres use an ensemble prediction system which either use perturbed initial conditions and/or have a stochastic physics in the model for short and medium range weather prediction. Currently, in India ensemble prediction system is not being used operationally. Hence it is essential to start work on implementing ensemble prediction system. A state-of-the art global ensemble prediction system that is most suited for short and medium range weather prediction over Indian region.
- Produce a regional reanalysis dataset for understanding the climate variability and climate change over South Asia:This will generate refined description of the regional hydroclimate state (from 1979 till date) through assimilation of conventional observations as well as radiance and precipitation observations in numerical weather prediction model finally at 15km horizontal resolution.
- To implement a Coupled Ocean Atmosphere system and test its utility for week-2 forecasts.
- Implement an ocean data assimilation system to provide input to the ocean model component.
- Real-time seasonal prediction for monsoon.
- Development of calibrated probabilistic high-resolution seasonal prediction system.
- Real-time medium range MME prediction for monsoon.
- Development and improvement of methods for location specific forecasts including dynamical and statistical approaches.
- Development and testing of new and novel applications like dust forecasting system, global transport of radioactive materials in the atmosphere etc.

- Daily Rainfall Analysis for Merged Satellite Gauge Gridded Product: To prepare daily gridded merged gauge-satellite rainfall data for Indian region.
- Improved prediction of severe weather systems: Assimilation of DWR data for improved forecasting of local storms and rainfall.

Acknowledgements

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Impact of Technological Innovations in Providing Affordable Healthcare

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Back ground

The health sector in India has undergone tremendous change in the last decade in tune with the developments globally. The economic and social status of the community has improved. There is more thrust towards comprehensive patient care. The health awareness of the people has also improved due to various factors including media, journals, magazines,internet etc. The diagnostic and therapeutic tools have developed in a big way. There are lot of technological innovations in the health care which led to most of these developments.

At the very same time, consequent to the increase in use of technology in health care, there is increase in healthcare cost. An attempt is made to highlight the impact of technological innovations in providing affordable healthcare.

Definitions

A "*health technology*" is any intervention that may be used to promote health, to prevent, diagnose or treat disease or for rehabilitation or long-term care. It thus encompasses medical devices ranging from simple wooden tongue depressors and assistive devices, to the most sophisticated implants, medical imaging systems, drugs, medical and surgical procedures, and the organizational and supportive systems within which such care is provided.

"*Innovation*" encompasses the entire process from the generation of new ideas to the transformation of those ideas into useful things(health services, products, methods, management practices and policies) to their implementation.

Information Technology

The computerization has developed at a rapid pace in all walks of life and health is not an exception. The digitization of the healthcare and the information systems has gone a long way in the profession of healthcare. Picture archiving and communication system (PACS) is a great innovation by which all the images can be viewed by the doctor soon after the imaging and is accessible from any computer in the network. This facility has saved the time and money with regard to the imaging

facilities. The procurement of x-ray films and development of films has dramatically reduced. It is convenient and resolution of the image is better. The doctor is able to view the image, zoom the image, rotate the image and also combine various images from different equipments and arrive at a diagnosis. Similarly, there are radiology information systems (RIS) for the various processes involved in the patient care like request generation, scheduling appointments, reporting, etc.. The lab information system (LIS) is utilized for request generation, reporting, quality systems and preventive maintenance of laboratory services. Electronic medical records (EMR) are the digitized version of medical records which has led to the paperless systems of medical records. The details of the patients are entered into the computer and the investigations and imaging results are integrated to provide for hospital information system (HIS). The prescriptions of doctor are E prescriptions. HIS has also incorporated the procurement, billing, inventory management, etc in hospitals. The archiving of the data is possible and utilization of the space for storage of records is bare minimum. HIS has also combined the clinical decision support systems and the treatment patterns have improved.

"Telemedicine" is another major innovation, which has transformed the healthcare. Telemedicine is "the delivery of healthcare services, where, distance is a critical factor by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of diseases and injuries; research and evaluation and for the continuing education of healthcare providers, all in the interest of advancing the health of individual and their communities". Telemedicine maximizes utilization of limited resources, saves travel time and money and the patient can access resources in a tertiary referral centre without constraints of distance. Instead of the conventional consultation, where the patient meets the doctor in hospital consultation rooms, the consultation is done with the help of video conferencing and the doctor and patient are geographically separate. Satellites, broadband, wireless technologies are all used for the transmission of the data and audio and video signals. Telemedicine incorporates Tele- radiology, where the images of the CT/MRI scan, X-ray can be transmitted live to the experts in specialist hospitals and obtain their advice. In Tele-ophthalmology, the images of the eye can be transmitted to the ophthalmologist in the specialist hospital from any remote location. In Tele-pathology, the histopathology slides examinations can be conducted by a pathologist in a specialist hospital by transmitting the images from a peripheral hospital. In Tele-cardiology, digital ECG and audio signals of the stethoscope can be transmitted to the cardiologist and the patients can also be monitored through the system. There are also modules for Tele Neurology,Tele Dermatology etc.The mobile technology has also been utilized for telemedicine purposes.

Bio Medical Equipments

Laboratory Services

With regard to the laboratory services, the transportation of specimens to the laboratory from the various areas of the hospital can be done through the vacuum (chute) systems replacing the manpower deployed for transportation of specimens.

The equipments in the laboratories have also undergone a transition to auto analysers instead of the mixing of blood with reagents and heating in test tubes. The auto analysers are able to provide the results within a short span of time. There is saving of manpower, time, material, and money. And the results are standardized.

Medical Imaging

Conventionally X Rays used to be the imaging device in health care. The Computerised Tomography (CT) scanning had transformed the imaging systems and later Magnetic Resonance Imaging (MRI) was added. SPECT scanning and PET scans are recent additions to the imaging devices. PACS and RIS has provided for integrations of the digital images in DICOM format. Catheterization laboratories, DSA,C Arm etc are also utilized for imaging and procedures in hospitals.

Interventional Procedures

Instead of open surgeries for various ailments, endoscopies and interventions using imaging has dramatically reduced mortality, morbidity and length of stay in hospitals.

Medical robotics

It is an illustration of a key technology with far-reaching contributions to vastly improved clinical care. There are six products and systems in medical robotics that are predicted to experience rapid development in the near future. First, smart medical capsules are used largely as diagnostics of tumours and their internal abnormalities. Second, intelligent prosthetics with smart functionalities that rely on information technologies will replace the current prosthetics. Third, robotized patient monitoring systems will be used in both hospitals and home care. Other technologies are robotized motor coordination analysis and therapy and robot-assisted mental and cognitive therapy targeted at elderly patients. The last technology, perhaps the most promising, is robotized surgery.

Medical Device development

It is noted that majority of the devices are imported which in turn led to increasing health care costs. “Make in India” is an initiative of the Govt of India. There should be encouragement for the development of medical devices within India. One classic example is the development of indigenous heart valve “ttk chitra heart valve” by Sree Chitra Tirunal Institute of Medical Sciences and Technology,(SCTIMST)Trivandrum. This valve developed by SCTIMST is priced at Rs 25000/-(Approx), when a substitute imported heart valve is priced above Rs 60,000/-.There are many other devices and implants developed by SCTIMST like blood bags, oxygenators etc and vein viewer are the latest edition.

It is worthwhile here to mention about another significant achievement of SCTIMST in developing a homograft valve bank programme in collaboration with Medical College, Trivandrum. In this programme, the heart valves from the cadavers are harvested by the cardiac surgeons of SCTIMST after obtaining consent from relatives. These valves are tested, processed and stored in the valve bank and implanted in children with congenital heart diseases. Till date 92 surgeries have been done with these valves which are a great step towards cost effective in house health technology.

While the device development is discussed, start-up mission activities which promotes young entrepreneurs to develop technologies with the help of institutions which have the capabilities to provide infrastructure and technical assistance need a mention. SCTIMST has a start-up venture which is involved with helping interested players in development of innovative technologies. Development of Anti snake venom is one of the projects which has started recently.

Green Technology

Green energy initiatives are commonly utilized by all institutions particularly hospitals. Uses of solar energy for lighting, heating are innovative affordable technologies which will benefit financially in the long run. Installation of Biogas plant, rain water harvesting and recycling of water are also useful technologies which are economically viable.

3D printing

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file.The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic with for instance a milling machine.3D printing enables us to produce complex (functional) shapes using less material than traditional manufacturing methods.

The technology of 3D bioprinting is utilized in research in health sector for manufacturing organs like ovary,kidney,skin etc.

Recombinant drugs,Depot preparations

The drug manufacturing sector also has innovative technologies like recombinant drugs. Depot preparations provide longer duration of action like delivery of insulin, hormones etc

Geospatial Technology for Sustainable Development and Governance

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INTRODUCTION

Sustainable and informed economic planning and decision making requires comprehensive and integrated data and information. About 80% (ISO Bulletin 2001) of the data and information used in planning and decision making relates to Geography, typically involving locations or positional data. Geo-spatial data or Geo-Information presented in the form of maps facilitate easy understanding.

Sustainable development is achieving human development needs and goals on the one hand and on the other hand protecting the natural systems and sustaining the ecosystem to provide the natural resources and ecosystem services upon which the economy and society depend. Coping up with the developmental needs to meet human needs without disrupting the integrity and stability of the natural systems and to sustain for the future generation is the desired result.

With the propagation of information technology, the geospatial regime is carving into the niche previously held by tabular data. Page after page of unending, insanely huge volumes of information moulded as insipid tables is now giving way to location specifying data in, often neat, graphical or real world representations. An abundant in detail and collaterally sophisticated map can be readily replaced for the benevolence of a user friendly interface. Pages of gibberish details on assets had given way for the easiness of a web portal which equips the user to skip through large numbers with nonchalance. The all seeing god-eyes of satellites are encapsulating the world into the familiarity of personal space. The ability to visualize and appreciate data in a spatial dimension is giving a new perspective to the schemes of things. It is becoming a world changer in its own right.

Geospatial technology is mainly categorized as Global Positioning System (GPS) technology, Geographical Information System (GIS) and Remote Sensing. The former is a navigation technology which can help guide the user, with varied levels of accuracy ranging from some meters to mere millimeters. GIS can collect, analyze, manipulate and manifest any geographical data. An old school survey map is a geographical information system. So is a highly sophisticated ground water flow model which uses high end mathematical equations in its background to depict

a real world 3D representation of the flow of water through soil spaces. The only difference between the two is that the former is for the studious, while the latter besides being an

Advanced mathematical tool is a canvas for the imagination of a layman. It is exactly this latter aspect that makes geospatial technologies a tailor made apparel for governance. It gives simplified representations of complex scenarios, in a spatial environment. Take for instance the vivid details of a satellite image. It would give every cluster of built up, the tranquility of water bodies, the wilderness of forest areas, the barrenness of arid lands, the structure of the city‘s transportation grid, everything from above.

This simplified representation of sophisticated mechanisms has enormous potential in sustainable planning. For instance, a simple Digital Elevation Model (DEM) can give the 3D representation of the real world. This can help in the planning of complex scenarios like canal alignment. This DEM induced 3D model can help the planning official to visualize the terrain, note for the change in elevation, plan a route and identify points of constraints. This oversight into the future itself is the prerequisite for sustainable development and that is exactly what a geospatial environment can provide.

In an era were governance is largely dependent on the digital space, such an ‘eye to the future’ can only be a norm. We can visualize the changing land use patterns of a city over the years and predict the urban space and its pattern of evolution years hence. A detailed study on all aspects of a watershed ranging from its morphometry to its geological and geomorphological characteristics, planning for its rejuvenation by assessing the runoff and infiltration characteristics, a total hydrological inventory consisting of surface and sub surface flow etc. can be easily simulated using a geospatial software package. Major transportation scenarios can be simulated using digitized road and rail networks and its routing be computed for various possibilities. Site suitability analyses could point out locations for various vocations.

With the resolution of satellite images on the rise, reaching sub meter levels, more and more details are discernible from them. This gives opportunity to plan on cadastral and further lower levels thus greatly aiding in administrative decision making. Planning on such basic levels could bring local bodies into the act and there understanding and appreciation of geospatial technology can entirely redefine boundaries of governance. For example, consider the benefits of a system where each household of a locality is mapped on a GIS platform and every detail pertaining to them added as corresponding attributes.

The input of geospatial technologies to disaster prediction, monitoring and mitigation is invaluable. GIS’ ability to bring together multiple disciplines and multiple criteria helps in the construction and visualization of complex models that could predict floods, droughts, earthquakes, landslides etc. Satellite image based change detection studies can provide major insights into illegal encroachments, anthropogenic pressures, climate changes etc.

The almost limitless potential of mobile apps and Web GIS is further enhancing the role of geospatial technologies in sustainable governance. The geotagging and

management of government assets is now possible with a touch of the button with little labor. We could even participate the common citizen in a Web GIS based enterprise thus making it a collective effort. Moreover, a GIS platform would suffice to bring together various government departments under one umbrella.

With geospatial technology itself advancing to territories like deep learning, semantic classification and essentially, artificial intelligence, the scope of it is becoming rather vast. We are moving in a direction where spatial technology can hardly be separated from the broader arena of information technology. Rather it is becoming a pre understood part of the larger whole. Thinking spatially is becoming a necessity.

II. GEOSPATIAL APPLICATIONS IN SUSTAINABLE DEVELOPMENT

Applications of geospatial technology is found in all the walks of life and it is very critical in the area of sustainable development and management goals and especially in the area of governance where public gets maximum benefit of informed decisions and transparent government.

A. Asset Mapping

One of the primary utilities of geospatial technologies in governance is the mapping of Government assets. To bring the activities of various department under one platform for better service delivery, it is essentially useful. The advent of mobile and WebGIS has made it possible for creating online portals were in the geotagged assets are readily displayed. The geotagging of assets itself can be facilitated using a mobile map. The methodology used for mapping of assets can be extended for mapping other aspects like diseases, accidents, challenges etc. in the participatory mode. The following figures gives some examples of asset mapping platforms.

Fig. 1
Anganwadies participatory mapping

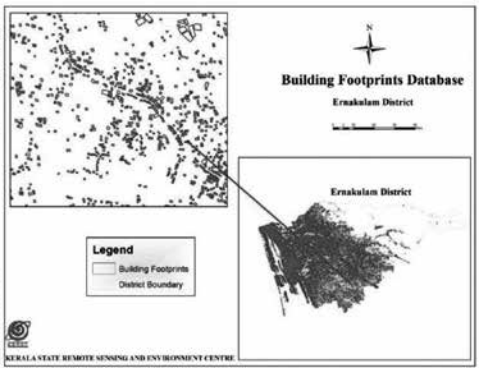

Fig.2.
Building Foot print mapping

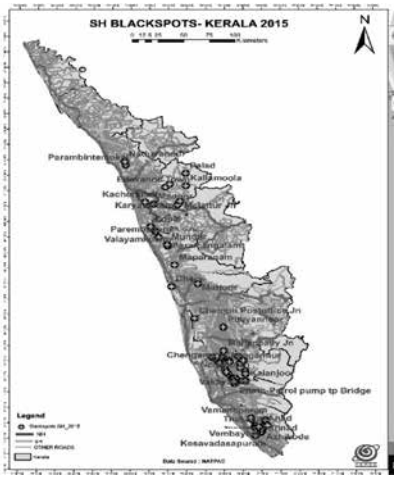

Fig.3
Accident Blackspots

Fig.4
Hospitals Mapping

B. Agriculture

One of the principal area of geospatial application is sustainable agricultural management is the mapping of cropland like paddy or plantations and wetland inventory. One major advantage of Remote Sensing in such studies is the ability for seasonal change detections. This is of immediate importance as no other form of mapping can give such a visual representation of change in environment. With dynamic techniques like animation or platforms like Bhuvan provide a real time visualization of these changes. This potential of satellite based change detection can be used in legal cases like implementing paddy wet land act. The act insists that wetland cannot be filled after the 8th of August, 2008. With the availability of satellite images before and after the dates, the change can be effectively observed and a verdict can be passed based on the expert opinion.

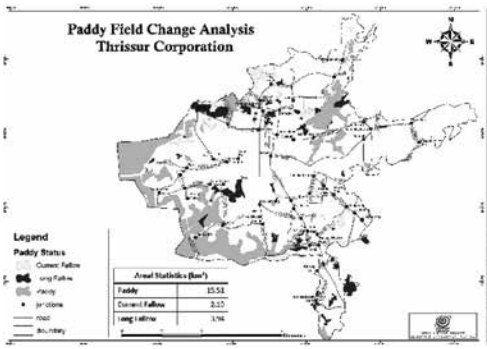

Fig. 5
Paddy Status of Thrissur Corporation

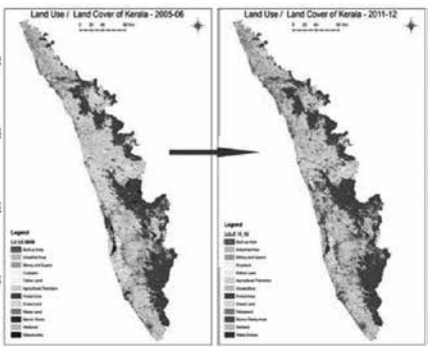

Fig.6
Land Use Change Mapping

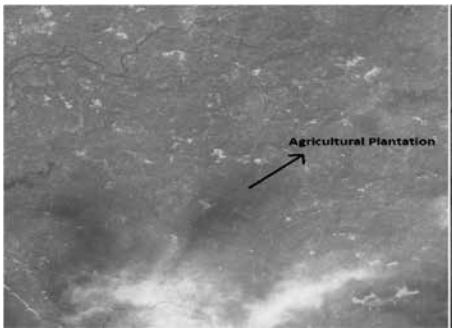

Fig. 7
2011 LISS III image

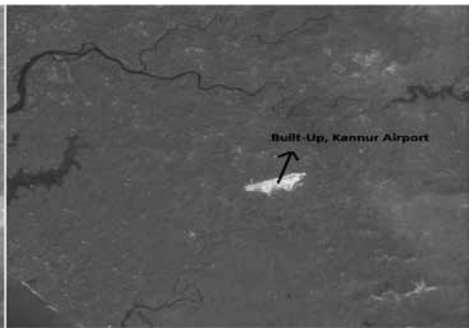

Fig.8
2016 LISS III image

Another developing area in the field of agriculture is Crop Health Monitoring. Low altitude imagery can be used along with an accurate image processing method to identify and monitor crop health. This can be achieved by comparing the variation in spectral signatures in Paddy fields from nursery to late vegetative stage. Based on these, an appropriate algorithm for paddy health monitoring can be initiated based on terrain and climatic conditions. An added advantage in such cases is the ability to overlay cadastral data over the satellite image. This would enable the identification of the particular survey plot were the status of crop which needs attention.

Weather data is an integral part of monitoring and decision making in Agriculture which is an activity highly dependent on weather. There are Geospatial tools which represents the spatial spread and helps to visualize the changes in weather in real time and also helps in disbursing the insurance claims to farmers based on the forecast data in the geospatial platform.

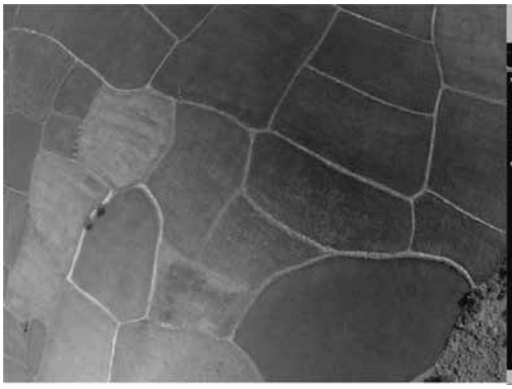

Fig. 9
Low Altitude Drone Image for crop health monitoring

Fig. 10
Weather Forecasting

C. Environmental modelling

Various aspects in the area of environment modelling like impact assessment, pollution assessment, Land Degradation, Groundwater vulnerability, site suitability, watershed management etc. can be carried out with the help of Geospatial techniques. In a scenario of illegal rock quarrying, the spread of quarrying area or the formation of new quarry areas can be readily delineated from satellite images and with the overlaying of cadastral data, the specific survey plot under consideration can be identified.

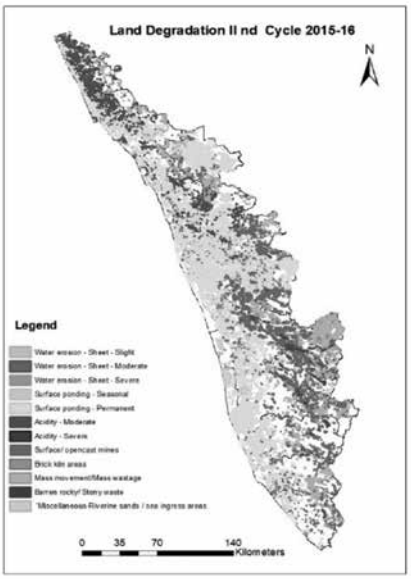

Fig. 10
Land Degradation

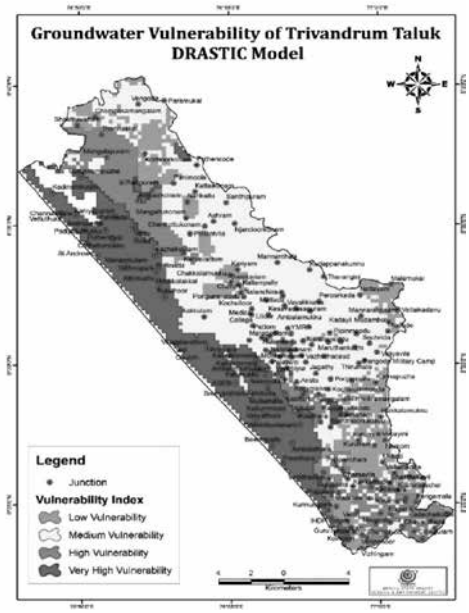

Fig. 11
Groundwater Vulnerability

The potential of Geospatial Technology is found extensively utilized especially in watershed management. A Digital Elevation Model (DEM) can aid in the generation of watershed and compute related models within the watershed like runoff, infiltration etc. Also, the slope, aspect, view sheds and other terrain characteristics could also be generated using a DEM, which are the most critical parameters for environmental related decision making.

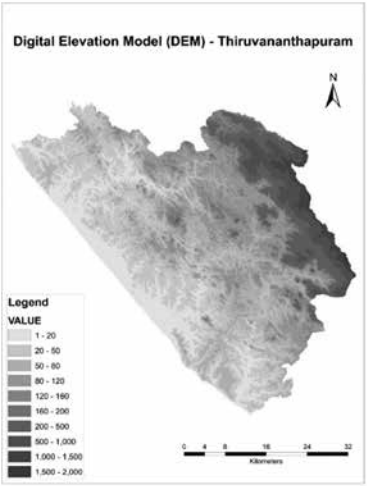

Fig. 12
Digital Elevation Model

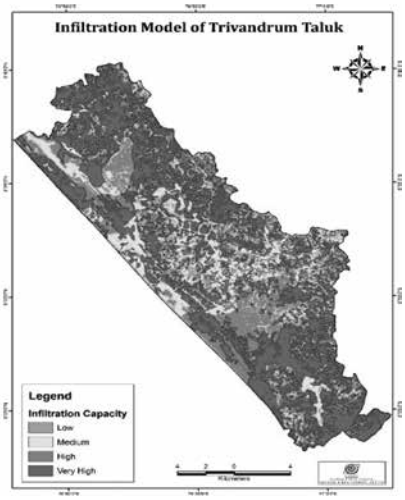

Fig. 13
Infiltration Model

D. Location Based Services

Real-time tracking of moving objects and finding optimum route, shortest route etc. is being implemented by Geospatial Technology for providing Location Based Services (LBS). LBS is the buzz word now in the Geospatial technology where services ae directly offered to individuals based on the location information. Fleet tracking, distress call support by police, ambulance, fire force etc. are done based on the location analytics. Even the online business and targeted advertisements are the offshoots of location based services.

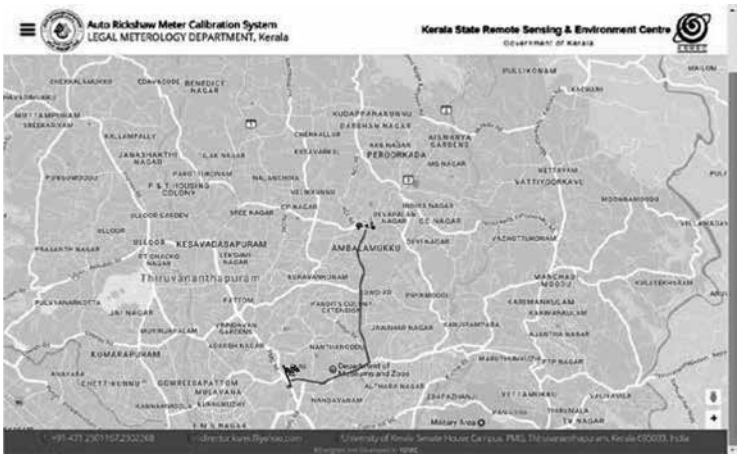

Fig.14
Real-time tracking of auto rickshaws for meter calibration

E. Disaster Management

The high impact utility of Geospatial technologies is the prediction of disasters, disaster proneness and impact sites revisiting, risk zones identification etc. Modeling of hydrological aspects like runoff, infiltration, etc. in a watershed can be done with Geospatial tools, as well as it can be utilized to calculate the flow parameters and estimate the flood routing in a river system. Various multi-criteria indexing methods could be used to generate results for similar disasters like drought, landslides etc.

Fig.15
Flood inundation zones for Vamanapuram river

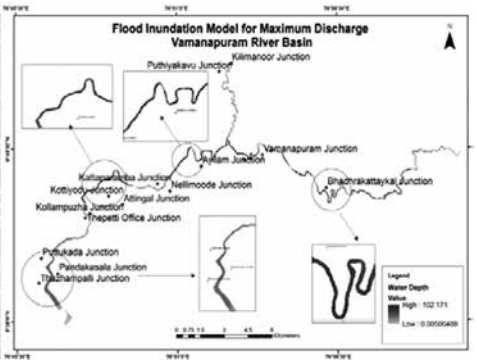

Fig.16
Flood inundation model for Vamanapuram river

F. Emerging Business Opportunities and Partnerships in Geospatial Technology

High resolution satellite images - Spatial, Spectral, Temporal, 3D Mapping, Internet Mapping Services

- Accessibility of high resolution satellite imagery, on-line map services and street maps
- Automation in creating, processing, integrating, analyzing and distributing digital geospatial data / products
- Advancements in data management technologies that are enabling faster transmission of large datasets
- Diversification of application areas of geo-information beyond the traditional areas (e.g Real Time Tracking)
- Development and integration of geospatial and wireless technologies that allow use of maps
- Development of integrated systems such as PDA, GIS/RS software, GPS, cellphone, camera/video
- Advent of open source Geospatial software
- Declining prices of satellite data and free availability
- New e-learning opportunities

G. Challenges of Geospatial Technology internalization in Governance

Activities that can Support the Use of Geospatial Technology in Sustainable development

- Awareness creation among decision makers
- Geospatial capacity building
- Formulation of State Geospatial policies
- Geospatial reference network
- Regional Centre's & institutions involved in the promotion of Geospatial Technology
- Updating and automation of base geospatial datasets
- Geospatial Curriculum

H. Conclusions

Governments at all levels—national, State and local—need data in order to govern. They use geospatial data in a wide variety of areas, including legislative and policy development, the allocation and management of natural resources, defense and public safety purposes, spatial planning and many others. Specialist government agencies around the world have long traditions in the collection of geospatial data. Each agency employs specialists to organize the collection, updating and management of the type of geospatial data for which it is responsible.

The academic study of Geospatial Technology is a cross-disciplinary research domain that draws on concepts and methods from engineering, natural and social sciences. It encompasses the methods, techniques and theories required to (1) generate information about Earth processes from Earth observation (EO) and from data stored in geographic information systems (GIS); and (2) examine the impacts of geospatial technology on individuals, organizations and society, and vice versa.

Geospatial Technology as a field has undergone significant transformation in recent years. In the past, the process of collecting geospatial data was laborious and performed with ground-based methods. The updating cycles often spanned several years, and the outcomes (such as paper maps) could not be easily shared across government agencies. The potential for integration and multiple applications, a key characteristic of geospatial data, could not be exploited.

Recent technological advancements have changed this state of affairs. GIS uses modern software and hardware to store, access, visualize, map, analyze and disseminate geographic data. Geospatial data can now be referenced to a globally defined coordinate system. Global Navigation Satellite Systems (GNSSs) such as the Global Positioning System (GPS) use satellites to allow users to determine their exact location, velocity, and time in any conditions, making traditional positioning instruments such as tapes and theodolites obsolete. The products of these new digital geospatial technologies include digital maps, satellite image maps, topographic maps, and land use change statistics. With GIS, it is easy to combine and share these different geospatial data sets. An integrated analysis of these combined data can provide new insights into the interaction of geographic phenomena for better decision making and governance.

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Applications of Remote Sensing and GIS for Natural Resource Management - An overview

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Land and water have been the basic elements of life support system on our planet since the dawn of civilization. All great civilizations, flourished where these resources were available in plenty and they declined or perished with the depletion of these resources.

In recent years, the land resource has been subjected to a variety of pressures. Still it is surviving and sustaining mankind. What is alarming in the way land is being used is the tendency towards over-exploitation on account of a number of reasons leading this pristine resource being robbed of its resilience. Land management is the process of managing the use and development (in both urban and rural settings) of land resources. Land resources are used for a variety of purposes which may include agriculture, plantation, both surface and ground water resource management, Land use planning, land reclamation, rural development etc. management can have positive or negative effects on the terrestrial ecosystems. Land being over- or misused can degrade and reduce productivity and dissrupt natural equilibriums

Watershed is a geo-hydrological unit which drains at a common point. Management of watershed thus entails the rational utilisation of land and water resources for optimum production but with minimum hazard to natural and human resources. The main objectives of watershed management are to protect the natural resources such as soil, water and vegetation from degradation. In the broader sense, it is an undertaking to maintain the equilibrium between elements of natural ecosystem of vegetation, land or water on the one hand and man's activities on the other hand.

INTRODUCTION

Remote Sensing (RS) is the science and art of acquiring spectral information at different spatial and temporal resolutions about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. A satellite with remote sensors to observe the Earth is called a remote-sensing satellite, or Earth observation satellite. Remote-Sensing Satellites are characterised by their altitude, orbit and sensor on-board.

Since the beginning of the space age, a remarkable progress has been made in utilising remote sensing data to describe, study, monitor and model the earth's

surface. Improvements in sensor technology, especially in the spatial, spectral, and radiometric resolution, have enabled the scientific community to operationalise the methodology.

India has extensive natural resources, minerals, forests and vast areas of grassland, much of which is suitable for development. Optimum utilization of the resources to ensure sustainable development is the need of the time. Here, Remote Sensing with its ability of synoptic viewing can be used as an important tool in the apt management of these resources. Using traditional techniques like ground surveys, field experiments or the establishment of research and observation sites into unpopulated areas would be difficult and economically non-viable. The advent of remote sensing data offers a solution to this observation gap. Therefore, great importance is attached to the development of remote sensing technology and its application to national economic development and management of environment.

The era of 1-meter and sub meter satellite imagery presents new and exciting opportunities for users of spatial data. With Space Imaging's IKONOS and DigitalGlobe's QuickBird satellite already in orbit and, of course, ISRO has launched high resolution Cartosat I and Catrosat-2 Satellites to provide entirely new level of geographic knowledge and detail to the intelligent maps that we create from imagery.

Geographic imagery is now widely used in GIS applications worldwide. Decisions made using these GIS systems by national, regional and local governments, as well as commercial companies affect millions of people, so it is critical that the information in the GIS is up to date. In most instances, aerial or satellite imagery provides the most up-to-date data source, helping to ensure precise and reliable decisions. The integration of image data into GIS is one of those great ideas whose time has come. Furthermore, remote sensing is often the most cost-effective source of information for updating a GIS and it is a valuable source of current land use/land cover data.

Thus, it is evident that conservation, preservation, and sustainable yield of natural resources are increasingly dependent upon remotely sensed data such as high-resolution satellite images, aerial photographs & GIS. In addition, new technologies, such as digital image processing (DIP), the Global Positioning System (GPS), and LiDAR altimetry are being used to generate, integrate and process spatial data required for various fine spatial level resource management applications.

Space-based remote sensing, due to its advantage of synoptic and repetitive coverage, has enabled the monitoring and assessment of natural resources and environment aiding in the economic development of our country. Under the aegis of the National Natural Resources Management System (NNRMS), many projects of direct national relevance are being carried out. NNRMS is an integrated resource management system aimed at optimum utilisation of the country's natural resources by a proper and systematic inventory of resources availability using EO data in conjunction with conventional techniques. The Planning Committee of NNRMS (PC-NNRMS) provides guidelines for implementation of the system and oversees the progress of remote sensing applications for natural resources management in the country.

Integrated landscape management

Ensures that by managing the underpinning natural resource base and ecosystem services through a coordinated process across sectors and stakeholders, the range of

societal needs can be met in the short and long terms. Diverse landscape management approaches have been developed from different entry points but aimed at realizing multiple outcomes simultaneously. Commonalities include: generating an agreed vision among stakeholders of long-term and wide-scale landscape goals; adopting a mosaic of practices that achieve multiple objectives; devising strategies to manage spatial interactions across different land uses and users; establishing institutions for stakeholder dialogue, negotiation and action; and shaping markets and policies to support desired outcomes. These process, technical, socioeconomic, market and policy dimensions are mutually reinforcing (Landscapes for People, Food and Nature, 2015).

Land use planning

This is the systematic assessment of land potential and alternatives for optimal land uses and improved economic and social conditions through participatory processes that are multi-sectoral, multi-stakeholder and scale dependent. The purpose of land-use planning is to support decision makers and land users in selecting and putting into practice those land uses that will best meet the needs of people while safeguarding natural resources and ecosystem services for current and future generations. Tools and methods for land-use planning at appropriate scales should encourage and assist the diverse and often competing users of land resources in selecting land-use and management options that increase their productivity, support sustainable agriculture and food systems, promote governance over land and water resources and meet the needs of society (adapted from FAO, 1993).

Land resource planning

This is similar to land-use planning but, in this paper, the term is used in a broader sense. Thus, land resource planning encompasses land evaluation and land-use planning and addresses the biophysical, socio-economic and negotiatory domains.

Sustainable Landuse Management (SLM)practices provide options for managing soil, water and plants and the ways these interact under a given set of biophysical and socio-economic conditions. Unfavourable climatic conditions (e.g. those imposed by climate change and climate variability), coupled with the mismanagement or misuse of resources, can increase degradation and vulnerability to change. On the other hand, the adoption of favourable practices, such as selecting proper land uses (based on land suitability evaluation) and implementing SLM, will enhance sustainability and resilience in the face of change. Understanding which part of the land resource is under threat is vital for selecting and putting into practice the most efficient and affordable solutions. The use of Land Resource Planning (LRP) in choosing land uses and adopting SLM, therefore, is an entry point to help decision-makers and communities increase the resilience of land-use systems. Selecting the most appropriate land uses and implementing SLM (favourable human activities) will enhance sustainability and the efficiency of resource use. LRP tools help decision-makers adopt appropriate options for the use of land resources based on their natural potential, thereby avoiding unsustainable exploitation and minimizing the risk of further degradation. LRP should also help land users in selecting and putting into

practice SLM options that support land and soil restoration in degraded areas (FAO, 2017b; FAO, 2017c).

A comprehensive land-based approach would involve identifying and prioritizing target areas where certain options have high potential for success; selecting the most appropriate SLM regime; and disseminating SLM practices, supported by proper policies, financial mechanisms and continuous monitoring to maintain adaptability in the face of climatic and socio-economic change. The needs and wishes of farmers should be at the centre of sustainable land development processes (Mediterra, 2016; Ziadat et al., 2015).

The multiuse nature of land involves various trade-offs that favour one use at the expense of others. Decisions that lead to changes in land use are often made on economic or political rather than ecological or social grounds. This can lead to the inappropriate use or management of land resources, with many potential negative impacts, such as the degradation of soil, water and biological resources; the loss of ecosystem functions and associated services; urbanization on productive soils; the use of poor quality water or inadequate water for irrigation, leading to salinization; and the disturbance of fragile coastal ecosystems accompanied by biodiversity losses and ecological disruption (Mediterra, 2016).

Integrated landscape management is the basis of natural resource management; it ensures that, by managing the underpinning natural resource base and ecosystem services through a coordinated process across sectors and stakeholders, the full range of societal needs can be met in the short and long terms. Land evaluation, land-use planning, negotiated territorial development and SLM are all tools that support LRP and integrated landscape management.

Rajiv Gandhi National Drinking Water Mission (RGNDWM)

Funded by the Department of Drinking Water Supply (DDWS) of the Ministry of Rural Development, preparation of Groundwater Prospects Mapping. It involves preparation of maps on 1:50,000 scale and generation of the digital database.

Updation of Wastelands Information

Subsequent to mapping and creation of digital database on wastelands of the country, a project has been taken-up at the behest of Ministry of Rural Development to update the wasteland information using recent satellite data. The wasteland atlas depicting the spatial information, identification and delineation of new areas under wastelands, identification of areas where reclamation programme has been implemented are generated.

Integrated Resources Information System for Desert Areas (IRIS-DA)

Funded by Ministry of Rural Development, this project envisages preparation of land and water resource management and utilisation plans to aid state and district/block level officials in planning development works.

National Agriculture Monitoring and Production Estimation

Crop Acreage and Production Estimation (CAPE) is a country wide project, which is funded by the Ministry of Agriculture and Cooperation, and executed by DOS

along with various State Remote Sensing Applications Centres, State Departments of Agriculture and Agricultural Universities. Acreage and production estimates for the principal crops such as wheat, rice, sorghum, cotton, mustard, and groundnut are generated under the project using stratified random sampling approach. Achievements of CAPE include evaluation of multi date remote sensing data for crop identification, development of yield models using trend and weather data. Mahalanobis National Crop Forecast Centre of Department of Agriculture, New Delhi is carrying out such assessments.

Large Scale Mapping

Large Scale Mapping (LSM) with the scope of creating a Large Scale Map of the country using high-resolution satellite images. The main objective is to generate one set of large-scale cartographic quality maps on 1:10,000 scale based on high-resolution space imagery and satellite based control survey for the entire country. The LSM project proposes to make available large-scale base maps as a new generation base maps for the country. The methodology will use high-resolution satellite images, GPS based precision control, ortho-correction of satellite images using DEM, feature extraction and mapping, field verification/annotation and final product generation. The LSM product is envisaged to be crucial for applications for City/Urban Planning and Panchayat Raj Applications.

Natural Resources Census

"Natural Resources Census (NR Census)" for the entire country. This project covers natural resources like land, water, soils, forests, etc. The census will be conducted with a repeat cycle to depict changes and modifications to provide a "snap-shot" of the country's status of natural resources. The census will start with the mapping and inventory using IRS images and generation of a national GIS repository.

Disaster Management Support

Natural disaster alleviation is a major topic for realizing the social sustainable development. Natural disasters are inevitable and it is almost impossible to fully recoup the damage caused by the disasters. But it is possible to minimise the potential risk by developing disaster early warning strategies, prepare and implement developmental plans to provide resilience to such disasters and to help in post disaster rehabilitation. Space technology plays a crucial role in efficient mitigation and management of disasters. The concerted efforts on addressing the major issues in the field of natural disasters monitoring and assessment have led to series of actions such as the establishing of integrated disaster monitoring and assessment operation system focusing on droughts and floods etc. In this process, remote sensing and Geographical Information System (GIS) could play a vital role in evolving a suitable strategy for disaster management and occupational framework for their monitoring, assessment and mitigation besides in identifying gap areas. The Disaster Management Support programme (DMSP) of DOS addresses theses aspects.

SUMMARY

On the basis of massive input and concerted efforts of the committed professionals associated with remote sensing technology for a long period of time in India, India's

remote sensing technology has now basically reached the internationally advanced level. It has also achieved remarkable social benefits in the fields of resources survey and disasters alleviation. These achievements indicate that India's remote sensing technologies have risen from the experimental phase to expansion phase for Land Resources monitoring and Management.

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Space Technology in Communication and Navigation

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In the last decade, ISRO has been augmenting space infrastructure specifically in communication, navigation and earth observation to meet the current demand. Through in-house launch capability and hired launches, ISRO could partially meet the demand on communication front. However, independent navigation system for our region has been successfully deployed.

Satcom*:* The Indian National Satellite (INSAT) system is one of the largest domestic communication satellite systems in Asia-Pacific region with nine operational communication satellites placed in Geo-stationary orbit. Established in 1983 with commissioning of INSAT-1B, it initiated a major revolution in India's communications sector and sustained the same later. GSAT-17 joins the constellation of INSAT System consisting 15 operational satellites, namely - INSAT- 4A, 4B, and GSAT-6, 7, 8, 9, 10, 12, 14, 15, 16, 17, 18 and 19. Satellite Communication utilisation has become wide spread and ubiquitous throughout the country for such diverse applications like Television, DTH Broadcasting, DSNG and VSAT to exploit the unique capabilities in terms of coverage and outreach. The Very Small Aperture Terminals (VSATs) to cater to the traffic and application requirements of varied users. The VSAT networks are designed to support all kinds of applications supporting video, voice and data, with a wide range of data rates from few kilobits per second (kbps) to 8 megabits per seconds (mbps). A VSAT network comprises of a central hub and hundreds of terminals, which are further interfaced to computers and other peripheral devices. The hub acts as a gateway with interface to external connectivity and several application servers. Many captive networks are deployed for governmental agencies and public sector usage.

An S-band Mobile Satellite Service (MSS) was added to INSAT system with the launch of INSAT-3C in 2002 and GSAT-2 in 2003. The following two classes of services were identified for MSS:

- A small portable satellite terminal that works with INSAT for voice/data communication has been developed with the participation of Indian industries. The terminal is useful for voice communication especially during disasters when other means of communication break down. It can be used from any location

in India for emergency communication. Transmit and receive frequencies of the terminal are in S-Band.

- The portable terminal is connected to the EPABX at central hub station through satellite channel and hence could be considered as an extension of EPABX and call could be made between any satellite terminals and local phones on EPABX. Central hub station is located at SAC, Ahmedabad.

Radio Networking (RN) through INSAT provides a reliable high-fidelity programme channels for National as well as Regional Networking. At present, 326 All India Radio (AIR) stations have been equipped with receive terminals. A total of 85 RN channels are being up-linked at present. For this, AIR is utilising one C-band transponder (C-11) of INSAT-3C.

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through LEOSAR (Low Earth Orbit Search And Rescue) satellite system. Under this programme, India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bengaluru. The Indian Mission Control Centre (INMCC) is located at ISTRAC, Bengaluru. The system is operational from the past 23 years. INSAT-3A, located at 93.5 deg East and INSAT-3D located at 82 deg East, are equipped with a 406 MHz Search and Rescue payload that picks up and relays alert signals originating from the distress beacons of maritime, aviation and land users.

In 2008, ISRO has set up a satcom based broadband Virtual Private Netwrok(BPN) for disaster management support(DMS). Present GSAT-12 satellite with Ext-C band, DMS have nine Primary Node supporting up to 2.5 Mbps and 33 User Nodes supporting upto 825kps data rates. It has a point to point n/w supporting video conference, IP data communication and telephony. This network was effectively utilized during disaster in Uttarakhand and Jammu & Kashmir.

Apart from communication service, these GEO satellites carry metrological payload and send the MET data (VHRR/CCD and Imager/Sounder) to ground stations.

High throughput satellite with multi-beam capability is getting ready for launch. This will improve the internet and video data transfer across the country.

Large number of societal applications viz, tele-medicine, tele-education, village resource centre, etc are built and operational over many states in India. The technology has matured substantially over past three decades and is being used on commercial basis for a large number of applications.

Navigation: Indian Regional Navigation Satellite System (IRNSS) is an autonomous regional satellite navigation system developed by ISRO (Indian Space Research Organization). It is renamed as NavIC (Navigation with Indian Constellation) by Honorable Prime Minister of India during dedicating to the nation. It has all the functionality of GPS signals except the fact that it is confined to Indian region. The Government of India approved the project in May 2006, with the intention of completing and implementing the system by 2016. The objective of the project is to establish an independent and indigenous regional space-borne navigation system for national applications. The NavIC design requirements call for a position accuracy better than 20m (2sigma) throughout India and a region extending around 1500 km.

The system is expected to provide accurate real-time position, velocity and time observables for users on a variety of platforms with 24x7 service availability under all weather conditions. The NavIC system consists of a constellation of seven satellites and a supporting ground segment. Three of the satellites in the constellation will be placed in a near geostationary orbit and the remaining four in a geosynchronous inclined orbit of 29° inclination. Such an arrangement would mean all seven satellites would have continuous radio visibility with Indian control stations. Cluster atomic clocks at ground and on-board keep the time preciously to an accuracy of less than 20 nanosec.

NavIC uses 24MHz bandwidth of spectrum in the L5-band (1164 – 1189 MHz) centered at 1176.45MHz and 16.5 MHz spectrum in S-band (2483.5 – 2500 MHz) centered at 2492.028MHz.

The satellites are kept in the following orbital slots

- 3 satellites in GEO (Geostationary Orbit) at 32.5°, 83° and 131.5° East
- 4 satellites in geosynchronous orbit placed at inclination of 29° with longitude crossing at 55° and 111.75° East. (Two spare satellites are also planned)

The NavIC constellation architecture consists of the following three segments like in any GNSS system:

Space segment: The NavIC satellites carry a navigation payload in a redundant configuration. A separate C-band transponder for precise CDMA ranging is included in the payload configuration. The important functions of the NavIC payload are: Transmission of the navigational timing information in the L5 band and S-band; Generation of navigation data on-board, CDMA ranging transponder for precise ranging. The navigation payload will have the following subsystems: NSGU (Navigation Signal Generation Unit), Atomic clock unit : comprising of Rubidium atomic clocks, clock management and control unit, frequency generation unit, modulation unit, high power amplifier unit, power combining unit and navigation antenna.

The NavIC spacecraft are dedicated for navigation services and they are configured to be of a class that can be launched by the PSLV launcher. The first satellite was launched in the summer of 2013. The full constellation was completed in April 28th, 2016.

Ground segment: The ground segment is responsible for the maintenance and operation of the NavIC constellation. It consists of : Master Control Center for spacecraft control and navigation, NavIC tracking and integrity monitoring stations, CDMA ranging stations, Uplinking and telemetry stations, Dedicated communication links between monitoring stations and master control center and timing enter with atomic clocks.

User segment: Specially designed receivers and antennas are needed to receive the NavIC signals. The receivers are also planned for receiving multi-constellation signals inclusive of GPS, GLONASS, Galileo and NavIC. It is planned to broadcast the time difference between the NavIC time and the time of the other constellations to enable the users to take advantage of the signals available to them.

NavIC has two services namely Standard Positioning Service (SPS) and Restricted Positioning Service (RS). SPS used BPSK modulated signal while RS signal used BOC(5,2) modulated (Binary Offset Carrier) signal. Both the signals are available in L5 and S band. RS signal is more robust, secured and precise compared to SPS signal. Unlike GPS or GLONASS system which are controlled by military agencies, NavIC is controlled by ISRO and ensure the free access of NavIC signals all the time. Specific text messaging scheme is unique in NavIC architecture.

GAGAN stands for GPS aided GEO augmented navigation, meaning the GPS navigation accuracy, integrity and availability are enhanced using a GEO satellite. The GPS timing signals are erroneous due to signal propagation through the troposphere, ionosphere and due clock related information. The GPS signal quality is not guaranteed all the time. The augmentation system like GAGAN observes the quality and other errors of GPS signal around Indian region using a set of ground monitoring station and uploads the information to GAGAN monitoring center. The monitoring center churn out the correction information and upload to GEO satellite viz GAGAN. Presently GSAT8, GSAT10, and GSAT15 are GAGAN enabled GEO satellites. The correction information is sent out in L1 band with unique PRN code. Thus the signal can be received by any GAGAN enabled GPS receiver and correct the GPS signal timing more accurately. Typically one can receive GPS signal with less than 3 to 4 m accuracy.

Application: Global Navigation Satellite System (GPS, GLONASS, GALIEO, COMPASS) applications are many in different areas of activity. GNSS receiver becomes a de-facto feature of mobile phone and thereby enables many location based services. Many of those applications can be ported with navIC enabled receivers and Bhuvan web site link to reap the benefit in Indian region. Land survey, intelligent transportation, defence, civil aviation, shipping, precision agriculture, distributed precision timing, fisheries, survey, science, electric network, geographic Information system are some of the applications. Since NavIC signal is available in 24x7 from the same satellite, RF signal property can be studied extensively studied to model ionosphere and troposphere. Many scientific activities are being time-marked using GNSS time to understand the physical phenomenon. Adventure sports and Augmented Reality are new avenues of GNSS application.

Environmental Friendly Model House of Tomorrow

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Last five decades witnessed the development and demonstration of several model houses built using different systems for reducing the cost. Several systems were experimented using local materials and traditional systems of construction.

I would like to express tribute and respect to late Master Architect Lauri Baker before talking about the subject. His arrival and works at Trivandrum in the 60's initiated the serious developments and debate on cost effective systems of construction.

The various medias and forums conducted seminars and discussions and built several models experimenting with various materials and techniques.

The subject became the 'talk of the time'. Several designers, architects, builders and environmentalists were attracted to this field demonstrating various models on the subject and slowly lost its priority.

In the mean time some of the Medias and channels changed over to various models of expensive houses creating a competitive outlook among the house-owners in building expensive and 'showy' houses as status-symbols. Some of the publications and channels started special items in regular programs and even competitions attracting the public to develop this competitive altitude with unpleasant display of wealth.

This trend confused the majority of common men with lesser income and lesser financial resources.

Since these homes are being accepted as status symbol in society, and majority of people with lesser income was confused, some of them even tried to borrow money beyond their capacity to create a 'false image' of riches. This undesirable trend is being followed ignoring the 'appropriate technology' for 'affordable houses' using appropriate materials suited to climate, culture and tradition.

Several professionals even tried to modify and distort the system demonstrated by Lauri Baker defeating the dominant quality of cost effectiveness and quality of architecture.

Now I think that it is right time to evaluate the models built and occupied by people these houses for decades. Also review the facts that Govt again who build major

portion of the construction including housing and even private builders who is going through several 'ups and downs' in the housing market, never utilised the glorified 'cost effective' technologies in a substantial way making use of the advantages.

Even though no comparative studies were conducted and published, I think it is high time to review the situation and make these two sectors to accept and follow the corrected and accepted 'appropriate technology' for the massive construction in future.

Effective steps in this direction will provide Govt and the private housing agencies can provide more number of houses and more of built up areas using the present budget allocation in future.

All the other advantages like correction of wrong approach to appropriate technology and cost effective buildings will generate even better outlook and approach to affordable system of construction in the future, evaluating the models and systems already built.

My observations and conclusions may not be fully correct. Only a detailed survey and study can make a correct assessment.

However my experience and observations are as follows.

1. The technical personnel handling the design and execution do not want to take unnecessary risk by adopting a new system and get a punishment in future. This fear of failure is one of the reasons.

   Government projects do not adopt even the proven systems because of the following factors.

2. There is a risk factor in deviating from the 'followed path'. The Engineering personal usually to avoid the risk.
3. There is a fact of 'vested interest' in the form of corruption among one section of technical personnel in Govt sector and public entrepreneurs.
4. The cost effective technology take away the provision in the budget for pilferage and 'kick-backs', even though this factor is denied by concerned person, it is the known fact to most of us.
5. Experimenting and trying a new technology involves extra effort, study and careful execution. The current lazy attitude of technical personals and administration persuades them to prefer the 'beaten-track' which is more expensive but not obligatory.
6. This type of expensive expenditure by the personal responsible for execution is never considered as a 'crime or drawback' and this increased loss to taxpayer's money which is being wasted or being looted. And this is increasing at a fast rate.
7. This is one of the reasons the budget provision are being increased beyond the normal escalation of prices.

The new cost effective technology and system of construction reduction is flatly denied at the beginning itself.

The real estate lobby which is carrying out construction of major part of the buildings in private sector do not care to adopt this technology for following reasons.

1. Motives of the builder is to make maximum profit. If he gets more profit in building an expensive flat or villa than building several cost effective villas or affordable flats, the private builders will be reluctant to build cheaper houses. The effort of marketing, mobilizing of funds and constructing will be easier for expensive buildings. Therefore in the initial stage itself cost effective technology will be ruled out.
2. Acceptance of the public is a major factor for marketing. The image of building also is an important factor. The expensive flats or buildings provide a boosting of false image. Therefore easy marketing will be possible in expensive buildings.
3. The cost effective buildings has more architectural value and aesthetical value. But they openly declare that this building is built using cost effective technology and the one invested only a lesser amount. Only an intelligent or sensible person will only appreciate this fact, whereas the owner want to show that he is a richer person. Even this fact attracts the marketing real-estate lobby aiming at quick-profit and maximum gains discard this technology of cost effective and environment friendly houses.

It is not legally obligatory on the part of builders to build affordable houses along with expensive houses. Therefore the private builders uphold the slogan 'maximum profit with minimum effort' and other good factors are ignored.

At this stage I feel that only a responsible administration, determined to stick to the good factors and make them adopt the proven technology for reducing the cost by obligatory steps on house-makers and builders. This wastage of public money is increasing to alarming scales. A detailed study and survey including positive suggestions for compulsory adoption of these systems at least for major projects and public buildings will create better results.

Finally the altitude and outlook of the public as well as the administrators and beneficiaries are to be in the right direction with obligatory and responsible guidelines.

ENVIRONMENTAL FRIENDLY MODEL HOUSE OF TOMORROW

Form the past experience of the 'one lakh' housing project and the past experience of building cost effective houses for the past 41/2 decades, we came to understand that the model house required should have following special features:-

1. The house should be cheaper and affordable than costly conventional system.
2. Future expansion should be possible either horizontally and vertically as per the changing requirements keeping the same land, same basic structure since the financial and social status of individuals are getting changed occasionally.
3. The house should be upgradable by finishing and furnishings keeping the original land and the basic structure the same.
4. The house should be self sufficient in water making use of rain-water through effective rain-water harvesting.
5. The house should be self sufficient in power using the solar and wind power and the other alternate ways of generating cheaper power and by use of LED, CFL etc.

6. The whole premises of the house should be zero waste zone by disposal method at source itself.
7. Other qualities like low maintenance cost in future.
8. Conservation and minimum use of source materials like steel, cement etc.
9. Reduction of labour cost by partial prefabrication and use of simplified construction mechanization and other simplified technology.
10. Effective use of manpower available through self help and mutual help and through utilization of idled labour-force through sponsorship and mutual help basis.
11. Several other qualities of environmental friendly methods and systems with appropriate materials can be introduced for the model house of tomorrow.

If these above qualities can be achieved in the future dwellings, this can be accepted as a model house of tomorrow.

Need for Technological Innovations for Safe, Energy Efficient and Low Emission Transport System - The Case of Mass Rapid Transit System

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INTRODUCTION

Transport is an integral part of most of the activities, delivery of goods and services required for supporting and improving people's lives. Yet, it also consumes resources and has adverse side effects. A balance has to be found that will enable people's transport needs to be met in a way that neither harms nor depletes finite resources. Transport is in the fore-front of green policy-making as a major consumer of fossil fuels and a leading source of air pollution. The producers of environmental pollution and the consumers of pollutants need to come together to formulate acceptable alternatives. Lack of response to evolve immediate actions would mean transport crisis, especially in surface transport sector.

Nowhere is the concept of sustainability more relevant than in the transportation sector. A sustainable transport is the one that allows basic access to all in the society to be met safely and in a manner consistent with human health. Environmentally, a sustainable transport system minimizes the use of land and emissions, waste and noise. In effect, sustainable transport is required to use renewable resources at or below their rates of generation, non-renewable resources at or below the rates of development of renewable substitutes, and limit the emissions and waste within the planet's ability to absorb them.

A sustainable transport means beyond controlling air pollution, traffic congestion or fuel use; it must balance the present and long-term needs for the environment, economic growth and equity - the *three E's of sustainability*. The Rio Earth Summit[1] (1992) recognized that the transport operations have a decisive role to play in bringing about a sustainable future. In terms of delivery of service, a sustainable transport is one that is safe, environment-friendly, affordable and accessible to all people.

PARADIGM SHIFT IN TRANSPORT DEVELOPMENT

The alarming growth of motor vehicles, especially the two wheelers, is a major concern. Recent trends indicate that motor vehicle population doubles in every 7 to 8 years. However, increased use of personal motor vehicles, especially in areas unable to afford proper facilities, comes at both economic and environmental cost.

Many cities have already begun to feel the adverse effects of motorization such as traffic congestion, higher fuel cost, increased levels of air pollutants and degradation of the environment.

The present course of transport development, which is wholly dependent on fossil fuels and over-dependence on motorized transport system, is leading more and more cities into crises. There is a need for providing mobility to people with improved safety, energy efficient and higher capacity mass transport system that do not pollute the atmosphere using cleaner and renewable energy sources.

Traditionally, the authorities respond to transport shortfalls by augmenting the road network. Although the augmentation of road network is important, road development comprise only one component of the entire transport system. Focusing on a single component, rather than the system as a whole, will lead to piece-meal solutions. This would result in unsustainable transportation development.

TRAFFIC CONGESTION AND POLLUTION EFFECTS

Most travel, with the exception of non-motorized modes like walking and cycling, causes environmental problems. The major environmental effects of transport arise from use of fossil fuels for vehicle with consequent exhaust emissions. In cities with extreme amounts of traffic congestion and transport emissions, investors stay away to avoid the inefficiency, causing even more economic harm to society. Tourism industry is one which is greatly affected in congested cities; potential tourists stay away to avoid the pollution and congestion, and those who do visit such cities often leave with a bad impression. Some advanced countries have begun to adopt road-pricing schemes to shift the cost burden to road users and discourage non-essential trips at peak times.

Energy consumption in urban transport largely depends on choice of mode as well as speed of vehicle. Energy consumption per passenger-km by public transport modes like bus, train and boat, is the least and highest for cars among the road based vehicles[2].

ISSUES AND INTERVENTIONS

Issues that are of particular importance are: a) Environmental capacity, b) Continued availability of fuels and c) Reversal of global warming. The actions which can mitigate the issues are:

i. Immediate action on alternatives means of transport which would be acceptable to people both as users of transport and as seekers of a better environment.

ii. Reductions in environmental pollution from movement and from the burning of fossil fuels.

iii. Reduction and ultimate elimination of crude oil as a source of fuel for transportation.

The last two options will gain public support if acceptable alternatives to the use of cars, buses and trucks become available. This makes the first option of paramount importance.

SUSTAINABLE AND LOW CARBON URBAN TRANSPORT

People are more concerned with deterioration of the quality of life in cities. They are now demanding a transport system that is safe, energy efficient, and easy access to goods, services, and activities. There are many options available that can be effectively applied to make urban transport operationally efficient and environment friendly.

Reducing the dependency on petroleum oil

Reducing the dependency on fossil fuels to a significant degree is a long-term strategy. While forecasts of alternative fuel use are risky, there are sufficiently encouraging signs to suggest that a significant reduction in petrol and diesel through fuel-shift can be achieved in the next 10 years.

For oil-importing countries, rising transport energy consumption means further depletion of already strained foreign exchange (forex) reserves. India spend over 70% of forex earnings towards crude oil import. History shows the economic and social ramifications of over-dependence on oil during the Gulf war in the last three decades. Increased demand of oil could precipitate the recurrence of such oil crisis in the future.

As such, motorized transport accounts for 80% of the total consumption of diesel and almost 95% of petrol in India. Given the limited nature of petroleum reserves, the importance of alternative fuels has already been felt all over the world. While demand for mobility continues to grow rapidly, fewer sources of oil deposits are being explored. The mobility of people and goods must, therefore, not be allowed to depend exclusively on petroleum oil. Several alternative fuels exist which have different characteristics in terms of eco-friendliness, large-scale availability, affordability and so on.

There exists a need to probe the efficacy of alternative fuels like bio-diesel, electricity, fuel cell technology, solar energy, and hydrogen for propulsion of vehicles. It is essential to experiment different technologies available and address the whole issue of energy security so that the dependency on fossil fuels is minimized.

Cleaner fuel for transportation

The Department of Non conventional Energy Sources (DNES), Govt. of India initiated field trials of diesel buses blend with methanol and ethanol, both renewable resources, as substitutes for diesel in Delhi Transport Corporation buses. The results of field trials demonstrate that it is possible to substitute 15% of the diesel with methanol or ethanol through a dual-fuel mode which results in 30 to 35% reduction in smoke emission. The advantage is that it eliminates the smoke emission completely[3]. This means a major reprieve for the environment of cities.

Public transport buses can also be operated using bio-diesel, produced from vegetable oils or *Jatropha Curcas (Kattu-amanakku)*. Large cities can even consider starting a city-wide solid waste based synthetic oil *(syn-gas)* collection service to run buses. Biodiesel has many downsides however, if it is made with edible food crops such as maize or soya. When fuels are manufactured from grains and other staple crops it can push up prices of food and thus impact most, on the poor. The production

of feedstock for biofuel production is often also water intensive and brings other problems associated with monoculture farming.

Hydrogen is a clean-burning fuel. To date, its use has been primarily experimental in space vehicles and rockets. One possible solution is to develop new engines designed specifically for use with hydrogen. This is feasible only in the long-term. The advantage of hydrogen over conventional fuel is that it is abundant in water and solar energy. Hydrogen as a fuel does not produce carbon residue. Not only is that fuel eco-friendly with zero emission, but also, it helps in scaling down the country's oil deficit. Cost competitive technology for producing hydrogen from water through electrolysis process is being developed. However, a number of barriers remain to be overcome before hydrogen can be considered for wide-spread application.

Eco-friendly and energy efficient technologies

Electric vehicles - Use of electricity in vehicles can come either from energy stored in a battery or from fuel-cell to electricity. Technological development around the world indicate that the future holds good for fuel cell technology. Use of fuel cells has many advantages, namely energy efficiency, free from noise, vibration, and exhaust fumes.

Battery or solar powered vehicles - Recently, battery operated vehicles have come into the focus because of their oil-free and pollution-free transport operation. This may serve effectively as a city bus-like service in busy commercial and congested areas. Incentives like cheaper power tariffs during off-peak hours and night-time, could encourage the use of such vehicles. There are several such vehicles running in cities transporting commuters and visitors to major work centers and tourist destinations. The batteries can also be charged using solar chargers.

Solar energy is used in very limited scale in transport sector except for demonstration projects. Solar panel fitted on vehicle rooftop can be used for propulsion of vehicles. The problem with solar powered vehicle is that it is expensive and inconvenient during operation. As such, the operating cost of this mode is not available for comparison with other alternative fuels.

Gas powered vehicles - There are several thousands of vehicles running on Compressed Natural Gas (CNG) in Delhi and in parts of the country. In fact, many taxis in Mumbai city are powered by CNG fuel. CNG buses have undergone extensive field trials in Vadodara and Tripura. The advantage of CNG is that it can power both petrol and diesel vehicles. Besides cutting down operating costs, the main advantage is that it is "environment friendly". Gas powered vehicles emit just 10 to 15% carbon monoxide while petrol vehicles emissions contain 60 - 65% carbon monoxide, which is a major air pollutant.

It is likely that newer technologies based on electricity, fuel-cell, propane, hydrogen or solar power may take over the current diesel bus technology. Future scenario indicate that the present IC engines will continue to dominate the road transport sector for the next 5-10 years. Beyond 10 years, fuel-cell technology and electricity could well be a viable option, with hydrogen as a long-term possibility.

Mode shifting

There is an obvious link between reduced vehicular travel and reduction of fossil fuel use and therefore, GHG emissions. Local Bodies need to vigorously support mode

shift from personal vehicles to public transport for daily commuters. Railways and inland waterways can offer more efficient, lower emission transport solutions for long-distance freight and passenger movement. This is particularly so when they are supported by improved logistic facilities and services to offer effective multimodal transport solutions. There is also potential for increasing the share of mass transit system to provide a safe, accessible, energy efficient and low carbon transport in cities.

Mass transit in the form of buses or rail can save energy, reduce pollution, reduce the need for parking, alleviate congestion and provide affordable transport alternatives. In many congested cities using mass transit can also be faster than driving a car. Bus Rapid Transit (BRT), has proven to be both cost efficient and popular with commuters. In BRT system, buses run on a dedicated bus lane segregated from other traffic, with its own signal timing. Allowing buses to bypass congestion induced by car traffic, increases the speed of bus travel which makes it highly competitive with private cars for commuters[4].

MASS RAPID TRANSIT SYSTEM FOR CITIES

Studies indicate that the ideal mode share of public transport should be around 70%. However, it is in the order of 35%–40% in Indian cities[5]. The public transport modes are: Bus, BRTS, MEMU service, and Mass Transit Systems like Metro Rail and Monorail.

Need for Mass Rapid Transit Systems

As the population of a city grows, share of public transport, whether road or rail-based, should increase. Experience has shown that, in cities where roads do not have adequate width and which cater to mixed traffic conditions, road transport can optimally carry up to 8,000 persons per hour per direction of traffic (phpdt). When the traffic density increases beyond this level, average speed of vehicles drops down and journey time increases, air pollution goes up and commuters are subjected to increased level of inconvenience. In any case, it is not feasible to operate bus transport beyond 10,000 phpdt in mixed transport scenario, prevailing in major cities[5].

Mass Rapid Transit System (MRTS) is an efficient user of space with minimum level of air pollution. Private vehicles emit about twice as much carbon monoxide and other volatile organic compounds than public vehicles. The main idea behind mass transit is to reduce the number of vehicles on the road by providing a larger facility which carries higher number of passengers thus eliminating congestion. Mass transit reduces the travel time to a great extent as it moves at high speeds and stops only at specific stops.

Advantages of MRTS

MRTS is known to provide travel at a very affordable cost. It is considered to be safer, faster, eco-friendly and more energy efficient means of transport compared to other available public transport modes. It is spatially efficient in terms of space utilisation and comfortable due to modern coaches, automatic ticketing, advanced protection and security systems. With a maximum speed of 80 km/hr and average speed of 40

km/hr helps in saving of time. With proper designing, the peak hour capacity could be @ 3-4 lakh passenger/hour. Delhi Metro is known to carry a passenger load of 30 lakh persons per day. The only disadvantage of metro system is the traffic diversion and congestion caused at the time of construction.

Metro rail systems in India

India has world class metro rail systems in Kolkata, Delhi, Mumbai, Bengaluru, Hyderabad, Chennai, Jaipur and Kochi, and more such systems coming up in Chandigarh, Pune, Ahmedabad, Kanpur, Ludhiana, Bhopal, Indore and Faridabad cities.

Kochi is the only city in India where Metro Rail is integrated with water transport. Taking advantage of waterways and canals, Water Metro (high speed boats) services are being planned to provide multimodal and seamless mobility to the commuters of the region. Similarly, Light Rail Transit System (popularly known as Light Metro) is proposed for Trivandrum and Kozhikode cities in Kerala. With the increasing traffic congestion and pollution levels in cities, innovative and state of the art technology oriented mass transit systems are sought to be considered for a safe, operationally efficient and low emission transport facility for the cities of Kerala.

TECHNOLOGIES FOR SAFE AND SPEEDY MOBILITY

Technology Vision for India[6] envisions: *"By the year 2035, technology should enable us to access public transportation within distance of one km from our home. No place will be more than three hours away from a district head-quarters, five hours from the state capital and eight hours from our national capital"*. Inter-modal connectivity should ensure that no two points in a metropolitan area would be more than an hour away.

Use of IT enabled services and intelligent transport systems to tackle traffic congestion and transport management will be essential. Development of vehicles that are twice as fuel efficient but emit half the current emissions will be required. High quality infrastructure, road transportation technologies and traffic management systems are organically interrelated and should be treated in an integrated manner. In addition, there will be a need for intercity connections through cost-effective modes such as high-speed trains and bullet trains for faster intercity access. Multi-modal mobility for goods and services will need to be enhanced with development of dedicated, high speed freight rail corridors. Providing last mile connectivity through multi-modal means is a huge challenge.

Mass transit is at the heart of any smart growth policy, because it allows people to get from home to work in the most efficient, least environmentally-harmful way possible. This is possible only when a high frequency, high capacity, and operationally efficient MRTS is in place. Major thrust will be implementation of the technologies in such a manner that provides for safe, affordable, energy efficient and reliable transportation for all citizens.

SUMMARY

An effective way to reduce traffic congestion is to provide adequate and reliable public transport. This would reduce the consumption of fossil oils and pollution

levels in urban areas, by shifting commuters from using personal vehicles to public transport (buses, boats and trains).

Introduction of mass transit systems such as Bus Rapid Transit System, Personal Rapid Transit System, Metro Rail System, Hybrid buses powered by bio-fuel, fuel cell, and gaseous fuels will reduce the dependency on fossil fuels, ensure low emission transport system for the commuters. Intelligent Transport Systems need to be applied to urban transport to improve safety and operational efficiency.

Technological innovations are essentially required in areas such as vehicle design, cleaner fuels, safety and energy efficiency. A sustainable and low emission transport believes that: *"Today's transportation development and its growth must not be achieved at tomorrow's expense"*.

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Issues, Challenges and Potentials for Integrating Science, Technology and Innovation in Energy Sector

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Science, Technology and Innovation (STI), with full realization of the local culture and its ability to absorb and utilize new knowledge, can significantly impact the three known pillars of 'sustainable development': viz., economic, social and environmental. For development to happen economies will have to be transformed and this can only be achieved through increase in productivity.

Science is understood by all as 'creation' of new knowledge (eg., telephony); technology as the application of such knowledge (eg., making of a mobile phone); and innovation as the application of technology (eg., such as in mobile banking). Culture is the empowering element for acceptance of new technologies and in upholding a sense of scientific temper.

The world as a whole – not Kerala or India as regional players – is facing severe challenges starting from feeding more than 0.8 billion people who are in a poverty trap, to reaching the 1.3 billion people without access to electricity and the 2.6 billion people who rely on traditional biomass for cooking and heating. Innovations in technology applications and expansion of R&D that meet local problems squarely and sustainably are required to solve these challenges. Energy and 'energy democracy' that empower the general public to use it as a tool to solve the twin issues of job creation and poverty reduction can definitely be the right innovation in energy sector for developing countries such as ours.

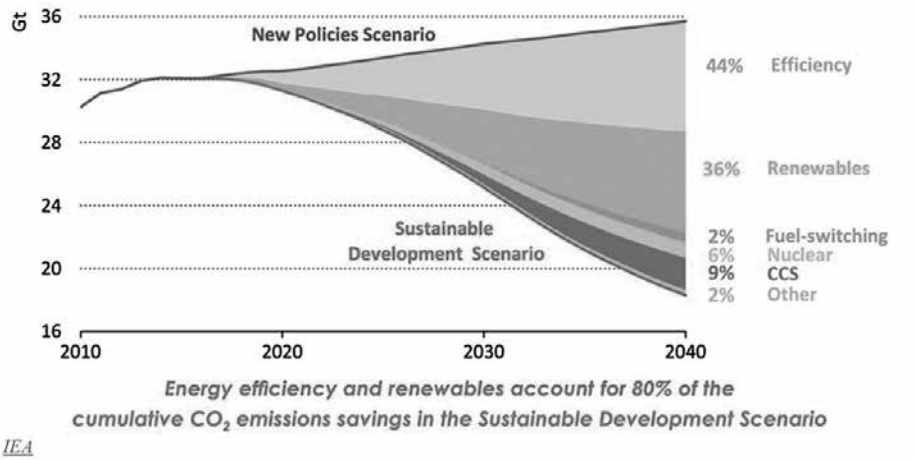
At the global level, United Nations have initiated two important steps to get the comity of nations to collectively focus on issues related to energy for sustainable development: 1. The UN Secretary General's initiative for achieving Sustainable Energy for All by 2030; and 2. United Nations General Assembly resolution No. 65/151 (December 2012), declaring the decade from 2014 to 2024 as the "Decade of Sustainable Energy for All (SE4ALL)".

At the national level, India is well aware of the fact that the largest chunk of people without access to modern energy sources in the world, amounting to more than 239 million (as of 2016), is in India. India is also not free from the other grave challenges afflicting a sizeable portion of the world population.

There is near total agreement among statesmen that the gravest current sustainability challenges facing humanity are: Climate Change impacts, Inadequate Energy Access, Natural Resources constraint, Widespread Pollution and Lack of Jobs for the millions. India has declared a Climate Change Action Plan in 2008, and its targets have been further enlarged substantially after the Modi Government took over. Vigorous action is afoot in India to see that as a nation, we do not sacrifice lives and property as well as dignity of even the poorest single individual. A rapid transition to renewable energy and a coordinated drive for improving energy efficiency are two of India's ongoing drives.

It will be worthwhile to look at global analyses of situation in respect of energy, as it is a powerful tool for an integrated solution for the gravest humanitarian challenges now facing India and the World.

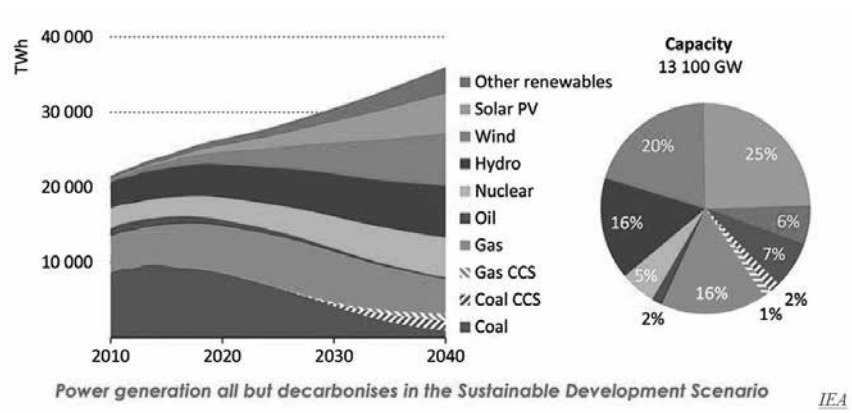
According to International Energy Agency (IEA) in its Special Report of 2017, the changes that would take place towards sustainable energy development can be summarized in the following three diagrams:



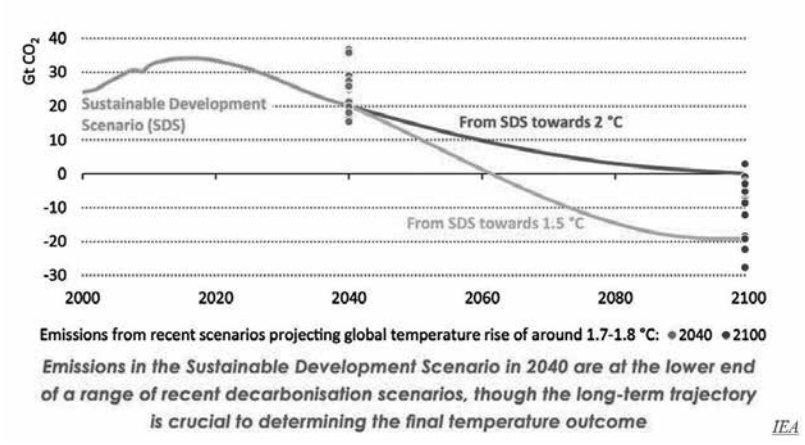
IEA

This diagram shows elevating the energy efficiency levels in all sectors of energy use as crucial to winning several battles. The largest contributor to de-carbonisation is energy efficiency. Next contribution is from the increased use of renewable energy. Both put together, other actions are dwarfed by the 80% share of compensation expected by 2040 from these. It is from now on, for two decades that we have to move forward with major action plans.

The next illustration is on how well distributed is the energy mix by 2040. We have no major contributors as individual sources, though all renewables put together will seize the central stage. Coal and Oil are belittled, much to meet our expectation of containing GHG emissions. Gas will have a larger role, presumably because of better power balancing during grid disturbances, in view of its ability to restore speedily – a quality which no other source can claim. It is less polluting in comparison to other fossil fuels.



The third diagram with projections up to the year 2100, gives us hope that through concerted actions globally, humanity can expect to survive beyond 2100, holding the global warming to well below 2^{0}C and hopefully to around 1.7 to 1.8^{0}C.



If actions are planned to meet the desired objectives and to reach achievable targets, the "out of our hands" situation on global warming and climate change can be reversed. If IEA's World Energy Outlook Special Report – Energy Access Outlook 2017, From Poverty to Prosperity, can highlight the achievement of India as 'colossal', India can well meet its goals as well as alleviate the global fix. Similar actions can be a repeat, globally, among countries with large populations. The concerned portion of the report reads like this:

"India has led recent global progress in electricity access

Half a billion people have gained access to electricity in India since 2000, almost doubling the country's electrification rate. This remarkable growth puts India

on course to achieving access to electricity for all in the early 2020s – a colossal achievement. The pace has accelerated in recent years, with an additional 40 million people gaining access each year since 2011. Nearly all those who gained access since 2000 have done so, as a result of new connections to the grid, which has been the main focus of government measures. Coal has fuelled about 75% of the new electricity access since 2000, with renewable sources accounting for around 20%. Still, 239 million people remain without electricity access in 2016, about a quarter of the worldwide total. But India's continued emphasis on electrifying households means it is expected to reach universal electricity access in the early 2020s, with renewables accounting for about 60% of those who gain access. Progress has also been made on clean cooking, although 830 million people in India still lack access. There are clear indications however that government policy efforts targeting LPG have begun to take hold. The share of the population relying primarily on biomass for cooking fell to 59% in 2015 from 66% in 2011. By 2030, the promotion of LPG and improved biomass cook stoves by the government means that more than 300 million people gain access to clean cooking facilities, but still more than one-in-three people remain without."

For increased access to renewable energy, and to integrate the varied 'variable renewable power' to the existing 'weak grids', much more research, innovation and adaptation and adoption of newer technologies are required. The structure and the nature of the power grids are to be totally revamped. Newer problems arise – technical, managerial and cultural.

The radial power lines from generation point to user points in a unidirectional flow will give way for bi-directional flows, AC and DC power will co-exist, utilities will no longer control the grid, the source of power that one uses will in most cases be unknown to the user, resilience of grids will be enhanced, transportation needs will be met substantially by power lines, even catenaries will be built over roads to power the trucks and EVs, non-chemical storage of solar and wind energy will gain prominence and utilities may trade storage to individual users - and much more are to come. They all need newer solutions through innovations and hard research.

S&T and Innovation for development, with energy for all in the new century, which is considered as that of renewables, distributed generation and myriads of micro grids, will be free of regulatory controls, intelligent, smart and self correcting, 'transactive' in terms of millions of producers, consumers, 'prosumers' and traders linked to it, is enormously challenging, with the hope that 'who own our tomorrow' will also find timely solutions for all the unprecedented problems that crop up on the way. Half of the energy infrastructure of 2040 is yet to be built and this gives us hope that the outdated energy practices will get wiped out in the process to give way for a sustainable one which is rooted in local resources - community managed and democratically shared according to needs.

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Mainstreaming Renewable Energy in Kerala

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INTRODUCTION

India has fixed a tentative target of 100 GW (1 lakh MW) solar power by 2022. For this Kerala is expected to have a solar capacity of 1870 MW, which shall consist of 1000 MW large scale solar power plants and 870 MW from rooftop solar systems (including grid-connected and off-grid). This would require achieving about 10 times the annual target of ANERT for rooftop systems so far. Given the constraint of land, possibility of more numbers of utility scale plants is limited. About 15 MW of rooftop systems have also been completed through ANERT-MNRE programmes. It is expected that rooftop systems with a total capacity ranging anywhere from the reported 15 MW to 50 MW capacity may have been already installed. Entirely depending on subsidy driven programmes may not be viable for achieving this target. ANERT is also proposing to set up about 1 MW of solar power plants in government buildings every year. The solar policy also mentions making solar water heaters mandatory in certain types of buildings. A target of 50,000 square metre of collector area per year could be targeted for the next five years.

ANERT has already started restructuring its programmes for this scaling up. Some of the initiatives are:

- **eGovernance Initiatives**

ANERT has initiated a number of eGovernance activities in the current year. ANERT has already been using eTender, eSMS, State Data Centre and KSWAN facilities for last few years. **eOffice**was adopted for electronic file management in ANERT. eOffice was launched in headquarters from 5-Jun-2017. With the procurement of necessary hardware and obtaining KSWAN connectivity to district offices, file management in district offices will also be made fully electronic.With these, most of the activities of ANERT are expected to be in electronic form, leveraging the advantages of information technology including mobile/smart phone platforms, as briefly detailed below:

- eMarketPlace for renewable energy systems and devices

eMarketplace

An online marketplace will be created. The details of various renewable energy equipment will be made available online. The details of ANERT's programmes also will be linked to it. Potential customers can register online, compare the equipment and place orders for systems and devices with or without subsidy. Initially, online empanelled vendors of ANERT will be allowed to list on the portal. Later on, it could even be made a self-sustaining, independently operated and maintained portal on a commercial or PPP mode.

Portal for Programme Management, Workflow

The management of programmes of ANERT, especially the subsidy programmes, and maintaining a list of installations will be handled in this portal. It was also have facility for other agencies such as the electricity distribution utility and Electrical Inspectorate to provide approvals for connectivity, energisation, etc. online through this portal.This portal will also be linked to the mobile apps which makes all field verification and the eMarketplace.

Mobile app for field verification of renewable energy systems, with geo-tagging

Mobile apps are being developed for the use of public and various field activities of ANERT. The app for public use, named *SouraVeedhi* is being developed for Android (already made available on Google Play Store) and iOS (for Apple App Store) platforms. The internal app (*m-ANERT*) shall be on Android platform only. Following are the features of the apps in brief:

- Individuals and institutions to express their interest to partner with ANERT in various areas such as promotion, awareness (e.g. NGOs, residential associations, individuals), financing (e.g. cooperative banks), technical verification, etc.
- To register a renewable energy system or device installed during the last 5 years, so that they could avail of free insurance for one year for the system (the details of the system with photographs and geo-tag to be captured).
- Checking the feasibility for installing a renewable energy system such as rooftop solar power plant, solar water heater, biogas plant, etc. (to be done by empanelled vendors on receiving an order from a customer through the eMarketplace)
- Submitting of installation reports by vendors for renewable energy systems such as rooftop solar power plant, solar water heater, biogas plant, etc., with photographs and geo-tag
- Verification of installations by ANERT officials or authorised representatives, with facility for identifying the location on a map
- Messaging to all or to groups

The *SouraVeedhi* mobile app (Android) have been developed and made available on Google Play Store, and the iOS version is under development. The *m-ANERT* app is also available on Play Store, but the backend integration with the portal for full functionality is under development.

Setting up 140 Akshaya Urja Service Centres at the Assembly-segment level for effective service support for installations, linked to the government call centre and an online web-portal for complaints handling with ticketing

Service support centres with CRM and ticketing

ANERT is planning to have a network of 140 AkshayaUrja Service Centres (AUSC) across the state (one per Legislative Assembly Constituency). These centres would provide support and maintenance services for all renewable energy installations. The Call Centre having a toll-free number can be called to report a problem with any renewable energy installation. A web-based software to log and manage the calls will be developed. This CRM-type software with ticketing facility shall be used by the Call Centre agents. It shall have the details of all the systems included in the portal and also those reported through the *SouraVeedhi* app. If the problem rectification requires a visit by service person, the support request shall be assigned to the concerned AUSC. The service centre shall send a technician to check the fault and take further action. A mobile app would be used by the support person to record the action taken on the service call and would update the CRM-ticketing software.

Accident insurance coverage including medical expenses to ANERT empanelled Renewable Energy (RE) Technicians all staff involved in field assignments.

Government have accorded Administrative Sanction for the implementation of project proposal to extend accident insurance coverage including medical expenses to ANERT empanelled Renewable Energy (RE) Technicians and all staff involved in field assignments through a Government of India owned insurance provider. Accordingly ANERT has selected M/s United India Insurance Co. Ltd as the service provider. Accident insurance coverage is for Rs 3 lakh and medical expense for Rs 30,000/- with Rs 500/- as premium per person.

The scheme started with extending the benefit to Self Employed Workers of improved chulha (172nos) and Turnkey agents of Biogas plants (113 nos).New technology demonstration programmes in renewable, including energy storage to overcome the perceived limitations of renewable energy (3 MW solar-wind hybrid with storage solutions initiated in Ramakkalmedu, Idukki

Ramakkalmedu demonstration project of Solar-Wind-Storage Hybrid (Phase 1)

The Solar-Wind-Storage hybrid power plant project is proposed to be implemented in the land available with ANERT at Ramakkalmedu, Idukki District. The project is planned as a Renewable Energy Park to demonstrate renewable energy technologies including indigenous ones and especially hybrid and storage technologies. A dispatchable renewable energy power plant with solar, wind and storage is planned in phases. In the first phase, a 3 MW plant is planned to be set up in the current year.

Government have sanctioned the project to be undertaken with the assistance of CDAC, Thiruvananthapuram. National Institute of Wind Energy, Chennai (NIWE of the Ministry of New and Renewable Energy, Government of India) who had earlier

conducted a micro-siting study for wind energy generators at the site has been entrusted with the task of hybrid micrositing for the solar and wind power plants.

- Innovative RE projects through viability gap funding
- Establishing centres of excellence on various RETs in reputed Universities/ Colleges

Other Activities

- Census of all renewable energy installations done in the state during the last 5 years, by requesting registration through a mobile app; and incentivising the registration by providing free one year insurance to such systems
- Installation of solar power plants in government buildings
- Arrangements with local self-governments for providing subsidy to the needy
- Partnership with cooperative banks for providing financial support to install renewable energy systems as specified by ANERT
- RE Awards for recognising initiatives by organisations and individuals
- Capacity building through trainings on system design, installation & up-keep
- Promotion of RE industry in Kerala through facilitating technology partnerships, business networks, etc.
- Integrated renewable energy complexes at district level, mobile exhibition unit, a professional public relations campaign, training and awareness programmes to spread the message of renewable energy

ANERT would also take steps to promote new business models for implementing renewable energy projects including RESCO, third-party leasing, community/ co-op investment, solar power pack on rental, etc.We invite reputed players in this field to empanel with ANERT as service providers and also solicit proposals on new technology/ business model demonstrations in Kerala.

Energy management and Climate Change Mitigation – Kerala Scenario

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Energy Usage and global environmental issues

As early as 1896, the Swedish scientist Svante Arrhenius had predicted that human activities would interfere with the way the sun interacts with the earth, resulting in global warming and climate change. His prediction has become true and climate change is now disrupting global environmental stability. The last few decades have seen many treaties, conventions, and protocols for the cause of global environmental protection.

Few examples of environmental issues of global significance are:

- Ozone layer depletion
- Global warming
- Loss of biodiversity

One of the most important characteristics of this environmental degradation is that it affects all mankind on a global scale without regard to any particular country, region, or race.

Global Warming

Before the Industrial Revolution, human activities released very few gases into the atmosphere and all climate changes happened naturally. After the Industrial Revolution, through fossil fuel combustion, changing agricultural practices and deforestation, the natural composition of gases in the atmosphere is getting affected and climate and environment began to alter significantly. Over the last 100 years, it was found out that the earth is getting warmer and warmer, unlike previous 8000 years when temperatures have been relatively constant. The present temperature is 0.3 - 0.6 °C warmer than it was 100 years ago. The key greenhouse gases (GHG) causing global warming is carbon dioxide. CFC's, even though they exist in very small quantities, are significant contributors to global warming. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human caused) sources: the combustion of fossil fuels and changes in land use.Net Project on Energy Management in Commercial Buildings Institute of Management Kerala Page 80 releases of carbon dioxide from these two sources

are believed to be contributing to the rapid rise in atmospheric concentrations since Industrial Revolution. Because estimates indicate that approximately 80 percent of all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the Centre of the climate change debate.

Carbon footprint

A carbon footprint is defined as "the total sets of greenhouse gas (GHG) emissions caused by an organisation, event, product or person. (Carbon Trust, 2008). 82% of anthropogenic Green House Gas emissions are in the form of CO2 from fossil fuel combustion. Greenhouse gas emissions attributed to campus can be classified as (as per UNEP)

Scope 1: GHG emissions that occur within territorial boundary of the campus.

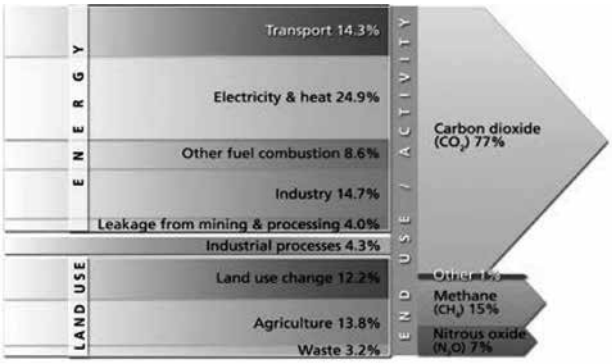
Scope 2: Indirect emissions that occur outside of the campus boundary as a result of activities that occur within the campus which includes Electricity consumption.

Scope 3: Other indirect emissions and embodied emissions that occurs outside of the campus boundary, as a result of activities of the city, which includes Electrical transmission and distribution losses, solid waste disposal, waste incineration, waste water handling, embodied emissions in imported water, embodied emissions in imported food, embodied emissions in fuel etc.

Energy Use – The Source for Most Carbon Emissions

About 85 percent of the energy consumed in modern society comes from fossil fuels. Vast sums have been invested in the existing energy landscape – the petroleum refineries, petrol stations, natural gas fields and pipelines, coal mines, and electric grids that power modern societies. To meet the growing need for electricity in developing countries while simultaneously reducing greenhouse gas emissions, the amount of carbon released per unit of electricity production must fall 75 percent by 2050. This will require phasing out older, inefficient coal plants, and replacing them with a mixture of combined- cycle natural gas, nuclear, wind, geothermal, biomass, and solar power, steps that would lead to dramatic air quality improvements in many mega cities of the developing world. Carbon capture and storage technology – if it proves cost effective and can be developed in a reasonable time frame – would enable the continued use of coal. The transport sector – trucks, cars, buses, airplanes, cargoships, railroads – is overwhelmingly dependent on petroleum. Today, transport of goods and people is responsible for about 19 percent of carbon emissions. With the global car population forecast to soon exceed 1 billion vehicles, while growth in crude oil production is likely to end, dramatic increases in vehicle fuel efficiency can advance economic prosperity, energy security, and climate protection. Hybrid, plug-in hybrid, and all-electric vehicles, along with large investments in mass transit, are needed to reduce transport sector emissions in the long run, and to extend limited petroleum supplies. Residential and commercial buildings consume the bulk of the world's electricity and much of its natural gas. Improving the design of new buildings and retrofitting old ones can dramatically improve their energy performance. Many existing buildings can be made more efficient, and new buildings are actually capable of producing more energy than they consume

It takes energy to get energy, and the gathering, processing, and delivery of fossil fuels account for 8 percent of carbon emissions. Production of steel, cement, automobiles, and other manufactured products is responsible for about 20 percent of global carbon emissions. Improvements in the carbon intensity of these activities are possible, profitable, and necessary.



Carbon Foot print due to electrical energy consumption

Carbon Foot print is the amount of carbon dioxide released into the atmosphere as a result of the activities of a particular individual, organization, or community. In the case of cars or airplanes, this occurs directly in the combustion chamber of the engines and the associated emissions are known as direct emissions since they occur at the point of consumption. When we consume electricity, the emissions are indirect since they occur at the generation plant and not at the point of consumption. The amount of carbon dioxide generated by direct emissions can be calculated through the use of emission factors. An emission factors is the ratio of carbon dioxide generated for a given quantity of fuel. Carbon Footprint be can calculated by using data from CO2 Baseline Database for the Indian Power Sector, User Guide Version 10.0, Ministry of Power, Central Electricity Authority, Government of India).As per this document the emission factor is 0.82 t Co2/mWh

Carbon emissions Sector Wise in the Kerala State due to energy consumption

Category	Electrical energy Consumption (MU)/ year	Carbon emission Tonnes/year
Domestic	9942.28	8.15267
Commercial	1923.14	1.576975
LT Industrial	1103.23	0.904649
LT Others	2042.71	1.675022
HT/EHT& Bulk licensees	4312.514	3.536261
Total	**19323.874**	8.15267

From the above facts and figure it is evident that any reduction in energy consumption leads to reduction in carbon emissions. With ample scope of energy saving in various sector we can reduce the carbon emission through energy audits and implementation of the energy efficiency improvement projects.

Scope for CO2 Mitigation in Energy Sector

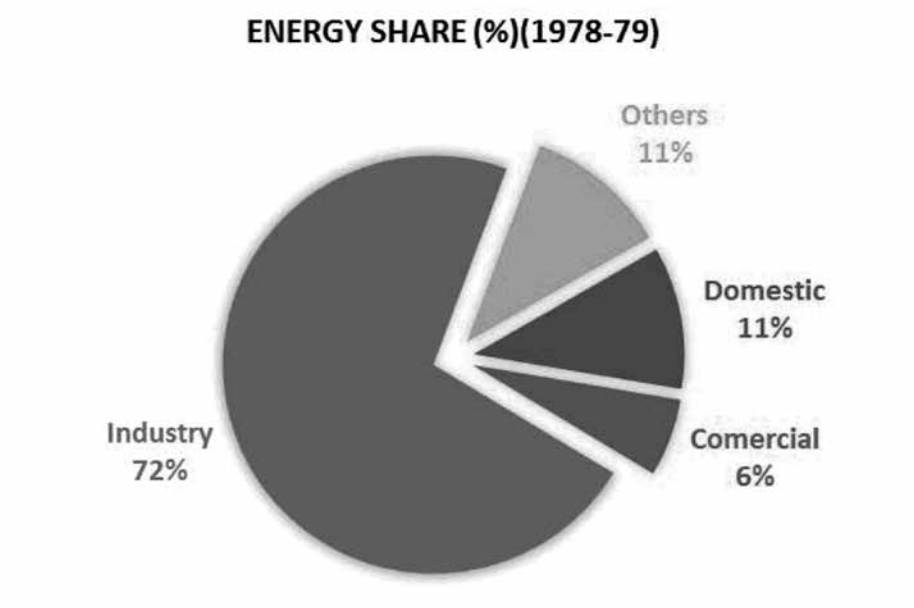
Energy sector continues as one of the major source of carbon foot print as the fossil fuel predominates the primary energy mix. The energy system of the future aims at increasing share of clean and green primary energy resource, highest efficiency in energy conservation process and lowest possible energy intensity in energy-using systems, process and appliances with energy efficient design, operation, maintenance and energy efficient technologies. Thus enhancement of energy efficiency followed by maximising the share renewable energy resources substantially contributes to climate change mitigation. So the following measures should be given the utmost importance in Co2 mitigation

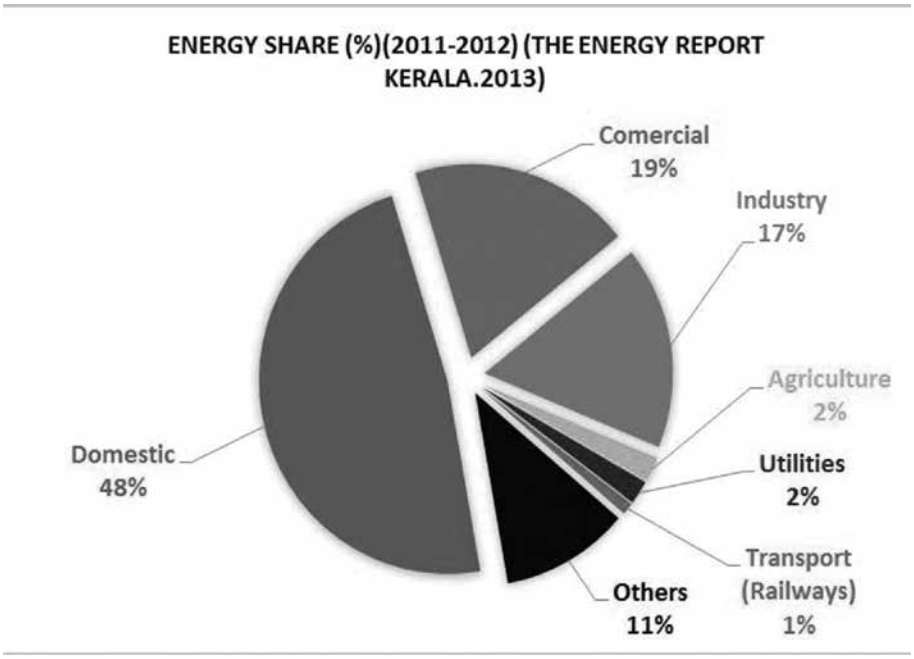
1. Energy Conservation and Energy efficiency
2. Harnessing renewable energy

Energy Conservation and Energy efficiency

Residential dwellings, individual or group such as flats, apartments, Commercial Builidngs, and Industries (Small, Medium and Large) etc. are prime consumers of energy in the state. The scope/potential of improving energy efficiency or implementing energy efficiency in this sector are enormous.

The change in energy share for the last three decades in Kerala is given below.





From the two pie chart shown it is clear that the contribution of domestic consumers were 11% in 1978 – 79 and it was 48 % in 2011- 12. This clearly shows that the contribution by domestic sector has increased by almost 78 % over the last 30 years.

These facts clearly indicate the importance of energy saving at domestic level i.e. mainly houses. Energy saving can be achieved through proper maintenance of equipment/appliances, installation of energy efficient fixtures, using star rated appliances and by proper housekeeping practices. There are good opportunities in Commercial and Industrial energy efficiency improvements as well

Energy Efficiency Paybacks

Over the years the cost of energy efficient equipment in all sectors become affordable and the paybacks from energy efficiency become more attractive. Now people realized the returns from energy efficiency in terms of reduced energy bills and improved performance of equipment. This leads to a direct impact in carbon mitigation too.

- Investment for energy efficiency retrofits become more affordable
- The cost of Energy become increasing.

The above said reasons are more influencing factors in better financial paybacks in energy efficiency investments.

Government Role

Government of India by implementing the Energy Conservation Act played a major role in increased energy efficiency in domestic sector. Bureau of Energy Efficiency through its Energy Star Labelling program influenced a lot to the consumers for

informed selection of energy efficient products. BEE even come up with mobile applications to help people for smart buying.

Apart from S&L program by BEE, the interventions of state governments in awareness creation in energy conservation made the consumes aware on the technology change and its role in energy efficiency. The works in the following area were really made an impact in the carbon mitigation.

1.1.1 Mandatory Energy Audits in all levels of consumers.

1.1.2 Technology interventions

1.2.3 Education, training and Awareness Programs

Mandatory Energy Audits in all levels of consumers

Based on Energy Efficiency activities in the State by EMC, Govt. of Kerala, Power Department has issued Govt. Order No. 2/2011/PD dtd. 1.1.2011 for conducting mandatory energy audit of all HT consumers. EMC Kerala has started conducting mandatory energy audit through their empanelled energy audit consultants since 2011.

The energy requirement of consumers of Kerala is met by the following electrical

Distribution licensee:

- Kerala State Electricity Board.
- Cochin Port Trust.(CPT)
- Kannan Devan Hills Plantations Company (P) Ltd.(KDHP)
- Technopark.
- Infopark.
- Rubber Park India (P) Ltd.
- KINESCO.
- Thrissur Corporation.
- Military Engineering Service
- Cochin Special Economic Zone Authority

The total HT consumer in Kerala is around is 5000 as per the data collected from various licensees. On categorizingit is found that there are 75 HT consumer categories and the major consumers are Govt. Departments (Centre & State), HT Industries, Commercial Establishments (Hotels,Malls, Cinema Theatre) , Govt. Hospitals, Education Institutions etc .

EMC has received around 290 energy audit reports till 2017 which accounts for 6% of HT / EHT consumers.

As per the study conducted by Energy management center in association with NPC Chennai the savings potential that can be achieved through energy audits and energy efficiency improvement projects is about 10-15% in industries and in commercial establishments is about 20-30%.

This indicates that once the savings is realized this will directly reduce the carbon emission due to energy usage -.For example in case of industrial sector the total

carbon emission due to energy usage is 3.5 tonnes per year (refer table 1) so an energy savings of 15% means a reduction of 0.5 tonnes of Co2 reduction .

Challenges in Energy Audits

- Unclear process and plant energy System.
- Lack of top official commitment in energy audits and energy efficiency improvement projects.
- Lack of monitoring and analysis of energy usage.
- Meager fund provisions for energy efficiency improvement projects.
- Lack of confidence in new and energy efficient technologies.
- Lack of Awareness.

Initiatives by EMC to increase the reach of energy Audits.

1. Energy Audit Subsidy Scheme (EAS)

Energy Management Centre Kerala is giving financial assistance as subsidy to Public Sector Undertakings/Government buildings, excluding Designated Consumers, for conducting energy audit

2. Walk-Through Energy Audit Scheme

This scheme is aiming for preliminary energy audit / Walk-though energy audit in Low Tension (LT) consumers. This category may include State and Central Public Sector Undertakings, State Government and Central Government Institutions and Government funded firms, BSNL telephone exchanges/ Buildings, Cooperative sector, Small Scale Industries, Cluster etc.

3. Investment grade energy Audit

EMC has conducted Investment Grade Energy Audit in 30 public buildings and implemented the audit findings in about ten public buildings; and promote implementation of Energy Audit findings in the case of other consumers

4. Empanelment of energy Auditing Firms and report evalution

For conducting energy audit, EMC empanelled 38 energy audit firms till date. EMC has published an energy audit manual as a guide line to conduct the energy audit EMC is regularly evaluating the quality of Energy Audit jointly with the auditor and client.

5. Energy efficiency financing scheme through Kerala financial corporation.

Provides loans to implement energy savings project at a low rate.

Technology interventions

The Objectives of Standards & Labelling Program is to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment. This is expected to impact the

energy savings in the medium and long run while at the same time it will position domestic industry to compete in such markets where norms for energy efficiency are mandatory.

Government of India has developed this scheme for energy efficiency labelling of equipment, i.e. Standards & Labelling Program (S & L Program) under clause (b) and (d) of Section 14 of the Energy Conservation Act 2001 (Central Act 52 of 2001). The scheme was launched to display labels on specified appliances or equipment notified by Government of India from time to time under. Section 14 (c)of EC Act 2001 provides the power to enforce minimum efficiency standards by prohibiting manufacture, sale and import of products not meeting the minimum standards. The BEE Standards & Labelling (S&L) scheme was launched in 2006. The labelled products started to appear in the markets in February –March 2007.

The list of appliances covered under BEE star labelling programme is shown below

Sl no	**Star labelled Appliances Mandatory Scheme**	**Sl no**	**Star labelled Appliances Voluntary scheme**
1	Room air conditioners	1	Induction motors
2	Tubular Fluorescent Lamps	2	Agricultural Pump sets
3	Frost Free Refrigerator	3	Ceiling fans
4	Distribution Transformers	4	Washing machine
5	Direct Cool refrigerator	5	Computers (Laptops / Notebooks)
6	Cassette & Floor Standing Air conditioners	6	Ballast
7	Electric Geyser	7	Office equipments (Printer, Copier, Scanner, MFD's).
8	Colour television	8	LPG Gas stoves
		9	Diesel Engine Driven Monoset Pumps for Agricultural Purposes
		10	Diesel Generator
		11	Solid State Inverters
		12	Variable Capacity Air Conditioners
		13	LED Lamps

The efficiency levels and rating are not static at any time. Manufacturers also seriously participate in the S&L program and compete in the market with better and better products, year after year.

As the time goes the efficiency levels get uprated. A Five Star in previous years may be downgraded to Four Star or lower due to constant, continuous energy efficiency

improvement mandates. Also the products under the voluntary scheme become mandatory after a stipulated time as notified the Bureau of energy efficiency.

Analysis based on survey in the State of Kerala indicates that in the new procurement, Star Labelled equipment's have penetrated over 60% of the market; and over 70% in the case of Refrigerators and Air-conditioners

Education, training and Awareness Programs

a. Smart Energy Programme

As a part of inculcating Energy Conservation among school children, EMC started a new programme titled 'Smart Energy Program (SEP)' in 2014. This scheme is made operational in all the 41 education districts(ED) spread over 14 revenue districts of the state. EMC has selected District Coordinators for each revenue district and joint coordinators for each educational district selected by respective District Coordinators. Smart energy Programme in 2015-16, EMC has enrolled 1523 schools with 62,400 students. SEP Technical programme is also launched for engineering colleges and management institutions, which include capacity building, projects and research activities

b. Urja Kiran

"Urja Kiran" program is an energy conservation awareness campaign for general public which comes under the Public Awareness Scheme of EMC. The objective of the program is to create awareness on the importance of energy efficiency and energy conservation among the general public of Kerala. The program is conducted through NGOs and Govt. Academic/R&D institutions (other than schools) in Kerala. Centre for Environment and Development (CED) was appointed as the Resource Agency (RA) to coordinate and monitor the activities of Participating Agencies (PA).About 200 programs were conducted covering all the 140 Legislative Assembly Constituencies in Kerala in 2015-16

c. Kerala State Energy Conservation Award & Energy Conservation month and day celebrations

To promote energy conservation efforts in the State in all sectors, State Level energy conservation awards in the categories of Large Scale energy consumers, Medium Scale energy consumers, Small scale energy consumers, Buildings, Individuals and Institutions & Organizations are operated by EMC since its inception. This is sandwiched with sensitisation campaign, Industrial Energy Conservation Awareness Program, visit to the facilities of Energy Conservation Award Winners and Publication of best practices Souvenir

d. EnergyClinic by women volunteers (EC)

Energy Clinic (EC) is a high impact programme of EMC for energy conservation activities in the domestic sector through women as agents. EMC trained 420 women volunteers in all the 14 districts conducted about 760 "energy clinics" wherein over 11400 house were covered in the last year and extensive house visits were also carried out. This imparts very interesting and informative interactions and inculcate

energy efficient life style, procurement of energy efficient appliances and adopt energy efficient best practices.

Energy savings realized by EMC as a result of various energy efficiency and conservation activities of all stakeholders in the State from 2003 to 2015.

Year	ELECTRICAL ENERGY SAVING		Oil Savings MT/yr	Coal Saving MT/yr
	MU/Year	Equivalent avoided Capacity (MW)		
2015	225.34	24.69	9610	
2014	282	53.6	41233	5920
2013	174	33.1	18318	5500
2012	152	28.9	4368	9976
2011	+584.1871	111.14	8012.51	2800
2010	*123.52	+25	13263.63	4554
2009	**449.72	85	18862.42	4000
2008	29.68	5.65	37000	3560
2007	59.735	11.34	1303.87	0
2006	40.00	7.61	6665	2870
2005	23.52	4.48	850	0
2004	12.82	2.44	3170	5558
2003	32.32	6.15	8169	6433
Total	2188.8421	399.1	170825.4	45251

CO2 Mitigation:1.72 million Tonnes (*As per CEA 0.82 kg CO2 per kWh*)

Case Study for Energy Efficiency Improvement and CO2 Mitigation

Case 1: Carbon foot print estimation; A pilot Study At Government secretariat Trivandrum

The study was conducted to assess of carbon emissions from the use of energy, water and other resources and disposal of wastes in Secretariat Complex, Thiruvananthapuram and to establish the possibility of technologically viable alternatives having multi-disciplinary dimensions to optimize the use of resources and minimize /reuse the wastes thus achieving carbon emission reduction inter alias leading to a carbon neutral campus

Component of study	**Present carbon foot print**	**How much Reduction in carbon foot print is possible through proposed activity**
Energy Audit	1821.3 Tonne CO2 /year	972.5 Tonne CO2/year
Transportation Mapping	343.48 Tonnes/year.	223.26 Tonnes/year
Water Balance	13695243.5 m^3/year	50662.2 m3/year

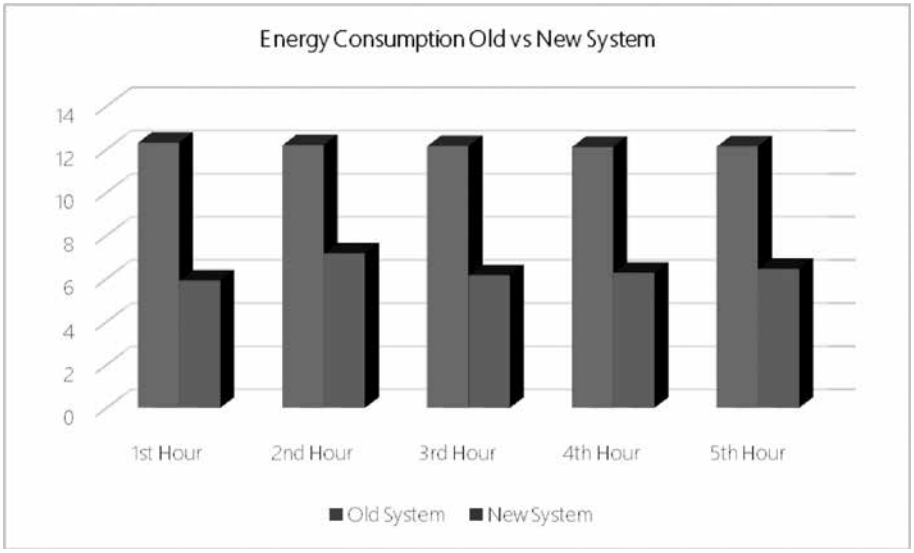
Waste Management	55 Tonnes/year CO_2	48.4 tonnes/year CO_2
Biodiversity	0.796 Tonnes/year CO_2 reduction by existing plants	1kg/year CO_2 reduction is possible by every 2 kg of dry biomass of newly planted trees

Case2: Installation of Variable Speed Pressure Booster Station for Chilled Water Circulation at a Dairy

The objective is to shut off unnecessary pumps or to reduce the load of an individual pump based in the Water Demand. Automatic controls enable pumping systems to be started and stopped relatively quickly and accurately and reduce the required labour with respect to traditional control systems.

The energy consumption system before and after installation were and found that the old system for 5 hours consumed 60.893KWh and the new system consumed 31.94 KWh for 5hrs. that is, the energy consumption is halved.

Sl No	Time	New System	Old System
1	1st Hour	5.91 KWh	12.299 KWh
2	2nd Hour	7.16 KWh	12.194 KWh
3	3rd Hour	6.15 KWh	12.152 KWh
4	4th Hour	6.27 KWh	12.116 KWh
5	5th Hour	6.45 KWh	12.132 KWh
Total 5 Hrs Consumption		**31.94 KWh**	**60.893KWh**



Renewable Energy

Energy produced from thermal power plants by burning fossil fuels leads to release of carbon dioxide (CO2) and other gases this contribute to the "green house" effect which cause global climate changes. Renewable energy sources mainly wind, small hydro, biomass and solar photovoltaic (SPY) etc. are the most suitable means to achieve the mitigation of CO2 emission.

Kerala's major portion of renewable energy potential remains unexplored and government is taking more attention in utilising this potential.

Challenges

There are associated challenges in these activates like

1. Adaptation of new technologies
2. Pricing of energy efficiency products
3. Problem of E-waste or solid waste management
4. Existing Energy Pricing and Government Policies.
5. Effect on Power System Quality
6. Effecton Grid system stability

CONCLUSION

Energy efficiency is crucial in climate change mitigation and the key to achieve energy efficiency is through framing policies that promotes the end use energy efficiency through technological interventions and through awareness and behavioural changes.

The efficient use of equipment matter if we want to realize the savings in terms of energy, money or environment (CO_2). Even if one have a high end energy efficient equipment and if it is not used efficiently it cannot be realized. So the major thrust has to be given to change the operational behaviour of the user along with penetrating more and more energy efficient technologies followed by maximising renewable energy mix in the State.

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ABSTRACT OF
YOUNG SCIENTIST AWARD PAPERS

Oral Presentations

Nutrient Management through Customization for Elephant Foot Yam in Two Agro Ecological Units of Kerala

Anju P.S.[1], Susan John K.[1]*, S. Bhadraray[2], Suja G.[1] and Jeena Mathew[3]
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Balanced application of nutrients is one of the essential crop production approaches not only to increase the agricultural productivity but also to safeguard the environment. Nutrient customization is a new tool in nutrient management which satisfies the crops' nutritional demands, specific to the area, soil and plant growth. Customized fertilizers are multi nutrient carriers containing macro, secondary and micronutrients, formulated through a specific systematic process of granulation so that each granule of the fertilizer contain the specific grade of all nutrients in the mixture. *Amorphophallus paeoniifolius* (Dennst). Nicolson commonly known as Elephant foot yam (EFY) is a highly potential tropical tuber crop of Araceae family and is an ideal intercrop in coconut gardens of Kerala. It is highly responsive to fertilizers and manures and provides reasonably good profit as an intercrop. The blanket recommendation of EFY is standardised as NPK @ 100:50:150 kg ha^{-1} along with 25 t ha^{-1} FYM. As there is no systematic fertilizer management strategy in place for the crop, there is widespread occurrence of nutrient deficiencies especially that of secondary and micronutrients. Since customized/designed fertilizers are specific to crops and soils, and are becoming popular nowadays, this study was planned to develop a customized fertilizer formulation for EFY intercropped in coconut gardens of the two agro ecological units (AEU's) of Kerala viz., AEU3 (Onattukara sandy Plain) comprising of 43 panchayats of two districts and AEU 9 (South central laterites) comprising of 161 panchayats of the five districts of Kerala where EFY is an important commercial tuberous vegetable.

The methodology for the evolution of the customized fertilizer formulation started with the building up of crop and soil database of the EFY growing regions. The secondary data on soil nutrient availability of the selected AEU's was obtained from the Kerala State Planning Board (KSPB) project soil database which inturn was used to arrive at soil test based fertilizer (STBF) rate and then the weighted average data of all the nutrients with respect to area of each panchayats. Nutrient omission plot technique and nutrient level experiments were conducted during the the first year and arrived at the optimum nutrient status of all nutrients based on the tuber yield data. The survey conducted among 72 farmers on the rate and mode of application of manures and fertilizers helped in finalizing the rate of application of the designed

custom made fertilizer @ 10- 15 bags ha^{-1} (500-750 kg ha^{-1}) to match with the present application rate of farmers for EFY. From the data collected, the grades of the fertilizer mixture for the two AEU's were arrived using two approaches viz., soil test crop response (STCR) and response curve (RC). In the STCR approach, for an yield target of 45 t ha^{-1}, the nutrient requirement (NR) (kg nutrient taken up for every ton of tuber), nutrient uptake, total soil nutrient availability (inclusive of soil innate nutrient supply and those applied through manures and fertilizers), percentage contribution from soil and fertilizer, fertilizer use efficiency in terms of N, P, K was arrived. The final grade of CF (application rate of 500 kg ha^{-1}) for EFY intercropped in coconut gardens based on STCR approach for an yield target of 45 t ha^{-1} was N: P_2O_5: K_2O: Mg: Zn: B as 8:11:21:3.5:1:0.3 for AEU 3 and 7:12:24:2.5:1.3:0.4 for AEU 9. The response curve (levels of each nutrient versus tuber yield) for an application rate of 500 kg ha^{-1} was developed as N, P_2O_5, K_2O, Mg, Zn, B @ 6:3: 30: 3.5: 0.8: 0.3% respectively for AEU 3 and for AEU 9, the grades were 7: 3: 25: 4: 1.25: 0.4%. In arriving at the four different grades of the CF, the manufacturing tips for better granulation of the product like N: P ratio, percentage of steam and filler, type of P fertilizer, DAP: TSP ratio, percentage share of K fertilizer are taken into consideration. Three grades of CF as CF1 (STCR AEU 3), CF 2 (STCR AEU 9), CF3 (RC AEU 9) were tested at two rates as 500 and 625 kg ha^{-1} during 2016-17 in three locations in AEU 9 and one location in AEU 3 with 8 treatments including PoP and farmer's practice. The tuber yield data indicated all the three CF grades were on par at 625 kg ha^{-1} and was significantly superior to the three CF's at 500 kg ha^{-1}.

To find out the best CF grade among the three, experiments were laid out in Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam and Ernakulam districts and is in progress. Though this concept is a new one, it is considered as a holistic solution for the present imbalanced and improper nutrient management strategies. Since this approach involves pro active soil and plant tissue testing, inclusion of all the required nutrients specific to soil and crop in the required proportion and involvement of advanced scientific principle in the development of the fertilizer, it will improve crop and soil productivity, tuber quality, increase profit with better nutrient use efficiency.

Hurdles of Using Natural Coagulants with reference to Dissolved Organics

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Changing climatic conditions affect the life and resources on earth in many ways. One of which is reduction in the availability of potable water. Adaptations to climate change have become one of the utmost required issues to be focused on in the present scenario. Tapping Indigenous knowledge will be the best method for adapting to climate change. Native technologies offer advantages of low cost, immediate availability, biodegradability and overall adaptability. The present study has been taken up in the above lines using natural coagulants sago and chitin for removing turbidity of surface water making it fit for consumption. Till date, most of the research has been concentrated on the coagulant efficiencies in synthetic water, but in this study, we have put our efforts towards testing the efficiency of the natural coagulants on surface water principally focusing on the total organic content in the waters treated with these coagulants. The experiments were carried out using a conventional jar test apparatus. Steps included were Preparation of Synthetic Turbid water samples and testing the efficiency of coagulants on synthetic turbid waters followed by collection of surface water samples for testing of coagulants efficiency. The results showed that the turbidity removal was 50% to 84% in the supernatant and 77% to 85% in the filtrate. Removal of other physico-chemical parameters was also observed to be more than 50% using the above coagulants. Results from these experiments have shown a precise inclination of amplified concentration of suspended solids in the settled sludge with growing concentration of the coagulant by all the three coagulants whereas the reduction in turbidity was contrary, i.e it increased with decreasing dosage (4.81, 6.08 and 6.48mg/l with alum, sago and chitin respectively). Turbidity removal efficiency of tested natural coagulants has been proved previously in studies conducted by various authors. Parameters like total settled sludge (wet & dry) and organic content were ignored which are one of the governing factors in disposal of sludge & for further characterization and management. Hence, it can be concluded that using natural coagulants will definitely provide safe drinking water along with aiding in adaptability in changing climatic conditions.

Anaerobic Digestion of Food Waste through Dry Digestion in Field Scale Units

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Anaerobic digestion (biomethanation) of waste food is a sustainable way of managing it where high value biogas (energy) and manure can be recovered. The conventional, vertical digesters are adopted extensively for at household and commercial levels. There are inherent problems with conventional digesters and these units often encounter failure. The solid loading (total solid) in these unit are <10 Kg/M3/D. To address the inherent problems and drawbacks of conventional digesters, a high solid loading (>20 Kg/M3/D) digester that works without any water addition (Dry digestion) is developed, and three units operational in field for the last eight months. Objective of this paper is to analyze the overall performance of these units in terms of waste treatment and biogas yield.

The field digesters were of 2000 l capacity with 1,750L working volume. Horizontal barrel shape, very compact. Mechanically crushed food waste without any additional water will be introduced through one end of the digester and the slurry will be collected through the other end. The solid retention time of the digester was around 40 days at 40 Kg wet food waste/day loading. The organic loading rate (OLR) will be around 5.2 Kg volatile solid/M3.D, equivalent to ~6.5 Kg COD M3/D. The food waste and sludge are slowly mixed mechanically to ensure more effective microbial action and stabilization of the waste.

The average biogas yield of the unit was 150-170 Lit/Kg wet food waste with an average >60% methane content. The volatile solid removal was around 90% ensuring complete stabilization of the food waste. The volume of slurry out is comparatively less (~80% of inlet volume) thick with ideal NPK ratio that can be used directly as manure. The compact size (less foot print even for large units), water less operation, it can treat any food waste (egg shell, lemon, onion peel etc.), high biogas yield, without any mosquito issue, portable nature, etc. offer high advantages over the existing vertical units and will be a better substitute. The performance of the field units are highly encouraging.

An Integrated Bio-Physical Process for Generating Potable Water from Rocket Fuel Contaminated Groundwater

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Perchlorate (rocket fuel) is a toxic oxyanion (ClO_4^-) and emerging groundwater contaminant reported to cause hypothyroidism. Perchlorate contamination of ground water was reported from few countries including India. Recently severe groundwater contamination of this chemical (~50,000 mg/L against US EPA guideline of 15 mg/L) was reported around bulk perchlorate handling sites in Kerala. In connection, a higher incidence of hypothyroidism (>70% higher than normal) was observed among people exposed to perchlorate contained drinking water in Keezhmad panchayat, Ernakulam district. In India, though severe groundwater contamination of perchlorate reported with incidence of thyroid dysfunction (Keezhmad project report, 2015), no technological intervention attempted or reported so far to address the problem. Currently, the community in the affected region is provided with alternate drinking water, which is not a sustainable solution. Being a persistent pollutant with half-life of ~100 years, lack of perchlorate decontamination can also lead to its widespread ground water contamination at dangerous level. In this scenario, an ex-situ biophysical process was developed for generating potable water by treating ClO_4^-contaminated ground water.

In the process developed, ClO_4^- was initially biodegraded into chloride and oxygen in an Anaerobic Fixed film Bioreactor (AFBR), dominated with an isolated perchlorate degrading bacterium, *Serratia marcescens*. This bacterium expresses two enzymes that sequentially reduce perchlorate into chloride and oxygen. The bio-treated water is subsequently passed through a microfiltration (MF) unit followed by a reverse osmosis (RO) unit (max 50 psig) to produce potable quality water. Back washing techniques were adopted to prevent membrane biofouling.

The concentration of perchlorate selected in this pilot scale study was 15,000 mg/L (15 mg/L), which is similar to actual field values present in the community well water at Kulakkad colony in Keezhmad, Ernakulam. The AFBR reduced perchlorate from 15 mg/L to 0.4±0.35mg/L (97%). The BOD, COD and TDS content of the treated water was 85 mg/L, 300 mg/L and 400 mg/L respectively. The average ORP inside the reactor was maintained above ⁻100 mV. The bacterial load in the treated water from AFBR was ~10^7 CFU/ml. After passing through the MF unit, the bacterial load diminished to 200 CFU/mL with a 50% further reduction in BOD and COD values.

The final RO unit completely removed microbial cells, BOD, COD, and the TDS was brought down to <25 mg/L. The perchlorate concentration in the final product was <10mg/L and which was within the permissible limit of drinking water standards by US EPA. The MF reject and backwash along with RO reject and backwash (all contain perchlorate) was sent to AFBR again for degrading the toxic perchlorate and ultimately there were no discharges containing perchlorate from this process.The pilot-scale integrated treatment unit produced ~200 L potable water per day.

The integrated Bio-MF/RO assembly developed effectively treated perchlorate contaminated ground water and generated drinking water meeting the standard. Being a zero discharge process, there is no need of secondary treatment. The small scale units will be ideal for individual houses in the affected areas, whereas large scale units can generate enough drinking water for large community. Installation and continuous operation of this system will gradually remove the perchlorate in ground water in affected area that will help in further spreading of the contaminant and thus ensuring environmental safety and public health. This unit will find direct application at places like Keezhmad (Ernakulam dist.) and Veli (Thiruvananthapuram) in Kerala and Sivakasi in Tamilnadu and similar places where severe ground water contamination of perchlorate was reported. Moreover, the process can be adopted for treating similar contaminants like chlorate, chlorite and nitrate.

Strategies to Mobilize Soil Iron for Minimising Iron Deficiency Chlorosis of Soybean (Glycine max (L.) Merr.) Under Ambient and Elevated CO_2 and Temperature Conditions

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The research was envisaged for the effective management of growth limiting nutritional stress *viz*. iron deficiency chlorosis (IDC) of soybean for successful crop production. The cost-effective mean for efficient management of nutrient stress is the use of iron efficient and responsive genotypes. In the first experiment, we have screened 50 genotypes of soybean for iron efficiency using hydroponics. Based on iron stress susceptibility index (FeSSI), we have categorised 50 genotypes of soybean into; Iron efficient and responsive (FeER), Iron efficient and nonresponsive (FeENR), Iron inefficient and responsive (FeIR) and Iron inefficient and nonresponsive (FeINR). JAVA-16, MONETA, KALITUR and EC-114526 were representative genotype for each category, respectively. Further, the efficiency of genotype was verified by cluster analysis using relative C-14 exudation with relative chlorophyll content. The ancillary observations revealed that relative abundance of oxalic (6.3 fold) and citric (4.2 fold) acid in the root exudate of efficient genotypes under iron stress condition. In the second experiment, we have conducted a pot culture study with soybean as test crop in the glass house of National Phytotron Facility. In resonance with FeER genotype, we have evaluated the effectiveness of the by-product from the sugar industry, Sulphitation Press Mud (SPM), as an amendment in soil with various microbial combinations for mobilizing soil iron and to minimise iron deficiency chlorosis (IDC). Among the twelve specific treatments evaluated, the treatment combination FeER + 50% Fe as $FeSO_4$ + SPM (*Aspergillus niger*) + AMF can be considered as the best. This is because of the combined effect of low molecular organic acid produced by *Aspergillus niger* through decomposition of SPM, and by virtue of the efficient genotype to secrete citric and oxalic acid. Further, the application of composite culture of AMF (*Glomus mosseae* and *Glomus fasciculatum*) increases the exploited soil volume, and facilitate better absorption of the nutrient. A futuristic study has been carried out in the third experiment. With the help of plant growth chambers, we have evaluated the interactive effect of a set of treatments with the ambient and elevated CO_2 and temperature conditions. As compared to the ambient CO_2 and temperature condition (a-[CO_2+T]), higher partial pressure of CO_2 (Pco_2) under elevated CO_2 and temperature (e-[CO_2+T]) condition, dissolves native $CaCO_3$ from calcareous vertisol soil and thereby induce greater HCO_3^- ion activity.

The antagonistic interaction between Fe^{2+} with HCO_3^- ion results in greater iron stress under e-[CO_2+T] condition. Soybean grown under e-[CO_2+T] condition matures 12 days earlier than a-[CO_2+T] condition because of the influence of temperature. We also found that Accumulated Growing Degree Days (AGDD) is significantly influenced by the genotype x environment (G x E) interaction and not by genotype x treatments (G x T). The genotype FeIR could be more susceptible to the temperature stress (10.3% more AGDD) than FeER. It was also observed that the yield under both ambient and elevated [CO_2+T] condition does not differ significantly. To combat the constraints in Fe nutrition, especially under e-[CO_2+T], the iron efficient genotype of soybean exude more amount of low molecular weight organic acids. Furthermore, ferric chelate reductase (FCR) activity gets reduced by e-[CO_2+T] through the influence of HCO_3^- ion. The study points out the need to adopt an integrated approach for the management of nutritional stress, especially under climate change scenario. Use of iron efficient and responsive genotypes, continuous supply of organic matter along with microbial inoculation could address the constraints of nutrient stress. The present study suggests that the combined application partly decomposed SPM with *Aspergillus niger* and mixed culture of AMF (*G. mosseae* and *G. fasciculatum*) was more effective than *Piriformospora indica* in mobilizing iron from soil to plant. This can be potentially exploited as better bioinoculant to enhance the IDC tolerance of soybean plants in calcareous soil. Under a-[CO_2+T] condition, the treatment combination of FeER + 50% Fe as $FeSO_4$ + SPM+ AMF can be considered as the best. The antagonistic interaction between Fe^{2+} with HCO_3^- ion, under e-[CO_2+T] results in greater iron stress, compels to modify the treatment as FeER + 65% Fe as $FeSO_4$ + SPM + AMF. To conclude, although our study concentrated one complete crop cycle, it clearly shows that increase in CO_2 and temperature could adversely impact plant nutrition.

Biomethanation of Water Hyacinth Biomass: Challenges and Solutions, an Experimental Approach

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The luxuriant growth of water hyacinth (WH) in eutrophic water bodies is a serious problem, impacting badly the socio-economics in tropical and sub-tropical countries. The proliferation of aquatic weed causes interference with or prohibits recreational activities such as swimming, fishing, and boating. Blockage of irrigation canals, and culverts, causing water to back up and further leads to odour issues. The possible method of controlling the proliferation of aquatic weed is only by the mechanical removal of plants.Valorization of harvested biomass in terms of biomass conversion; livestock feed, land use or for production of bio-ethanol or paper can accelerates the process of aquatic restoration. Among the value added products extracted, biomethanation of the plants for biogas production is often reported as a promising approach for the utilization of the biomass. However, the lower solid content and continuous availability of the biomass are inherent problems with this approach. The present study tries to address these practical problems through practical approaches like increasing the solid content, preservation of the biomass and co-digestion to increase the biogas yield.

The period of maximum proliferation of the plants was identified using geographical information tools and this information was used for quantifying the biomass yield and fixing the WH harvesting period which is pre-monsoon and post monsoon period. To increase the solid content of the biomass, simple and inexpensive method of wilting was proposed. Increasing the solid content to 20%−30% through partial sun drying for 4 to 6 hours has increased biogas production by 13 % during batch digestion. The harvested biomass will be preserved by ensilation approach, for ensuring continuous feed for the reactor. A two stage anaerobic bio-methanation system (UASB coupled ALBR) was used for digestion of WH biomass and ~8 L per kg of wet weight of biomass with 68 % methane content was obtained. Co-digestion of WH biomass with commonly available substrates like STP waste sludge and waste food was also tried to increase the biogas yield and ~150 ml and ~400 ml biogas/gm VS was obtained respectively against ~140 ml/g VS of WH biomass alone.

This study reveals that inexpensive pre-treatment like sun wilting and simple anaerobic preservation technique like ensilation and co-digestion with low cost and easily available substrates like waste aerobic sludge or food waste can make biomethanation of WH more feasible, which in turn encourages the usage of the noxious weed for sustainable energy production.

Avian Feathers as Non-Invasive Bio-Monitoring Tool for Heavy Metal Pollution: A Case Study

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Urbanisation and technological development by humans has directly influenced its impact on the natural environment. Humans including all other living organisms are at great risk due to the presence of pollutants which also includes heavy metals. Heavy metals are potentially harmful to most organisms at some level of exposure and absorption. Despite of control measures, the entry of heavy metals into our environment is inevitable. Various natural and anthropogenic sources have continued to pollute our environment over time leading to omnipresence of heavy metals. One of the fastest and technically advanced methods which can be employed to assess the impact of the pollutants on organisms includes the use of biomonitors. This technique indulges the use of living organisms to measure the concentration of pollutants and their adverse effects on organisms and ecosystems. Birds can act as useful biomonitors for a number of reasons which includes their seasonal availability; hierarchy in the food chain and yield information over a vast geographical area because of their feeding habit and foraging activities. Being top level predators of the food web, water birds, seabirds, raptors are susceptible to bioaccumulation of a wide range of metals. They can be used to monitor toxic pollutants that are amplified in concentration up the trophic levels. As birds tend to deposit heavy metals in their feathers externally during flight and internally during their growth and development, hence, it makes avian feathers an excellent tool for biomonitoring. Birds can get rid of heavy metals through excretion of faeces or by depositing them in the uropygial gland, salt gland and feathers. Several studies have conducted on internal tissues and involved invasive methods, but the number of studies making use of non-destructive methods, like measuring the concentrations in feathers, faeces and eggs, has increased over the past years. Feathers are basically keratinaceous structures that provide protection, thermoregulation, enable flight, as well as decoration necessary for species recognition, camouflage, aggression, and mating. At the same time, they can be used as useful tools to monitor exposure to heavy metals. During moulting, birds are known to excrete heavy metals into growing feathers and these metals might get bonded to the keratin structure. After feather formation, the blood supply atrophies and the feather becomes completely isolated from the rest of the body. As a consequence the accumulation of heavy

metals from the bloodstream into the feathers is therefore eliminated. Feathers thus contain information about circulating heavy metal concentrations in the blood at the time of their development. Moreover, the collection of feathers can be easily carried and can be stored at room temperature and a small number can be removed without causing enduring damage. In the present study, Crow (*Corvus splendens*) feathers bird feathers were collected opportunistically from different areas based on their availability in order to determine presence of certain heavy metals (Pb, As, Ni). The concentrations of the heavy metals recorded in the present study suggested that feathers can be considered as an indicator of heavy metal contamination in birds.

ABSTRACT OF
YOUNG SCIENTIST AWARD PAPERS

Poster Presentations

Studies on Coir Pith as an Adsorbent in Pollutant Removal from Waste Water

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Water pollution control is presently one of the major thrust areas of scientific research. While coloured organic compounds generally impart only a minor fraction of the organic load to waste waters, their colour renders them aesthetically unacceptable. In India, textile industry ranks first among other industries in the usage of dyes for the colouration of fibre. However, a variety of synthetic dye stuff released by the textile industry has been posing a threat to safety of the environment due to the presence of a large number of toxic contaminants such as acids, organic waste, base and organic pollutants. It was observed that about 30-50L of the textile effluent is generated per kg of cloth produced. Dyes are extremely coloured substances which attach themselves to fabrics or surface shells to impart colour. The occupational exposure of workers in the textile industry is linked to a higher bladder cancer risk, cause allergies such as contact dermatitis and respiratory diseases, allergic reaction in eyes, skin irritation and irritation to mucous membrane and upper respiratory tract. Hence decolourisation of dye effluent has become an important aspect of waste water treatment.

The conventional methods of removing dyes include coagulation, flocculation, oxidation, electrochemical destruction, membrane filtration, ion exchange etc. The disadvantages of using conventional methods is that they are expensive and also produce large quantities of toxic sludge. All these shortcomings are overcome by using adsorption technology. Adsorption is the separation of a substance from one phase accompanied by its accumulation or concentration at the surface of another.

In this the adsorbent used was Coir pith. Coir pith is the byproduct gained during extraction of coir fibre from coconut husk. It is biodegradable and ecofriendly and it is purely a natural organic product. It is free from any admixtured heavy metals. Coir pith is a lignocellulosic residue. Coir pith being easily available and cheap, provides wide opportunities in waste water purification processes.

The presence of dyes in water makes it undesirable to drink, reduces photosynthesis, makes it difficult to treat, toxic, mutagenic and carcinogenic. This study investigates the potential use of coir pith to remove dye. It involves the use of two commercial synthetic dyes i.e, crystal violet and reactive orange 16. The effect of different

parameters such as agitation time, pH, adsorbent dosage, initial dye concentration and agitation speed were studied and the effectiveness of this method to remove the dye solution was determined by measuring the percentage of colour removal. Results showed that for coir pith,a color removal of 98.46% was obtained for crystal violet. There was no significant color removal for reactive orange 16 by using coir pith because its structure is not an easily biodegradable due to the presence of azo bond in the structure. Use of pretreated coir pith should be explored for better color removal of reactive orange 16. In order to widen the applicability of both the adsorbent, it must be tested using real textile wastewater.

Environment Impact Assessment for a Precast Manufacturing Plant: Impact Assessment, Impact Prediction and Environmental Management Plan

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Precast concrete is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted to places. India is a developing country and there is a need for faster and environmentally friendly construction activities. Many developed countries have overcome this problem by adopting the precast concrete technology. Although precast manufacturing is being adopted in India, but limited to civil structures like tunnels, bridges, flyovers and underpass. The adaptation of precast manufacturing in the urban housing is a new concept and can bring major changes in construction industry of our country. The use of precast manufacturing facility offers many advantages such as fast, reliable, consistent quality construction, enhanced health conditions and safety. The present study aims in developing a precast facility which will be economical and environmental friendly. Environmental Impact Assessment (EIA) is the most universally approved technique which identifies the impacts, predicts impacts due to the proposed activity, delineate management plans to mitigate / minimize the impact. For the proposed plant, an area of 17.5 acres, in an industrial park has been allocated and the site selection was done by using various geographical tools to check the impacts over an urban area. The proposed design for the manufacturing unit was made by GIS tools and the plan made accordingly so that the energy consumption is minimized and at the same time the available land area was utilized effectively in line with the landuse pattern. The main aim of the study was to propose a plan for sustainable operation of the plant with minimum environmental impacts and cost-effectiveness. Primarily through desk research, we identified the various infrastructures and machinery used in a precast facility and also checked what could be the impacts contributed by each activity.The ready mixed concrete plants may discharge highly alkaline wastewater, emit fine particles into the atmosphere and be a source of noise pollution. It is important that appropriate safeguards are put in place to ensure sustainable growth and make sure that the related environmental concerns (related to water, air/noise, and land) are appropriately managed.The baseline of the study area was established by analyzing the present water, air, noise quality of the area. After the establishment of a baseline, the next step employed was the impact assessment using an impact prediction tool

i.e, Battelle Environmental Evaluation System. A checklist of anticipated impacts was created and analyzed and the EIU was calculated using the values. The parameters have been classified as Environmental Pollution, Ecology, Aesthetics and Human Interest. Each parameter has been analyzed with Environmental Management plan and without Environmental Management Plan. This impact assessment shows the importance of the project and its contribution to the society. After the impact assessment, a proper Environmental Management Plan was formulated by assessing the impact parameters. The conclusions drawn from the present study shows that major impact during operation phase will be on water quality and noise quality. Water will be polluted by the process water coming out of the factory and huge amount of noise will be generated during the operation of machinery. The study revealed that this noise will have a significant impact inside the factory. These two major impacts can be minimized by adopting measures such as usage of reclaimers in a factory for the reuse of cement and sand, a water treatment plant for treating the process water. Noise problems can be mitigated by adopting measures like job rotation, automation to the maximum level, protective measures and soundproof control rooms.The study also included a disaster management plan to handle any disasters that may happen in future. The report has a well-planned Environmental Monitoring Programme, this becomes essential to ensure that the mitigation measures planned by way of environmental protection function effectively during the entire period of plant operation. However, changes external to the plant may at any future stage endanger environmental conditions rendering the existing mitigation measures inadequate. Hence, the necessity of remaining vigilant through a well-planned and meticulously implemented environmental monitoring programme is essential. Costing / and manpower requirement for running the EMP is worked out for effective implementation which also gives a check on the prediction tools and results.

Diurnal and seasonal variation of trace gases over the tropical coastal station, Thumba, Thiruvanathapuram

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Industrialization and the increasing human activities resulted in the marked changes in the composition of the atmosphere in terms its minor constituents like ozone (O_3), Nitrogen oxides, carbon monoxide (CO), SO_2, Greenhouse gases (GHGs) like CO_2,CH_4,etc. Air pollution, global warming and stratospheric O_3 depletion are the well known examples of human impact on the composition of the atmosphere. O_3, CO, NO_2, SO_2, etc. are considered to be major pollutants, severely affecting human life, their major sources being anthropogenic activities. O_3, a trace constituent presents in both troposphere and stratosphere; photolysis of oxygen molecule by UV radiation is the natural means by which O_3 is formed in the stratosphere and the O_3 production in troposphere is through photochemical reactions of precursor molecules like NO_2, CO, methane (CH_4) etc. Tropospheric O_3 has a crucial role in scheming the chemistry of the troposphere and the weather and climate. It is a secondary air pollutant with adverse effect on human health and vegetation, playing role in smog causing health hazards and poor visibility .In stratosphere; it filters out the detrimental solar UV radiation reaching the Earth's surface and shields the life on earth. CO is one of the major pollutants having adverse effect on humans and animals. The main sources of CO are the emission from the fossil fuel, biomass burning and oxidation of hydrocarbons. CH_4 is the most abundant organic gas and reactive greenhouse gas in the Earth's atmosphere. It is an important target in the mitigation policy owing to its shorter lifetime and high warming potential compared to CO_2. Anthropogenic sources like rice cultivation, livestock, fossil fuel allied emission, landfill, etc., accounts about 70% of global CH_4 emission. The remaining 30% comes from the natural sources of wetland, freshwater reservoir, termites, ocean, etc. The removal mechanism involves photochemical or biological oxidation.

At any location, all these gases exhibit temporal variations with varying timescales like diurnal, seasonal, inter annual and long-term controlled by temporally varying sources and sinks and in tune with the regional meteorology. The present study addresses the diurnal and seasonal changes in the atmospheric gases O_3, NO_2, CH_4 at the tropical coastal environment of Thumba; TVM- a location affected by SB and LB activities on diurnal scale and the Asiatic monsoon, a synoptic scale phenomenon. The simultaneous measurement of gases like O_3, nitrogen oxides (NO, NO_x and NO_2)

and CH_4 were carried out using the on-line analyzers of the respective gases (all data averaged for 5 minute interval). Except for O_3, all other trace gases NO_x ($NO+NO_2$) and CH_4, which are precursors of O_3 follows the similar diurnal pattern over the location. The diurnal variation of CH_4 and NO_x shows a daytime low and nighttime high, extending till early morning hours. These changes are closely associated with the mesoscale circulations, namely sea and land breeze, as observed through the meteorological observations and also the diurnal variation of boundary layer height as observed by the microwave radiometer profiler. The diurnal enhancement in CH_4 and NO_x always coincides with the onset of land breeze. The O_3 enhancement during daytime is due to strong photochemical production at the expense of the precursor gases like NO_2/NO_x, CH_4, CO, volatile organic compounds etc and night time low to NO_x titration. The seasonal variation of the trace gases over the location shows minimum value from May to September and starts to increase from October onwards with a maximum during winter.

Soil Quality Assessment of Paddy Fields in Chathannoor Panchayat, Kollam District, Kerala

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A paddy field is a flooded parcel of arable land used for growing rice. Rice is the staple food for a large part of human population in South India. The area chosen for present study include the selected paddy fields of Chathannoor panchayat in Kollam district, Kerala which are irrigated by the water drained from Ithikkara river. The major objective of the present study is to assess the physical and chemical attributes and the soil quality of the selected paddy fields of Chathannoor panchayat in Kollam district, Kerala. Soil samples were collected from nine sites (S1, S2, S3, S4, S5, S6, S7, S8 and S9) of the selected paddy field before and after harvest of the crop season (September 2015 to January 2016).The physico-chemical characteristics (moisture, bulk density, specific gravity, pH, electrical conductivity, chlorides, organic carbon, organic matter, total phosphorous, sodium, potassium, calcium, magnesium) were assessed following the standard procedures in Trivedi and Goel (1986) and Saxena (1998). The soil quality index has been formulated by the following method given by Brejda and Moorman (2001). The study revealed that the low values obtained for physical parameters such as moisture, bulk density and specific gravity indicates the low fertility of paddy field soil. But the overall soil quality index rating assessed using the selected physico-chemical parameters shows that the paddy field soils before and after harvest comes under 'Good' category.

Comparative Account of Orchids Species Distribution in India with special emphasis on The Himalayan range along with Northeast Region and Peninsular India.

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As we know Orchids is among the dominant and most advance form of flowering plants with several specialized features. It is distributed in almost every part of the world ranging from tropical condition to alpine. The comparative analysis of orchids distribution of India shows the total account of 1331 species belong to 186 genera same as Mishra reported in 2007.. Approximately 6 % of total world orchids species belongs to 24 % of total world orchids genera found in India. The diverse Indian macroclimatic and microclimatic regime, forest types, habitat condition is responsible for accommodating such a huge part of endemic and non-endemic orchids in just 2.4 percentage of the total world geographic landmass. It is distributed in all biogeographic regions in India except desert regions and has lowest representation in semi-arid region. The distribution analysis of orchids in India shows Himalaya and Northeast regions combined holds 53 % and the Peninsular India which includes Western Ghats, Deccan plateau and coasts biogeographical regions host 40.7 % of the total orchids diversity. The special distribution pattern shows greater concentration patches over Western Ghats and Western and Central Himalaya region which host two of the major hottest hotspot in India. Our special query analysis in QGIS 2.0 shows, Central Himalaya in area one and Malabar region in area two holds the highest concentration of endemic orchid species. Of the two listed target area, the endemism is higher in Himalaya region followed by Western Ghats region. The geographical isolation due to Himalaya in the North, Arabian Sea in the South West and Bay of Bengal in the south eastern part of India contribute to such a high rate of endemism.

Keywords: Biogeography, Orchids, Peninsular India, Western Ghats, Distribution Map, Endemism.

Preliminary Investigations on Corynespora Leaf Fall Disease of Hevea brasiliensis through iI vitro Screening and Biochemical Assay

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Corynespora cassiicola is a devastating fungal pathogen which causes *Corynespora* Leaf Fall disease (CLFD) in *Hevea brasiliensis*, a perennial tree crop widely cultivated throughout the Asian countries as the sole commercial source of Natural Rubber. The severity of infection varies among different clones of *Hevea*. Cassiicolin, the toxin secreted by the fungus, is the primary determinant of *Corynespora* pathogenicity. Objectives of the present study are *in vitro* confirmation of susceptibility/tolerance of various clones of *Hevea* towards CLFD and a preliminary investigation towards the correlation between chitinase activity and incidence of CLFD. Eight clones of *Hevea*, four each from susceptible and tolerant groups were selected for this study. *In vitro* experiments were carried out using two sources viz. detached leaves and calli for determining the degree of tolerance of these clones to the disease. Detached leaves were subjected to vacuum infiltration with the crude toxin for specific time intervals and the extent of damage caused was determined from the necrotic lesions induced in each case. The necrotic browning effect was predominantly observed in leaf pieces of susceptible clones after 12 hours of toxin treatment whereas the treated leaves of tolerant clones remained green and unaffected even after 24 - 36 hrs. In the second experiment, newly developed calli were exposed to cassiicolin by transferring to media enriched with different concentrations of the crude toxin (0.5, 1, 2 & 3 ml/100 ml of medium). Calli of susceptible clones turned brown and became necrotic in the presence of lower levels (0.5 & 1.0 ml) of toxin whereas calli from tolerant clones survived and remained intact even in the presence of 2.0 - 3.0 ml of toxin. Pathogenic infection also causes the coordinate induction of chitinase, a PR protein which is capable of inhibiting fungal growth *in vitro*. Assay of chitinase activity was carried out in the field grown *Hevea* clones belonging to both susceptible and tolerant groups. Leaves of these plants were exposed to casssiicolin toxin for 12 hrs and the induced chitinase activity was measured. Untreated leaves were taken as the control. Comparison of control plants of different clones showed difference in chitinase activity, tolerant ones having more chitinase activity than the susceptible clones. It was observed that upon exposure to cassiicolin there was significant increase in chitinase activity in tolerant clones as compared to susceptible ones.

Inference from the initial screening experiments using detached leaves and callus cultures are clearly in conformity with the earlier observations and field reports. Results from these preliminary studies open up the scope of *in vitro* screening of pipeline clones of *Hevea* towards CLFD thus enabling early selection of tolerant clones. Moreover the positive correlation between high chitinase activity and increased tolerance to CLFD throws light into the possibility of imparting CLF tolerance to elite clones of *Hevea* by overexpression of chitinase gene through genetic manipulation techniques.

Mapping of Trees, Shrubs and Herbs in Western Ghats based on IUCN Conservation Status and Strategies for Biodiversity Conservation

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Western Ghats, being one of the global hotspots of biodiversity, supports an enormous vegetation wealth, which over the years is undergoing great stress due to anthropogenic disturbances. The present study is focus to develop a database of flora from the literatures for the period 1986 to 2016. The informations such as species name, study area, Latitude and Longitude, distribution of species and conservation status are included in this database. Based on this primary database, species distribution map is prepared separately for trees, shrubs and herbs of Northern and Southern Western Ghats region using Q GIS 2.4.0 and analysed. The analysis shows that Southern Western Ghats supports more number of floras than the Northern Western Ghats. Floral distribution is widely seen in Kerala, Karnataka and Tamil Nadu. The complex topography and the heavy rainfall were the important variables for the development of its rich biodiversity. From the species distribution map it is identified that Nilgiri hills, Agasthyamalai hills Sathuragiri hills, Kalakad Mundanthurai Reserve and Boluvampatti forests region in Southern Western Ghats are the main centres of floral biodiversity. Compared to continuous stretches of forest in Southern Western Ghats, the vegetation in Northern Western Ghats is in the form of fragmented patches. These patches support less number of species. The floral community in the Northern Western Ghats are located mainly in the tropical wet evergreen forests in Rathnagiri district, the montane evergreen forests in the Mahabaleshwar and Bhimasankar and moist deciduous forest in Mulsi. This study also created a secondary database which includes the flora under IUCN conservation categories and prepared species distribution map based on the above fact. In total, 3% of flora in Western Ghats falls under critically endangered category, 5% under Endangered, 6% under vulnerable, 1% under near threatened and 9% under least concern/lower risk category. Also it was found that in Tree category, 10 species are critically endangered, 28 species are endangered, 49 species are vulnerable, and 31 species are lower risk/least concern. In shrub category, 5 species are critically endangered, 2 species are endangered, 5 species are vulnerable, 6 species are near threatened and 7 species are lower risk/least concern. However, in the case of herbs, it was found that 13 species are critically endangered, 16 species are endangered, 4 species are vulnerable and 4 species are near threatened 51 species are lower

risk/ least concern. So any human interventions or anthropogenic activities have a negative impact on the species distribution. This study shows that there is an urgent need to generate a proper documentation system for the flora of Western Ghats. Many of the species in Western Ghats region are under threat and hence it is necessary to adapt conservation strategy for protecting floral biodiversity of the Western Ghats. Based on the above fact the following strategies are proposed i) Strengthening the effectiveness of present Protected Areas ii) Study the threatened ecosystems iii) Identify and map large forest fragments iv) Identify and study the hyper-diversity areas and also develop strategies for their conservation v) Identify over exploited species and reduce anthropogenic pressure vi) Develop strategies that involve indigenous people vii) Develop regional and national biodiversity database viii) Incorporate biodiversity concerns in Environmental Impact Assessments ix) Environmental awareness programmes x) Ecological restoration and rehabilitation xi) Community participation in conservation xii) Afforestation programmes xiii) Eradication of invasive species and xiv) Conservation of landscapes.

Assessing the Effectiveness of IAY and PMAY-G Schemes in Gender Mainstreaming: A case of Vellanad Panchayat

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Housing has been categorized as a basic need and one which improves the quality of life of the individual with far reaching multiplier effects to the extent of being defined as the engine of economic growth by the Government of India. Beginning with the First Five Year Plan, incentives have been provided to promote housing on both, the demand and supply sides. Since independence, housing related schemes have been launched under various names with successive ones addressing the issues of homelessness in a better way. As per the government's commitment to providing 'Housing for All', inclusive and adequate shelter for all has to be achieved by the year 2022. This requires that various schemes be formulated through a gender perspective and inclusive to all since men and women experience the city in different ways. This study is an exploration of the PMAY-G Scheme launched in the year 2016, its various steps in beneficiary selection, implementation and analysis. It also analyses whether this scheme is effective in providing equal opportunities and living conditions to all irrespective of gender using a study of Vellanad Block in Trivandrum district as a sample case. The study proposes that there be a Gender Mainstreaming Strategy to create a sustainable and equitable habitat development for the homeless. This study model can be replicated to study similar scenarios in rural areas in Thiruvananthapuram district to create gender analysis and address issues related to non-completion of dwelling units. Vellanad Block is located in the Nedumangad sub-district of Thiruvananthapuram district in the state of Kerala, India. The study has been conducted by a group of 18 students guided by 2 faculty members of College of Engineering Trivandrum under the Third party Technical Agency Scheme of the Government in 4 phases: the first phase involved the initiation of the project by conducting meetings with the Block Development Officer and Village Extension Officers of the Vellanad Block Panchayat to discuss scope of the project. The second phase involved site visits to conduct first a Pilot Survey (5 households) followed by a detailed questionnaire survey of the 168 incomplete Households as per data from the Vellanad Block Panchayat. The data from the survey was analysed based on socio-economic conditions of the households including gender analysis, the stage at which construction was halted and various issues that prevented the completion of construction, concluding the third phase of the study.

Analysis of data obtained through primary survey point to the fact that since water and inadequate sanitary facilities impacts the quality of life of women including health implications and by reducing the amount of time in the triple role of women: reproductive, productive and community development. Besides the NRDWP and other schemes being converged, there is no mandatory requirement and pre-feasibility site analysis under PMAY-G to ensure quality and availability of water to the Dwelling Unit. Besides the Open Defecation Scheme and the Swacch Bharat Mission by the Government of India, housing literacy is inadequate and beneficiaries are either not educated regarding the social and environmental impacts of inadequate sanitary facilities or do not construct it due to small plot sizes (or built up area of the dwelling unit exceeding the minimum, with increased coverage). Minimum plot size with provision for soak pits have not been mandated under the PMAY-G Scheme. Housing security is important since it addresses (Mahadevia, 2011) multi-dimensional poverty. Physical factors which have caused delay in dwelling unit construction in Vellanad include poor site suitability, due to poor accessibility and heightened labour and transportation costs via increased distance of site from motor able roads and difficult terrain of the construction site. Property ownership though registered under the woman's name under the PMAY-G Scheme, till completion of dwelling units' have to stay in temporary sheds and shanties on the construction site posing threat to the safety. The provision for additional support to beneficiary in the case of less abled or vulnerable households including women headed households' need to be incorporated as part of the PMAY-G Scheme. Transport and mobility have an important role to play not only in helping to meet women's daily needs including access to maternal healthcare and contributing to the strategic empowerment of women through promoting access to employment helping in socio political growth of the individual. Difficulty in accessing safe and reliable transportation and footpaths is a form of social exclusion which restricts movement of women, and is particularly restrictive in regards to potential economic output. (Duchene, 2011) This needs to be incorporated in the pre-feasibility study during site selection and approval being given to the beneficiary as part of the PMAY-G as the predecessor to fund release. Female WPR for Vellanad block is 16.5 % which is less when compared to the Female WPR of Thiruvananthapuram district (21.4 %) and Kerala State (18.2%) as per Census 2011. Security of livelihood is an important factor which ensures social sustainability of the housing layout. Thus PMAY-G should perform the two tired role of conducting pre-feasibility site location studies and ensuring livelihood generation activities as part of Panchayat level development.

Gender Equality and Gender Equity should be achieved through the strategy of Gender mainstreaming since the housing sector is the microcosm of a city and is the driver for economic growth and social sustainability. As observed from the case of Vellanad block in Trivandrum district, there are many areas which have not been given due focus under the PMAY-G Scheme with regard to a holistic growth through the gender lens. Thus there needs to be a Gender Mainstreaming Strategy as part of the PMAY-G scheme to create a sustainable and equitable habitat development for the homeless.

Sponsor's Profile

KERALA STATE COUNCIL FOR SCIENCE, TECHNOLOGY AND ENVIRONMENT

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Kerala State Council for Science, Technology and Environment (KSCSTE) is an organization committed towards the promotion of Science, Education, Research and Scientific temper.

Sharing Kerala's constant endeavourers in supporting developmental Schemes the Science & Technology Programme of KSCSTE is in the process of various creative Schemes in the Science sector. KSCSTE is now looking at the future by providing world class research and implementing globally accepted quality parameters pertaining to the State's overall development.

RESEARCH AVENUES, FELLOWSHIPS & SCHOLARSHIPS

- *Emeritus Scientist Scheme for senior Scientists*
- *Doctoral & Post-Doctoral Fellowships*
- *Fellowships in Science writing & Science Communication*
- *Prathibha Scholarships for Students opting Science learning*

FINANCIAL SUPPORT FOR PROJECTS

- *Grant for Research Projects in emerging areas of Science (SRS Scheme), Technology (ETP Scheme) & Environment (E&E Scheme)*
- *Project for School and College Students*
- *Individual and collaborative projects in Engineering & Environment areas*
- *Industry linked biotechnology Schemes*
- *Intensive programmes for Innovators of Rural Technology(RTP Programme) and Biotechnology*
- *SARD Scheme focusing activity specific areas*
- *Innovation & Technology Development(TDAP)and Patent Information Centre*

PROMOTIONAL PROGRAMMES

- *Kerala Shastra Puraskaram for eminent scientists*
- *Science Literature Award*
- *Back to Lab Programme for Women*
- *Vocational skill oriented reinstated training [VSORT]*
- *Tech Fest, Green Corps, Eco Clubs*
- *Sasthra Poshini & Sasthra Bhodhini*

POPULARISATION PROGRAMMES

- *Science Popularization Programme*
- *Support for Seminar, Symposia and Workshop*
- *National Science Day, National Technology Day, World Environmental Day, Ozone Day etc.*

KSCSTE IS ALSO SPREADING THE ACTIVITIES TO THE FOLLOWING AREAS:

- *Technology Transfer*
- *Science City*
- *Scientific Management Training*
- *Innovation Warehouse & River Rejuvenation Projects*
- *Video Production on Science Awareness*

KERALA STATE BIODIVERSITY BOARD (KSBB)

Kerala State Biodiversity Board is an autonomous body of the State Government and come under the Kerala State Environment Department. With the Head Quarter at Thiruvananthapuram the Board falls under the provision of the State Biodiversity Act set up in 2008 and the Biodiversity Act of 2002. The KSBB is dedicated into conservation and protection of the agro, plant and fish diversity of the State. The Board is headed by a Chairman, a Member Secretary and followed by a team of expert Government officials, leading the Board in its all vibrant activities.

History

India is the first country to have the Biological Diversity Act and implement it in effective manner. The Act was conceived in the Convention on Biological Diversity (CBD) which was held in 1992 and latter in 2002 the Act was passed. The Act provides a legal framework for conservation of biological diversity of the country, sustainable use of its components, fair and equitable sharing of the benefits arising out of the use of biological resources and generation and dissemination of knowledge.

In accordance with the provisions of Act of 2002 the State Biodiversity Board (KSBB) was established in 2004. And in the same year the Biodiversity Rules was also framed.

Vision

Our vision is the conservation of biodiversity and its sustainable utilization of the biological resources for the benefit of man kind

Mission

To ensure clean air, clean water, healthy soil and safe food to mankind

Activities

The major function of the State Biodiversity Board is to advise the State Government on any guidelines issued by the Central Government on matters relating to the conservation of biodiversity. SBB also advocate for sustainable use of biological resources and equitable sharing of the benefits arising out of the utilisation of these.

Board has the authority to grant approvals on requests for commercial utilisation or bio-survey and bio-utilisation of any biological resource by Indians. The Board also perform functions necessary to carry out the provisions of Biodiversity Act or as prescribed by the State Government.

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AGENCY FOR NON-CONVENTIONAL ENERGY AND RURAL TECHNOLOGY

Agency for Non-conventional Energy and Rural Technology (ANERT) is an autonomous organisation established during 1986 under Societies Act by the Government of Kerala, now functioning under power dept; with its Head Quarters at Thiruvananthapuram.

The objective of the Agency is to gather and disseminate useful knowledge in various fields of Non-Conventional Energy, Energy Conservation and Rural Technology; conduct studies, demonstrate, implement and support implementations of schemes and project in these fields and thereby deal with the problems arising out of the rapid depletion of conventional energy sources; update the technologies used in rural areas as well as introduce appropriate new technologies with an aim to reduce drudgery, increase production and improve quality of life.

The Agency is better known by its acronym ANERT and has become a synonym for Renewable Sources of Energy and Energy Conservation in the State. ANERT is guided by an Executive Committee chaired by the Chairman, Secretary power dept; and a Governing Body chaired by the Minister of Electricity, Govt. of Kerala to provide guidelines for ANERT's activities in various energy related areas.

ANERT is the State Nodal Agency (SNA) for the Ministry of New and Renewable Energy (MNRE), Govt. of India, to carry out the Centrally Assisted Programmes in Kerala.

ANERT is the state agency for Renewable Purchase Obligations (RPO) and Renewable Energy Certificates (REC) for Kerala.

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GJ Nature Care & Energy

G J Nature Care & Energy Private Limited is founded in 2012 as a waste to energy solution provider with excellent local knowledge of Municipal Solid Waste (MSW), industrial waste and organic effluent problems in India and converts the waste problem into an energy solution for the society and the betterment of our environment.

GJ Nature Care & Energy Private Limited (GJNCE), an Indian subsidiary of a UK based consortium with industry leading professionals from United Kingdom, Germany and other parts of the world to provide 'Waste to Energy solutions. We provide consultancy, project management, project ownership, project financing, technology evaluations and feasibility assessments.

We design, install and operate waste to energy plants, having highly optimized and proven technology of staged thermal conversion, with steam cycle, which ensures to meet the criteria of advanced conversion technology without any technological risk. Our extensive in-house fluid dynamic simulations and analysis capabilities enable us to achieve maximum energy output from significantly varied, unsorted, and high moisture containing municipal waste with minimal landfill ash generation. Our combined design of heat and power system efficiently utilizes the energy from steam, allowing us to process the waste with excellent emission controls and minimal residue discharge.

We consider waste as a precious resource and convert it to clean green renewable source of energy. We have over 200 years of combined experience in waste-to-energy projects all over the world. Our team of professionals and experienced technical experts deliver sustainable green energy concepts.

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