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Review Paper

Effective technologies and lifestyle changes to reuse and control waste generation from natural and anthropogenic activities for sustainable future

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Abstract

Environmental pollution has increased drastically in few decades. Various natural as well as anthropogenic activities have inevitably increased greenhouse gases leading to climate change and chronic disease development. The extreme globalisation, urbanisation and population rise together with natural disasters, improper resource management and vehicle exhaust had created a holocaust of environmental contaminants. To counter it, numerous short-term and long-term interventions are available by government organisations, NGOs and civil societies. In long term interventions, environmental biotechnology is the best method to preserve ecosystem from pollution in an eco-friendly manner. Some of its applications include bioremediation, biocomposting, bioenergy and biomarkers that can substitute the fossil fuel and reduce waste generation. Significant progress is being done in India's National Solar Mission to achieve renewable and clean energy sources thereby fulfilling Goal 7 of the SDGs. There are several sustainable working models available that can be modified according to the need of location. Furthermore, advance studies for biodiversity exploration, adequate and strict government policies implementation and change in lifestyle are required to reap the environmental pollution and move towards sustainable future.

Keywords: Biocomposting, bioenergy, biomarkers, bioremediation, environmental biotechnology, pollution, working models.

Introduction

Currently world is struggling with pollution and climate change that has increased abruptly during the last few decades. With the industrialisation and population rise, pollution has reached above carrying capacity leading to chronic human diseases. Air pollution alone is responsible for over 3 million premature deaths worldwide[1] caused due to $PM_{2.5 \text{ and } 10}$ inhalation. Among these, $PM_{2.5}$ is more deadly due to their greater penetration into the lung alveoli causing chronic diseases. Other risk factors are radiation, chemical exposures, water and soil pollution that contributes to about 12.6 million deaths each year[2].

Air pollution due to natural and anthropogenic activities: Air quality is associated with the changing state of weather, type of climate and meteorological factors such as atmospheric wind speed, its direction and temperature. During winter, moisture laden cold air become heavier and forms thin layer near the earth's atmosphere. This layer traps the pollutants at ground level where people breathe. The condition reverted during summer however, forest fire, industrial pollution, particulates mixing with ground ozone form summer smog that adversely affect the human health[3]. Volcanic eruption also contributes various greenhouse gasses leading to global warming, air pollution, ozone layer depletion *etc*. They severely damage vegetation and are hazardous to human health ranging from minor to life threatening outcome[4].

According to 2018 database of WHO, 97% of the low- and middle-income countries do not meet WHO air quality guidelines[5]. The highest urban air pollution often exceeding 5-10 times of WHO limits in eastern Mediterranean and south-east Asian regions followed by low-income cities in the western Pacific region. In 2016, India had highest levels of $PM_{2.5}$ and out of 30 most polluted cities of world, India had 16 cities having worst air pollution[6]. In India, HAP and AAP contribute about 6% and 3% of the total national burden of disease[7].

Stubble burning is a common practice adopted by north Indian farmers releasing toxic atmospheric gasses (CO_2, CH_4, CO, N_2O, NOx and SO_2) into ambient air which are responsible for 20% of smog in winter season. They also cause rise of ground temperature that kills friendly microbes and decreases soil fertility[8]. Though, there are technology available to use dry fodder effectively, they are expensive, farmers are ill-equipped to adopt new technology, low income status, lack of seamless alternatives and little time left between crop harvesting and sowing exacerbate the problem.

The arms race between the countries is being going on mainly to become superpower. It was estimated that nine countries hold

nearly 16,000 nuclear weapons that are enough to destroy the planet. There is global threat of nuclear war as many countries such as Iran, North Korea and Syria have violated their nuclear proliferation commitments. India and Pakistan are also involved in regional conflicts. USA and Russia account for 93% of nuclear stockpile and about 2,000 nuclear weapons are ready for immediate launch against each other[9]. However, United Nation trying to implement multilateral treaty on NPT by nuclear weapon states to ensure accountability.

Water and soil pollution due to natural and anthropogenic activities: Water and soil pollution are the most prominent environmental problems that affect the economic development as well as the quality of life in the region. Water and farmlands are affected by natural disasters such as hurricanes, volcanoes, tsunamis, earthquakes, floods, typhoons, droughts, heat waves *etc*. Tornadoes and hurricanes deposit silt in the water bodies that reduces its portability. Farm waste, detergents, chemicals, fertilizers are swept on land due to flood that pollute drinking water as well as farmland. Earthquakes and tsunamis cause saltwater contamination in drinking water supplies and hence infertility of farmland[10]. Oil or natural gas spill over the water bodies are of serious concern for aquatic ecosystem as well as coral reef. Recent Kerela flood indicates the disaster due to natural and anthropogenic activities.

Most of the rivers of India are highly polluted due to irregular agricultural-industrial effluents discharge and incorporation of chemicals, heavy metals as well as domestic wastes in the mainstream[11]. Since 1940s, pesticides were continuously used and improper concentration of herbicides, pesticides as well as fertilizers envisaged soil and water pollution[12]. It resulted in various complex physical, muscular, neurological degenerative diseases. In Punjab, the cancer prevalence (per million per year) found to be 1,089 in 4 districts of the Malwa region including Muktsar, Mansa, Faridkot, and Bathinda due to excessive use of mineral fertilizers in farming[13,14]. Metal exposure tested for physically and mentally challenged children of Punjab shows high amount of uranium concentrations that are above the European maximum contaminant level[15].

According to WHO, approximately 3 million cases of pesticide poisoning occur every year with death toll to 250,000[16]. In July 2017, over 1,000 farmers of Yavatmal (Maharashtra, India) have suffered from a toxic pesticides spraying on the BT cotton crop. There are some pesticide regulation available in India including 'The Insecticides Act, 1968 and Insecticides Rules, 1971' that regulate import, registration process, manufacture, sale, transport, distribution and use of insecticides (pesticides) throughout India[17]. Therefore, only need is strict implementation with advance knowledge and skill development of farmers.

Electronic waste: India is among top 5 e-waste generator in world after China, US, Japan and Germany. e-waste is discarded electrical or electronic devices such as DVDs, CDs, chips, processors, mother boards *etc*. They contain hazardous as well as precious metals. Over the past two decades, the production of EEE grows exponentially due to technology upgradation thereby rise in e-waste. According to ASSOCHAM-NEC study on June 2018, about 52.2 MT of e-waste will become obsolete globally by 2021 from 44.7 in 2016 and India has contributed 2 MT in it[18].

Recycling raw materials from e-waste is the best solution for curbing e-waste pollution. It has social and economic benefits such as employment and revenue generation, landfills prevention *etc*. In September 2005, India's first Government authorized e-waste recycler was started as E-Parisaraa Pvt. Ltd, Bangalore. It is engaged in handling, recycling and reusing of WEEE in an eco-friendly way[19]. There are about 23 units have been registered with CPCB by 2010 and a large number of small scale unorganized units involved in processing the waste[20]. Recycling include chemical and biological leaching method. Chemical leaching use acid or ligand supported complexation while biological leaching use acidophilic group of bacteria (*Acidithiobacillus ferrooxidans, A. thiooxidans, Leptospirillum ferrooxidans, Sulfolobus* sp.) which dissolve the precious metals from e-waste[21]. Some hybrid techniques have also been used to impede the drawbacks of both the processes.

However, according to EPA, only 15-20% of e-waste is recycled globally and India recycles only 5% of it. Over 95% of e-waste is managed by unorganised sectors and scrap dealers[18]. Recycling through burning is the easiest method adopted that cause exposure of range of heavy metals and their byproducts (lead, cadmium, chromium, brominated flame retardants or PCBs, toxic fumes) to humans and their accumulation in soil, water and food give rise to life-threatening health issues[22]. Hence, awareness creation about the hazardous nature of e-waste is essentially required.

Methods to clean up pollution

Overall scenario shows that the natural ecosystems have been declining rapidly and the crucial challenge for every country is to protect the endangered world from pollution. Pollution is inevitable and cannot be controlled immediately however, there are short-term, mid-term, and long-term interventions prepared by various commissions. Short-term interventions for improving air quality include identification and control of key pollutants, installation of dust management systems, establishing monitoring systems, mandating improved fuel quality, engine standards and design thereby implementation of effective enforcement systems. For water and soil improvement, polluted sites listing, high-impact sites clean-up and technical assistance as well as training provisions can be done. In mid-term interventions, proper waste disposal facilities and remediation projects expansion should be done. Long-term interventions for cleaning air include public transport upgradation, awareness and lifestyle changes. For water and soil improvement, stress should be given on expansion of remediation programmes[23] and

environmental biotechnology plays crucial role for making clean atmosphere.

Environmental biotechnology is the use of scientific and engineering technologies to explore the microorganisms and their products for pollution prevention in an eco-friendly manner[24]. They can clean up different categories of wastes more efficiently than conventional methods thus reducing the number of landfills. Historically, microorganisms have been used in agricultural wastes composting and sewage treatment date back to 6000 BC. However, in last 15 years, hazardous waste comprising of solvents, explosives, PAH, PCBs has been raised and microbes are successfully used to clean them[25]. Technological advances in computing and data processing has increased our information about the microbes that can be used in particular environments to decompose the toxic compounds.

Bioremediation and its applications

Bioremediation use indigenous microbes to consume waste materials and die off or return to their normal population levels in the environment without any side-effect. Bacteria, fungi and yeasts are the major microbes involved in biodegradation process[26]. Other methods such as bioaugmentation, biosorption, biosparging, biostimulation, bioventing, phytoremediation are used to stimulate the activity of microbes at a polluted site. New microbes may also be added to the soil to scavenge or reduce the wastes. Various studies are going on to discover an era of new possibilities in the world of biodegradation using microbes.

Namami Gange Programme: In India, National Mission for Clean Ganga intended to implement a project "In-situ Bioremediation of drain joining river Ganga" under 'Namami Gange Programme' with objectives of effective abatement of pollution, conservation and rejuvenation[27]. Sewage treatment through CW may be developed along river by raising potential aquatic acrophytes; *Typha*, *Phragmites*, *Colocasia*, *Polygonum etc.*, in gravel as medium act as alternative technology to check river water quality deterioration[28].

Oil/ natural gas eating microbes: Oil spills are global problem with no boundary. Dr. Anand Mohan Chakrabarty, an Indian-born American scientist had constructed a bacterial superbug by genetically engineered *Pseudomonas putida* in 1971. Researches going on to explore indigenous microbes and a study in Germany found two bacteria *Alcanivorax boskumensis* and *Oleispira antarctica* from the marine water that are involved in the oil eating[29]. Various other oil eating[30], carcinogenic constituent's scavenging[31], hydrocarbon utilizing[32] microbes have been found however, conclusive study is yet required.

Biocomposting to reduce organic waste: Economic revolution and population growth are the key factors for the increasing trend of waste production worldwide. Biocomposting is an eco-friendly conversion of organic waste into fine soil using various microorganisms along with earthworm (Vermicompost), housefly *etc*. It enhances soil biodiversity thereby suppressing the plant pathogens and pests population[33].

Currently, China is the world's fastest waste producing region which will shift to south Asia (mainly India) by 2025, and then to sub-Saharan Africa in around 2050[34,35]. Therefore, efficient and effective steps are required to improve the present scenario. Many countries such as San Francisco (California), Kawasaki (Japan), North America and Europe have started various methods such as conversion and reuse, zero-waste goal, disposal fee *etc.*, for effective waste management[36,37]. Out of all the waste produced, about 50% of residential wastes contain organic matter that can be managed by biocomposting (Table-1). The first full scale compost plant was established in 1932 in the Netherlands using Van Maanen Process in large windrows[38].

In India, average MSW produced is approximately 41 % which is nearly 700 million tonnes of organic waste generated annually and can be managed through biocomposting. Compost plants were set up in Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur, Puri and Kanpur during 1975-1998 using saprophytic microbes[39]. Largest MSW treatment and processing plant based on vermincompost is situated in Bangalore having 100 MT waste/day capacities[40]. However, India is still struggling for waste management, hence decentralised composting plant, appropriated segregation techniques and community participation is highly recommended.

Bioenergy: clean fuel (SDG7): Bioenergy is renewable energy that substitutes the fast depletion of fossil fuel. Wood resources from forest are the foremost source followed by agriculture and organic waste to produce bioenergy worldwide. According to WBA, India leads Japan, Canada and Australia in electricity production from plants[42]. Researchers found bioenergy crops to reduce the CO_2 emissions and support the biodiversity[43]. Numerous studies found the use of rice straw in the production of methane[44], bioethanol[45] and paper[46]. However, the major challenge of the present world is the production of bioenergy crops in low productive land with marginal soils without competing with the staple food crops[47].

Biowaste (agricultural wastes, MSW and sludge) have now recognized as sources for eco-friendly and sustainable energy production in India. According to Ministry of Statistics and Program Implementation[48], waste to energy production contribute >4% of the total renewable sources. Ministry of New and Renewable Energy, GoI has installed 3 MW capacity plant at Solapur, Maharashtra, 16 MW capacity at Okhla, Delhi, and has planned to support few more waste to-energy projects at Bangalore (8 MW), Hyderabad (11 MW), Pune (10 MW), and Delhi at Gazipur (12 MW). Narela (24 MW) in Delhi, waste-to-energy plant is under installation[49]. Ghosh[50] has found number of constrains in using biowaste as bioenergy such as biomass burning, transportation cost, land use pattern, technology

adoption *etc.*, and suggested their appropriate solutions also. However, intense research, trials and monitoring is needed in the production system on the basis of climate, land pattern, waste supply chain, technology adaptation and final application. In addition, qualified engineers and experienced environmental professionals are required to best deliver improved waste management systems in India[51].

Biofuel: Major sources of biofuel are microalgae, jatropha and vegetable oils, starchy and cellulosic materials, municipal wastes *etc.*, used as a substitute for petroleum products. It has great potential to mitigate climate change, provide job opportunities and improve the income thereby poverty alleviation. The National Policy on Biofuel-2018 helps in regulating biofuel production and its marketing. It comprise mandate blending of ethanol with gasoline and biodiesel with diesel[52]. Rajasthan becomes the first state to implement Biofuel policy in India. India's first biofuel powered flight has been successfully operated from Delhi to Dehradun paving way of alternative and clean fuel in the aviation sector.

Table-1: Types of biocomposting in India and abroad[41].

Types	Methods
Traditional methods	
Anaerobic composting	Alternate layers of leaves, organic residues and soil are put into a pit, watering for three months; require scanty rainfall, minimal labour and equipment, no mixing required.
Bangalore, Karnataka, India method	
Aerobic composting	For straw, vegetable refuse, weeds and leaves, wet animal dung put over it and water sprinkled, require 4 months.
Coimbatore, TamilNadu, India, method	
Indore, MP, India, method	Mixed plant residues, animal dung and urine, wood ash and water layered in a pit and plastered with soil, mixture turned after 15-30 days. Completion in 3-4 months.
Chinese rural composting- pit method	Rice stubble, dung (usually pig), aquatic weeds and green manure crops layered in a pit, plastered with mud and turned after 1-2 months. Completion in 3 months.
Aerobic high temperature composting	Alternate layers of sewage, dung and chopped stubble at a ratio of 1:4 with human and animal wastes. Optimum water addition aeration through bamboo poles and sealed with mud. After 4-5 days, temperature rises to 60-70°C, turning after 2 weeks and completion in 2 months.
Chinese rural composting	
Passively aerated windrow system	Long narrow windrows built on the base of straw, peat moss, or finished compost to absorb moisture, windrow insulation, retain moisture, odour, and ammonia, and help to discourages flies. No turning required, aeration naturally or convection and gaseous diffusion. Completion in 2 months.
Rapid methods	
Berkley rapid composting method	Organic matter of 1.25-3.75 cm in size, C:N ratio of 30:1(equal volume of green and dried materials), mixed in beans and heated upto 71°C for proper functioning of indigenous microbes. Turn everyday and complete in 2 weeks. Don't add soil, ashes from a stove or fireplace, and manure from carnivorous animals.
North Dakota State University hot composting	Organic matter of 15-23 cm long, nitrogenous fertilizer added for aerobic bacteria action, holes were made. Turn the composting material every three or four days and completed in three to four weeks.
High lignin content for composting organic materials	Organic wastes containing hard wood materials and dry fallen leaves mixed with lime in a ratio of 5/1000 kg of waste material. Lime enhances decomposition process of hard materials, microbial population and their activity.
Aerobic high temperature composting with inoculation EM based quick composting	Cow dung, rice husk, rice husk-charcoal, rice bran mixed together n the pit and accelerator (*Trichoderma* solution) sprinkled on it. Cover with plastic sheet, turn every week and compost ready in 2 weeks.

Electric vehicles: An effort to reduce pollution and heavy dependence on oil imports, India embraced electric vehicles with an aim to reach zero emission by 2040. Mobility is the key driver of economy and therefore our government outlined the vision of future mobility in 7C's *i.e.*, common, connected, convenient, congestion-free, charged, clean and cutting-edge[53]. However, inadequate charging infrastructure, higher cost of AC to DC converter, pollution due to fossil burning in electricity production, use of lithium batteries that increase dependency on China and Japan are the major challenges for its fast adoption.

Solar power mission: International Solar Alliance proposed in 2015, is an alliance of more than 121 tropic countries. The objectives of the alliance are on solar power utilization and fulfilling Paris Agreement (2015) on climate change. The National Solar Mission launched in 2010 with a target to produce 4 to 5 GW solar energy installed capacity by 2020 has increased to 100 GW by 2022[54]. This is one of the eight initiatives of NAPCC. In 2018, Diu becomes the first smart city to run on 100% renewable energy during day. Surat (Gujarat) is the first district to have 100% solar powered primary health centres and Cochin International airport is the world's first airport to operate completely on solar power. For these achievements, Cochin airport and Narendra Modi were awarded with UN's Champions of Earth award. World's first UN certified carbon-neutral football club is Forest Green Rovers, England and on that path the Chinnaswamy cricket stadium at Bangalore is the first 'Green Stadium' utilising solar energy after installing 400 kW rooftop solar power plant[55]. However, key issues like lack of public-private partnership, expensive manufacturer export policies and inadequate investors impede the solar energy development in India[56].

Biomarker/instrumentation: Contamination of the toxic chlorinated organic and heavy metal pollutants to the environment is a crucial problem of every nation. For the identification and estimation of these heavy metals, biomarkers (Table-2) are available that show various physiological, biochemical, cellular or behavioural variation which can be measured in tissue, body fluid or in whole organisms.

In a global survey for practice of bioremediation technologies for cleaning pollution, air pollution was at lowest priority while groundwater had higher priority in developed countries/regions[57]. In 2010, India setup SAFAR introduced by MoES, for air quality monitoring in Delhi that assess the gaseous pollutants and $PM_{2.5 \text{ and } 10}$ in real time with 24 hours forecasting[58]. In 2018, WAYU was developed by CSIR-NEERI that can purify air from PM, poisonous gasses and convert them to CO_2 in an area of 10,000 m^2. Similarly, CPCB analyses 28 parameters for microbial load, various trace metals, pesticides and biomonitoring to check inland water qualities under three-tier programme *i.e.* GEMS, MINARS and YAP[59].

Table-2: List of biomarkers for marine, air and soil pollution.

Pollutions	Biomarkers	Pollution type	References
Marine	*Gibbula umbilicalis*	Cd, Hg, Ni	60
	Holothuria grisea	Sn	61
	Utricularia gibba	Cr	62
	Mytilus species*; M. galloprovincialis, M. edulis* and *M. Trossulus*	Cu	63
	Test species: rohu (*Labeo rohita*), katla (*Catla catla*) and mrigel (*Cirrhinus mrigala*)	Various heavy metals	64
Air	PAH	PM, NO_2	65
	Alcaligenes sp.11SO, *A. feacalis*	Naphthalene and phenanthrene	66
	E. cloacae LSRC11, *Staphylococcus* sp. A1 and *P. Aeruginos*	Xylene	67
	MicroRNA	Smoke-related diseases	68
	Pseudomonas sp. Ph6-gfp	Phenanthrene	69
	1-hydroxypyrene (1-OHP)	Traffic-related exhaust	70
Soil	*Eisenia fetida*	Cd, Cu, Pb or Zn	71
	Lycopersicon esculentum	Cd, Cr, Hg, or Pb	72
	Eichhornia crassipes	Hg	73

Cu- copper, Cd- cadmium, Hg-mercury, Ni-nickel, Pb-lead, Zn- zinc, PM- Particulate matter, NO_2-nitrogen dioxide, Sn- tin, Cr- chromium.

Lifestyle changes can check pollution

Environment protection is the fundamental duty of the citizens. One powerful way of reducing pollution on individual basis is the change in lifestyle. We can opt for eco-friendly bicycle, public transport, carpooling *etc.* We can minimize food waste that result in landfills and greenhouse gas emission. Trash log keeping, compost formation for kitchen waste, habit of taking carry bags can be promoted to reduce waste. Nevertheless, get into gardening and follow '5R rule' *i.e.*, reduce, reuse, recycle, refuse and rot[74]. On society level, we can create environmental awareness among people through green blog, social media, symposium or through religious podium. Civil society should demand the supplies of clean water, hygiene services, sustainable use of natural resources, preserve nature and must be committed to biodiversity richness[75].

Most effective and simplest way to reduce the pollution is to increase flora in the surroundings with useful and ornamental plants. They help to increase oxygen level and eliminate toxins. According to air pollution tolerance index, *Taraxacum officinale* and *Betul apendula* species deemed tolerant and are suitable plants to combat atmospheric pollution[76]. We can plant them in our communities and as personal landscaping. Indoor and vertical plantation practices can be adopted that not only gives aesthetics feel but also reduces air pollution and insulates buildings. Vertical garden was invented by Stanley Hart White in the late 1930s that plants upward on vertical surfaces. These plants mainly belong to hydroponics group that grows by using nutrients through water and requires little maintenance[77].

Effective enforcement of regulatory policies

Pollution is inevitable and effective pollution control plans require support and cooperation from government, NGOs, national and international organizations. Government has great power to address individual and organizations against pollution especially against industrial pollution which is in the hand of corporate sector. In addition, pollution control policies should be ambitious and attainable. Every intervention should be strictly applied and accountability must be continuously assessed. A strong, transparent and clear environmental law is utmost components of policy and it should meet the 17 SDGs. Broad partnerships across civil society and their leadership commitment are highly required as they act as watchdogs, representatives of the public interest, advocate for specific policies, regulations, and practices to common people[23]. Government should implement 'price to pollute principle', carbon taxing, cap and trade schemes strictly to limit the environmental pollution. Above all, there are various committees and tribunals that provide us the stepwise procedures to tackle pollution and therefore the only requirement is there strict implementation by government.

Successful models to clean pollutions worldwide

Overall scenario shows that there are effective methods that sway sustainable development and clean environment. The only requirement is the implementation of these programmes in right direction. There are working models that clearly suggests that the powerful implementation envisage the revival of the clean environment. To clean pollution, source of contamination and site characterization is the critical step for application of *ex situ* or *in situ* techniques.

Working model 1: Mawlynnong located in the east Khasi hills of Meghalaya, India is the cleanest village in Asia in 2003 as well as the cleanest village in India in 2005[78]. The dedicated and environmentally conscious village population have zero tolerance for littering. They consider sanitation as community responsibility and there is a village leader who assigns daily work regarding waste collection and their disposal. The village community has collectively banned smoking and plastic usage, thus ensuring basic environmental cleanliness. They manage biodegradable waste by converting them in compost and reuse non-biodegradable waste by using some innovative ideas. Villagers are blessed with natural beauty and they maintain it by adopting rain water harvesting in natural basins, plantation along houses as well as maintaining the environmental sanctity.

Working model 2: Kali Bein, a holy river of Punjab, India that flows into the confluence of the rivers Beas and Satluj. The condition of the rivulet was pitiable due to high toxic effluent disposal from factories, sewage water disposal, deposition of silt, encroachment, dam construction causing water scarcity, change in river course *etc.* Sant Balbir Singh Seechewal took the initiative to clean the stretch of 160 km river. For this, he first started awareness amongst the people of the villages and towns about conservation of environment and to join voluntary service followed by prohibiting wastewater disposal in the river. Villagers started participating in the noble cause and gave their labour and implements to build infrastructure such as road for enhancing connectivity, installing underground sewerage system and pond for collecting water outside the village. He designed an indigenous sewerage treatment plant to treat the wastewater which works on the principle of sedimentation and aerobic treatment. The treated water from this plant is used for irrigation, farm forestry or community forestry and to recharge groundwater. The groundwater contamination, water logging and disease prevalence reduced with time.

Working model 3: Sikkim, also known as the Land of Flower is the first fully organic state of India that has strictly discouraged artificial fertilizers and pesticides and substituted chemical inputs by organic manures. In addition, establishment of basic infrastructure for compost production from farm waste to effectively mobilise them were also designed. Modern technology has been embraced through researches for rapid development of organic farming practices with collaboration of ICCOA Bangalore, and FiBL, Switzerland[79].

Working model worldwide: Historically, river offers various kind of ecological services to the living beings therefore many countries around the world had taken river restoration projects that were successful. Some of them are: i. Cleaning of Singapore River and Kallang Basin became successful in 1987 (started in 1977) due to strict government regulations, cultivating an environmentally conscious population, environmental management strategy, cooperation amongst the various government agencies and implementing as well as monitoring programme to inhibit pollutant entry into the river[80]. ii. Thames river (London) was declared biologically dead in 1957 but after 50 years, it is habitat of 125 fish species and another 400 invertebrate species[81]. This happened by strict government policies for industrial effluents discharge into the river and building up mud banks for plant growth as well as rubble piles that provide habitat for fishes, invertebrates and mollusc. iii. The improvement of water quality was observed in the New River (USA) by treating the sewage water before entering into river, planting marsh grass alongside and digging sediment ponds to decrease bacterial load[82].

Conclusion

Both the natural as well as anthropogenic activities have drastically increased the pollution worldwide. Globally, there is an urgent need of support and cooperation from all sectors of the society to resolve this malicious issue. Several tribunals and organisations are working together to provide attainable and scalable methodologies to conserve the environment. For long-term practices, environmental biotechnology has proved to be the best eco-friendly method for identification of the key pollutants and their tamed disposal. This is also helpful in generating compost and converting waste into energy. Various successful models are available that can be modified according to the requirement of the location. However, advance studies on waste management, effective government policies implementation, exploring renewable resources can transform the present scenario. In addition, lifestyle changes, conscience on resource utilisation as well as environmental awareness at individual and community level urgently needed. We should protect our environment and should always look for sustainable methods to fulfil amenities.

Future perspectives: Human are the centre of any development and development means to improve the quality of life of human and not just quantity of economy. According to Prof. Amartya Sen, development is the process of enlarging people's choices[83]. Therefore, our aim should be to fulfil need and not the greed of human. In present scenario, every nation indulge in improving their economy by exploiting their resources as well as environment which ultimately degrading the standard of living. Fast depletion of resources has been reported worldwide. Current technology uses remote sensing and GIS for resource mapping process. India has launched the 'South Asia Satellite' on 5th May, 2017 that will help in management and conservation of water resource, disaster and resource management and many more. The satellite photograph generates lot of data that are incorporated with topographical maps to show the variation of climate, soils, vegetation and other factors that will help to take effective steps in resource management and control pollution. It will also help in EIA of various projects (building of roads, buildings, pipe ways, dams *etc*.) on the flora and fauna of the ecosystem[84]. Moreover, developing indigenous methods for waste management and converting them into valuable products in energy efficient and eco-friendly manner is the present demand. Considering the present scenario, value of clean air, water and locality should be embraced by humans to bring sustainable development and peaceful environment.

Abbreviations: PM- Particulate Matter, HAP- Household Air Pollution, AAP- Ambient Air Pollution, NPT-Non-Proliferation of Nuclear Weapons, e waste- Electronic Waste, EEE- Electrical and Electronic Equipment, MT- Million Tonnes, WEEE- Waste Electrical and Electronic Equipment, EPA- Environmental Protection Agency, PCBs-Polychlorinated Biphenyls, PAH-Polycyclic Aromatic Hydrocarbons, CW- Constructed Wetland, MSW- Municipal Solid Waste, EM- Effective Microorganisms, WBA- World Bioenergy Association, NAPCC- National Action Plan on Climate Change, SAFAR- System of Air Quality and Weather Forecasting and Research, MoES- Ministry of Earth Sciences, WAYU-Wind Augmentaion Purifying Unit, GEMS-Global Environment Monitoring System, MINARS- Monitoring of Indian National Aquatic Resources System, YAP- Yamuna Action Plan, ICCOA- International Competence Centre for Organic Agriculture, GIS-Geographic Information Systems, EIA - Environmental Impact Assessment, SDG- Sustainable Development Goal.

References

1. Lelieveld, J., Evans, J.S., Fnais, M., Giannadaki, D. and Pozzer, A. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*, *525*(7569), 367-371.

2. News (2019). An estimated 12.6 million deaths each year are attributable to unhealthy environments. Available via http://www.who.int/mediacentre/news/ releases/2016/deaths-attributable-to-unhealthy-environments/en/ Accessed 11 Jun 2019

3. Cichowicz, R., Wielgosinski, G. and Fetter, W. (2017). Dispersion of atmospheric air pollution in summer and winter season. *Environ. Monit. Assess.*, 189(12), 605.

4. Report (2019). Volcanic gases can be harmful to health, vegetation and infrastructure. Available https:// volcanoes.usgs.gov/vhp/ gas.html Accessed 11 Jun 2019

5. News (2019). Air Pollution. http:// www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/ Accessed 11 Jun 2019

6. News (2019). Air Pollution Rises at 8%, 10 Countries With Most Polluted Air Revealed. Available via

http://www.natureworldnews.com/articles/22113/20160516/air-pollution-rises-8-10-countries-polluted-revealed.htm Accessed 11 Jun 2019

7. Metrics, I.H. (2013). Evaluation: the global burden of disease: generating evidence, guiding policy. WA: IHME Seattle.

8. Pal Singh, R., Ch, L., & Dhir, A. (2015). Impacts of Stubble Burning on Ambient Air Quality of a Critically Polluted Areaâ Mandi-Gobindgarh. *Journal of Pollution Effects & Control*, 1-6.

9. Report (2019). The nuclear threat. Available via http://www.nti.org/learn/nuclear/ Accessed 11 Jun 2019

10. Report (2019). Natural Disasters & Pollution. Available via http://education.seattlepi.com/natural-disasters-pollution-4892.html Accessed 11 Jun 2019

11. Report (2019). Status of Trace and Toxic Metals in Indian Rivers. Available via http://www.cwc.nic.in /main/downloads/Trace%20&%20Toxic%20Report% 2025% 20June%202014.pdf Accessed 11 Jun 2019

12. Schwarzenbach, R.P., Egli, T., Hofstetter, T.B., Von Gunten, U. and Wehrli, B. (2010). Global water pollution and human health. *Annu. Rev. Environ. Resour.*, 35, 109-136.

13. Dept of Health and Family Welfare (2013). State Wide Door to Door Campaign, Cancer Awareness and Symptom Based Early Detection. Government of Punjab; Chandigarh, India: 2013. Available via, http://pbhealth.gov.in/cancerawareness/CAC%20Report%201.1.pdf. Accessed 11 Jun 2019

14. Singh, B.P. (2008). Cancer deaths in agricultural heartland: a study in Malwa region of Indian Punjab. Available via http://www. gem-msc. org/Academic% 20Output/Academic% 20Output, 202006. Accessed 11 Jun 2019

15. Blaurock-Busch, E., Friedle, A., Godfrey, M. and Schulte-Uebbing, C.E. (2010). Metal exposure in the physically and mentally challenged children of Punjab, India. *Maedica*, 5(2), 102-110.

16. Report (2019). The Impact of Pesticides on Health: Preventing Intentional and Unintentional Deaths from Pesticide Poisoning. Available via http:// www.who.int/mental_health/prevention/suicide/en/Pesticides Health2.pdf Accessed 11 Jun 2019

17. IPCA Report (2019). Pesticide Regulations. Available via http://ipca.org.in/pesticide-regulations/Accessed 11 Jun 2019

18. NEWS (2019). Associated Chambers of Commerce and Industry of India. India among the top five countries in e-waste generation. Available via, http://www.assocham.org/newsdetail.php?id=6850.

19. NEWS (2019). E-Parisaraa Pvt. Ltd. Available via http://ewasteindia.com/Accessed 11 Jun 2019

20. Electronic-waste-management. Available via . Accessed 11 Jun 2019

21. Mishra, D. and Rhee, Y.H. (2010). Current research trends of microbiological leaching for metal recovery from industrial wastes. *Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology*, 2, 1289-1292.

22. Report (2019). Electronic waste. Available via http://www.who.int/ceh/risks/ewaste/en/ Accessed 11 Jun 2019

23. Landrigan, P.J., Fuller, R., Acosta, N.J., Adeyi, O., Arnold, R., Balde, A.B., Bertollini, R., Bose-O'Reilly, S., Boufford, J.I., Breysse, P.N. and Chiles, T. (2017). The Lancet Commission on pollution and health. *The Lancet*, 391(10119), 462-512.

24. Wang, L.K., Ivanov, V., Tay, J.H. and Hung, Y.T. eds. (2010). *Environ. Biotechnol.*, Vol. 10. Springer Science & Business Media.

25. Sinha, R. K., Valani, D., Sinha, S., Singh, S., & Herat, S. (2009). Bioremediation of contaminated sites: a low-cost nature's biotechnology for environmental clean up by versatile microbes, plants & earthworms. *Solid waste management and environmental remediation*, 978-1.

26. Das, N., & Chandran, P. (2011). Microbial degradation of petroleum hydrocarbon contaminants: an overview. *Biotechnology research international*.

27. Article (2019). National Mission for Clean Ganga. Namami Gange Programme. Available via http://nmcg.nic.in/Namami Ganga.aspx. Accessed 11 Jun 2019

28. Rai, U.N., Tripathi, R.D., Singh, N.K., Upadhyay, A.K., Dwivedi, S., Shukla, M.K., Mallick, S., Singh, S.N. and Nautiyal, C.S. (2013). Constructed wetland as an ecotechnological tool for pollution treatment for conservation of Ganga river. *Biores. Technol.*, 148, 535-541.

29. Lemak, S., Tchigvintsev, A., Petit, P., Flick, R., Singer, A.U., Brown, G., Evdokimova, E., Egorova, O., Gonzalez, C.F., Chernikova, T.N. and Yakimov, M.M. (2012). Structure and activity of the cold-active and anion-activated carboxyl esterase OLEI01171 from the oil-degrading marine bacterium Oleispira antarctica. *Biochem. J.*, 445(2), 193-203.

30. Kostka, J.E., Prakash, O., Overholt, W.A., Green, S.J., Freyer, G., Canion, A., Delgardio, J., Norton, N., Hazen, T.C. and Huettel, M. (2011). Hydrocarbon-degrading

bacteria and the bacterial community response in Gulf of Mexico beach sands impacted by the Deepwater Horizon oil spill. *Appl. Environ. Microbiol.*, 77(22), 7962-7974.

31. Biello, D. (2010). Meet the microbes eating the gulf oil spill. A series of stories. Scientific American. August.

32. Cao, Y., Chastain, R. A., Eloe, E. A., Nogi, Y., Kato, C., & Bartlett, D. H. (2014). Novel psychropiezophilic Oceanospirillales species Profundimonas piezophila gen. nov., sp. nov., isolated from the deep-sea environment of the Puerto Rico Trench. *Applied and Environmental Microbiology*, 80(1), 54-60.

33. Nayeem-Shah, M., Gajalakshmi, S. & Abbasi, S. A. (2015). Direct, rapid and sustainable vermicomposting of the leaf litter of neem (Azadirachta indica). *Applied Biochemistry and Biotechnology*, 175(2), 792-801.

34. Hoornweg, D., Bhada-Tata, P., & Kennedy, C. (2013). Environment: Waste production must peak this century. *Nature News*, 502(7473), 615.

35. Repot (2019). Waste Generation. Available via http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap3.pdf Accessed 11 Jun 2019

36. Berkel, R.V., Fujita, T., Hashimoto, S. and Fujii, M. (2009). Quantitative assessment of urban and industrial symbiosis in Kawasaki, Japan.

37. Ausubel, J.H. and Waggoner, P.E. (2008). Dematerialization: Variety, caution, and persistence. *Proceedings of the National Academy of Sciences*, 105(35), 12774-12779.

Book Chapter (2019). Chapter 14 composting. Available via http://moud.gov.in/upload/uploadfiles/files/chap14(1).pdf Accessed 11 Jun 2019

38. Sharholy, M., Ahmad, K., Mahmood, G. and Trivedi, R.C. (2008). Municipal solid waste management in Indian cities–A review. *Waste Manag.*, 28(2), 459-467.

39. Joshi, R. and Ahmed, S. (2016). Status and challenges of municipal solid waste management in India: A review. *Cogent Environ. Sci.*, 2(1), 1139434.

40. Report (2019). Biocomposting methods. Available via http://www.fao.org/docrep/007/y5104e/y5104e06.htm Accessed 11 Jun 2019

41. Article (2019). Bioenergy association of Ukraine. WBA 2014. WBA Global Bioenergy Statistics 2014.Available via http://www.uabio.org/img/files/docs/ 140526-wba-gbs-2014.pdf Accessed 11 Jun 2019

42. Meehan, T.D., Hurlbert, A.H. and Gratton, C. (2010). Bird communities in future bioenergy landscapes of the Upper Midwest. *Proceedings of the National Academy of Sciences*, 107(43), 18533-18538.

43. Contreras, L.M., Schelle, H., Sebrango, C.R. and Pereda, I. (2012). Methane potential and biodegradability of rice straw, rice husk and rice residues from the drying process. *Wat. Sci.Technol.*, 65(6), 1142-1149.

44. Belal, E.B. (2013). Bioethanol production from rice straw residues. *Braz. J. Microbiol.*, 44(1), 225-234.

45. Kaur, D., Bhardwaj, N.K. and Lohchab, R.K. (2017). Prospects of rice straw as a raw material for paper making. *Waste Manag.*, 60, 127-139.

46. Bandaru, V., Izaurralde, R.C., Manowitz, D., Link, R., Zhang, X. and Post, W.M. (2013). Soil carbon change and net energy associated with biofuel production on marginal lands: a regional modeling perspective. *J. environ. Qual.*, 42(6), 1802-1814.

47. Energy Statistics (2017). Central Statistics Office Ministry of Statistics and Programme Implementation Government of India. Available via http://mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017.pdf Accessed 11 Jun 2019

48. Report (2019). Ministry of New and Renewable Energy (2014–2015). Annual report. Government of India. Available via http://mnre.gov.in/mission-and-vision-2/publications /annual-report-2 Accessed 11 Jun 2019

49. Ghosh, P.R., Fawcett, D., Sharma, S.B. and Poinern, G.E.J. (2016). Progress towards sustainable utilisation and management of food wastes in the global economy. *Int. J. Food Sci.*.

50. Kumar, S., Smith, S.R., Fowler, G., Velis, C., Kumar, S.J., Arya, S., Kumar, R. and Cheeseman, C. (2017). Challenges and opportunities associated with waste management in India. *Royal Society Open Science*, 4(3), 160764.

51. Press Information Bureau (2019). National Policy on Biofuels – 2018. Available via http://pib.nic.in/newsite/PrintRelease.aspx?relid=179313 Accessed 11 Jun 2019

52. Press Information Bureau (2019). MOVE. Available via http://pib.nic.in/newsite/PrintRelease.aspx?relid= 183324 Accessed 11 Jun 2019

53. Information (2019). Ministry of New and Renewable Energy. The national solar mission. Available via https://mnre.gov.in/file-manager/akshay-urja/june-2016/11-15.pdf Accessed 11 Jun 2019

54. Die Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2019). Cricket stadium in Bangalore goes green, 400 kW solar plant installed on the stadium roof. Available via https://www.giz.de/en/worldwide/ 32077.html Accessed 11 Jun 2019

55. Article (2019). Key challenges in solar power development. Available via http://www.iea.org/

publications/freepublications/publication/India_study_ FINAL_WEB.pdf Accessed 11 Jun 2019

56. Elekwachi, C.O., Andresen, J., Hodgman, T.C. (2014). Global use of bioremediation technologies for decontamination of ecosystems. *J. Bioremediat. Biodegrad.*, 5(4), 225.

57. Press Information Bureau (2010). Air Quality Forecasting System (SAFAR) and weather services dedicated to nation today for CWGs New Delhi 2010. Available via http://pib.nic.in/newsite/PrintRelease. aspx?relid=65912 Accessed 11 Jun 2019

58. Central Pollution Control Board (2019). Global environmental monitoring stations/ monitoring of Indian national aquatic resource. Available via http://cpcb.nic.in/water.php Accessed 11 Jun 2019

59. Silva, C.O., Simões, T., Novais, S.C., Pimparel, I., Granada, L., Soares, A.M., Barata, C. and Lemos, M.F. (2017). Fatty acid profile of the sea snail Gibbula umbilicalis as a biomarker for coastal metal pollution. *Sci. Total Environ.*, 586, 542-550.

60. Pereira, T.M., Mattar, L.P., Pereira, E.R., Merçon, J., da Silva, A.G. and Cruz, Z.M. (2017). Effects of Tin on Enzyme Activity in Holothuria grisea (Echinodermata: Holothuroidea). *Bull. Environ. Contam. Toxicol.*, 98(5), 607-611.

61. Augustynowicz, J., Łukowicz, K., Tokarz, K. and Płachno, B.J. (2015). Potential for chromium (VI) bioremediation by the aquatic carnivorous plant Utricularia gibba L.(Lentibulariaceae). *Environ. Sci. Pollut. Res.*, 22(13), 9742-9748.

62. Brooks, S.J., Farmen, E., Heier, L.S., Blanco-Rayón, E. and Izagirre, U. (2015). Differences in copper bioaccumulation and biological responses in three Mytilus species. *Aquat. Toxicol.*, 160, 1-12.

63. Roy, S.U., Chattopadhyay, B., Datta, S. and Mukhopadhyay, S.K. (2011). Metallothionein as a biomarker to assess the effects of pollution on Indian Major carp species from wastewater-fed fishponds of East Calcutta wetlands (a Ramsar Site). *Environ. Res. Eng. Managt.*, 58(4), 10-17.

64. Desai, G., Chu, L., Guo, Y., Myneni, A.A. and Mu, L. (2017). Biomarkers Used in Studying Air Pollution Exposure During Pregnancy and Perinatal Outcomes: A Review. *Biomarkers*, 22(6), 489-501.

65. Undugoda, L.J.S., Kannangara, S. and Sirisena, D.M. (2016). Genetic Basis of Naphthalene and Phenanthrene Degradation by Phyllosphere Bacterial Strains Alcaligenes faecalis and Alcaligenes sp. 11SO. *J. Bioremed. Biodegrad.*, 7(2), 333.

66. Sangthong, S., Suksabye, P. and Thiravetyan, P. (2016). Air-borne xylene degradation by Bougainvillea Buttiana and the role of epiphytic bacteria in the degradation. *Ecotoxicol. Environ. Saf.*, 126, 273-280.

67. Vrijens, K., Bollati, V. and Nawrot, T.S. (2015). Micro RNAs as potential signatures of environmental exposure or effect: a systematic review. *Environ. Health Perspect.*, 123(5), 399-411.

68. Sun, K., Liu, J., Gao, Y., Jin, L., Gu, Y. and Wang, W. (2014). Isolation, plant colonization potential, and phenanthrene degradation performance of the endophytic bacterium Pseudomonas sp. Ph6-gfp. *Sci. Rep.*, 4, 5462.

69. Brucker, N., Moro, A.M., Charao, M.F., Durgante, J., Freitas, F., Baierle, M., Nascimento, S., Gauer, B., Bulcao, R.P., Bubols, G.B. and Ferrari, P.D. (2013). Biomarkers of occupational exposure to air pollution, inflammation and oxidative damage in taxi drivers. *Sci. Total Environ.*, 463, 884-893.

70. Cao, X., Bi, R. and Song, Y. (2017). Toxic responses of cytochrome P450 sub-enzyme activities to heavy metals exposure in soil and correlation with their bioaccumulation in Eisenia fetida. *Ecotoxicol. Environ. Saf.*, 144, 158-165.

71. Hou, J., Bai, L., Xie, Y., Liu, X. and Cui, B. (2015). Biomarker discovery and gene expression responses in Lycopersicon esculentum root exposed to lead. *J. Hazard. Mater.*, 299, 495-503.

72. Malar, S., Sahi, S.V., Favas, P.J. and Venkatachalam, P. (2015). Mercury heavy-metal-induced physiochemical changes and genotoxic alterations in water hyacinths [Eichhornia crassipes (Mart.)]. *Environ. Sci. Pollut. Res.*, 22(6), 4597-4608.

73. Global stewards (2019). Green Eco Tips for Sustainable Living. Available via http://www.globalstewards.org/ ecotips.htm Accessed 11 Jun 2019

74. Government web portal of Vietnam (2019). Strategies to control pollution. Available via http:// www.chinhphu.vn/portal/page/portal/English/strategies/strategiesdetails?categoryId=30&articleId=10051159 Accessed 11 Jun 2019

75. Nadgorska-Socha, A., Kandziora-Ciupa, M., Trzęsicki, M. and Barczyk, G. (2017). Air pollution tolerance index and heavy metal bioaccumulation in selected plant species from urban biotopes. *Chemosphere*, 183, 471-482.

76. Hindle, R.L. (2012). A vertical garden: origins of the Vegetation-Bearing Architectonic Structure and System (1938). *J, Gard. Hist.*, 32(2), 99-110.

77. Information (2019). Mawlynnong village. Available via http://www.mawlynnong.com/About-Mawlynnong. php Accessed 11 Jun 2019

78. Information (2019). Sikkim organic mission. Available via http://www.sikkimorganicmission.gov.in/ towards-

organic-sikkim/technology-development/ Accessed 11 Jun 2019

79. Information (2019). Water Sustainable Development Planning Asia Singapore Fact Sheet. Available via http://apfed-db.iges.or.jp/dtlbpp.php?no=23 Accessed 11 Jun 2019

80. Report (2019). The clean-up of the River Thames. Available via http://www.telegraph.co.uk/earth/wildlife/8059970/The-clean-up-of-the-River-Thames.html Accessed 11 Jun 2019

81. Story (2019). The New River: An environmental success story. Available via http://www.utsandiego.com/news/2014/apr/23/new-river-pollution-wetlands-mexicali-environment/?article-copy Accessed 11 Jun 2019

82. Information (2019). GIS and Natural Resource Management. Available via https://www.gislounge.com/gis-and-natural-resource-management/Accessed 11 Jun 2019

83. Human Development Report (2019). Human Development is about putting people at the center. Available via http://hdr.undp.org/en/content/human-development-about-putting-people-center. Accessed 11 Jun 2019.