THE ENVIRONMENT MANAGEMENT

A Quarterly E- Magazine on Environment and Sustainable Development

पर्यावरणो रक्षति रक्षितः

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Newsletter Theme: Only One Earth: Actions for Sustainable Environment

CONTENTS

From Director's Desk

The current issue of 'The Environment Management' is commemorating World Environment Day 2022 on the theme 'Only One Earth; Actions for Sustainable Environment' that was also the slogan of the 1972 Stockholm Conference. After 50 years of this conference the earth's condition has further deteriorated enormously. The depletion of resources, rise in environmental pollution and threat of climate change associated hazards is posing high risk for human survival. A collective action for environment management is a need of an hour,

Due to concretization and decrease in green cover the urban heat island effects are increasing and is affecting the dynamics of different natural resources that are very important for urban sustainability. Climate change and associated impacts are having enormous effect on different ecosystems, living organisms and sustainability. At this juncture it is important to adopt an integrated approach by implementing best practices in environment management, build knowledge repositories through capacity building and refocusing on nature-based solutions for sustainable environment management.

The current issue of the newsletter is focusing on policies, sustainable technologies and best practices for the conservation and management of our mother earth.

Dr. Seema Mishra

Zero Waste to Landfill

Mr. Ashish Gupta
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Introduction

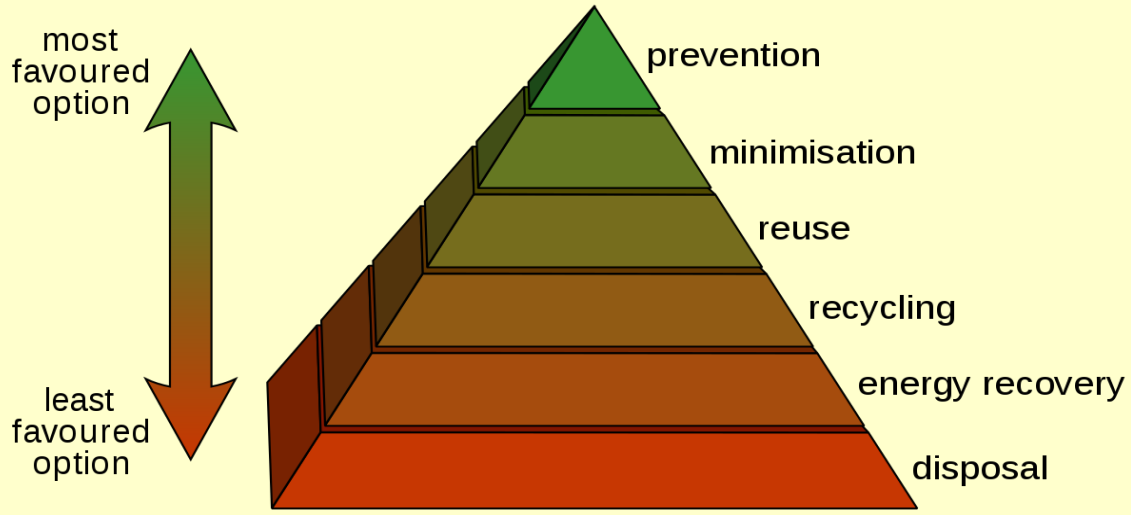
Today, more than ever, organizations are recognizing the need to improve environmental performance. Whether to "do the right thing" as good environmental stewards, or to meet the increasing demands of customers and the public, there is a need to demonstrate real environmental achievements. Third party verification lends credibility to green claims, providing assurance to organizations, their customers, and other interested parties. Landfill is one of the primitive waste disposal methods which can lead to environmental pollution such as soil contamination, surface water pollution, groundwater pollution, air pollution and many nuisances such as unpleasant odour and surrounding, etc. In America, there is a separate legislation called, "Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or SARA), 1980" which deals with remediation of historical contaminated sites based on polluter pay principle and industries operational at that time are still paying hefty amounts towards remediation cost for past few decades. In 2016, Central Pollution Control Board (CPCB) issued a similar Guideline on Implementing Liabilities for Environmental Damages due to Handling & Disposal of Hazardous Waste. The penalty based on polluter pay principle, includes: ·

- Liability for taking up immediate measures
- Liability for assessment of contamination
- Liability for remediation of contaminated sites
- Liability to pay for natural resource damages and compensation to the third parties for personal injury, property damage, and economic loss.

The generation of waste means loss of resources and the avoidance of waste to landfill can be achieved by effective waste management through waste hierarchy as below: (a) Prevention (b) Minimization (c) Reuse (d) Recycling (e) Recovery, utilization including co-processing (f) Safe disposal.

Zero Waste to Landfill "Zero Waste to Landfill" means zero manufacturing waste is disposed directly to landfill or to Incineration without energy recovery by the site, except where local legal requirements specify that regulated wastes must be disposed in a landfill only. The regulated waste includes and not limited to such as hazardous waste, biomedical waste, e-waste, batteries waste, etc. In today's World, environment has become the key

issue. All industries are striving to reduce the load on environment and improve performance. There is a growing demand by customers, investors, Government body, NGOs for responsible organization to demonstrate the excellent environmental stewardship. In this context, Zero Waste to Landfill certification is used by facilities to define, pursue and achieve their zero waste goals, cutting their carbon footprint and supporting public health.



Waste Hierarchy Pyramid

Zero Waste to Landfill certification program is to divert all solid waste from the landfill. Third party verification bring the credibility to green sustainable claims, providing assurance to organizations, their customers, and other interested parties. Proactive management of byproducts and solid wastes has been a primary means of reducing environmental impacts. 3 R program (Recycle, Reuse, Reduce) can help to divert the solid waste from landfills. Advantages Responsible and clean manufacturing have become expectations of customers and interested parties within industry. Sustainability efforts such as waste diversion from landfills is an important step to demonstrate environmental stewardship. Zero Waste to Landfill certification has the following benefits to any facility looking for a better approach to resource use and facility operations:

1. Helps eliminate pollution, in our air, water and land which threaten public health and ecosystems

2. Improves their bottom line by reducing costs

3. Cuts the ecological footprint by reducing materials, using recycled and more benign materials, and giving products longer lives by increasing reparability and ease of disassembly at end of life.

4. Promotes positive forces for environmental and economic sustainability in the built environment by protecting the environment, reducing costs, driving the

development of new markets, and

5. Fosters strong total participation including training of all employees and zero waste relationships with vendors and customers

6. Allows the facility to showcase their responsibility and commitment to the local and global community and the environment

7. Reduction in Green House Gases

8. Improved Corporate Social Responsibility

9. Institute as leader in the peer community Zero Waste to Landfill Program Absolute "zero" waste being generated and disposed by any organization is nearly impossible.

Hence, after assessing various methodologies, we selected the following approach to implement the program and provide verifications: Zero Waste to Landfill – at least 99% diversion rate; Near Zero Waste to Landfill – between 95% and 99% diversion rates; Advanced Waste Diversion – from 85% to below 95% diversion rates.

Verification Criteria Ø The solid waste (diverted from landfill) data shall be traceable, verifiable, true, accurate, materially correct;

- Verified solid waste (diverted from landfill) data shall demonstrate the level of diversion claimed;
- Undertaking from the waste handler shall state assurance that byproducts and wastes are not being placed into landfills;
- The organization must develop and implement a policy committing the

producing jobs throughout our economy.

organization to the waste diversion claim (e.g., Zero Waste Policy);

- Organization shall effectively implement documented waste management processes and procedures;
- Capacity building program, internal/external training to ensure competency of resources whose work may affect the performance toward the zero waste goal;
- Organization shall demonstrate the compliance with applicable regulatory requirements related to by-products and waste materials.

Organization shall effectively implement the waste management information system in order to demonstrate quantification of wastes, tracking systems, appropriate manifesting, shipping records, and other waste handling and disposal information.

What qualifies as diversion of waste material?

o Finding useful application of wastes in the process (reuse)

o One organization's waste can be useful resource for other organization (selling to other organization)

o Recycling of wastes o Recovering energy by anaerobic digestion

o Composting of bio-degradable material

o Incinerating the waste material for energy recovery

o Incineration as per law of land o Returning the waste product to supplier

o All process by-products and waste within the defined scope of activities

o Construction/demolition/renovation waste is excluded

o Recycled and reused wastes count toward diversion

o Incinerated waste is not counted toward waste diversion

o Incineration resulting in energy production (waste-to-energy plants) may be counted. Ash from Waste to Energy plants is excluded. Incineration From an environmental perspective,

Incineration without Energy Recovery is considered to have few benefits over landfill and much less benefit than Incineration involving Energy Recovery. This position is reflected in the globally accepted Waste Hierarchy. Therefore, sending waste to incineration without energy recovery will not count as diverting the material from landfill. Incineration with Energy Recovery is considered under the diversion rate calculation. In case, Incineration of waste is mandatory by law and beyond control of manufacturer to decide the disposal method, then incinerated quantity of waste material will be considered for diversion rate calculation.

What is evaluated while verifying waste data?

· Mass of product produced · Movement of the waste material
· Process flow diagram with mass balance
· Waste elimination methods
· Waste reduction methods
· Waste diversion methods
· Associated records of movement of waste
· Legal compliance records
· Total hazardous/non-hazardous waste generated in the plant, quantity.
· Description of monitoring process of hazardous waste
· List of hazardous waste generated
· Quantity of hazardous /non-hazardous waste recycled
· Quantity of hazardous /non-hazardous waste reduced
· Quantity of hazardous /non-hazardous waste reused
· Quantity of hazardous waste incinerated (Only waste to energy project)
· Quantity of hazardous waste that goes to landfill or incineration (without waste to energy). · List of recyclers / Hazardous waste handlers – Legal Consent to Operate
· Undertaking from hazardous waste handler w.r.t. process of each type of hazardous waste with Quantity.

All the above information is required for a duration of at least 12 months or more. Certification Procedure The verification process generally includes the following steps:

- Outlining the scope of work of Zero Waste to Landfill as per proposed methodology; · Submission of data as requested by Third Party on waste generation and landfill diversion data for preliminary review and audit planning;
- An on-site audit to check records, reviews, observations, and interviews to verify effective waste management and the diversion rate. Verification of records from waste recyclers and other vendors, as well as landfills;
- In the end, findings and recommendations related to the verification criteria, opportunities to

improve waste management practice are provided, as observed;

- Once all findings are closed through acceptance of corrective actions, audit team will recommend the appropriate verification statement;
- Then on the recommendations of the Audit team, Zero Waste to Landfill certification is issued. The certification program is valid for 3 years. First year is the certification audit, followed by first and second surveillance audits for year 2 and 3 respectively. This will include off-site review of data as well as on-site review of waste management operations.

VERIFIED
ZERO WASTE
TO LANDFILL

Intertek does hereby certify that an independent assessment has been conducted on behalf of

BHARAT PETROLEUM CORPORATION LTD.

Certificate Number: ZWL-2020-06
Certificate Issued: 3 April 2020

Initial Verification Date: 3 April 2020
Certificate Valid Until: 2 April 2023

Applicant Address: Mallet Road Wadibunder
Mumbai, Maharashtra, 400009, India

Product Industry/Category: Oil & Gas: Lubricating Oil

Conformance Criteria: Zero Waste to landfill diversion rate exceeding 99% is applicable to blending, storage, packaging & dispatch of automotive, industrial lubricating oil, specialty oil & insulating oil.

Issuing Office Name & Address: Intertek Testing Services NA, Inc.
4700 Broadmoor Ave SE, Suite 200
Kentwood, MI 49512 USA
Ph: +1-616-656-7401

Brian Knelbel
Certification Manager

VERIFIED
ZERO WASTE
TO LANDFILL

Intertek does hereby certify that an independent assessment has been conducted on behalf of

BHARAT PETROLEUM CORPORATION, LTD.

Certificate Number: ZWL-2020-08
Certificate Issued: 20 May 2020

Initial Verification Date: 20 May 2020
Certificate Valid Until: 19 May 2023

Applicant Address: Manmad Installation, Bharat Petroleum Corporation Ltd.
Nandgaon Road, Manmad
Maharashtra, 423014, India

Product Industry/Category: Oil & Gas: Oil

Conformance Criteria: Zero Waste to landfill diversion rate exceeding 99% is applicable to the Receipt, Storage and Distribution of White Oil (MS,HSD,SKO).

Issuing Office Name & Address: Intertek Testing Services NA, Inc.
4700 Broadmoor Ave SE, Suite 200
Kentwood, MI 49512 USA
Ph: +1-616-656-7401

Brian Knelbel
Certification Manager

Things to do

The organization must effectively implement documented waste management processes and procedures;

· Training programs must be implemented as appropriate to ensure competency of persons whose work may affect the performance toward the zero waste goal.

· A waste management information system must be developed in order to demonstrate quantification of wastes, tracking systems, appropriate manifesting, shipping records, and other waste handling and disposal information.

· Utilization of management systems such as operational controls, monitoring, and corrective actions to ensure the waste management processes are effectively implemented. These processes should reside within ISO 14001 or ISO 9001 management systems, if implemented. · Compliance with applicable regulatory requirements related to byproducts and waste materials is required. Where noncompliance is observed, acceptable corrective actions must be implemented. Corporate HSSE is pleased to inform that out of the three Pilots initiated by us, two of them, namely Manmad Retail Location and Wadilube Plant, have been a huge success with both scoring the highest level of "at least 99% diversion rate" in the Zero Waste to Landfill Certification. Our compliments to the team at both these plants. The third Pilot at Pune LPG Plant could not take off due to COVID pandemic.

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2) Guidelines on Implementing Liabilities for Environmental Damages due to Handling & Disposal of Hazardous Waste and Penalty issued by Central Pollution Control Board in Jan-2016

3) Waste Hierarchy Image from Wikipedia (https://en.wikipedia.org/wiki/Waste_hierarchy

Climate Adaptation is a Huge Opportunity to Improve the Quality of Life in Cities

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Introduction

The world is urbanizing. In 2050 over 6 billion people will live in cities. Europe is one of the most urbanised continents in the world. More than two thirds of the European population lives in urban areas and this share continues to grow. Cities around the world are confronted with many challenges, such as traffic congestion, inadequate energy supply, lack of basic services, informal dwellings, poor management of natural hazards, crime, environmental degradation, climate change, poor governance, urban poverty, informal economy and unplanned development (WEF, 2016). Urban growth will have large impact on the liveability of cities and will put large pressure on theavailability of water, food, energy and materials. Climate change will put even more pressure on cities, as it leads to increased risks of flooding, droughts and heat waves. The sense of urgency for climate mitigation and adaptation is growing. Urban

development is a huge opportunity to create resilient and livable cities The world is expected to invest around US$90 trillion in infrastructure over the next 15 years. These investments are needed to replace ageing infrastructure in advanced economies and to accommodate growth and structural change in emerging markets and developing countries (Global Commission on the Economy and Climate (GCEC), 2016). The world's existing infrastructure – spanning sectors such as energy, public transport, buildings, water supply and sanitation – is estimated to be responsible for 60 per cent of the world's GHG emissions. Yet an alternative is starting to emerge – one focused on compact, connected and sustainable urban growth to create cities that are economically dynamic, vibrant and healthy. Such cities are more productive, socially inclusive and resilient, as well as cleaner, quieter and safer. Cities around the world face great challenges with water – ranging from too much and/or too little. Water becomes more and more a scarce resource because ofurbanization and increased competition between various uses and economic sectors. Climate change will put more pressure on cities by increasing the

risk for floods, droughts and heat waves. These challenges ask for a systemic approach and a transition in urban planning need to (re)design cities from drained cities to green, resilient and circular cities, so called Water Sustainable Cities. 2. Literature Study:- The world is urbanising and climate changing will have large impact on cities ¬ In 2050 worldwide over 6 billion people will live in cities. Europe is one of the most urbanised continents in the world. More than two thirds of the European population lives in urban areas and this share continues to grow. ¬ City densification is both, an opportunity for economic growth and a threat for liveability. Urban growth will put large pressure on the availability of water, food and energy. Climate change will put more pressure on cities by increasing the risk for floods, droughts and heat waves. The sense of urgency for climate mitigation and adaptation is growing. Water plays a central role in sustainable urban development. Cities around the world face great challenges with water –too much and/or too little ¬ The World Economic Forum Global Risk Report identified water crises – droughts and floods, sea level rise and pollution – as the risk with the largest expected global impact over the coming decades. ¬ Flood events are occurring more frequently all over Europe causing major damage in urban areas. The frequency and and urban water management. We have to rethink the way we deal with water in our cities and there is a intensity of rain events will increase in the future. ¬ Resources are limited while at the same time demand for these resources is increasing due to the larger number of people living in urban areas. Water, energy and materials sources need to be used more efficient, and where possible recycled and reused. The Water Sustainable City approach integrates urban planning and water management to increase climate resilience + creating value for citizens ¬ A transition is needed to (re)design cities from drained cities towards water sustainable cities in order to restore the natural drainage capacity of cities and close the urban water cycle. Every drop of water in our cities has a value. A Water Sustainable City treats water as a resource instead of as a nuisance. Collaboration between businesses, public authorities, researchers and citizens plays a unique part to ensure rapid transition. 3. Conclusion: - Integrating urban development and climate adaptation offers huge opportunities to improve the quality of urban life: ¬ Sustainable urban infrastructure is receiving increasing attention from the private sector, governments and researchers. ¬ Every redevelopment project offers huge opportunities to create value and synergy with climate mitigation and adaptation goals

by applying the Water Sustainable City approach. Climate adaptation is a huge opportunity to improve the quality of urban life: Adaptation creates opportunities to develop more sustainable and liveable cities. It should be seen as an opportunity, rather than a problem that may lead to additional costs. Cities should shift the perspective from risk to an opportunity to create value for citizens and make the city more attractive, resilient and economically sound. Redesigning cities from drained cities to Water Sustainable Cities will become more important in the near future: Water plays an important role for the liveability of cities. Many cities deal with increasing risks for water shortage, floods and heat waves. These challenges ask for a systemic approach and a transition in urban planning and urban water management. Climate adaptation will create large business opportunities: Redesigning cities from drained cities towards Water Sustainable Cities creates business opportunities. There are already many businesses available and this market and the need for new innovative water sustainable solutions is growing. The transition towards Water Sustainable Cities will boost innovation opportunities.

Challenges & Opportunities for Recycling of EV Batteries in India

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India is the second-most populous country in the world (1.37 billion 2019and expected to be 273 million more by 2050). Reducing CO_2 emission and meeting the energy requirement for such a huge population, will be the major challenges for India's sustainable development. This has given a spur to Electric Vehicle (EV) and Renewable Energy (RE) sector. Battery is one of the cleanest technologies if integrated with RE.The EV battery market in India is expected to grow by 35% to 132 GWh by 2030which will lead to a massive increase in the stockpiles of spent batteries in the next decade despite its disposal as municipal solid toxic waste after its useful life. Proper utilization of waste batteries have two fold benefits, as these wastes are capable of creating a million-dollar economic opportunity as well as jobs for a country by efficient recycling of such wastes. The battery waste generation and environmental issues may negatively affect India's target to become 100% EV country.

According to Greenpeace, 22 of the 30 most polluted cities in the world are found in India mainly due to emission by fossil fueled-based vehicles. Consequently, the government is facing increasing pressure, both domestically and internationally, to reduce emissions and pollution.

Indian electric bus market to account for 10 % of world e-bus market in 2025 not only to combat environmental issues, but due to limited oil reserves of India resulted in one of the biggest oil importers in the world. Further, the Indian economy is tightly correlated to the price of oil resulting in a greater current account deficit during periods of high oil prices.

Challenges of disposal of EV battery (LIB)

- Toxic and costly metals (Li, Co, Ni,
- Lithium reacts vigorously with water, can significantly alter, and destroy the natural chemistry of soil and water bodies.
- Electrolyte composed of $LiPF_6$ salt in organic solvent mixture is highly pyrophoric in presence of air and moisture.
- Blanket incineration is not feasible, as simply incinerating the 2 million tons of its e-waste, would result in 77 million tons CO_2equivalent emission.

Present Rules and Regulations in India

- Batteries (Management and Handling) Rules, 2001: Stated about battery, but limited to lead acid battery only which contains toxic lead and hazardous sulfuric acid.
- E-waste (Management and Handling) Rules, 2011:Introduced that aimed to put in place an environmentally sound e-waste management system by regulating issues of disposal, import and recycling of e-wastes. The E-waste Rules apply to every producer, consumer or bulk consumer (including factories under Factories Act).
- E-Waste Management Rules, 2016 & 2018:Work towards implementing revised percentages of EPR targets for companies within Schedule III. DO NOT mention Lithium.
- Battery Waste Management Rules, 2020 (Draft): Does include Lithium, but not notified yet, not specific to EV batteries.

etc.) present in used battery.

Opportunities of Recycling in India

Among the several extant battery technologies, the lithium-ion battery (LIB) is now the most suitable alternative. Although different LIB battery chemistries are commercially available, most electric vehicles use cathodes of (i)layered metal oxide of Li, Ni, Mn & Co (NMC), (ii) layered metal oxide of Li, Ni, Co & Al and (iii) lithium iron phosphate (LFP) either in combination with graphite anode or lithium titanate oxide (LTO). These batteries have a shelf life of eight to ten years, but once their energy-generating capability falls below 80%, they are no longer suitable for electric vehicles. On the other hand, these batteries can still be employed in other applications such as stationary storage (inverters, grid, etc.). To prevent improper handling and treatment of LIB, the Indian government has issued guidelines on battery waste management. These guidelines propose mandating extended producer responsibility (EPR), which would require manufacturers to be responsible for the collecting, storage, transportation, recycling and safe disposal of spent batteries. The government also provides some financial incentives to encourage LIB recycling investments.

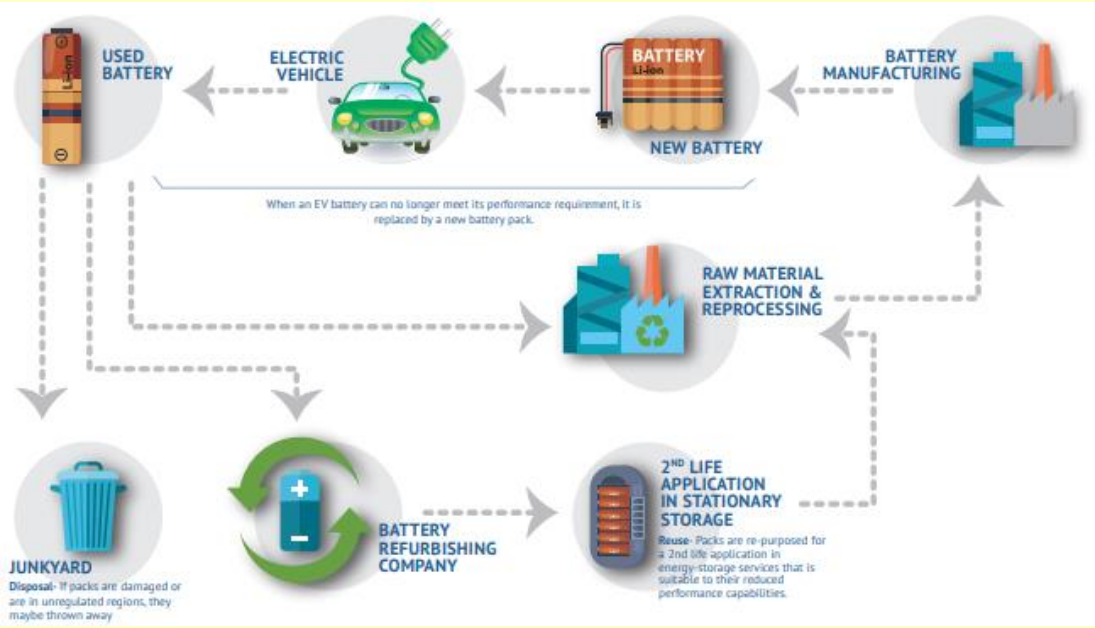
Challenges in India

Now India has a technical gap in LIB waste collection, storage, and recycling infrastructure. Retired LIBs must be handled, stored, transported, treated, recycled, and disposed of according to laws and regulations that have yet to be implemented. For cost-effectiveness in large-scale deployment in renewable and

other stationary applications, standards for second-use applications of old EV batteries are also required. However, economic feasibility should be properly evaluated. India currently lacks a commercial-scale recycling system. End-of-life batteries are piled up and discarded in landfills without being adequately treated. Li is highly reactive and pyrophoric, whereas Ni and Co are hazardous elements present in LIB.

End-of-life battery management for EV

Lithium-ion or Li-ion batteries store energy and can be recharged in EV. From two-wheelers to commercial vehicles and public transportation buses, the batteries utilized in EV are virtually the same. However, depending on the amount of power required to operate them, their composition and size vary from vehicle to vehicle. There is a lack of understanding and implementation of how EV end-of-life battery management should be handled. However, recent research underlines that recycling would be the best and most feasible option in this context.



Way forward

Since the EV penetration rate in India is 0.8%, one could witness significant growth in the segment, owing to the large automobile sector of the country. Battery recycling is a crucial aspect of the overall EV industry.It is anticipated that many opportunities will be available in this sector. There are a few challenges, including a lack of proper legislation and guidelines that should be addressed in the future, thereby paving the way for several players to benefit from the expected growth in the sector.

The manufacturing, re-use, and recycling of batteries would lead to a circular economy where the manufacturers would either double up as recyclers or new entrants with the sole focus on recycling of batteries would enter the market. New business models providing better solutions are likely to emerge with time. One such model could be battery leasing wherein the battery is returned at the end of the lease period for

repurposing and recycling by the manufacturers. Battery suppliers in India have already started selling with a buy-back option.

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Dynamics of Urban Growth vis-à-vis Micro-Climate: Remote Sensing, GIS and Water-Balancing Perspectives

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1. INTRODUCTION

Urban areas across the world today are experiencing massive alterations in their character of urban form and land use, with increasing levels of economic development due to rapid increase in population, urbanization and industrialization. These changes have resulted in typical urban growth trends having drastic influence on urban morphology which plays a significant role on transforming the local energy balances. Human induced land use/land cover practices have far reaching impact on the local environmental and climatic conditions and result in the alteration of atmospheric temperature affecting the natural and man-made environment adversely. Population is a major factor in the extent of warming and will very much determine the quality of the livelihoods. Complex urban forms with wide variations in built density, layout typology, and architectural form results in more complicated microclimate conditions. Microclimate conditions affect the energy performance of buildings and bioclimatic design strategies. Urban sprawl is often associated with density of people and buildings, mixed land use, a reliance on vehicles with subsequent increase in air pollution and other related health and social effects. Regions with high levels of urban sprawl have more than twice as many days with extreme heat compared to regions with more compact growth patterns. In addition to that, many other adverse affects like growing incidence of droughts, floods, rising temperatures of oceans and sea levels, coastal erosion, increase in the intensity of extreme weather events, melting of glaciers, loss of ecosystems, etc. are directly or indirectly linked to rapidly growing population and indiscriminate consumption of the natural resources. Land use / land cover change may result in the magnitude and spatial redistribution of precipitation

and moisture conditions which, in turn influence the wet and dry climates of an area, thereby affecting the likelihood of floods and drought. Changes in the surface albedo and aerodynamic roughness also affect the climate. Climate change prevention is dependent on human influences which require rechecking of planning especially taking care of poor performance of modern urban settlement patterns. In this context, Remote sensing and GIS techniques are highly effective, especially for constant monitoring, detailed mapping and proper planning and management of urban growth patterns with respect to the surrounding environment.

2. THE CHALLENGE OF CHANGE IN URBAN MICRO-CLIMATES

Urban microclimate conditions have a significant impact on urban climates, urban comfort and the energy performance of buildings. At the urban microscale level, the average wind speed is lower, with more complex flow patterns as compared to rural areas. Moreover, due to the urban heat island (UHI), the average air temperature is higher in urban areas. The fluctuations in wind speed and air temperature affect a wide range of engineering applications in urban areas and buildings.

Over the past 60 years, average annual global temperatures have been rising to levels unprecedented in the past 100,000 years. Scientists believe this is due primarily to human activity, and that the burning of carbon fuels has been the principal contributor to the overproduction of green house gases (GHG) that create a blanket in the earth's atmosphere, trapping the warmth of the sun. Because greenhouse gases accumulate rather than dissipate over time, the earth's atmospheric temperature has been rising and will raise further, likely producing two primary phenomena over the next several decades that could have enormous consequences for natural systems and human settlements. These changes in global and local weather patterns and dynamics could result in substantially higher incidences of flooding, drought, wildfires, and landslides.

Most scientists now predict that temperatures will rise even faster over the next 40 years than recently, due in part to the accumulation of GHGs in the earth's atmosphere, and in part to rapidly growing populations and economies in Asia and South America. They believe that some amount of global temperature rise is now inevitable (on the order of 1 to 2 degrees Celsius by 2050) and will result in increases in sea level and changes in weather patterns with concomitant impacts on food supply, natural hazards, and economic activity.

This phenomenon will require aggressive adaptation strategies to address the unavoidable results of climate change. Among the measures to be considered are limiting developments in flood-prone areas, enhancing flood control systems, ramping up water and soil conservation measures, rationing water, and improving inoculation rates for infectious diseases.

Further global climate change (another 2 degrees Celsius or more) and its most catastrophic effects are avoidable through aggressive mitigation strategies. Mitigation actions generally fall into two categories: altering the supply source of energy, and reducing the demand for energy. Since changing the supply source - shifting from carbon-based to alternative fuels and energy sources - will take decades, even under aggressive carbon taxation scenarios, strategies to reduce demand are extremely important. Increasing the fuel efficiency of vehicles and machinery and the energy efficiency of buildings are two paths to reducing demand, but more profound measures involve shifts in societal behavior and settlement patterns.

2.1. Urban Heat Island (UHI) Effect

An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The temperature difference is usually larger at night than during the day, and is most apparent when winds are weak. UHI is most noticeable during the summer and winter. The main cause of the urban heat island effect is from the modification of land surfaces. UHIs have the potential to directly influence the health and welfare of urban residents. UHIs are characterized by increased temperature, therefore they can potentially increase the magnitude and duration of heat waves within cities. It's noted that in the urban regions the mortality rate during a heat wave increases exponentially with the increase in temperature, which is exacerbated by the UHIs. On the other hand, the night time effect of UHIs can be particularly harmful during a heat wave, as it deprives urban residents of the cool relief found in rural areas. High UHI intensity correlates with increased concentrations of air pollutants that gathered at night, which can affect the next day's air quality in the urban areas. Studies suggest that increased temperatures in UHIs can increase polluted days by influencing the meteorological conditions such as, air pressure, cloud cover, wind speed and can also have an impact on air pollution.

3. PARAMETERS RESPONSIBLE

3.1. Interrelationship of Meteorological Conditions

The temperature, relative humidity, wind speed, and rainfall together play collective role in the total climatic condition of the area. These parameters are interrelated to one another during the most of time. Hydro meteorological data helps to determine the water balance of an area for developing and managing its water resources. The most useful elements are precipitation particularly rainfall, evaporation, transpiration, temperature, humidity and wind velocity. The study of hydrology necessitates the collection of these data for the area under investigation.

3.2. Analysis of Climate Conditions

Climate set up of a region mainly characterized by the distinctive meteorological conditions of the regions like temperature (which determines the

composition of rainfall), relative humidity and wind speed. These parameters are interrelated and inter-dependent and collectively responsible for characterizing the local climatic conditions of a region.

3.2.1. Temperature Variations

Temperature plays a vital role in typifying the climatological setup of a region. When atmospheric temperature reaches a highest, the condition results in the formation of cloud and finally results in precipitation. Temperature variation depends on various factors, like, urbanization which increases the temperatures considerably.

Temperature changes over different biotic regions play an important role in climate impacts and feedbacks within the climate system. For example, the atmospheric methane concentration has a close relationship to the atmospheric temperature record (Wuebbles and Hayhoe, 2001) and the emission of methane from melting tundra increases in association with surface warming of this region. Different biota also responds to surface temperature changes through different mechanisms. As such, the analysis of simulated and observed changes over these separate regions may enhance our understanding of biotic feedbacks operating within the climate system.

Since temperature changes over specific biome regions have not been systematically studied, it is useful to evaluate how the surface temperature has changed over Hyderabad and surrounding region.

3.2.2. Rainfall Trends

Rainfall is one of the important constituents of climate and is the consequence of alteration in atmospheric temperature. Relative humidity and temperature in the atmosphere are controlled by the rainfall and improves the efficiency of other factors which are important for vegetative growth and agriculture of the region. Rainfall helps to determine the characteristics, amounts, percentage, intensity, variability and areal distribution of other climatological components, monthly and seasonally. Rainfall between any two stations varies linearly unless abrupt changes in topography indicate otherwise.

3.2.3. Relative Humidity

Humidity is one of the gaseous forms of the atmosphere. Humidity is affected by atmospheric temperature and becomes the source of other atmospheric entities, such as, dew, frost, fog, cloud, rain, snow, drizzle and hail.

3.2.4. Wind Speed

Wind direction and speed can play a huge role in changing the weather conditions of a region. Wind is caused by the movement of air from high pressure to low pressure. Speedy wind brings cloud and rain by transferring heat and moisture present in the atmosphere. It directly comes in contact

with evaporation and strongly affects the temperature.

3.3. Ambient Air Quality

Air quality is important simply because we can't avoid breathing the air around us. The air is made up of nitrogen and oxygen, with traces of other gases such as carbon dioxide, plus minute particles like dust. Although clean air should be freely available to all plant and animal life, humans have been gradually polluting it, putting their health at risk and the well-being of the earth itself.

Rapid urbanization of the cities combined with growing demand for energy resources and exponential growth of vehicular fleet are contributing to deteriorating air quality in the urban centers. Other important source of pollution is the coal and oil combustion at the industrial sites. In the coming years, given the economic trends in developing country cities, motorized transport is only expected to increase, further threatening air quality.

The inhabitants of cities should be especially concerned, since they are exposed to a greater amount of pollutants coming from automobile traffic, commercial, industrial and manufacturing facilities, as well as other sources. Increased levels of air pollution are affecting the well-being of inhabitants and imposing not just a direct economic cost by impacting human health but also threatening long-term productivity (material and vegetation damage, quality of life, reduced tourism to the country, discourage foreign investment etc.).

These pollutants include volatile organic compounds, carbon monoxide, nitrogen oxides, and particulate matter. The production of these pollutants combined with the higher temperatures in UHIs can quicken the production of ozone.

3.4. Population

Demographic factors play vital role in environmental change and sustainability evaluation of an urban area. This changes/evaluation is a combination of several demographic, institutional and technological factors. The response of demographic variables relevant to diffusion and adoption of agricultural / environmental innovations include population size, its spatial distribution, dynamics of growth, physical, cultural and economic attributes of the urban area.

3.5. Urban Form

Physical form of cities is the result of a "multitude of social and economic processes, constrained and shaped by the geometry of the natural and man-made world" (Batty 1994). Identifying wide variations in urban form of the city helps understanding the gradual degeneration of the core, tendencies towards sprawl, etc. Studying the change in form also unravels the varying socio-economic dynamics of urban landscape and makes it imperative to understand the inter-relationships. One also needs to question whether the planning interventions coming up in these urban regions can be sustained by the intrinsic urban form. Thus, instead of mere visual interpretation of the form of a city, use of quantitative indicators would provide a

scientific basis, thereby analyzing the prospects of form being a determinant of use. Various indicators of urban form or patterns include (i) land use / land cover composition and distribution, (ii) Size, (iii) Compactness, (iv) Centrality, (v) Porosity, (vi) Complexity, (vii) density, and (viii) Continuity. Analyzing these indicators provides vital clues about the functioning mechanism, performance and sustainability of the urban landscape and its varying climate.

3.6. Urban Sprawl

Urban sprawl is a side-effect of rapid growth in cities in a changing socio-economic setting. Urban sprawl has negative impacts on sustainable use of resources available surrounding the cities. It gives a patchy development often under pressures different from natural demand and supply, thereby causing a fragmentation of natural ecosystem. Urban sprawl therefore is linked with dissatisfaction due to uneven distribution of urban areas and services therefore it was important to put it as a social environment parameter.

In order to detect urban sprawl Shannon's entropy is to be calculated using urban growth as a spatial variable. The relative entropy is the normalized value of entropy which scales between 0 and 1 thereby making it easy to do a comparative understanding of sprawl among wards.

4. TECHNOLOGY AND METHODS FOR ANALYSING CHANGE IN URBAN FORM AND MICRO-CLIMATE

This study attempts to provide a strategy for the application of remote sensing and GIS technologies for the effective evaluation of various urban phenomena especially the urban land use/land cover interplays, inter-relationships between urban form and social form of the city.

4.1. Remote Sensing

Remotely sensed data have a substantial role to play in investigating urban alterations. Satellite remote sensing offers a tremendous advantage over historical maps or air photos, as it reveals recurrent and explicit patterns of land use and presents a synoptic view of the landscape (Schneider and Woodcock, 2008). In the recent past, remote sensing has emerged as a powerful tool for natural resource management with the ability of obtaining systematic, synoptic, rapid and repetitive coverage. Remote sensing provides extracting information data stream that involves the earth's surface, the atmosphere that lies between it and the image forming sensors. The modeling stages would require accounting for the dynamic atmosphere variables. This makes each 'scene' of the vegetative landscape unique with respect to the spectral behavior.

The analysis of all remotely sensed data involves models of many processes wherein the electromagnetic radiation is transformed (the scene, atmosphere and sensor) and whereby inference is made about the scene from the image data.

4.1.1. Vegetation Indices

The most common strategy for relating remote sensing data to vegetation canopies has been via the correlation of vegetation indices with vegetation structure and functional variables.

Healthy green vegetation generally absorbs 80 to 90% of the incident radiation for photosynthesis. Green Chlorophyll pigment is actually responsible for this absorption at red region of the EM. The healthy vegetation on the contrary reflects 40 to 50% of the incident in near infrared energy. The stress in vegetation reduces the difference in the red absorption and infrared reflectance. Dry soil generally has higher reflectance and no absorption in red region in the EM. Such unique spectral behaviors have been used in developing vegetation indexes. They have been termed as 'robus' mathematical treatment to the spectral band to discriminate vegetation from non-vegetation surfaces or stratify vegetation based on vegetation amount (Wiegand et al., 1974; Tucker, 1979).

Rouse et al., (1973) developed normalized difference of brightness values from infrared and red for monitoring vegetation. They called it as normalized difference index. Deering et al., (1975) added 0.5 to the normalized difference vegetation index and took the square root producing transformed vegetation index.

Normalized Difference Index (NDVI) = (IR - R) / (IR + R)

Transformed Vegetation Index (TVI) = [(IR - R) / (IR + R)] + 0.5

The Landsat TM bands [TM band 5 {1.55 - 1.75 um} and TM band 7 {2.08 - 2.35 um}] provided middle infrared bands and have been found to be sensitive to canopy moisture variation. Indexes developed using these bands has also shown strong positive relationships with canopy cover, leaf area index and phytomass (Roy et al., 1992). These indexes are mathematically estimation as below:

MIR Normalized Difference Vegetation Index = (IR - MIR) / (IR + MIR)

The vegetation index, normalized difference vegetation index Transformed Vegetation index and MIR normalized difference vegetation index show relationship with presence of vegetation cover, foliage density, leaf area index (LAI), absorbed photosynthetic active radiation (APAR) but have been found to be largely site dependent, year specific and sensitive to the presence of senescent vegetation. The daily NOAA-AVHRR data of visible and infrared regions have been extensively used to monitor global vegetation using normalized difference vegetation index (NDVI). The maximum different vegetation index (MNDVI) estimated by compositing daily NOAA-AVHRR image during a fortnight provided better relationships with LAI, APAR, productivity, yield and biomass (Curran, 1980; Tucker et al., 1986).

(a) Normalized Difference Vegetation Index

With the advent of satellite remote sensing it has become possible to understand the green leaf concentration or chlorophyll status of vegetation for a large area of the earth surface with the help of a single digital image. Out of the numerous Digital Image Processing techniques (like TNDVI, VI etc.) used; NDVI (or Normalized Difference

Vegetation Index) happens to be the most widely used technique to help understand the vegetation health status (Campbell, 1996). This technique not only highlights the vegetated areas of an image but also gives an idea regarding as to how healthy the plants are.

The basic equation behind this operation can be expressed as:

NDVI = (NIR - R) / (NIR + R)

Where, NIR = Near Infrared Band value, R = Red Band value, recorded by the satellite sensor.

(b) Ratio Based Indices

Ratio images are often useful for discriminating spectral variation in a scene that is masked by the brightness variations in images from individual spectral bands or in standard colour composites. This enhanced discrimination is due to the fact that ratioed images clearly portray the variations in the slopes of spectral reflectance curves between two bands involved; regardless of the absolute reflectance values observed in the bands. These slopes are markedly different for various cover types in certain bands of sensing. Sometime the different in brightness values from similar surface material are caused by topographic conditions, shadows, or seasonal changes in sunlight illumination angle and intensity. These conditions may hamper the ability of an interpreter of classification algorithm to correctly identify surface materials or land use in a remotely sensed image. The ratio transformations of the remote sensing data in certain instances are applied to reduce the effects of such environmental conditions (Friedman, 1980). In addition to minimize the effects of environmental factors ratios may also provide unique information not available in single band that is useful for discriminating between soil and vegetation.

4.2. GIS and AHP Multi-criteria Modelling

Geographic information systems (GIS) have made remote sensing a unique technology and widened the spectrum of remote sensing applications on natural resources management and urban sustainability evaluation. Quantified indicators of urban form can be effectively derived using AHP based multi-criteria method, and spatial metrics, incorporating the influence of socio-economic factors, thus, and trying to portray the internal variations of urban form in the city. Of much significance in study of urban form is to explore and evaluate the quantitative descriptors of spatial urban form (Herold Liu and Clarke, 2003) on the basis of the distinct relationship between the physical form and the land use, socio-economic, demographic, and ecological characteristics of a region.

4.2.1. Spatial Metrics for Measuring Urban Form

Time and often there has been a lot of research on the description, mapping, characterization, measurement, understanding and explanation of urban form and morphology. The classical theories of urban morphology define urban patterns as concentric rings with different land use types (Burgess's Concentric Zone Theory, 1925). Since 1960s various modern theories

have been experimented with to characterize urban form, viz fractals, cellular automata landscape metrics, etc. But the inadequacy with the other models in comparison to spatial metrics is that these models fail to interact with the causal factors such as population characteristics, availability of land and proximity to city centres and highways (Sudhira, Ramachandra, and Jagadish; 2004). Spatial metrics indicators offer improved description and representation of heterogeneous urban areas. It provides a link between the physical landscape structure and urban form, functionality and processes (Barnsley and Barr, 1997). The very spatial dimension of an urban area enables indicators to be developed using remote sensing analysis techniques.

Recently, attempts have been made to develop "a global comparative analysis urban form" (Huang, Lu, and Sellers, 2007) using spatial metrics and remote sensing. Various techniques which are highly efficient for analyzing and computing urban form / morphology are (i) Area weighted mean shape index (ii) Area weighted mean patch fractal dimension (iii) Centrality (iv) Compactness Index (v) Open Space ratio (vi) Density (vii) Compactness of largest patch index, etc.

4.2.2. Shannon's Entropy for Urban Sprawl Measurement

Urban sprawl is a measure to map and quantify the extent of growth occurred spatially. Shannon's Entropy proposed by Yeh and Li, (2001), can measure the degree of spatial concentration or dispersion of a geographical variable among the zones been considered. The entropy of an area with less density of built-up will have less entropy compared to high density of built-up. Measuring urban sprawl helps in understanding the extent of growth and its direction. Shannon's entropy is calculated by the equation as mentioned below.

$$H_n = \sum_{i}^{n} P_i \log\left(\frac{1}{P_i}\right) \quad \ldots (1)$$

where, P_i represents the proportion of occurrence of built up in the i^{th} spatial unit among n units. P_i is calculated as an area of built-up in i^{th} unit divided by total built-up inside all units.

$$P_i = x_i / \sum_{i}^{n} x_i \quad \ldots (2)$$

where, x_i is the area of built up in the i^{th} unit. Entropy value ranges from zero to log (n).

4.3. Climatic Water Balance

The Water table calculated for a single soil profile or for an entire area, refers to the balance between incoming of water by precipitation and outflow of water by evapotranspiration, ground water recharge and stream flow. The water balance is useful for predicting some of human impacts on the hydrologic cycle. The hydrologic effects of

weather modification or changes of vegetation cover can be quickly estimated at a very early stage in the planning. The method is valuable for helping to phrase precise questions about the chances of success, mode of operation, and environmental impact of proposed changes. It is, therefore, a valuable tool in the analysis of water problems in a region.

4.3.1. Estimation of the Water Balance

The water balance of a small drainage basin underlain by impervious rock at depth can be expressed in the Equation-3.

$$P = I + AET + OF + \Delta SM + \Delta GWS + GWR \quad \text{……………………………………………. (3)}$$

Where the symbols, expressed as equivalent depth of water for some time interval, represent precipitation, interception, evapotranspiration, overland flow, change of soil moisture storage, change of ground water storage, and ground water runoff.

4.3.2. Computation Method to Evaluate the Monthly Water Budget

To compute the climatic water balance, it is first necessary to obtain data of water supply (precipitation) and climatic water need (potential evapotranspiration). For the computation of water balance potential evaporation data can be calculated by using either evaporation data or empirical equation or by analytical methods.

PET is a primarily function of climatic conditions (energy from the sun) and is not a function of type of vegetation, type of soil, soil moisture content, or land management practices (Mather, J., 1978). PET can be calculated using different methods like penman's method, Thornthwaite method etc.

(a) Penman - Monteith Method

The FAO Penman-Monteith method is widely used as the standard method for computing reference evapotranspiration (ETo) from meteorological data. The FAO Penman – Monteith method is recommended as the sole ETo method for determining reference evapotranspiration. It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data short situations. The FAO Penman-Monteith method is selected as the method by which the evapotranspiration of a reference surface (ETo) can be unambiguously determined, and as the method which provides consistent ETo values in all regions and climates.

$$ETo = (0.408\ \Delta\ (R_n\text{-}G) + \gamma 900\ u_2\ (e_s - e_a) / (T+273)) / (\Delta + \gamma\ (1+0.34\ u_2)) \quad \text{……….. (4)}$$

Where:

ETo reference evapotranspiration [mm day-1]

R_n net radiation at the crop surface [MJ m-2 day-1]

G soil heat flux density [MJ m-2 day-1]

T means daily air temperature at 2 m height [°C]

u_2 wind speed at 2 m height [m s-1]

e_s saturation vapors pressure [kPa]

e_a actual vapour pressure [kPa]

e_s - e_a saturation vapour pressure deficit [kPa]

Δ slope vapour pressure curve [k Pa °C-1] Psychometrics constant [k Pa °C-1]

(b) Thornthwaite Method

Computation of ET in this method is mainly based on temperature data only. By using the equation (3) a monthly heat index (j) is calculated employing the mean monthly temperatures.

$$j = ((t_n) / 5)^{1.514} \quad \ldots\ldots (5)$$

Where:

j = monthly heat index

t_n = monthly mean temperature, 0c (where n= 1,2,3……12).

Annual heat index (J) is given by the equation (3) adding together twelve monthly heat indices.

$$J = {}^{12}\sum_{1} \mathbf{j} \quad \ldots\ldots (6)$$

Then, monthly PET for any month is calculated by means of the following equation (7)

$$PET = (16\ f\ (10\ t_n / J))\ mm \quad \ldots\ldots (8)$$

Where:

a is the cubic function of J

$a = (675*10^{-9}) J3 - (771*10^{-7}) J2 + (179*10^{-4}) J + 0.492$

f = factor, to correct for unequal day length between months.

It is necessary to adjust the value of unadjusted 30-day potential evapotranspiration and 12 hours of sunshine per day, modulating by factor (f).

For other latitudes f value has to be interpolated from the above table. After the calculation of PET, the dry and wet seasons should be identified. If the difference between P and PET is positive, it is considered as wet season, otherwise it is dry season.

The severity of the dry season increases during the sequence of months with excessive potential evapotranspiration. The accumulated potential water loss (La), which is the cumulative of negative values of (P-PET) for the dry season only, is calculated from the end of the wet season.

Next, the water storage capacity (SM), which depends upon the soil texture type, rooting depth of vegetation and land use, in the root zone of the soil must be determined. Then, from the readily available tables or graphs or by using the empirical formula for dry season months we can find how much water will be retained in the soil after various amounts of accumulated potential water loss. For the case of wet season's soil moisture values can be determined by adding the excess precipitation to the soil moisture value of the previous month until the total storage again reaches the water-holding capacity of the soil.

The soil moisture status for each month with evapotranspiration exceeding precipitation is calculated using the following equation (6):

$$SM = W * exp.\ (-La / W) \quad \ldots\ldots (9)$$

Where:

SM = soil moisture, mm

La = accumulated potential water loss,

W = water capacity, which has been calculated for the different land use class and soil texture, mm

The ability of soil to retain water depends upon the amount of silt and clay present; the higher the amount, the greater is the soil moisture content.

The change in moisture content (ΔSM) that is equal to the difference of soil moisture in a month and its proceeding month should be calculated.

Actual evapotranspiration (AET) represents the actual transfer of moisture from the soil and vegetation to the atmosphere. When P exceeds PET, it is assumed that there is sufficient moisture to meet the climatic demands and

$$AET = PET \quad \ldots\ldots (10)$$

Even if the soil moisture of root zone is not at its storage capacity but if P > PET it can be assumed that P will be sufficient to satisfy climatic moisture requirements, i.e. AET=PET.

When meteorological demand must be partially satisfied from the stored soil water (when P<PET);

$$AET = P + |\Delta SM| \quad \ldots\ldots (11)$$

Then, we should identify that in which months occurs moisture deficit (D) that means there is not enough water to satisfy the vegetation needs. D that exists only in dry period when P<PET, is calculated by the equation (9).

$$D = PET - AET \quad \ldots\ldots (12)$$

The amount of excess water that cannot be stored is termed as moisture surplus (S). When storage reaches its capacity, surplus is calculated using the equation (10).

$$S = P - (AET+|\Delta SM|) \quad \ldots\ldots (13)$$

By definition, actual runoff equals to the available annual surplus. However due the lag between the time of precipitation and the time the water actually passes the gauging station, monthly computed surplus is not the same as monthly runoff (RO). As per Thornthwaite and Mather's suggestion it can be assumed that for large catchments approximately 50% of the surplus water that is available for runoff in any month runs off. The rest of the surplus is detained in the subsoil, groundwater, small lakes, and the channels of the basin and is available for runoff during the next month. If the water balance is calculated for short periods or for catchment whose area is very small, the amount of moisture detention will be considered less than 50%.

(c) The TM Model

For computing the climatic water balance using the TM model, monthly potential evapotranspiration was calculated using the following equation:

$$PET = 16 \times C \times (10 \times T / I)^{a} \quad \ldots\ldots (14)$$

Where PET is the potential evapotranspiration (mm month - 1); T is the mean monthly temperature (°C); I is the annual heat index for the 12 months in a year ($I = \Sigma i$); i is the monthly heat index ($i = [T / 5]^{1.514}$); $a = 6.75 \times 10^{-7} \times I_3 - 7.71 \times 10^{-5} \times I_2 + 1.792 \times 10^{-2} \times I + 0.49239$; and C is a correction factor for each month ($C = [m / 30] \times [d / 12]$), where m is the number of days in the month and d is the monthly mean daily duration (i.e. number of hours between sunrise and sunset and expressed as the average for the month).

P - PET, which is an estimation of the quantitative water excess (+) or deficit (–) with P as precipitation was calculated. Then the accumulated values of (P - PET), i.e. the accumulated potential water loss (APWL) for each month, were calculated. This will be zero for months having positive (P - PET) and starting with the first month having a negative value after the monsoon. Then the actual storage of soil moisture (STOR) for each month was calculated as follows:

$$STOR = AWC \times e^{(APWL / AWC)} \quad \ldots\ldots (15)$$

Where AWC is the moisture storage capacity (i.e. the available water capacity) of the soil

This was calculated based upon the land use, soil texture and rooting depth as suggested by Thornthwaite & Mather (1955, 1957). Changes of actual storage (ΔSM) for all the months were calculated as:

$$\Delta SM_{month} = STOR_{month} - STOR_{previous\ month} \quad \ldots\ldots (16)$$

A negative value of ΔSM implies subtraction of water from the storage to be used for evapotranspiration, whereas a positive value of ΔSM implies infiltration of water into the soil and its addition to the soil moisture storage.

The actual evapotranspiration (AET) was computed for all the months, as given in equations (17) and (18):

$$AET = \Delta SM + P \quad \Delta SM < 0 \quad \ldots\ldots (17)$$

$$AET = PET \quad \Delta SM > 0 \quad \ldots\ldots (18)$$

The water deficit (DEF) for crop evapotranspiration in each month was calculated for the months having negative (P - PET) as follows:

$$DEF = PET - AET \quad \ldots\ldots (19)$$

The amount of excess water that cannot be stored is denoted as moisture surplus (SUR). When storage reaches its capacity, SUR is calculated using equation (20):

$$SUR = P - PET \quad \ldots\ldots (20)$$

When the soil storage is not at its capacity, no surplus exists. In a month in which the soil moisture storage capacity is just satisfied, SUR is obtained using equation (21):

SUR = P - (AET + ΔSM) …….. (21)

Where: ΔSM is the change in actual soil moisture storage

By definition, actual runoff should be equal to the available annual surplus. However, due to the lag between the time of precipitation and the time when water actually passes the gauging station, monthly computed surplus is higher than monthly runoff (RO). As a rule of thumb, it can be assumed that, for large catchments, approximately 50% of the surplus water that is available for runoff in any month runs off (Thornthwaite & Mather, 1957). The rest of the surplus is detained in the subsoil, groundwater, small lakes and the channels of the basin and is available for runoff during the next month.

5. CONCLUSIONS & RECOMMENDATIONS

This study invariably provides an overview of technologies and methods for monitoring and measuring the built-up, ecological quality of cities and micro-climate dynamics. The study recommends the utility of Remote sensing, GIS technologies coupled with AHP-MCE and Water balance methods as the efficient combination for evaluating change in urban morphology and micro-climate scenarios and making efficient decisions concerning urban environmental sustainability. In order to ensure the urban life systems more prudent, lively and sustainable, the study recommends the following pragmatic approaches which auger the integrated sustainable economic and environmental development of a city. (i) Living off of nature's income: promote the use of renewable energy and clean technologies to protect the environment and prevent any harmful impacts. (ii) Protect the quality of natural environment by conserving the open spaces and keeping the pollution and waste levels as low as possible.

(iii) Compare and bring the carbon footprint to a desired level. (iv) Encourage businesses which use clean/green technologies which are environmental friendly and cost-effective. (v) Encourage investments in businesses which engage in energy conservation, renewable energy, green transportation technology and smarter buildings.

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Role of Beneficial Micro-organisms for Climate Change Adaptation in Sustainable Agriculture

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1. Introduction

Climate is defined as the average weather conditions, e.g. the average temperature in different seasons, rainfall, and wind in a given region over a longer period of time. Climate change involves a systematic change in the long-term statistics of climatic variables such as temperature, precipitation, pressure, or wind over several years or decades. Climate change can be due to natural external forces or it can be human induced. Anthropogenic activities like industrialization, urbanization, and development of infrastructure etc. contribute to changes in the climate which is expected to turn detrimental for crop production. Since climate plays a crucial role in total production and productivity of agricultural crops, these climatic changes through their direct or indirect effect on plants are impacting agricultural ecosystems and food security across the globe. Shifting weather patterns affects agriculture through changes in average temperatures, increased rainfall variability, and climate extremes (e.g., heat waves); changes in pests and diseases, fostering their spread and evolution of new strains of insect pests; fungal, bacterial and virus diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods.

2.Effects of climate change phenomenon on crops

The major impacts of climate change involve variations in annual rainfall, average temperature, global increase of atmospheric CO_2, and sea level fluctuations decreasing crop yields (Raza et al.,2019) by as much as 70% (Boyer,1982).

2.a. Effects of Temperature:

The growth, development, physiology, and productivity of plants has long known to be affected by global warming, caused by gradual increase in temperatures world-wide 3445 occurring due to an increase in the concentration of CO_2 and other greenhouse gasses. Higher Temperature is known to increase the transpiration and stomatal conductance in plants and causes a significant reduction in the plant biomass yield by decreasing the photosynthetic rate (Djanaguiraman et al., 2010; Qaderi et al., 2012). Soil warming leads to alteration in the release of soluble metal ions in to soil solution and changes the metal bioavailability, their uptake and distribution in plant tissues through the decomposition of Soil Organic Matter, lysis of the microbial cell and the destruction of soil aggregates. Elevated temperature also enhances the soil

enzymatic activity (Sardans and Penuelas, 2006) causing the release of trace elements from organic to exchangeable complex thus leading to an increase in plant metal uptake. The active sites on the root surfaces are also known to be increased at the elevated temperatures along with changes the lipid composition and fluidity of the plasma membrane (Lynch and Steponkus, 1987) facilitating active and passive metal flux through the membrane (Fritioff etal., 2005). The element uptake or their accumulation (e.g., Cu, Zn and Fe) in plants is greatly influenced by elevated temperatures via enhancing the various physiological processes and consequently the nutrient demand.

2.b. Effects of elevated carbon-dioxide: By the year 2050, tropospheric concentration of CO_2 is expected to increase from 355 ppm (v/v) to 710 ppm. It has been shown in many studies that elevated CO_2 concentrations are beneficial for plant growth which varies from species to species. A ten-to-twenty-fold increases in atmospheric CO is also well tolerated by most soil-inhabiting fungi including some species of pathogenic fungi e.g. *Phytophthora, Sclerotium, Fusarium* which show better multiplication rates at high CO* and low O_2 levels. Growth and physiological processes in plants and changes in plant metabolism are promoted by increased CO_2 concentrations involving a significant increase in the photosynthetic rate, reduced transpiration rate per unit leaf area and an increase in total plant transpiration (due to the larger leaf area) Li et al., 2003). The Stimulation of plant growth by carbon dioxide has been attributed to the fixation of CO by the fungi. Some fungi use carbon dioxide as an additional C-source for energy supply and growth (Wells & Uota, 1970).

3.Changes in rainfall pattern: Crop productivity is vulnerable to rainfall variations and major part of agriculture in developing countries being rain-fed, changes in agro-climatic conditions like droughts and floods directly affect the livelihood and survival of people.

a. Effects of Drought: It is the most devastating environmental stress decreasing crop production more than any other environmental stress leading to reduced rate of cell division and expansion, reduced leaf size, decrease in stem elongation and root proliferation, altered stomata oscillations and plant water and nutrient relations along with decreased crop productivity and reduced dry matter accumulations. Microbes are more tolerant to water stress as compared to plants. The main effect on soil processes include limited diffusion and limited supply of resources to the soil organisms. Severe drought leads to restrained metabolic activity of the microbes and a decrease in their functional diversity. Thus rains that end a drought release the microbes from stress along with creating a resource pulse fuelling their microbial activity.

b. Effects of Flooding: Plants exposed to flooding undergo wilting within a few hours to 2-4 days as waterlogging leads to a decrease in the oxygen diffusion capacity creating hypoxic or even anoxic environments. These conditions lead to nutrient deficiency especially inhibiting the activity of nitrifying communities causing depletion of available nitrogen, reduced photosynthesis and net carbon fixation ultimately leading to reduced overall growth and crop yield. Decreasing oxygen levels also alters the physico-chemical properties of the soil causing the tissues to produce some toxic by-products damaging the plant roots. Increase in the secondary metabolite

concentration e.g. phenolics and volatile acids, reduced soil pH, increased CO2 levels are other consequences of water logged soil. Flooding also changes the microbial communities' composition leading to anaerobic conditions which favour the growth of microorganisms that can survive in such conditions.

Role of Beneficial Micro-organisms in mitigation of climate change effects

To feed the ever-increasing population, there is pressure in many countries to increase the crop production involving land area expansion and use of numerous agricultural practices involving huge and continuous inputs of inorganic chemical fertilizers and synthetic chemicals for pest and weed control. This has led to soil degradation, reduced water quality, groundwater contamination, decline in food quality and acceleration of soil erosion threatening the sustainable management of plant and agricultural systems. There is an urgent need of sustainable initiatives including integrated nutrient management systems to increase the crop yields on the farms while minimising the environmental impact of agriculture. Microbial inoculants have emerged as a promising tool of such management systems.

Improper utilization of the applied fertilizers is mainly responsible for their harmful environmental effects. Use of fertilizers has led to the loss of more than 50% of the applied nitrogen from the agricultural systems in the form of nitrogen, as trace gases, or as leached nitrates (Vitousek et al. 1997) causing long term global environmental degrading impacts. Likewise, phosphorous which is another growth-limiting nutrient is precipitated by metal complexes in the soil (at times up to 90%) (Rodriguez and Fraga 1999) when applied in high soil concentrations leading to phosphorous pollution.

The microbial inoculants have emerged as promising solution to the agro-environmental problems as they help in regulating plant adaptations and their tolerance to various climate change stresses through their ability to promote plant growth, enhancing nutrient availability and uptake and supporting the health of plants (Han and Lee 2005). There are three major groups of microbial inoculants:

(1) Arbuscular Mycorrhiza Fungi (AMF), (2) PGPR (Plant Growth Promoting Rhizobacteria) and (3) Nitrogen-fixing rhizobia.

Plant –PGPR interactions are known to benefit the plants in the following ways:

1.Increase in seed germination rate, leaf area, shoot and root weights, chlorophyll content, nutrient uptake, protein content and hydraulic activity 2. Root growth enhancement 3. Yield enhancement 4. Tolerance to abiotic stress, 5. Biocontrol 6. Delayed senescence7. Enhancing phosphorous uptake 8. Atmospheric nitrogen fixation 9. Iron sequestration for plants through siderophore production and 10. Production of plant growth hormones such as gibberellins, cytokinins , and auxins.

There are direct and indirect mechanisms through which the PGPRs enhance the uptake of nutrients. They mainly involve the enhancement of growth and development of root and root systems thereby creating larger surface area and increase in the number of root hairs so as to access more nutrients. The AMF especially are responsible for highly efficient P-uptake mechanism in

plants which involve their hyphae that have large surface areas and the extra radical hyphae on them act as a bridge between the plant roots and the soil.

Microbes involved in the alleviation of some environmental stresses

Environmental stress	Species	Mechanism of action/Function performed
Salinity stress	Pseudomonas fluorescence, AM fungi	Through osmolytes and salt stress induced proteins
Drought	Combination of AM fungi and nitrogen fixing bacteria	Photosynthetic efficiency and antioxidative response
Flooding	Arbuscular Mycorrhiza	Photosynthetic efficiency and antioxidative response
High temperature tolerance	Bacillus Polymyxa, Mycobacterium phlei	Through calcisol production

There is a need for better understanding of the environmental stresses that decrease the crop productivity and useful aspects of plant associated microbes as fertilizers in preventing the damaging effects of climate change.

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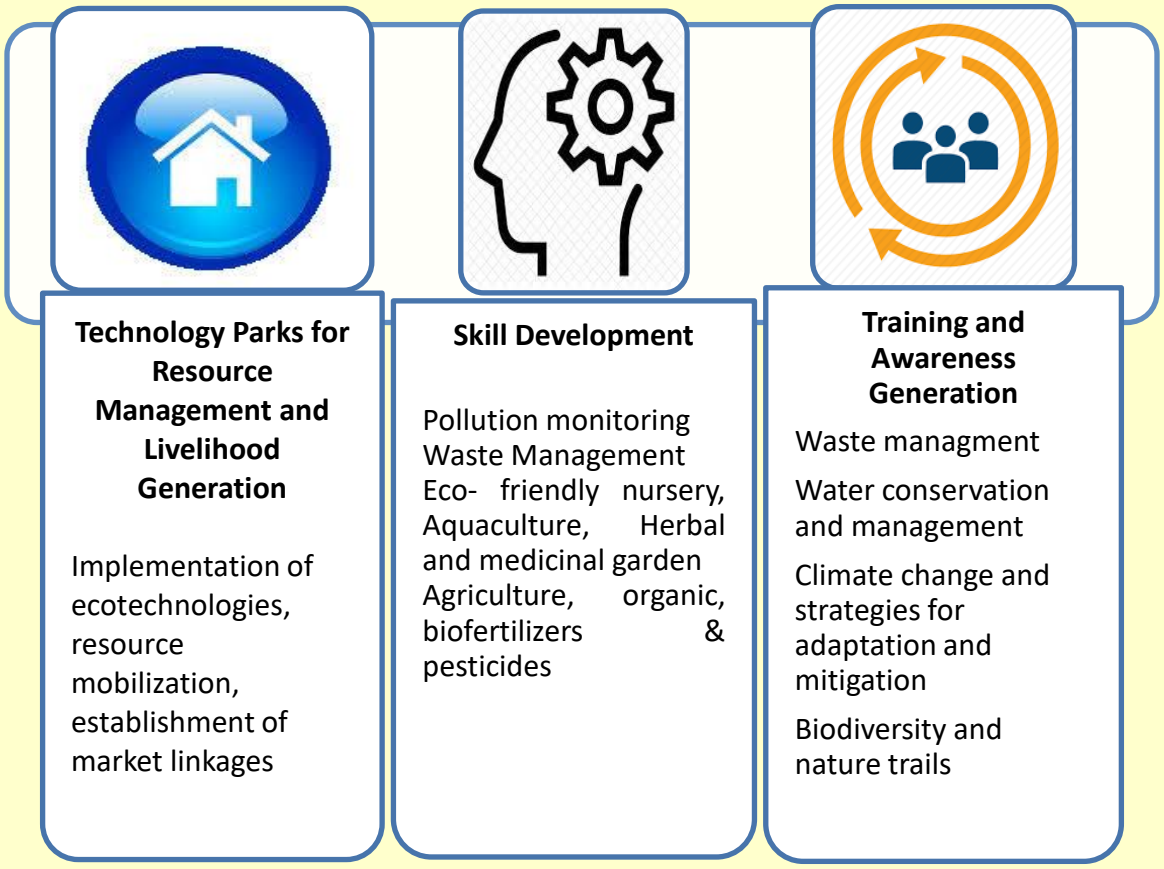
MAJOR AREAS COVERED UNDER OUTREACH ACTIVITIES AND COMMUNITY MOBILIZATION AT SIES IIEM



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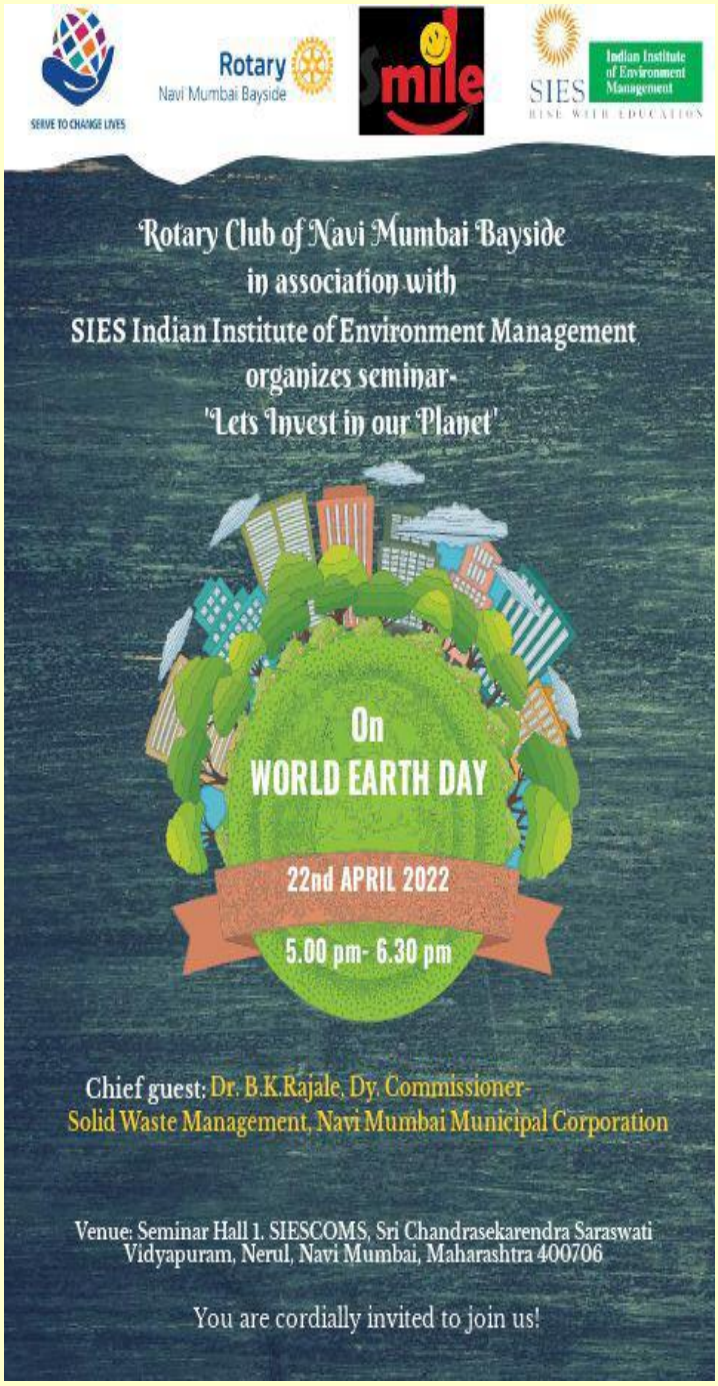
Report On the Seminar Organised on Earth Day, 2022

A seminar on Earth Day, 2022 was organised on the theme 'Let's Invest in our Planet' on 22nd April, 2022 with Rotary Club of Navi Mumbai. The programme was conducted by Ms. Shruti Panchal. Ms. Pritika Matkar has given a presentation on the topic 'Mission 6 R for plastic waste management'. Dr. Dilip Sathe has delivered a lecture on the theme 'Current Scenario in Solar Power'. Dr. Prachi Ugle Pimpalkhute has delivered a lecture on the 'Sustainable Actions in Current Scenario for the Conservation of Earth'.



Themes of Previous Issues of Quarterly Newsletter 'The Environment Management'

Volume I: Issue- 1 **Environmental Monitoring and Assessment for Pollution Control**	**Volume IV: Issue- 1** **Green Jobs for Sustainable Environment Management**	**Volume VI: Issue- 2** **Biodiversity Conservation and Management**
Volume II: Issue- 1 **Natural Resources and their Management**	**Volume IV: Issue- 2** **Beat Plastic Pollution**	**Volume VI: Issue- 3** **Sustainable Management of River Ecosystem**
Volume II: Issue- 2 **Environment Management for Sustainable Development**	**Volume IV: Issue- 3** **Waste Management Technologies**	**Volume VI: Issue- 4** **Emerging Opportunities in Environment Management in Post Covid- 19 Era**
Volume II: Issue- 3 **Water Treatment Technologies**	**Volume IV: Issue- 4** **Geospatial Technologies for Environment Management**	**Volume VII: Issue- 1** **Ecopreneurship**
Volume II: Issue- 4 **Environment Management and Sustainability**	**Volume V: Issue- 1** **Environment Management Systems in Pollution Control**	**Volume VII: Issue- 2** **Ecological Restoration for Sustainable Future**
Volume III: Issue- 1 **Wetlands: Conservation and Management**	**Volume V: Issue- 2** **Beat Air Pollution**	**Volume VII: Issue -3** **Research and Publication Ethics**
Volume III: Issue- 2 **Green technologies in pollution control and management**	**Volume V: Issue- 3** **Environmentally Sound Technologies**	**Volume VII: Issue- 4** **Youth in Sustainable Environment Management**
Volume III: Issue- 3 **Wealth from the Waste**	**Volume V: Issue- 4** **Environment Law and Policy in Sustainable Development**	**Volume VIII: Issue- 1** **In Pursuit of Sustainable Development Goals: Challenges and Opportunities**
Volume III: Issue- 4 **Corporate Social Responsibility in Environment Management and Sustainability**	**Volume VI: Issue- 1** **Zero Carbon Emission by 2050: Challenges and Future Prospects**	**Volume VIII: Issue- 2** **Only One Earth: Actions for Sustainable Environment**

Previous issues of newsletter are available on www.siesiiem.edu.in

Environment in News Headlines

Global Plastic Waste is Projected to Triple by 2060

The annual production of fossil fuel-based plastics is set to top 1.2 billion tonnes by 2060 and waste to exceed 1 billion tonnes, according to a report by Organisations for Economic Cooperation and development (OECD)

Indian Express, June 2022

Satellite Used to Detect Major Offshore Methane Gas Release for the First Time

A new study in the journal of Environmental Science and Technology Letters identified a plume from an oil and gas production platform in Gulf of Mexico that release around 40,000 tonnes for a period of over 17 days in December 2021. In this study of Valencia Polytechnic University, satellite is used for the first time in world for the monitoring of gas release.

Agence France Presse, June 2022

Algae Powered Computing

Researchers at University of Cambridge have developed Blue Green based fuel to power microprocessor for one year by using only water and light. The system used *Synechocystis,* a blue green alga that naturally harvests energy from the sun that is linked with aluminum electrode to run microprocessor

Journal of Energy and Environmental Science, May 2022

Synthetic Leather or Vegan Leather is More Environmentally Sound than Natural Fibers

Petroleum based leather is being promoted as an environment friendly leather by leading fashion brands because it is having less environmental impacts than cotton, wool, or leather. Higg Index, a Rating system is introduced in 2011 by leading fashion brands that given preference to synthetic materials over natural. It fives more preference to ecological footprints over environmental footprints that is why it is criticized by environmental experts.

The New York Times, June 2022

The Microplastics are Present in Snow in Antarctica

A study published in The Cryosphere reported that 29 microplastic particles were present in per liter of melted snow from Antarctica. These particles measured up to 5 mm. The microplastics were three times more in the samples collected from near the research stations.

Mongabay Series, June 2022

Forthcoming Event

Internal Training Programme on Instrumentation Techniques in Air Pollution monitoring

Articles, photos etc. are invited for next issue (July - September) of the Newsletter on the theme "Nature Based Solutions in Environment Management'

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