SUSTAINABLE ENVIRONMENT PRACTICES (SEP)

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Kripa Drishti Publications, Pune.

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CONTENT

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1. Integration of Livestock Farming in Agriculture Practices for Sustainable Rural Livelihood

Vinita Pandey

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Abstract:

Livestock farming is a part of animal husbandry. Livestock often includes cows, buffalo, ox, poultry, and goat. Sustainable livelihood produces almost all kinds of food needs itself. The concept of sustainable rural livelihood amalgamates livestock farming with agriculture farming. The livestock mainly provides milk (cow, buffalo, and goat) and meat (goat and poultry). The livestock i.e., ox and buffalo utilized for ploughing and transporting.

The manure of live stocks, especially cow, acts as rich mineral fertilizer e.g., nitrogen, phosphorus, and potassium, and also nourish agricultural soil microbes. Manure has also a diverse group of microbiota used for agriculture fertility and produces fuels such as methane biogas. Non-agriculture land produces fodder for livestock as a payoff and mitigates the environmental footprint of livestock diet and unwanted grazing.

The literature claimed that the Green House Gas i.e., CH_4 and N_2O, emissions from livestock farming can be diminished by livestock integration with farming. Hence the integration of livestock farming with agriculture practices serves milk, meat, agricultural crop products, fertilizer, biogas, ploughing, and transportation.

Keywords:

Livestock farming, Agriculture practices, Sustainable rural livelihood, Greenhouse gas, environmental footprint, and manure

1.1 Introduction:

The appropriate food production is needed to fulfil physiological needs.

The quality food is sold at higher prices, thereby the farmers should aware of the quality of food production by using quality seeds from recognized vendors or agricultural units or preparing themselves. As the global population has increased day by day, food security come up as a prime concern globally (Lemaire et al., 2015).

It is estimated that the population would be about 9.7 billion by 2050 (UN, 2019). Each member of the population has the right to get sufficient quality food.

Hence, the farmer has to be ensured the maximum yield from agricultural land for both society and their monetary benefits. The World Bank datasheet stated that India is a Lower Middle-Income Country along with other 55 countries (Lower Middle Income | Data).

India, Indonesia, Bangladesh, and Vietnam are contributed around 53% of global food needs (Samberg, 2016). The crops and foods are the major sources of food in ancient India but for the last 50 years, animal protein are in higher demand. The demand for animal protein boosts livestock farming (WHO, 2003; McLeod, 2011).

The quality lifestyle concept is also subsidizing the natural resources depletion and environmental pollution that cause climate change, as result, the environmental change decreases crop yields.

Some insect’s play an important role in the pollination of fruit and vegetable flora and due to environmental degradation, the insects are affected which reduces the yields.

The IFPs can cope with up abovementioned issues that arose in the last three decades. The farmers are not aware of the value of their crops and other products. Corporate societies and dealers are generating plenty of revenue from farmer’s products.

The problematic situation is that the farmers are getting poor and the consumers are paying much higher for food.

Therefore, if the farmers produce and process the food and directly sell the product to the consumer then the farmers and consumers both are getting benefited.

The integration of livestock farming in agriculture has several advantages but some complexities are also associated.

To overcome such complexities, the farmers need to be educated in livestock management along with agriculture.

Thereby, the Government agricultural universities are promoting farmers to join training programs developed for farmer entrepreneurship. These initiatives serve the farmers with notable success (Muttanna et al., 2018).

The Department of Agricultural Research and Education (DARE) was established by the Ministry of Agriculture in 1973 to promote agricultural research and education and also launched the Krishi Vigyan Kendra (KVK) in agriculture institutions where the agricultural experts provide training to farmers and institutional professors help farmers to solve agricultural problems arise in fields.

The KVK provides comprehensive training in advanced techniques associated with agriculture i.e., horticulture, floriculture, pomology, and other relevant areas.

The vermicomposting, Vermiwash, Vermiculture, Mushroom cultivation, Azola pond, Bio floc fish culture and microbial biofertilizer i.e., *Rhizobium*, Phosphate solubilizing bacteria, Iron oxidizing bacteria and other Plant growth promoting microbes, bio pesticides i.e., *Trichoderma* and *Bacillus thuringiensis* mushroom cultivation and other related training are offered to farmers at KVK.

1.1.1 Background:

The farmers of the country often seek stable financial conditions due to the least knowledge about integrated farming practices and agricultural advancement. Integrated Farming practices (IFPs) include interdependent and interrelated farming in agricultural fields.

The crops are often integrated with animal husbandry i.e., livestock farming, and further, the products are processed and stored by the farmer themselves.

These practices ensure the extreme possible utilization of available nutrients at various levels of feeding or fortification to crops and livestock and generate a sustainable ecosystem i.e., zero waste concept, in the agricultural land.

As an example, the livestock is fed with the waste of agricultural biomass, and the crops are fertilized by livestock waste i.e., cow dung or excretion of other livestock, and the crop yield and livestock milk and meat are the finished products of integrated farming that generates revenue for farmers (Figure.1.1).

Even they, produce all necessary food products i.e., rice, pulses, fruits, oils, milk, and meat. Above all, it is environmentally benign and hence this practice would reduce environmental degradation.

1.2 Need of IFPS For Sustainability and Environmental Health:

The labour-intensive cropping, quick crop rotations, grazing, excessive use of synthetic harmful chemicals as biocide and fertilizer, and large machinery for agricultural practices cause environmental pollution (such as soil, water, and atmospheric pollution), erosion of soil, microbial and insect biodiversity loss and introduction of resistance insect and microbial strains (Walia and Walia, 2015; Tilman, 1999; WHO, 2017; Liebman and Schulte-Moore, 2015). The harmful chemical fertilizer encourages the resistance development in insect and microbial strains that cause harm to crops and reduce yields. Moreover, hazardous chemicals are causing serious health hazards i.e., mental and physical disorders (Sharma and Singhvi, 2017) and a variety of cancer (Bassil et al., 2017). Aforesaid practices are an expensive and serious threat to environmental pollution and degradation.

The IFP includes optimum utilization of available resources by nutrient cycling within farmyard, use of draught animals for transportation and plow, livestock farming (includes beef cattle, dairy cows, buffalo, poultry, sheep, and goats), earthworms farming and vermicomposting, fish ponds and bio-floc, a diverse range of cropping pattern (such as rice, wheat, pulses, oil seeds, fruits, vegetables, and animal fodders). The IFPs are a sustainable zero waste eco-friendly approach.

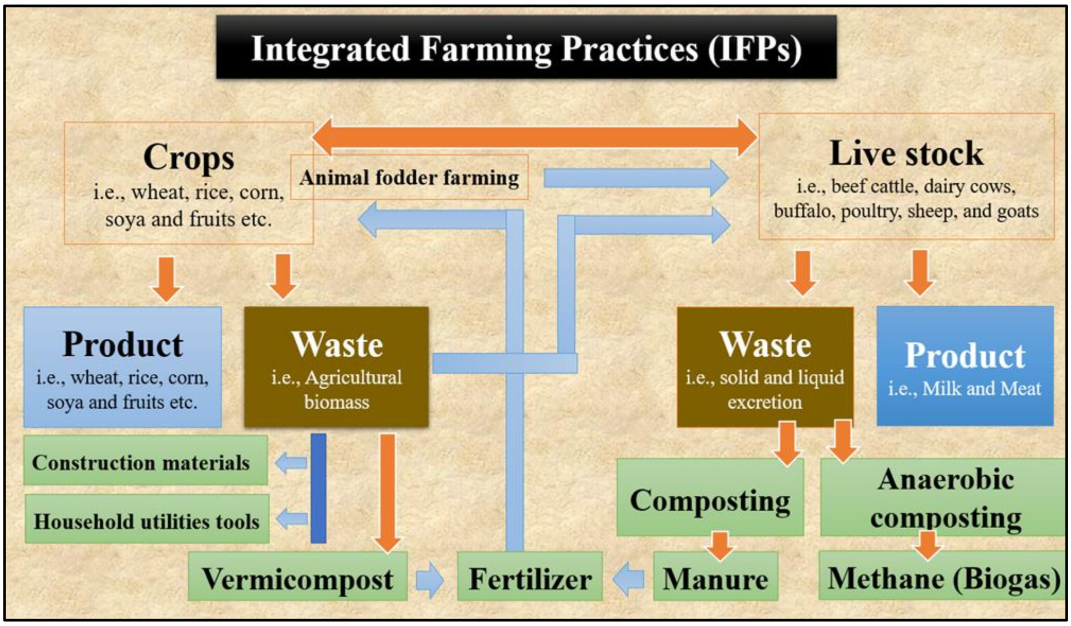

Figure 1.1: Overview of Integrated Farming Practices

Advantages and Associated Complexities of IFPs

The agricultural sector is seeking higher yields and quality food without harming the environment. The IFPs open a way to do so. A customized IFPs need to implement by amelioration of agriculture with livestock farming for higher yield and quality food (Franzluebbers, 2007; Lemaire et al., 2014; Russelle et al., 2007).

IFPs ensure agriculture sustainability in an eco-friendly manner. The sole use of organic fertilizers in agricultural land is considered organic farming and the crop produced are free from harmful chemicals, thereby suitable for human health. Hence, it has a higher market price. The IFP boosts agricultural diversification.

The advantages and certain complexities are associated with IFPs (Figure 1.2). The advantageous part of IFPs includes high return, and stable income throughout the year, organic farming products are often costly but under IFPs organic farming is cost-effective, due to diversified products, the IFPs improved nutrition by plant and animal-derived food and helps to increase soil health and soil biodiversity that reduced greenhouse gas emission.

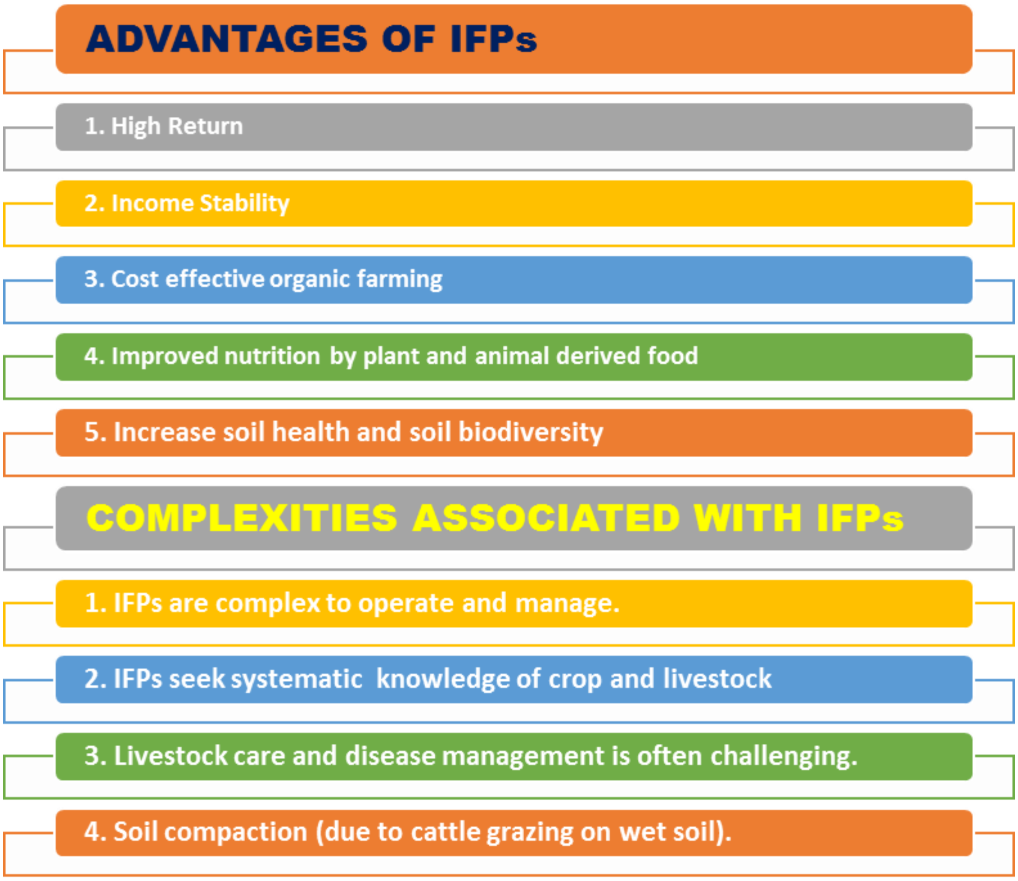

Figure 1.2: Advantages and Associated Complexities of IFPs

Along beneficial aspects, some complexity associated with IFPs are

a. it is complex to operate and manage due to diverse groups of crop and livestock;
b. IFPs seek systematic knowledge of crop and livestock to manage and utilize them effectively;
c. Livestock care and disease management is often challenging;
d. Soil compaction caused due to cattle grazing on wet soil and this reduces crop yields.

1.3 Conclusions:

The implementation of IFPs, an amelioration of crop and livestock in the farmyard, assure the substantial income of farmers throughout the year.

The diversified food production provides stable income to the farmers. The efficient utilization of natural resources with zero waste generation ensures sustainability and eco-friendly farming.

Additionally, IFPs offer cost-effective organic farming for farmer's livelihood. However, the IFPs demand depth knowledge about crop rotation, crop combination, livestock farming, disease management, and other relevant information. The significant participation of women's self-help groups could help to effective implementation of IFPs.

The IFPs also contribute to the purchasing power of farmers for quality lifestyle and help to overcome food security. To encourage the IFPs, The Ministry of Agriculture & Farmers Welfare, initiate various subsidized activities to strengthen farmer's communities by monetary subsidies for infrastructure for small and marginal farmers, on-field demonstrations of advanced agriculture techniques, and supply of genetically modified diseases resistance quality seeds.

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2. Environment Sustainability: Reduce, Reuse and Recycle

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Abstract:

The Reduce, Reuse, and Recycle (3Rs) principle administer minimization of waste and energy requirement, a circular economy for reducing waste, and a maximum level of recycling of the products as possible. Sustainable energy and water management practices are applied in fewer industrial settings to prevent environmental degradation. The term reuse is defined as the product utilization in further subsequent life cycle i.e., reusable plastic and containers.

Reusing the product processing accessories reduce the manufacturing cost and uplift revenues. The reusing of products by consumers also contributes to mitigating carbon footprint. Recycle often used for the conversion of organic or inorganic materials into fresh products rather than reusing the same product.

The Hospitality sector is required high resources, energy, and water consumption. The single-use goods are extensively used in this sector so the effective 3Rs strategy needs to be developed in the hospital sector without compromising the quality of service. Similarly, the tourism and hospitality sectors are using single-use products for their customers to serve excellent service quality and to maintain hygiene around. A possible strategy could be the use of biodegradable single-used products instead of non-biodegradable synthetic products.

Keywords:

3Rs, Reduce, Reuse, Recycle, Sustainable energy, Environmental degradation, Biodegradable, Carbon footprint

2.1 Introduction:

The growing population demands Reduce, Reuse, and Recycle (3Rs) approach in waste management practices. The waste needs to reduce and reuse and recycle by promoting science and technological research in 3Rs. The 3Rs approach enforces reduced waste generation, selects reusable products and encourages people to reuse the stuff, and inspires people to use recycled articles. The 3Rs are further extended to 7Rs i.e., Reduce, Reuse, Recycle, Resource, Regenerate, Replace and Recover (Figure 2.1).

Several scientific and technological measures are developed to prevent the rate of pollution and energy-saving strategies. The introduction of clean and green technology helps to mitigate undesirable waste effluents and emissions from industrial manufacturing practices. The 3Rs ensure minimum damage to the ecosystem (Ilgin and Gupta, 2010).

Environmental degradation is an area of concern due to excessive pollutants are entered the biological food chain of the ecosystem. To minimize environmental degradation academic institutions, organizations, enterprises, and manufacturing units are coming forward to take responsibility for sustainability in various aspects with a suitable strategy with an aim to improve environmental health (Tanwer et al., 2015; Ordóñez et al., 2019).

Corporate societies are now concerned about the environment and working on various environmental practices and ensure the proper allocation of resources to mitigate waste generation (Aragón-Correa and Sharma 2003).

The hospitality sector is also producing waste abundantly and needs to follow environmental sustainability at a different level of operations. 3Rs is a sustainable environmental strategy that safeguards the wastage of product and energy to make the commercial sector eco-friendly.

2.1.1 Concept of Reduce, Reuse, and Recycle:

The concept of 3Rs was introduced by Japan in 2004 at G8 Summit which was held in Georgia. Presently, the 3Rs are considered a significant approach to a sustainable and cleaner environment.

The waste materials generated from the industrial process first need to be analysed and assessed for the implantation of 3Rs. Bioremediation, Composting, Fermentation of waste for value-added products, and Bioenergy production are the common approach used under 3Rs (Ordóñez et al., 2019; Xu et al., 2018; Singh et al., 2012). Bioremediation offers the remediation of toxic pollutants from soil and water.

The microorganisms (such as bacteria, fungi, and algae) and plant species are participated in the bioremediation process due to their extensive metabolic competency, immobilizing capability, and toxic absorption efficacy to deal with environmental pollutants. Bioremediation has often used two approaches viz., biodegradation or biotransformation composting is a classic example of biodegradation of biomass to compost.

The biotransformation can be explained by the simple example of chromium toxicity. Trivalent chromium is essential for human health while Hexavalent chromium is unambiguous and toxic to humans.

The bacteria e.g., *Lactobacillus* are able to transform the Hexavalent chromium to its Trivalent form. Composting is one of the oldest practices in the agriculture field.

The waste and unused fruit and vegetable, fish scrap, processed meat, grains, and weeds could potentially be used for composting (Schaub and Leonard, 1996). The waste olive and palm biomass produce oils that are considered toxins for plants and animals due to their tannin and phenolic content.

The *Pleurotus* mushrooms can be used to detoxify olive and palm biomass by secreting certain enzymes and growing over them.

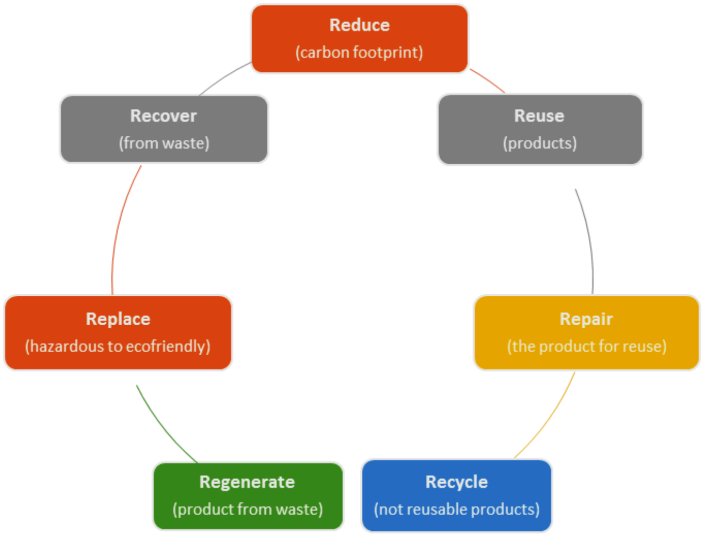

Figure 2.1: The 7Rs (Reduce, Reuse, and Recycle, Resource, Regenerate, Replace and Recover)

Persistent organic pollutants: Persistent organic pollutants (popular as POPs) are a group of toxic chemicals that cause harm to the environment and human health. They are considered a severe threat because they might cross the placenta and transfer through breast milk to offspring. The POPs are often manufactured as biocides and disease control agents. The pesticide e.g., aldrin and chlordane, insecticides i.e., *dichloro-diphenyl-trichloroethane* (DDT), dieldrin and heptachlor, and many more man-made biocides are considered as POPs. Some POPs are synthesized intentionally i.e., polychlorinated biphenyls, and others i.e., dioxins are generated by default as a by-product. Pariatamby and LingKee, (2016) revealed that Guar gum and Xanthan gum are the most suitable polymer for the treatment of POPs due to their biodegradability, non-toxic nature, cost-effective treatment procedure, and easy availability.

Plastics: Plastic pollution management practice could be linked to the reduction of single-use plastics and plastic food packaging. The natural fibres are tending to degrade rapidly through biological mechanisms. Hence, the use of such fibres to make biodegradable plastic i.e., green polymers, comes into practice nowadays. The environmental half-life of bioplastic is pretty much shorter than synthetic polymers. The reusable BPA-free plastic bottles are promoted for daily use.

The plastic ware is recycled to make a variety of stuff useful for day-to-day life. Plastic waste is increased by around 300%, especially in the tourism sector, which is considered a severe threat to the ecosystem nowadays. Hence, single-use plastic ware needs to be beaned immediately or introduced into a proper recycling system to ensure the safeguard of human and animal health (EU Commission, 2018).

2.2 Possibilities of 3Rs Implementation in Healthcare Waste Management:

Healthcare waste is a key concern after COVID-19 because in the last two years plenty of waste generated. People are now taking excess concern for hygiene practices so lots of waste i.e., disposable tissue papers, several antiseptic liquids, phenolic compounds, cleaning agents, masks, and gloves, are generated by maintaining routine hygiene. However, this could be minimized by using reusable stuff as much as possible. Moreover, well-established healthcare settings are using disposable stuff excessively due to legislation guidelines offering flexibility in the choice of selecting disposable and reusable materials as per the necessity.

Thereby, sustainable waste management practices need to be implemented. Healthcare wastes are broadly categorized into infectious waste i.e., contaminated blood and bandages), pathological waste i.e., human tissues and fluids, samples, sharps waste i.e., syringes middle and disposable blades, chemical waste i.e., test reagents and disinfectants along with heavy metals, pharmaceutical waste i.e., expired medicines, Radioactive waste that generated from radioactive diagnosis, and other non-hazardous waste that free from biological, hazardous chemicals and radioactive wastes. Surprisingly, World Health Organization (WHO) stated that only 15 % of waste generated by the healthcare sector is hazardous and the rest of 85% of waste is mostly non-hazardous that can be treated and reused effectively. As an example, 16 billion injections are used annually worldwide but due to the lack of a recycling system, they are dumped as plastic waste. The mitigation of "waste crime" is another area of concern because the operators or owners often ignore the *waste* disposable regulations and hence, and the public may expose to such hazardous or toxic chemicals. The strict monitoring of healthcare procedures helps to control such activities. The open burning of health care wastes generates dioxins and furans like particulate which mix with the atmosphere and cause harm to the people.

The concept of "*waste hierarchy*" guides the people on which category of waste best suited the relevant management practices as the eco-friendliness. The healthcare sector is highly recommended to follow such practices. European Waste Catalogue provided the List of Wastes (LoW) under European Commission guidelines for healthcare in the United Kingdom (UK) to minimize the risk of human health from healthcare waste.

2.2.1 Circular Economy and Zero Waste Model:

The concept of circular economy deals with the sophisticated sustainable model from the manufacturing of goods or products to end disposal which comprises different levels of consumption including share, reuse, repair, refurbishment, and recycling of goods or products at the best possible long-lasting. This tactic helps to the extent of the product life cycle and reduces waste generation. The Zero Waste Model (ZWM) comprises of 3Rs method which is closely related to the natural systems of the earth's crust where the byproduct of one individual becomes a source of sustenance for another individual.

For example, humans and other animals exhale CO_2 as a byproduct of cellular metabolism, and the same CO_2 is consumed by Photosynthetic plants with and aid of photons to produce energy for the cellular process and the produced food stored as starch in the cell. Later when the starchy cell is consumed by herbivorous animals then after their cellular metabolism the starch is converted into CO_2 and water. However, ZWM can be implemented only when all the stakeholders take care of these management practices together.

2.2.2 Initiatives on 3Rs:

The 3Rs concept was first proposed by Japan and later spread globally. The 8th Regional 3R Forum in Asia-Pacific was hosted by the Ministry of Housing and Urban Affairs, Government of India in association with The Environment Ministry, Government of Japan, and UNCRD, United Nations, which was held in Indore, Madhya Pradesh, India in April 2018. The Regional 3R Forum was launched in Japan in 2009 to make policy, planning, and development strategy regarding 3Rs. The theme of the 8th Regional 3R Forum was "to achieve Clean Water, Clean Land, and Clean Air through 3R and Resource Efficiency (RE) - A 21st Century Vision for Asia-Pacific Communities.

A British charitable trust, Waste and Resources Action Programme (WRAP) was established in 2000 to ensure that all the resources could be used sustainably. WRAP is working to promote and accelerate the efficient use of resources and to guard natural resources. The TripAdvisor online platform initiated Trip Advisor Green Leaders Programme (TAGLP) in collaboration with United Nations Environment Programme, Energy star, U.S. Green Building Council (USGBC). The TAGLP showcases eco-friendly hotels and resorts those committed to following green practices like recycling products, serving local organic food and dishes, and offering electric cars and charging stations to travellers.

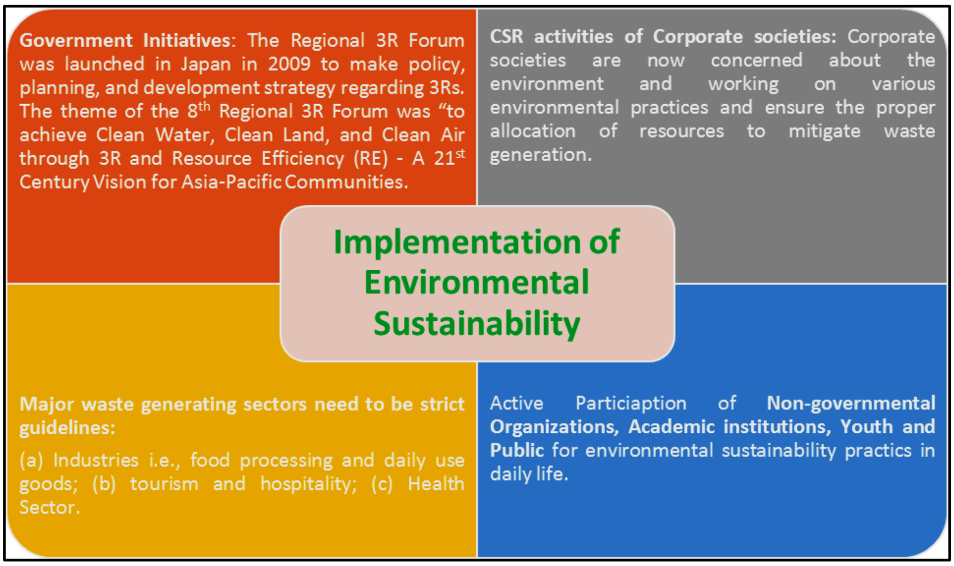

Figure 2.2: A summarized View of Implementation of Environmental Sustainability

Moreover, the Forest Act, 1927, Wild Life Protection Act, 1972, Clean Water (Prevention and control of Pollution) Act, 1972, Clean Air (Prevention and control of Pollution) Act, 1970, and The Environment (Protection) Act, 1986 were drafted to protect the environment and wildlife. The summarized view of Implementation of Environmental Sustainability is depicted in Figure 2.2 Policymakers of the corporate units, industrial sectors, and service providers have played an imperative role to adopt a standard protocol for any operation and service. If the government offers a tax credit system for green work culture or processing units, regular eco-assessments, and spread campaigns regarding the same, could encourage the adoption of the 3Rs strategy among commercial units or service providers.

2.3 Conclusion:

The 3Rs inculcate the introduction of sustainable practices in every sector that produces and releases waste or effluent to the ecosystem. Environmental could be protected by the development of sustainable practices and by efficient resource utilization. The sustainable economic growth model needs to be bridged with the circular economy.

The government also enforces the corporate sector to follow the guidelines recommended to maintain the environmental sustainability. Hence, the industries are getting aware of the effective utilization of energy and water with minimum waste generation using eco-friendly strategies. The recovery, remanufacturing, and redesign of products are the extended version of 3Rs.

The strict implementation of the 3Rs strategy is crucial for tourism and hospitality, manufacturing units, and municipality waste processing units because these are the key players to generate plenty of wastes that could be reused and recycled effectively.

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3. E-Waste Management for better tomorrow

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Abstract:

The electronic waste (e-waste) generated from the disposal of electrical and electronic equipment is a prime environmental concern. E-waste recycling is a systematic collection of e-waste and recycling of it into value-added products. The recycling of e-waste is associated with the generation of toxic substances. The efficiently recycling of e-waste without threatening public health is a holistic tactic to ensure the minimal emission of perilous e-waste to the ecosystem.

The present chapter dealt with the possible prospects, constrictions, and approaches for enhanced e-waste management. The global inclination toward e-waste recycling progression and strategies makes it efficient and environmentally benign. The holistic paradigm of e-waste management is discussed in the chapter with an aim of the proper implantation of the best possible way for e-waste management.

Keywords:

E-waste management, electrical and electronic equipment, value-added products.

3.1 Introduction:

Invest India, an investment promotion agency quoted that India would reach up to $ 1 TN of the digital economy by 2025. The Indian electronic Market (e-Market) is now $118 billion and contributes 2.7% of GDP and the Indian manufacturers export electronic goods of $10.6 billion by 2020-21. The electrical and electronic equipment (EEE) are serving comfort, luxury, and accuracy with cross-cutting customized automation and utmost wellbeing in modern societies.

The electronic items viz., workstation electronics (i.e., mobile handset, air condition, computers, and lights), household electrical apparatus and tools (i.e., televisions, refrigerators, induction, oven, fan, lights, washing machine, air condition, and investors), medical devices and tools (i.e., diagnosis machinery such as MRI, CT-Scan, X-Ray, Radiological instruments, Analytical machinery, Testing tools and testing kit readers and so on).

The medical devices and household EEE have a larger market cap due to the extensive variety of products. International Energy Agency has released Key World Energy Statistics (International Energy Agency. 2017) and Energy Efficiency: Industry (International Energy Agency, 2019) and stated that the global energy demand has doubled in the last three decades due to the growing population and expanding industrial sector.

The energy-efficient and compact EEE has a shorter lifespan, limited repair options, and better alternatives; therefore, people replace them with a new ones (Chi et al., 2014). Hence, the huge defected EEE is accumulated as e-waste.

They are being used due to the physical damage, improper working, and accessibility to better alternatives. Rapid technological advancement has encouraged more e-waste generation. The research and development cells of EEE companies are releasing new EEE integrated with advanced technology in a short period that attracts most of the population having enough financial strength to buy those products.

The e-waste includes all components of EEE discarded. The massive e-waste accumulation, inappropriate disposal, unidentified recycling measures, and its associated health hazards (via plastic, metal, and hazardous chemical components) are now considered a global concern (Ongondo et al., 2011)

3.2 Characteristics of E-Waste:

Toxic substances e.g., polychlorinated biphenyls, brominated flame retardants (BFRs), and heavy metals i.e., arsenic (Ar), cadmium (Cd), hexavalent chromium (Cr-VI), lead (Pb), mercury (Hg) and selenium (Se) are present in the e-waste (Pinto, 2008).

The polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) are the major hazardous chemicals generated during the recycling of e-waste (Robinson, 2009).

These perilous chemicals are emitted into the environment and enter the ecosystem and their long-term exposure causes environmental pollution and degradation (Needhidasan et al., 2014).

One advantageous part of e-waste is the existence of recoverable metals e.g., aluminium, antimony, bismuth, copper, cobalt, gold, germanium, iridium, indium, iron, platinum, palladium, ruthenium, rhodium, and silver as a striking source of economy for recycling units and scrap dealers (Hubbert, 1956).

3.2.1 E-waste Disposal Guidelines:

e-Waste Management & Handling Rules (2011) were notified and come into implementation in 2012 But the actual implementation of e-Waste management was notified under Rules, 2016, dated 23.03.2016 under vide G.S.R. 338(E) and was effective from 01-10-2016.

The notification was published on 23rd March 2016 in the Gazette of India, Extraordinary Part-II, Sec. 3, Sub-Sec. (I), Government of India, Ministry of Environment, Forest and Climate Change published the Responsibilities of the manufacturer, collection centres, dealers and refurbishes, bulk consumer, and dismantler.

The Authorities for e-waste management are the Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCB), Committees of Union territories (CUT), Urban Local Bodies viz., Municipal Committee or Council or Corporation, Port Authority (PA) under Indian Ports Act (IPA), 1908 (15 of 1908) and Customs Authority (CAs) under the Customs Act (CA), 1962 (52 of 1962) are allotted by Government of India (Lower Middle-Income Data, 2022; CPCB, 2018). The EEE manufacturing and disposal without authorization from CPCB, is considered a violation of e-Waste Management Rules (2016) notified under E(P) Act 1986 and are punishable as per section 15 of the Act, 29 of 1986 (CPCB, 2017).

3.2.3 Strategies for Minimizing E-Waste:

EEE repairs include fixing the particular electrical fault by untrained mechanics but it is only practiced by lower-middle-income families. But, the Original equipment manufacturers (OEMs) companies have a monopoly over product design thereby the repairing cost is much higher. To overcome the situation, the argument was raised that the Right to Repair is not equivalent to the Right to replicate but not worked well.

The further advancement of the repairing system is Refurbishment. Refurbishment involves the repairing, servicing, and replacement of damaged consumable items, polishing, finishing, and packaging to make the old product close to the freshly brought new product.

The refurbishment is often executed by professionals. Such practices are very effective for the minimization of e-waste. Some online vendors like Amazon, are practicing refurbishment of old exchanged products.

3.2.4 E-waste Recycling Opportunities:

The EEE is the largest and fastest-growing manufacturing sector. Besides, the upsurge in sales of EEE and rapid obsolescence i.e., technological advancement, fashionable looks, and style push the huge e-waste generation. The hazardous components of e-waste laid adverse effects on the environment and human health.

The e-waste management system in India lacks proper implementation of suggested guidelines and protocols and seeks infrastructure augmentation for e-waste disposal and recycling (Vats and Singh, 2014). Thereby, the implementation of well-organized, innovative, and cost-effective practices is needed to safeguard the ecosystem and environment.

The state viz., Maharashtra (MS), Tamilnadu (TN), Telangana (TL), Andhra Pradesh (AP), Uttar Pradesh (UP), West Bengal (WB), Delhi (DL), Karnataka (KR), Gujarat (GJ), Madhya Pradesh (MP) and Punjab (PB) are account for 70% of the total e-waste generated in Indian continent (Agarwal, 2014) due to a large number of Tech Parks & electronic manufacturing units situated in their premises.

The categorization of E-Waste is depicted in Figure 3.1.

Figure 3.1: Different Categories of E-Waste

When repair and refurbishment are not appealing then the EEE goods come under the recycling process. The recycling process includes; (a) collection, (b) storage, (c) shortening, dismantling, and shredding, (d) mechanical separation, and (e) recovery of valuable products.

A printed circuit board (PCB) is a sandwich construct of conductive and insulating layers E-waste recycling and resource reimbursement are the multi-directional tactics that are required for a holistic solution to the e-waste threat to the global economy and eco-conservation.

The e-waste recycling methodology, regulatory affairs and legislation, circular economy models, the impact of e-waste on the environment and human health, and sustainable management (Islam et al., 2020; Pini et al., 2019; Awasthi et al., 2016; Gupta et al., 2014; Jadhav, 2013; Kahhat et al., 2008;) have been extensively explored in various works of literature. PCBs occupy up to 70 wt. % of the non-metallic e-waste and it is a challenging task for recycling (Yoo et al., 2009).

The component of non-metallic PCBs is including thermosetting plastics (TS), glass fibers (GF), and ceramic fractions (CF). The TS resists reformation due to its cross-linked polymeric assembly.

The first option is to Incinerate but glass fiber content reduces its efficiency as fuel (Goosey and Kellner, 2003). The second one is to dispose of by landfill but it is resource-wasting and causes pollution (Guo et al., 2009).

The modern approach is mechanical pre-treatment for the removal of plastic or ceramic materials coated over metallic elements and facilitates the liberation and separation of value-added products by hydrometallurgical methods (Yoo et al., 2009). Recent research has suggested that powdered PCBs can be used as wood fillers substitute, epoxy resin, adhesives, decorating agents, and building materials due to their high mechanical and thermal expansion properties (Zheng et al., 2009; Iji, 1998). Steps involved in the metal recovery from e-waste are depicted in Figure 3.2.

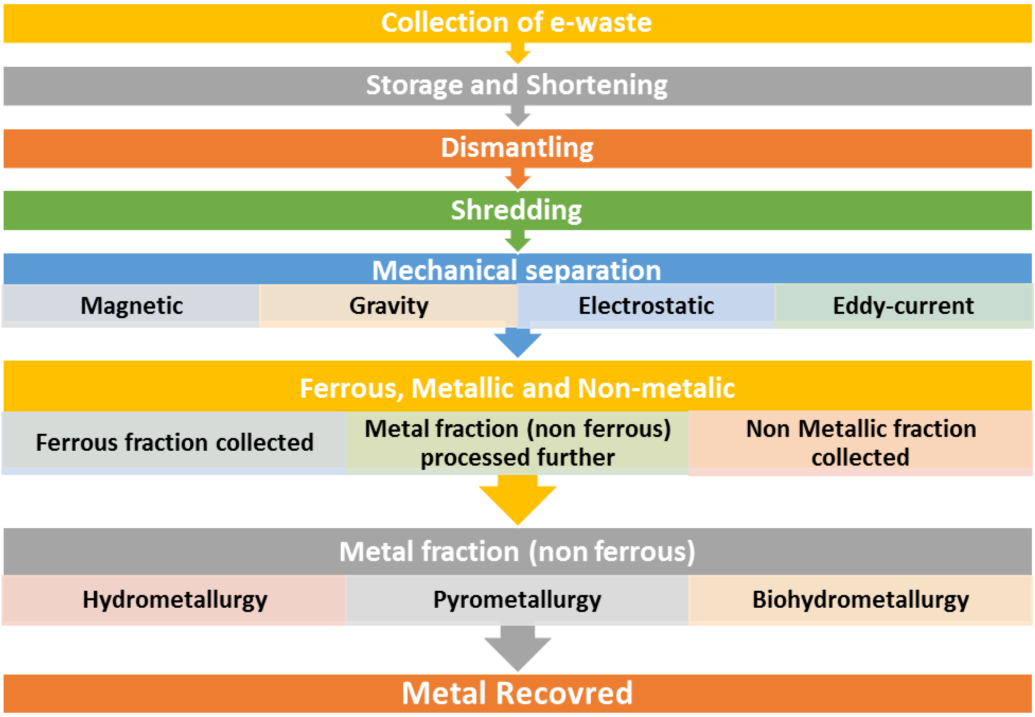

Figure 3.2: General Outline of the Metal Recovery from E-Waste

3.3 Conclusion:

Electrical and Electronics Equipment (EEE) occupy around $118 billion. The rapid technological advancement attracts consumers to replace much faster their EEE with the latest model of EEE having updated configuration and advanced features. Most consumers are not interested in repairing or using refurbished EEE due to the unavailability of trustable repair or refurbishment shops. Moreover, the energy-efficient and technologically advanced EEE has a short lifespan.

Due to the aforementioned reasons a huge amount of e-waste is accumulated. The traditional e-waste recycling approach is associated with environmental and health concerns. The present tactics offer the opportunities to extract value-added products i.e., precious metals and epoxy resin additives, from e-waste. The well-documented regulations and legislative frameworks available for e-waste management.

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4. Conversion of Waste to Energy

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Abstract:

Exponential growth in population, economic growth, and increasing rates of urbanization are the main factors for the generation of Municipal Solid Wastes (MSW). Rates of the generation of waste and its composition are also being affected by urbanization. Developed countries are the major contributors to MSW as a general trend there is a parallel relationship between economic development and waste generation. In high-income countries percentage of plastic and paper has been increased in the overall composition of waste. Waste to energy (WtE) technologies are the treatment of wastes to generate energy in the form of heat, electricity, or transport fuel.

These technologies convert the energy content of different types of wastes into different forms of valuable energy. There are various methodologies included in WtE technologies like thermo-chemical which includes incineration, co-combustion, thermal gasification, etc., and a bio-chemical conversion which includes the production of bioethanol, bio hydrogen, biogas production, and microbial fuel cell generation, and chemical conversions. WtE plants can bridge the gap between the waste recycling problem and power generation in the country.

Keywords:

Municipal Solid Waste, waste to energy, urbanization.

4.1 Introduction:

The unwanted, worthless, defective substance discarded after primary use is known as waste like municipal solid waste, industrial waste, biomedical waste, radioactive waste, etc. (1).

Municipal solid waste is mainly produced by households, industries, and commercial activity it consists of biodegradable, recyclable, inert and other materials. About 1.3 billion tonnes of Municipal Solid Waste (MSW) is being produced annually and this figure is going to increase up to 2.2 billion tonnes up to 2025. Such type of prediction is forcing the human race for the development of alternative waste management technologies (2). Waste to energy (WtE) technologies can be promising solutions for this.

4.2 What is a Waste to Energy?

A new technology that converts Municipal Solid Waste into electricity or heat is known as Waste to Energy (WtE) conversion technology (3). Waste conversion technology involves the following steps:

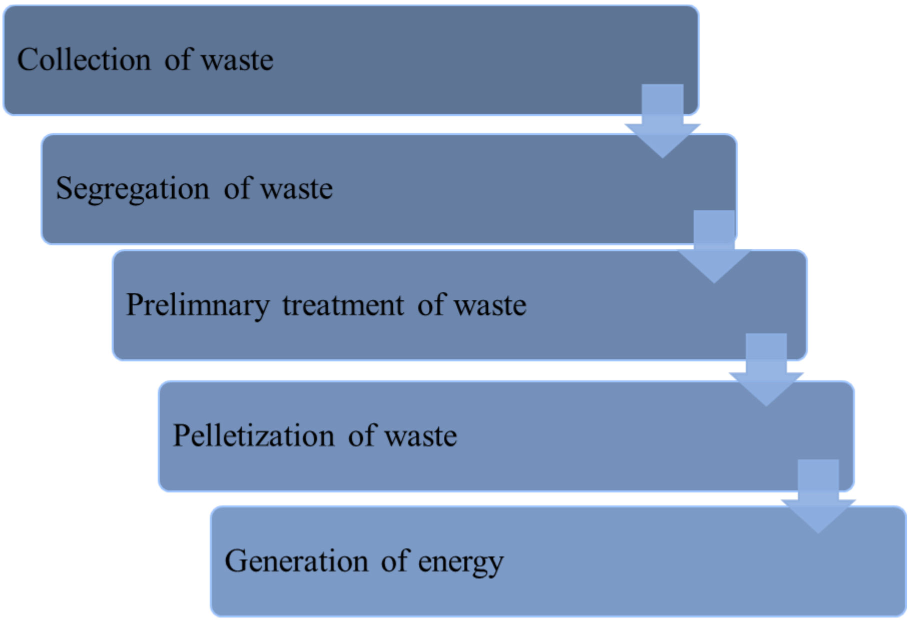

Figure 4.1: Components of WtE Technology

4.2.1 Collection of Waste:

When the solid wastes are being transferred to the end of treatment or landfill from the point of use and disposal. The waste is generally collected from the household door to door, factories, restaurants, etc. by waste collection vehicles.

The waste is then dumped in a waste collection or dumping zone and it has to be optimized. The most significant challenge in WtE is waste collection since local participation and public involvement is dependent upon adequate and reliable collection services (4).

4.2.2 Waste Segregation:

The collected waste consists of different kinds of materials like organic waste, paper, plastic, metal, glass, etc. so all these are separated either manually or with the help of a conveyer belt. This is one of the most crucial steps as it is not suitable to burn all these items as will cause the release of toxic pollutants into the atmosphere.

4.2.3 Preliminary Treatment of Waste:

In landfills, excess emission of methane gas takes place which can be minimized by the process of WtE technology. Most suitable wastes for energy generation are separated and further sorted according to their calorific value, lower pollution content, low moisture content, deodorized etc. The chemical or physical characteristics of biological wastes are also modified (5).

4.2.4 Pelletization of Waste:

Basically this is a method where the waste is generally condensed or its physical form is changed and by removing the inorganic content and moisture its organic content is enriched. Pellets are prepared from the solid wastes by various processes such as segregation, crushing, mixing high and low heat value organic waste material, and finally producing fuel pellets or briquettes from it. The pellets produced have a high calorific value. These pellets are used for energy generation in various areas like cement kilns, coal-fired power plants, industrial steam or heat boilers, pellet stoves, etc. (6).

4.2.5 Energy Generation from Waste:

Depending upon the feed stock and energy generation various methods such as combustion, biological treatment, landfills, etc. are used for WtE.

4.2.6 Conversion of Waste to Energy Technology:

Various technologies are now used for the production of energy from various wastes depending upon the feedstock. Following are some:

4.2.7 Thermal Combustion:

For generating heat and steam thermal combustion is used which is probably the oldest technology where biomass is burned in the presence of oxygen. Through direct firing steam, electricity, and combined heat are produced by biomass combustion.

High steam pressure is produced in the boiler after burning of biomass this steam flows through a series of turbine blades which makes the turbine rotate and then electricity is produced.

The feedstock for direct combustion comes from sugarcane mills, rice mills, and paper mills. Sometimes co-combustion technology is also used where biomass is burned along with fossil fuels such as coal and natural gas. Combined heat and power generation (CHP) can be performed by the use of biomass (7).

In the power plants where electricity is produced, a large amount of heat is also generated which is discharged into the atmosphere whereas in CHP this heat is used in district heating.

Energy from waste (EfW) is another form of direct combustion, where the waste is burned in a controlled manner so that the volume and mass of MSW can be reduced. During this process, gases are produced which contain a mixture of combustible products which then produce heat and which are further converted into steam and then to electrical energy.

4.2.8 Thermal Treatment:

When compared with fossil fuels biomass have certain limitations such as low bulk density, high moisture content, and a low calorific value which does not allow the large-scale burning of the biomass. Hence the raw biomass is reprocessed for energy production which involves the following steps.

Torrefaction: This is basically a thermal pre-treatment process where the physical and chemical composition of raw biomass is altered.

This is a heating process of biomass between 200^0C - 400^0C temperature in the absence of air which results in evaporation of moisture and driving out of low calorific components.

Hemicellulose in the biomass is also decomposed and at the end, a coal-like substance is produced. As a result of torrefaction, high-grade biofuels are produced this can be used as a replacement for coal in electricity production (8).

Gasification: When carbon present in organic waste is converted into a synthetic gas (syngas) which largely comprises carbon monoxide and hydrogen with the help of air or steam at 800^0C-1000^0C the process is known as gasification.

These syngas is burned to produce heat energy. This process takes place through partial oxidation where the involvement of oxygen is very less.

The process of gasification takes place in a gasifier which consists of various zones like drying, pyrolysis, combustion, and reduction. Removal or evaporation of surface water through filtration, evaporation, or both is known as drying. The process involving the charring of biomass is known as pyrolysis. In this process, solid biomass is broken down around 240^0C.

The broken down by-product including the liquid and gas is known as the tar. Further breakdown of this tar into simpler gases is known as cracking. Removal of oxygen from waste products at high temperatures to produce combustible gases is known as reduction.

Pyrolysis: This is a thermochemical process where the organic matter does not combust but the compounds present in it such as cellulose hemicelluloses and lignin decompose into charcoal and combustible gases.

The suitable temperature for this process ranges between 400^0C-600^0C. Three types of products are formed biochar, bio-oil, and syngas depending upon the process and factors such as temperature, pressure, and heating (9).

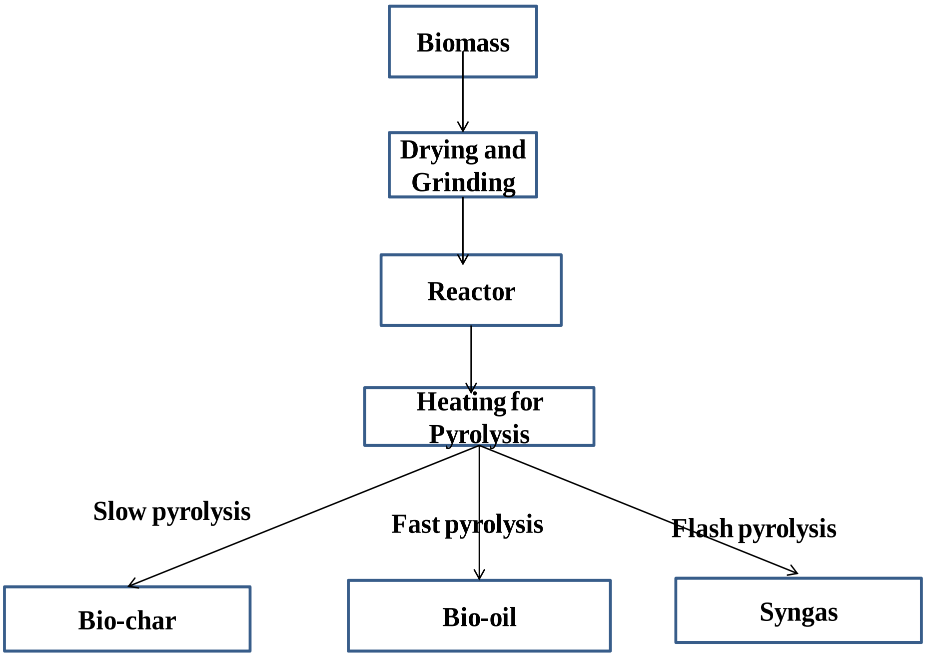

Figure 4.2: Process of Pyrolysis and Formation of Various Products

1. **Biochemical:** Biochemical processes like fermentation and anaerobic digestion are used to derive various forms of energy from biomass. This is an anaerobic process where complex carbohydrates are broken down into simple sugars with the action of microorganisms. Further, these simple sugars are converted into alcohols like bioethanol and gases like bio hydrogen (10). Now a day's bioethanol is blended with petrol. The biogas produced can be separated as bio methane and bio hydrogen and can be used as fuel (11).
2. **Benefits from WtE:** WtE technology is very helpful in the safe disposal of waste. This technology utilizes the waste material and provides a number of useful out puts from it which are summarised in Figure 4.3. These are various energy forms either they directly act as fuel source or as substrate for energy generation (12).

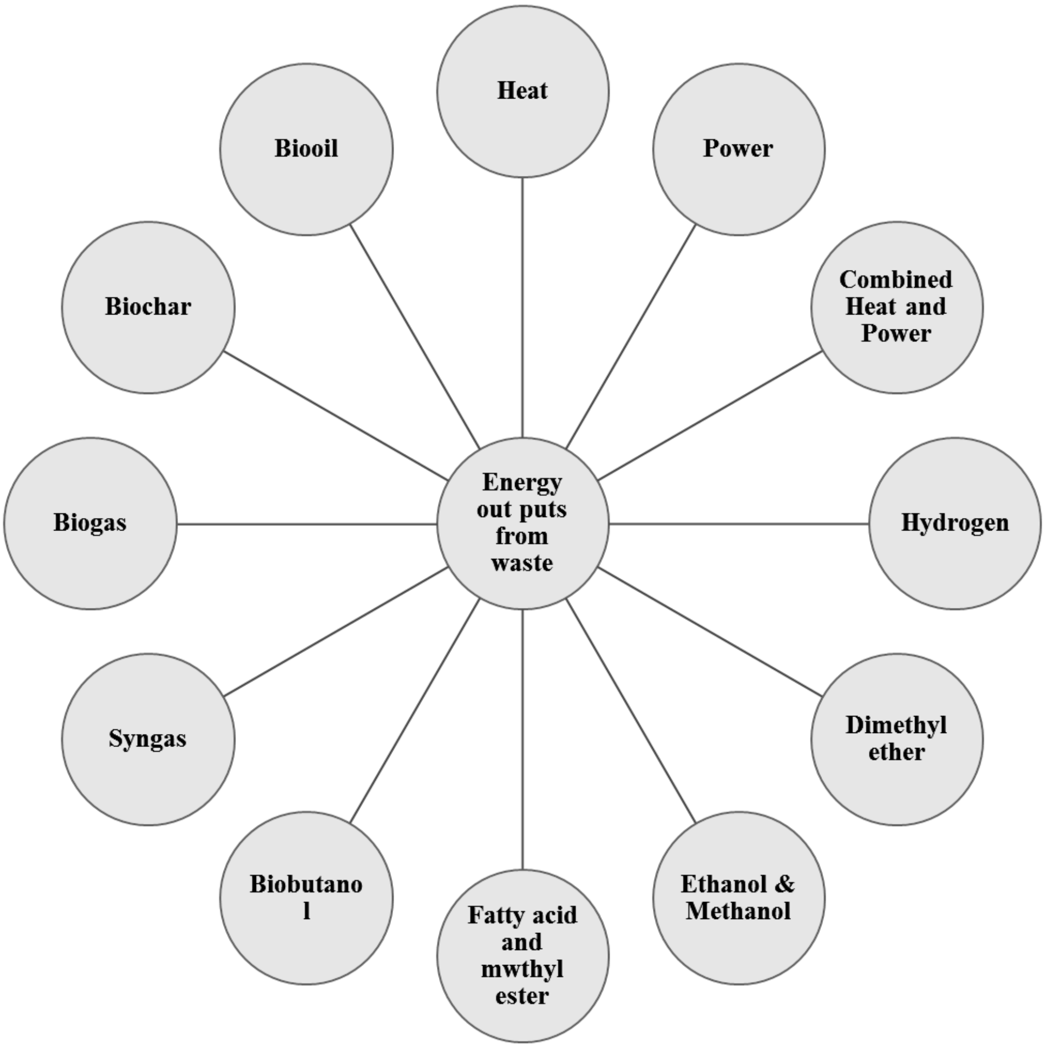

Figure 4.3: Various forms of Energy Sources Derived from Waste

WtE is one of the important aspect of waste management. There is a conceptual designed hierarchy which gives an idea of most and least preferred steps for waste management.

Top priority is given to waste prevention and generation of energy from it followed by reuse, recycle recovery and then disposal of waste.

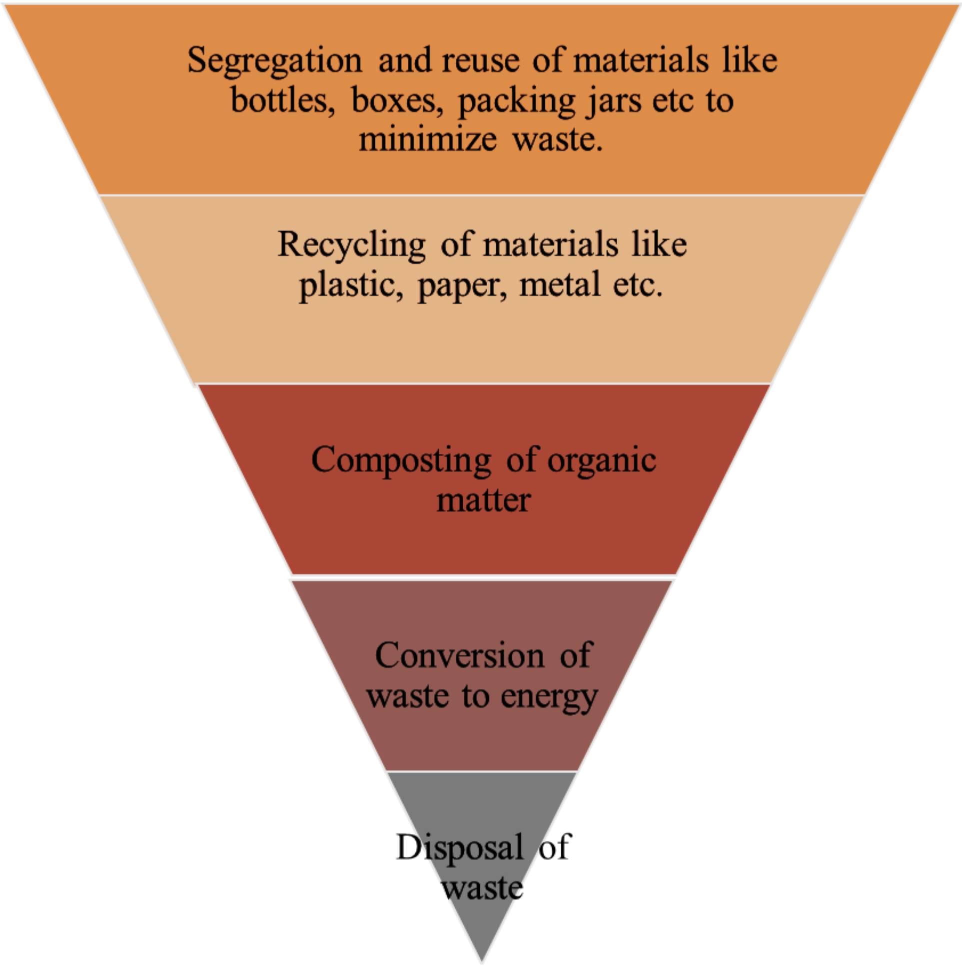

Figure 4.4: Hierarchy of Sustainable Waste Management Showing Most Preferred Process at the Top and Least Preferred Process at the Bottom

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5. Environmental Pollution

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5.1 Introduction:

About 3.5 billion years ago life evolved on earth and it is the place in the universe where Human beings and other life forms evolved and started to survive depending on the environment of the earth. The word environment originated from the French word 'environment' meaning to encircle or to surround. Presently, pollution occurs in an unpreceded scale around the globe. Elements of the environment including water, land, and the ecosystem is hampered by man which results in pollution. Trends in two ominous directions, principally by burning fossil fuels, and the release of biocidal products and substances. Also, presently pollution is integrally webbed due to modern technology, population increase, lifestyle, and other factors taking a synoptic view, our atmosphere is polluted both globally and on a regional scale.

The ozone shield, the protective layer is thinning twice due to the build-up of greenhouse gases leading to global warming leading to a significant change in weathering patterns. Destruction of the ozone layer leads to catastrophic consequences including disturbance of the food chain, and rising sea levels that can lead to submersion of many islands. Due to the melting of glaciers, flooding is caused in many low-lying coastal areas leading to harvest loss. To address these pollution challenges and safeguard the ecosystem several technological translations must be implemented on a large scale. Cost-effective waste-intensive strategies must be implemented including shifting fossil fuels.

Managing pollution must be perceived with transboundary globally and progressing to stable world pollution. Also, the environmental problems can be ruled out by a multidisciplinary approach by scientific experts, and public awareness; sustainable solutions must be addressed by national and international organizations with reference to the threat of environmental pollution

Environmental pollution can be defined as "The phenomenon in which pollutants or contaminants are added to the natural environment that can cause undesirable change". According to the United Nations pollution is defined as the "presence of substances and heat in environmental media (air, water, land) whose nature, location, or quantity produces undesirable environmental effects."[1]

A Pollutant can be defined as "any substance when introduced to the natural environment can cause unwanted or adverse changes." These pollutants or contaminants may belong to any phase (solid, liquid, or gas). They can either be of the anthropogenic origin or natural origin. Pollution can happen to any component of the environment like water, air, soil, etc.

The overuse of some energy sources like sound, radioactivity, light, and heat. Environmental pollution is one of the major causes of death worldwide causing one in six deaths worldwide and around 9 million death per year[2] Environmental pollution is usually classified as a point source and nonpoint source pollution.

5.1.1 Point Source Pollution:

Point source pollution is the type of pollution that has a single discrete source. The pollutants causing this type of pollution has a single source of emergence. The magnitude of point source pollution is usually less due to the single number of sources. For example, air pollution is caused by effluents from a single factory, sound pollution is caused by air jets.

5.1.2 Nonpoint Source Pollution:

Nonpoint source pollution is the type of pollution that has multiple sources. The contaminants emerge from different sources often combining so that it becomes difficult to identify these sources.

The magnitude of pollution is high since different types of pollutants come together from multiple different sources. Examples include water pollution due to agricultural runoff and pesticides and sound pollution in market areas. Environmental pollution can be mainly classified into the following types:

a. Air pollution
b. Water pollution
c. Soil pollution
d. Sound pollution
e. Light pollution
f. Thermal pollution
g. Radioactive pollution.

5.2 Air Pollution:

5.2.1 Definition:

According to the United Nations, organization air pollution can be defined as "the presence of contaminants or pollutant substances in the air that do not disperse properly and that interfere with human health or welfare or produce other harmful environmental effects[3][4]." The presence of unwanted substances in the air that can have undesirable effects on humans, animals, plants, and the planet as a whole is called air pollution.

5.2.2 Pollutants:

The pollutants that cause air pollution can be classified into gas particulate and biological molecules. The gases that cause air pollution include carbon dioxide, carbon monoxide, nitrous oxide, methane, sulphur oxide, chlorofluorocarbons (CFC)s, hydrofluorocarbons (HFC)s, ammonia ozone, etc.

Particulate matter (PM) includes smoke, soot, dirt, dust, and drops of liquids or solvents. Biological molecules include microbes like bacteria, viruses, house dust, animal dander, pollen, agricultural dust, etc.

5.2.3 Sources of Air Pollution:

The sources of air pollution include anthropogenic (human-made) and natural. The anthropogenic sources include the burning of fossil fuels like petrol and diesel. Burning of wood, agricultural waste, and dung.

Burning of plastics and other substances that contain hydrocarbons, emissions from factories and industries, emissions from automobiles, use of pesticides, insecticides in agriculture, fumes that arise from paint, aerosols, hair spray, and other solvents, use of fireworks, emissions from weapons testing, rocket launches, etc.

The natural sources include methane which is naturally produced by methanogenic bacteria, dust in the atmosphere, volcanic eruptions that release harmful and toxic gases, gases released during wildfires, etc.

5.2.4 Effects of Air Pollution:

Air pollution can cause difficulty in breathing, wheezing, coughing, asthma, chronic obstructive pulmonary disease(COPD), heart diseases, stroke, and lung cancer[5, 6] It can also worsen already existing heart and lung conditions like pneumonia.

It can also be associated with psychiatric disorders like depression, reduced intelligence quotient(IQ) and impaired cognition etc.[5].

Air pollution can also cause agricultural problems like decreased yield, toxicity to crop plants, etc. All of these effects lead to a huge amount of economic losses due to health expenses, agricultural losses, deaths, etc.

Air pollution causes around 7 million deaths worldwide annually and is considered a highly dangerous environmental risk [7]. Urban outdoor pollution causes around 1.3 million deaths annually worldwide [8] India and China are the countries with the highest death rate caused by air pollution [8] Air pollution is also estimated to cause about $5 trillion loss to the world economy per year.

5.2.5 Preventive Measures:

Using clean alternative energy instead of using fossil fuels can reduce air pollution. Increasing usage of wind energy, solar energy, hydropower, etc. can reduce air pollution significantly. The transition from petrol or diesel-powered vehicles to electric vehicles, and bicycles, and also promoting the use of public transport are some of the options.

Recycling and reusing plastics instead of burning them, Increasing Forest cover, planting more trees in urban areas, and treating effluents from factories and industries before releasing them into the atmosphere are some of the important preventive measures that can curb air pollution.

5.3 Water Pollution:

5.3.1 Definition:

Water pollution is the contamination of the water bodies like the ocean, seas, rivers, lakes, streams, etc. Anthropogenic activities pose a negative impact on the aquatic ecosystem and pollute unfit for any human use.

When contaminants are introduced into water bodies it makes water less useful and reduces it's ecosystem services it generally provides[9]. Water pollution can be classified as surface water pollution and groundwater pollution. Surface water pollution occurs when surface water bodies like rivers, lakes, streams, etc. get polluted while groundwater pollution occurs when groundwater sources like aquifers get polluted due to seepage of contaminants.

5.3.2 Pollutants:

Domestically used water and household water that is released into drainage systems often contain chemicals like detergents, vegetable waste, excretory waste, cosmetics, plastics, and other solid materials when this water is released to natural water bodies without treatment it causes pollution. Industrial effluents are usually released directly into nearby water bodies, they contain toxic compounds like heavy metals, no biodegradable hydrocarbons, inorganic compounds, etc. Pesticides and fertilizers used for agriculture make their way into the water bodies as agricultural runoff these contain nutrients like nitrogen, phosphorus, potassium, calcium, etc.

This promotes excessive growth of unwanted, toxin-producing, invasive algal species which are called algal blooms which utilize all the dissolved oxygen for their growth leading to the death of other aquatic species due to insufficient oxygen in the process known as eutrophication.

Groundwater is usually polluted due to seepage of agricultural waste like pesticides and insecticides into groundwater, effluents from wastewater treatment, leachates from landfills, and percolation of water through polluted soil. Marine water pollution occurs often due to the release of industrial effluents, oil spillages from cargo ships, deep-sea mining, polluted water from rivers, and entry of no biodegradable substances like plastics into oceans and seas. Polluted water also contains pathogens like bacteria, viruses, and parasites that spread rapidly causing large-scale deaths. These diseases are called water-borne diseases.

5.3.3 Sources:

Sewage is one of the main sources of water pollution. It usually contains 99.9% of water and around 0.1% of solids [11].

Sewage usually contains chemicals like cosmetics, surfactants, and sanitary products, hydrocarbons that includes fats and oils, pharmaceutical drugs, and other metabolites. Industrial wastewater is another major source that usually contains heavy metals like mercury, lead, arsenic, chromium, etc. Organic and inorganic waste, toxins, plastics, and solvents. Oil spillage from ships, boats, drilling rigs, wells, etc., and deep-sea mining is the major source of marine water pollution.

Agricultural runoff is another source that can cause both surface and groundwater pollution. Acid rain is another contributor which results in high acidity in water bodies. Mining activities can also result in the entry of inorganic elements into the water bodies. The disposal of radioactive waste produced from nuclear energy plants can also cause water contamination.

5.3.4 Effects of Water Pollution:

The main negative impact of water pollution is the disruption of the aquatic ecosystem. It has resulted in the death of millions of species of aquatic organisms and plants affecting their food chain and food web. Human consumption of polluted water results in the rapid spread of infectious diseases like typhoid, cholera, hepatitis, diarrhoea, and other parasitic infections, these diseases are therefore classified as waterborne diseases.

Inorganic contaminants in the water often cause several human disorders like colon cancer, digestive problems, urinary problems, skin disorder, etc. As mentioned previously eutrophication is another phenomenon that causes anoxia (decrease in oxygen levels) and affects aquatic life in rivers, ponds, lakes, etc.

According to WHO around 2 billion people around the world consume water contaminated by faces [10]. Water pollution caused around 1.8 million deaths worldwide according to a lancet study in 2015[11]About 14 billion pounds of plastics are dumped into the water every year[12]Anthropogenic activities is also responsible for releasing 1.2 trillion gallons of no treated wastewater to various water bodies[13]. According to estimates, 47% of the world population may face a shortage of water pollution by the years 2050 if the same trend continues

5.3.5 Prevention:

Treating sewage water before releasing it into water bodies can reduce water pollution significantly. Establishing wastewater treatment plants with proper infrastructure can play an important role in this process.

Reduction in the use of chemical pesticides and fertilizers and replacing them with bio pesticides and organic manure. Industries and factories should treat effluents before releasing them into water bodies or can even reuse that water.

Proper disposal of waste and preventing entry of solid waste into water bodies. Reducing the use of detergents and other cleaning agents, and proper disposal of pharmaceutical drugs. Reducing recycling and reusing plastics are some options to prevent water pollution.

5.4 Soil Pollution:

5.4.1 Definition:

Soil pollution also called soil contamination or land contamination is a type of land degradation caused by the presence of undesirable chemical agents that cause an unwanted change in the natural soil environment.

The entry of human-made synthetic substances called xenobiotics usually affects the existing soil condition including changes in the soil composition, chemistry, and microbial population which can cause a decrease in soil fertility. Along with the decrease in soil fertility polluted soil may also become dangerous for plants growing in it and other organisms that depend on plants.

5.4.2 Pollutants:

Non-biodegradable plastics like polythene and polystyrene are one of the main soil polluting agents. Other chemicals involve include petroleum hydrocarbons, pesticides, heavy metals, chemical solvents, etc. pesticides and herbicides that are used in agriculture contain complex chemicals which can not only pollute soil but can also kill several beneficial microbes in the soil, they can also cause toxicity to humans and other organisms[14]. Insecticides like organochlorines, DDT, Dieldrin, Aldrin, organophosphates, etc. persist for a very long time in the soil causing toxicity in both plants and animals. Mining activities can also release heavy metals into soil layers due to metal leaching.

Fertilizers used in agriculture can also cause an increase in inorganic nutrients in soil like nitrogen, potassium, calcium, phosphorus, etc. which can cause toxicity in plants and eutrophication in lakes when agricultural runoff reaches lakes. The burning of coal releases coal ash into the soil which contains hazardous levels of lead and other hydrocarbons. Oil spills also pollute soil to significant levels.

5.4.3 Sources:

The major sources of soil pollutants come from agriculture procedures which make use of chemical fertilizers, pesticides, insecticides, etc. other important sources include mining, disposal of solid waste in the open grounds and landfills especially hazardous wastes and plastics. Oil spills because long-term land degradation other and the disposal of electronic waste, radioactive waste, and medical waste from hospitals are other minor sources.

The burning of fossil fuels can also cause the deposition of toxic compounds on the soil layer. Acid rain is another source that leads increases acidity in the soil. Various construction activities can also release dust which may deposit on soil causing pollution.

5.4.4 Effects of Soil Pollution:

Health consequences due to soil pollution depend on the type of pollutants. According to existing lines of evidence the pesticides and heavy metals that contaminate soil may have a negative impact on cardiovascular health, causing inflammation and alterations in the body's internal clock called the circadian rhythm. [14]

Long-term exposure to heavy metals like lead, chromium, petroleum hydrocarbons, pesticides, and herbicides may cause chronic health conditions, digestive problems, and congenital disorders. Insecticides like organophosphates and carbonates can cause neuromuscular disorders.

The contaminants like DDT usually undergo bio magnification and bioaccumulation in food chains causing various disorders in humans and higher trophic levels like peregrine falcon birds where they can interfere with calcium metabolism leading to the formation of fragile eggs which easily break causing the reduction in bird population[14] The pollutants in soil reduce soil fertility affecting plant growth and thereby affecting food chains in an ecosystem.

According to the UNO report at present, the degradation of land and soil is affecting at least 3.2 billion people which is 40% of the world population. [15, 16] According to the FAO report of 2018 Australia had more than 80k sites suffering from soil pollution.

In China, 16% of all soil including 19% of agricultural soil is polluted. There were more than 1300 polluted sites in Europe alone. [1] In India, there were more than 43 critically polluted zones in more than 16 states. Out of 43 sites, 21 sites alone exist in 4 states namely Gujarat, Uttar Pradesh, Maharashtra, and Tamil Nadu[17].

5.4.5 Prevention:

Limiting the use of plastics and recycling, and reusing it can reduce plastic soil pollution. Reducing the use of pesticides, herbicides, and insecticides and using biological pesticides instead can reduce the majority of soil pollution.

Other measures include reducing oil spills, taking care during mining to prevent the leaching of metals into soil layers, and reducing the use of fossil fuels. In the soil already affected by pollutants, bioremediation techniques like phytoremediation, mycoremediation and genetically engineered microbes like *Pseudomonas putida* can be used to remove pollutants and clean up the soil.

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6. Green Audit: A Weapon to Reduce Environmental Pollution

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Abstract:

All the physical surroundings on earth are called the environment, the atmosphere, the hydrosphere, and the lithosphere. A person's good health depends on the environment around him. Increasing population, civilization, urbanization, and industrialization are some main factors that contaminate our environment greatly. We have to protect our environment from being spoiled. For the protection and conservation of the environment, the Green Audit is an important tool for the management system that suggests different standard parameters, methods, and projects. The present study aims to focus on the current scenario of Green Audit. It also describes the causes for Green Audit and various processes under this. This study also mentions some of the regular practices, which we always continue as our part of daily life for the management of a clean environment such as the use of renewable energy resources, use of CFL, water harvesting, compost pit, etc. Green Auditing encourages financial savings through the reduction of various resources utilized. It develops the personal and social responsibility for all of us to clean our environment and save our earth.

Keywords:

Green Audit, Environment, Renewable energy, Water Harvesting

Key Concepts:

After the completion of this chapter, we will able to understand some of the points given below:

- What is Green Audit and Why Green Audit is necessary?
- Is Green Audit and Environmental Audit are same?
- What are the objectives of the Green Audit?
- What is the process of Green Audit?
- What are the types of Green audits?
- Who needs to do the Green Audit?
- What are Green policies?

6.1 Introduction:

Due to infinite anthropogenic activities, the ecosystem is gradually disintegrating and it is becoming difficult to save the environment. It is a moral duty of man to keep his environment clean and to give clean air, water, and soil to his future generation. Today we are facing some global environmental issues like air, water, soil pollution, smog, global warming, acid rain, deforestation, wildfire, etc.

Earth is the only planet for life, so everyone's responsibility is to take care of the environment and save the earth. By making some simple changes in our daily lifestyle, we can make the environment clean and reduce the carbon footprint on the environment [1]. Now the question arises, why do we have to save our environment and how?

Everyone should save the environment for its individual benefits:

- The environment helps in protecting the ecosystem and generating a successful food chain and maintaining the earth's balance.

- Forest provides raw materials for various consumer products give us clean air to breathe and provides habitats for a variety of species.
- The tree keeps the atmosphere clean and plays a critical character in the refilling of aquifers, blocking the wind.
- Maintaining the environment could prevent soil erosion, such as the growth of forest stability and its results to slow down global warming.
- Availability of food for organisms is possible only by preventing the environment.

Humans have a moral obligation to preserve the beauty of nature and reflect their personality. By protecting the environment, Protect humanity, feel good, relax and renew spiritual energy. Environmental protection encourages better physical and mental health, increases tourism, and promotes economic stability.

This way the environment around us is extremely essential for us and we should try to keep it good at any cost. Thus, Green Audit is a way to monitor the accuracy of the surrounding environment.

6.2 What is Green Audit?

The word Green means eco-friendly or not harmful to the environment and living beings. GREEN means “Global Readiness in Ensuring Ecological Neutrality”. Green Auditing is also known as Environmental Auditing, which is an umbrella term.

The green audit is **a weapon to identify the area of environmental impacts and evaluate the compliance of the operations on the development and regular activities within an organization.**

It is one of the processes of systematic recognition, quantification, recording, investigating, and analysis of constituents of environmental dissimilarity of various enterprises [2]. It is one of the processes where all the institutions or organizations are analyzed for environmental performance and investigated against their environmental policies and objectives. Therefore the official investigation of the institutions or organizations to know the effects on their environment is called Green Audit.

6.2.1 Green Audit: Environmental Audit in India:

Environmental Audit in India was conducted by the Comptroller and Auditor General (CG) of India. In the Constitution of India, Articles 148 to 151 related to this mandate.

India is one of the first countries to conduct environmental auditing mandatory. Environmental auditing is a type of environmental management tool for evaluating all those activities that have an impact on the environment against its standard set of criteria.

Each organization is familiar with the importance of the environment and knows the issues related to environmental performance which will be investigated and reported by different interested teams.

Thus, Environmental auditing is useful for the analysis and investigation of the environmental performance of different organizations. Types of Environmental Audit:

- Environmental compliance audits
- Environmental management audits
- Functional environmental audits

The environmental compliance audit checks the company's or site's legal compliance status.

The environmental management audit is very helpful to check and understand the organization or company's performance against its environmental standard set of criteria.

And the third type of functional environmental audit is useful to analyze and investigate the effects of particular activities and issues related to environmental performance. It investigates the particular field of concern such as air quality observation, materials management, or wastewater management.

6.2.2 History of Green Audit:

The Green audit began in the 1970s by looking at the problem caused by work conducted within the factory or any organizations whose activities are harmful to the surrounding environment and also create health issues for all. Mathew, Iencis, and Matis found that environmental accounting has been developed in four stages (1970-1980, 1981-1994, 1995-2001, 2002-onwards) and now at the current stage known as green auditing.

Although four stages of environmental auditing have been developed, only the last two stages are familiar to us because during this period a beneficial study was conducted and also we came to know the concept of environmental auditing [3-5].

Now, it is necessary to have complete knowledge of environmental audits. The first scientist who guided and provides a comprehensive study about the use of environmental audits is Ellington. During this period three journals are published where environmental matters are mentioned environmental auditors, European environment, and business strategy and environment [6-8].

In 2008 Porter, Simon & Hatchery is the first who mentions exactly what is the Green Audit? And after that, worldwide accepted the concept related to the green audit.

They well explained the concept of a green audit as an" Environmental Management System"(EMS) that is a continuous increase in environment and communication of the results of the EMS activities with the organization's directions [9].

In 2008 Adeniji [10] is the first who was primarily concerned with an environmental audit of the companies to the growing importance of green issues [11].

6.2.3 Why Green Audit is Needed?

The rapid urbanization and economic development at the local, regional and global levels have led to several environmental and ecological crises. In this context, it is necessary to maintain the Green Campus environment for all the organizations and institutes which will help in sustainable development and simultaneously reduce the amount of atmospheric carbon dioxide from the environment.

The green audit can be an effective tool for an organization/institute/industry to evaluate how and where they are utilizing the most energy or water or resources; after that the organization/institute/industry can consider how to execute implement and make changes and preserve their resources. To enhance the waste minimization plan and recycling project, the type and volume of waste can be determined.

It can improve health and promote environmental activities, values, and ethics. So, all the staff and students have a better understanding of Green's impact on campus. If self-inquiry is a natural and necessary outgrowth of quality education, it could also be stated that institutional self-inquiry is a natural and necessary outgrowth of a quality educational institution. Thus the college must evaluate its contributions toward a sustainable future.

As environmental sustainability is becoming one of the major issues for the nation, therefore the role of higher education institutions in environmental sustainability is more widespread. Recently, the Green Audit of an institution has been very important for its self-assessment that maintained the institution better and mitigates the present environmental problems.

Many institutions adopted lots of good measures to remove these issues but do not have proper documentation due to a lack of awareness of green audits.

All these non-scholastic efforts of the administrations play a crucial role in ensuring the green quotient of the campus is intact. Therefore, this chapter aims to identify, quantify, investigate and prioritize the framework of Environment Sustainability in compliance with the applicable regulations, policies, and standards.

6.2.4 Benefits of the Green Auditing:

- It helps to protect the environment and solve many environmental issues.
- It suppresses the environmental impacts like wastewater and energy costs.
- Improving relations with stakeholders and users to evaluate environmental standards.
- Providing the basis for an environmental management system (EMS).
- Encourage and empower the organizations to frame a better environmental performance.
- More efficient resource management and provide the basis for improved sustainability.
- To create a green and plastic-free campus.

- To enable waste management by reducing waste generation such as solid and water recycling. It also recognizes the cost-saving methods through waste minimization and management.
- Enhance the environmental guidelines and alert about duties.
- Impart environmental education through a systematic environmental management system and improve environmental standards.

So, Green auditing should become a precise tool in the management and monitoring of the environmental performance and sustainable development programs of all institutions.

6.2.5 Objectives:

- To observe Geographical Location.
- Tabulate Floral and Faunal diversity.
- To observe Meteorological parameter.
- To reduce Energy Consumption.
- To conduct a proper waste disposal system.
- Keen observation of Ecological Environmental conditions.
- To conduct awareness and Training on Sustainability for Students.
- To ensure development along with saving the environment.
- To ensure some legal rules should be framed for the cleanliness of the environment with present legislations of the State and other legal requirements.
- Installation of devices that reduces the pollution and authentication of such devices by the competent authority.
- To ensure optimum utilization of resources.
- To ensure that industries have taken sufficient precautions to protect their employees from pollution resulting from it.
- To encourage and suggest improving the system and also promote a safe and clean environment.

6.2.6 Types of Green Audit:

A. Based on frequency such audit is of two types:

a. **Concurrent/ Cyclical Audit:** It is mainly managed by the entity's environmental unit segment/outside consultants or a combination of both on a scheduled cycle.
b. **Single Special Purpose Audit:** It is proposed for a special purpose and is normally managed by outside agencies. It is carried in the special need, not regularly.

B. Based on scope, objectives, and risk assessment such audit may be categorized as:

a. **Compliance Audit: This audit involves the review's** level of compliance with relevant environmental and safety standards.
b. **Performance Audit:** This audit check the environmental impact of programmers, EMS, compliance with environmental laws, etc.
c. **Transactional Audit:** It evaluates the environmental risks and accountabilities of land/facilities before a real estate acquisition or divesture of business. This audit is very important as both the buyers and sellers **are directly involved and** want to know the limit of any liabilities due to environmental contamination.
d. **Product/Activity Audit:** It is the audit that involved specific products, processes, and their distribution that determine the requirements to make them environmentally friendly and to confirm that they are meeting products and chemical restrictions. Such type of audits also assesses packaging materials for their reusability and recyclability.
e. **Issues Audit:** It estimates the corporate performance in a particular field (e.g. Oil and Natural Gas Corporation's impact on habitats or impacts on Sundarban for the potential chemical factory in Nayachar of West Bengal)
f. **Risks Audit:** Considers occupational health and safety/risks to employees and the public.
g. **Energy and Waste Audit:** Evaluate usages of energy with alternative sources and track the reasons for waste, risks involved, etc.
h. **Process and Safety Audit:** It evaluates whether policies, processes, monitoring, appraisal, documentation, etc. are in the proper place. It also considers present/potential hazards and risks arising from processes.

i. **Quality Audit:** It checks total quality management (TQM) from the perspective of the environment.

j. **EMS Audit: It e**xamines whether the given facility meets EMS standards (viz., ISO 14001, EMAS).

k. **Baseline Audit/Future Scenario Assessment:** It helps to identify all the possibilities of environmental issues in addition to the current one and planned to evaluate the probability/intensity of an organization's ability to respond to new challenges.

6.2.7 Methodology:

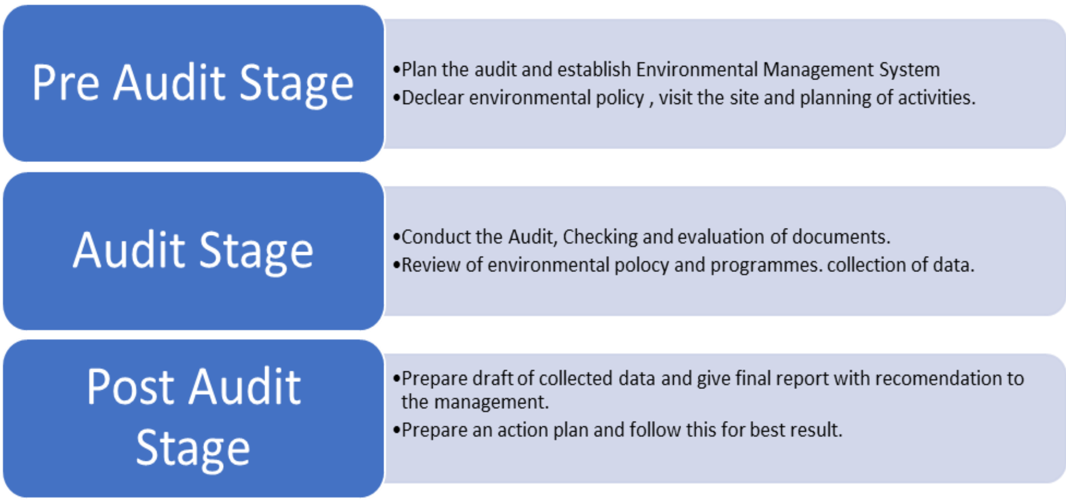

Figure 6.1: Stages to Perform the Audit

6.2.8 Tools for Performing Green Audit:

- Physical inspection of the campus.
- Preparation of questionnaires.
- Observation and review of the documentations.
- Data analysis and measurements.

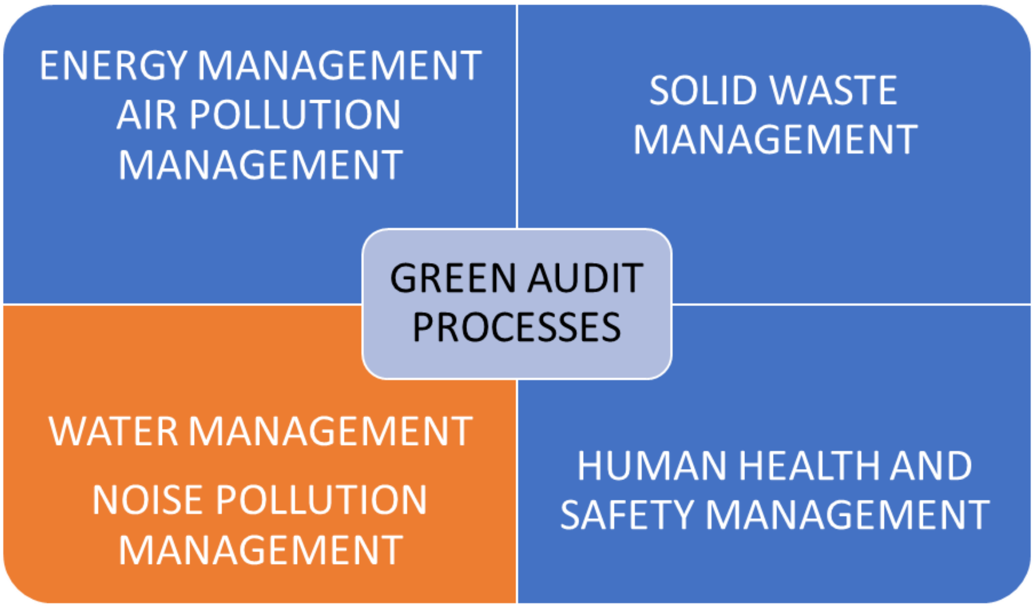

Figure 6.2: Process of Green Audit

6.2.9 Status of Environmental Management Summarized by these Following Studies:

a. **Biodiversity Audit:** Butterflies and Avifauna are attracted by host plants, so more species, and diverse host plants can be planted. In a botanical garden, plants are arranged in a taxonomical manner.

b. **Solid Waste Management:** Solid waste includes paper, glass, plastic, biodegradable, canteen, construction waste, laboratory waste, etc. Vermicomposting and compose pits are installed for biodegradable/ Garden waste.

   Some National and International Days related to cleanliness and solid waste management activities are conducted by students and other staff members. The standard procedure should be developed by organizing committee members for recycling waste materials. Storage and management of laboratory waste should be properly.

c. **Energy Management:** LED and CFL should be used to reduce power consumption. Energy conservation awareness programs should be conducted by the college. 5 Star rating electrical appliances should be installed on campus. The use of renewable sources of energy like solar energy is the best way for saving electricity.

d. **Water Management:** On any campus, water sinks are toilets, garden, laboratory, bathroom canteen, mess, etc. To prevent overflow of water through overhead tank, there is a need to a fitted auto cut system in every water storage tank. Regular checking of leakage of water from water channels, pipes, and taps should be a must. To reduce water use and reduce wastage of water, the micro irrigation system can be set up for gardening.

e. **Air Quality Management:** For an aesthetic look of the campus and to improve environmental quality, a good canopy of trees is a must, so keeping the campus green is everyone's responsibility.

   NSS and NCC Volunteers are responsible for plantation programs in and around campus and conduct awareness programs for other students. The more trees are there on campus, the more pure air there will be.

f. **Sound Management:** Thick green belts are the best remedy for noise pollution. Banning student vehicles and pressure horns vehicles within the college premises. In the classroom, installing noise-absorbing fixtures and promoting awareness programs for the campus community about the effects of noise pollution. There should be silence zones in college like the library, auditorium, and seminar hall.

g. **Human Health and Safety Management:** An awareness program for vector-borne diseases should be conducted. Regular health check-up is necessary and emergency phone numbers should be displayed in the proper place.

6.3 Conclusion:

In the end, it can be concluded that if the environment is clean, only then life go on, so it is the responsibility of all to keep the environment clean and maintain life on the earth. For continuous monitoring of environment, the Green Audit is very important .Green Audit or the Environmental Audit is a continuous process and everyone should understand and implement this process and help to clean the environment.

Any college building can be rebuilt based on of environmental standards and convert into the Green building. Follow some simple eco-friendly rules like reducing plastic use, implementation of rain water harvesting, creating garden in campus, using electronics instead of paper also helps to create green campus and healthy future. .

6.3.1 Questions for Review:

- What is Green Audit?
- Objectives and benefits of Green Audit.
- Necessity for Green Audit.
- Process of Green Audit.

6.3.2 Questions for Discussion:

- How to conduct a Green Audit in an establishment in a low budget?
- Will the process of Green Audit be the same for every institution?
- Does the green audit of an institution be influenced by the geographical environment there?
- What are the differences between the Green Audit of educational institutions and industrial milieu?

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7. Microbes in Agriculture

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Abstract:

In agriculture, the soil is the basis of plant production and the microorganisms play a crucial role in forming the connection between the plant and the soil, so the microorganisms are very necessary to improve the quality of the soil for the growth of healthy plants.

Soil microorganisms are dynamic components of soil and perform many useful functions in the soil system. Biological transformations such as organic matter conversion and biological nitrogen fixation help microorganisms.

Apart from that, they help increase the availability of nutrients for plants. In general, one gram of soil with over 90 million bacteria helps plants absorb nutrients by easily converting unavailable nutrients into available nutrients. Microorganisms are very beneficial for plant growth from an agricultural point of view.

Biological stress is a major problem for farmers today, as an increase in the human population causes soil degradation and a declining microbial population. Ultimately, the use of hybrid seeds, high-yielding varieties, fertilizers, and frequent watering adversely affect plant growth. Therefore, this chapter describes the role of microorganisms in crop production.

Keywords:

Biological nitrogen fixation, fertilizers, biological transformation.

7.1 Introduction:

In modern agriculture, along with the use of hybrid seeds, high yielding varieties, chemical fertilizers and regular irrigation, the use of microorganisms as natural fertilizers is becoming the most popular field of agriculture in the present era. The harmful effects and high cost of chemical fertilizers make them unsuitable for agriculture.

It is estimated that by 2020, 28.8 million tons of nutrients are needed to produce 321 million tons of food grains. However, the amount of nutrients available is 21.6 million tons. There is a huge gap of 7.2 million tons between nutrient intake and elimination (Kalsoom *et al*., 2020).

Agricultural soil productivity can also be enhanced by soil microorganisms. Today, people use natural microorganisms to produce organic products that recycle nutrients and respect the environment (Vyas *et al*., 2017).

Microorganisms are an integral part of soil and contribute to soil and plant health. Microorganisms can fix atmospheric nitrogen, solubilize and mobilize phosphorus, producing antibiotics and disease-fighting molecules. Due to these properties, they are used in agriculture as bio-fertilizers and bio-pesticides (Vyas *et al.*, 2017). Thus, we can say that microorganisms can improve crop nutrition and the ability of crops to resist biotic and abiotic stress. Thus, greater utilization of microorganisms in agricultural systems has the potential to allow reductions in the use of inorganic fertilizers, water, herbicides, and pesticides.

The biological role of microbes in agriculture

Biocontrol agents | **Biofertilizers**

7.2 Microbes as Biocontrol Agents:

Biocontrol agents are those organisms that are employed to control some harmful organisms like pests of plants.

Need for bio pesticides - presently pest control is generally done by the use of chemical pesticides and the trends are increasing year after year. These chemical pesticides are divided into several categories like weedicides, insecticides, rodenticides, etc. (Ruiu, 2018). But non-judicious use of these chemical pesticides has several ill effects;

- Improper use of pesticides may damage the crop and even useful flora and fauna of the area. So may decrease the production and neutrality of crops.
- These encourage the development of resistant strains.
- These kill both useful and harmful organisms indiscriminately.

So there is an urgent need for biological control to replace or supplement chemical control so that the ill-effect of chemical pesticides is reduced. These bio pesticides are of biological origin and again divided into categories like bio herbicides, bio insecticides, etc. Biological control involves the natural predation of pests. These have the following benefits;

a. These are non-persistent, non-toxic, and biodegradable.
b. These do not eradicate the pests but keep them at a manageable level through food chains and food webs so that the survival of beneficial predatory and parasitic insects is ensured. So these maintain the biodiversity and stability of the ecosystem.
c. These reduce our dependency on toxic chemical pesticides and decrease the chance of environmental pollution and degradation.

So, biocontrol involves a holistic approach. Examples;

A. Bio herbicides (Living organisms that control the weeds) (Radhakrishnan *et al.*, 2018)

a. The first bio herbicide was developed in 1961 and it was a mycoherbicide derived from a fungus ***Phytophthora palmivora*** which controls the growth of milkweed virus in citrus orchads.

b. Cohineal insect (***Cactoblastis cactorum***) is another example of bio pesticides which is used to control the growth of cacti.
c. **“Devine”** and **“Collego”** (fungal spore product) are recently used to control weeds.

B. Bio insecticides (Living organisms that control the pests) (Koul, 2011).

a. Lady bird beetle (Cocci Nella) – controls aphids
b. Dragonflies (sympetrum) – control mosquito hawk
c. Baculoviruses *Nucleopolyhedro* virus, *Entomopox* virus (for controlling grasshopper)
d. *Bacillus thuringiensis* – Produce **thurioside** and **Cry protein** (Kill larvae of some insects)
e. *Beauveria bassiana* – control forestry pests.

7.2 Microbes as Biofertilizers:

Constant leaching and harvesting of crops deprive the soil of mineral content. It is estimated that different crops in India remove about 4.27 million tonnes of Nitrogen, 2.13million tonnes of phosphorus, 7. 42 million tonnes of potassium, and 4.8 million tonnes of calcium every year. The total consumption of fertilizers in India was about 1.98 million tonnes in the year 1969-70.

Which increased to more than 16.80 million tonnes till now. Fertilizers are inorganic materials containing elements in the form of soluble or readily available chemical compounds. In common, fertilizers are sometimes called chemical or artificial, or inorganic manures (Nosheen *et al.*, 2021)

7.2.1 The Ill Effects of Chemical Fertilizers:

a. These are expensive.
b. Their manufacture depends upon the dwindling resources of energy.
c. Their production releases pollutants.
d. These are lost readily when applied in the field by surface run-off and thus pollute soil and other water resources.

Biofertilizers are organisms that can bring about soil nutrient enrichment. The main sources of biofertilizers are bacteria, cyanobacteria, and fungi (Fuentes-Ramirez *et al*., 2005; Rao, 1982).

a. **Legume – Rhizobium symbiosis**: - Rhizobium fixes nitrogen in the presence of leghaemoglobin and nitrogenase enzyme by using the nitrogen fixing gene (nif). Rhizobium show species-specific symbiotic relationships with the member of the family Leguminosae (*R. meliloti* with alfalfa group, *R. legumiosarum* with pea group, *R. phaseoli* with bean group, etc.)
b. **A loose association of nitrogen-fixing bacteria**: - *Azospirillum lipoferum* has been reported in Brazilian grasses and maize.
c. **Free-living bacteria: -** *Azotobactor* and *Beijerinckia* (Obligatory aerobes), *Clostridium* (Obligatory anaerobes), *Rhodospirillium* and *Chromatium* (Photosynthetic).
d. **Azolla-Anabaena symbiosis: -** Among the symbiotic cyanobacteria *Anabaena azollae* occurs as an endophyte in the leaves of *Azolla pinnata*.
e. ***Anabaena cycadae*:** These cyanobacteria live in the coralloid roots of gymnosperm *Cycas*.
f. **Anabaena and Nostoc –** free living cyanobacteria.
g. **Mycorrhizae** – It refers to the symbiotic association between the fungus and roots of higher plants such as Ectomycorrhizae, Endomycorrhizae, and VAM (vesicular-arbuscular mycorrhizae).

Table 7.1: List of some Biofertilizers

Biofertilizers	Target crops
Rhizobium	Leguminous crops
Azotobacter	Wheat, Maize, Cotton, Mustard, and Vegetables
Azospirillum	Cereals crops and Sugarcane
Cyanobacteria	Rice
Azolla	Rice
VAM	Nursery raised crops and orchard trees

(Anand and Masthihole, 2020)

Table 7.2: Nitrogen-Fixing Bacteria

Category	Example
Symbiotic	Rhizobium – legume symbiosis Rhizobium – Parasponia (non-legume) symbiosis Frankia- Trees (e.g. Alder, Casuarina) Azolla- Anabaena Azotobacter paspali – Paspalum notatum
Free living	
Aerobic	Azotobacter Beijerinckia Cyanobacteria (e.g. Nostoc, Anabaena, Tolypothrix, Aulosira)
2.Facultative	Klebsiella pneumoniae Bacillus polymyxa
3. Anaerobic	Clostridium Desulfovibrio Rhodospirillum Rhodospeudomonas Desulfotomaculum Desulfovibrio Chromatium Chlorobium
Associative	Azospirillum Herbaspirillum Acetobacter Diazotrophicus Azoarcus

(Anand and Masthihole, 2020)

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8. Phosphate Solubilizing Microbes: Their Role in Soil Health and Plant Growth Promotion

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Abstract:

Phosphorous is the major essential macronutrient of plants. It is known to involve many functions in the plant growth and metabolism. Soil microorganisms have the ability to solubilize the insoluble phosphates and to improve the quality of soil health and its fertility. Microorganisms play an essential role to facilitate the availability of soil phosphate to the root system and enhance the mobilization of phosphate in soil Efficacy of phosphate solubilizing microorganisms has been identified on the basis of kinetics and phosphorous accumulation.

Phosphate solubilizing microorganisms include bacteria, fungi and actinomycetes. The strains of Pseudomonas, Bacillus, Aspergillus, Penicillium, etc. are some known phosphate solubilizers. The ability to convert the insoluble phosphate into soluble form by secreting organic acids resulting in improved phosphate availability to the plants.

This chapter focuses on the identification on the based morphological, biochemical and molecular level and Phosphorus dynamics in soils and its availability to plants, metabolic pathways effecting the release of organic acids by phosphate solubilizing microorganisms are covered.

Keywords:

Phosphorous, phosphate solubilizing microorganisms, Macronutrient, organic acids.

8.1 Introduction:

8.1.1 Phosphorus:

The world population is increasing day by day. Hence there is need for plenty of food crops requirement for growing population. Crops need several nutrients to reach their maximum potential yield.

The nutrients, which are required by the plants, occur naturally in the soil, but sometimes these are added as fertilizer into the soil [1]. After the nitrogen, Phosphorus is an essential element for plant development and growth. It plays a major role in the process of energy transfer, photosynthesis, nutrient transport, cell division, early growth and root formation, DNA and RNA formation, flower blooms, seed development, improvement in plant strength and to tolerance for unfavourable environmental conditions. Phosphorus rich soils, most of this element is in insoluble form and only a small proportion (0.1%) is available to the plants [2].

Soil contains both organic and inorganic forms of phosphorus. Phosphate is found to be present in form of phosphatic compounds like: Mineral forms- (oxyapatite, hydroxyapatite, apatite [Gen. formula $Ca_{10}(PO_4,CO_3)_6(F,OH,Cl)_2$]); Organic forms (phytins, phospholipids, nucleic acids, inositol phosphate, soil phytate, etc.); Phosphatic rock - ($Ca_{10}(PO_4)_6F_2$) [3]. Natural rock mined from P rich deposits contains 14-37% P_2O_5 and are rich in minor elements such as B, Zn, Ni, I; Soluble phosphorus - sometimes called available inorganic phosphorus. It can include Organic phosphorus and orthophosphate, which form taken up by plants for normal growth and plant productivity [4]. Plant take phosphate in the form of soluble orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}) but due to the presence of Ca, Mg, K, Na, Al, and Fe ions in soil, the soluble orthophosphate is converted to insoluble form. Due to this action plants utilized very low amount of phosphorus, even though phosphorus rich fertilizers are used. In order to increase crop yields, chemical phosphate fertilizers are regularly incorporated into the soil.

This excessive application of phosphate causes environmental problems [5]. Current trends in modern agriculture are focused on the diminution of the use of chemical pesticides and inorganic fertilizers, compelling the search for alternative ways to improve soil fertility and crop production. In recent years much attention has been paid to natural agricultural practices in expectation of moving towards environmentally sustainable development [6]. Improving soil organic matter is therefore, vital in sustenance of soil quality and agricultural productivity.

Crop residues are the organic wastes generated by agricultural activities. These organic wastes contain lots of nutrition which are necessary for the growth of plants. They improve the quality of soil and environmental conditions [7]. The rhizosphere soil surrounding roots influenced physically, chemically, and biologically by Plant root, is an extremely encouraging habitat for the reproduction of micro-organisms that have a potential impact on soil fertility and plant health. In the rhizosphere, important and intensive Interactions occur among plants, soil, micro-organisms [8].

8.2 Role of Phosphorus in Plants Growth:

Most soils are deficient in soluble forms of phosphorus (P), one of the major essential macronutrients required for growth and productivity of plants. It plays an important role in plants in many physiological activities such as cell division, photosynthesis, and development of good root system and utilization of carbohydrate [9]. Its functions cannot be performed by any other nutrient. Adequate supply of phosphorus is required by plants for optimum growth and yield. This deficiency is a result of low inherent P fertility due to weathering, in combination with intensive, nutrient-extracting agricultural practices. Plants can absorb phosphate only in soluble form of orthophosphate ion (HPO_4^{-2} and H_2PO_4). A large fraction of soil microbes can dissolve insoluble inorganic phosphates present in the soil and make them available to the plants [10].

About 10-20% of fertilizer is acquired by the plants for promoting their functions. Once inside the plant root, phosphorus may be stored in the root or transported to the upper portions of the plant. It is also one of the primary structural components of membranes that surround plant cells.

The deficiency of phosphorus affects not only growth and development in plants, but also crop yield and the quality of fruit and formation of seeds. Deficiency of phosphorus can delay the ripening of crops which can set back the harvest, risking the quality of the produce [11].

8 3 Soil Phosphorus:

A greater part of soil phosphorous, approximately 95-99% is present in the form of insoluble phosphates and hence cannot be utilized by the plants. Phosphorus does not occur in pure form in nature. It is always combined with other elements to form phosphates. In these forms, P is highly insoluble and unavailable to plants. As a result, the amount available to plants is usually a small proportion of this total [12].

Table 8.1: common minerals phosphorous found in Indian soils [Adapted from Yadav and Verma (2012)].

Minerals	Chemical formula
Acid soils	
Dicalcium phosphate	$CaHPO_4$
Dicalcium phosphate dihydrate	$CaHPO_4 \cdot 2H_2O$
Variscite	$AlPO_4.2H_2O$
Strengite	$FePO_4.2H_2O$
Hydroxyapatite	$Ca_5(PO_4)_3\ OH$
B-tricalcium phosphate	$Ca_3(PO_4)_2$
Fluorapatite	$Ca_5(PO_4)_3\ F$
Octacalcium phosphate	$Ca_4H(PO_4)_3 \cdot 2–5\ H_2O$

The soil P cycle is a dynamic process involving the transformation of P by geochemical and biological processes.

Plant-available P occurs in the soil solution as orthophosphate anions, predominantly $H_2PO_4^{-1}$ and $H_2PO_4^{-2}$. The type of phosphorus bearing minerals that form in soil is highly dependent on soil pH. If we look at the global phosphorus fluxes, most of the phosphorus is insoluble or poorly soluble inorganic compounds [13]. Phosphates can be very complex and more than one form of phosphate is found in nature.

The diverse soil phosphate forms can be categorized as soil solution phosphates, insoluble inorganic and insoluble organic phosphates [14].

8.4 Applied Phosphate:

Majority of the Indian soils are low in available phosphorus and 98 percent of the cultivated soils require P fertilizers for optimum crop production. Phosphorus is generally provided to the plants in the form of water-soluble phosphatic fertilizers such as superphosphate and diammonium phosphate. However, more than 70-80 percent of the applied P gets fixed in soil as insoluble phosphates of calcium, iron and aluminium which are unavailable for plant uptake [15]. Overcome the phosphorus deficiency, phosphorus fertilizers are added 3-4 times more than the actual crop requirement. This is cost prohibitive to the farmers in general and poor marginal farmers in particular. The situation calls for the ways and means to increase phsophorus use efficiency by making the applied P available to plants. Under the above circumstances, efficient and eco-friendly methods to release chemically fixed phosphorus from soil pool and to supplement the nitrogen through biological nitrogen fixation have immense potential in improving crop production and quality [16]. Efficiency of P fertilizer throughout the world is around 10-25% and concentration of bioavailable P in soil is very low reaching the level of 1.0 mg kg–1 soil. The addition of rock phosphate will increase total soil P with the potential to replenish labile P and plant available P. [17].

8.5 Phosphate Solubilisation Problem in Soil:

Soil contains both organic and inorganic forms of phosphorus. The soil being poor in organic matter (1.5- 4.2 mg kg^{-1}), most of the phosphorus is present in inorganic form as minerals of insoluble calcium, iron or aluminium phosphates. Calcium phosphate dominates in neutral to alkaline soils whereas iron and aluminium phosphates dominate in acidic soils.

The release of P from these bound forms in soils is relatively a slow process [18]. Plant take phosphate in the form of soluble orthophosphate ions $H_2PO_4^{-1}$, HPO_4^{-2} and PO_4^{-3} but due to the presence of Ca, Mg, K, Na, Al and Fe ions in soil, the soluble orthophosphate is converted to insoluble form. Because of is not available for plants growth, even though phosphorus containing fertilizers are added [19].

8.6 Phosphate Solubilizing Microorganisms and Phosphate Solubilization:

Phosphate solubilizing microorganisms have been isolated from numerous terrestrial and aquatic sources. Rhizospheric microorganisms are metabolically more active than non-rhizospheric microorganisms. Numerous strains of bacteria have been reported and investigated for their phosphate solubilizing abilities.

The important genera of phosphate solubilizing Bacteria include *Pseudomonas, Bacilli, Rhizobium* and *Enterobacter* are great phosphate solubilizers. Other microorganisms playing an important role in P acquisition by plants include mycorrhizal fungi and endosymbiotic rhizobia [20]. Different sources of insoluble inorganic phosphate are used like aluminium phosphate, iron phosphate, tricalcium phosphate and zinc phosphate.

PSMs exhibiting inorganic phosphate solubilization produce a clear zone or halo around their colonies. PSMs exhibiting inorganic phosphate solubilization produce a clear zone or halo around their colonies. The selection of inorganic and organic phosphate compound for testing phosphate solubilizing microorganisms depends upon the type of soil where the phosphate solubilizing microbes will be used.

Soil microorganisms play a significant role in mobilizing phosphorus for the use of plants from the native soil phosphorous pool as well as from added insoluble phosphates such as rock phosphates.

PSM could produce effective chelating materials in the immediate vicinity of rock phosphate or phosphatic fertilizer or in the rhizosphere. The application of PSMs as inoculums or the management of their populations in soil is alternatives to improve P availability for plants [21].

Table 8.2: Diversity of phosphate solubilizing microorganisms [Adapted from Mendes et al (2013)].

Microorganism	Examples
Bacteria	*Bacillus* sp., *Bacillus circulans*, *B. cereus*, *B. fusiformis*, *B. megaterium*, *B. mycoides*, *B. polymyxa*, *B. chitinolyticus*, *B. subtilis*, *Bradyrhizobium* sp., *Pseudomonas* sp., *P putida*, *P. striata*, *P. fluorescens*, *Flavobacterium* sp., *Nitrosomonas* sp., *Micrococcus* sp., *Agrobacterium* sp., *Azospirillum brasilense*, *Escherichia intermedia*, *Enterobacter asburiae*, *Nitrobacter* sp., *Thiobacillus ferrooxidans*, *Rhizobium meliloti*, *Xanthomonas* sp. *Alcaligenes* sp., *Aerobactor aerogenes*, *Achromobacter* sp., *Actinomadura*
Fungi	*Aspergillus awamori*, *A. niger*, *A. flavus*, *A. nidulans*, *Fusarium oxysporum*, *Alternaria tenuis*, *Achrothcium* sp., *Penicillium digitatum*, *P. lilacinium*, *P. funiculosum*, *Cephalosporium* sp., *Cladosporium* sp., *Candida* sp., *Chaetomium globosum*, *Humicola insolens*, *Helminthosporium* sp., *Pythium* sp.,*Phoma* sp., *Populospora mytilina*, *Myrothecium roridum*, *Mortierella* sp., *Micromonospora* sp., *Oidiodendron* sp., *Rhizoctonia solani*, *Rhizopus* sp., *Mucor* sp., *Trichoderma viride*, *Torula Sclerotium rolfsii*
Cyanobacteria	*Nostoc* sp., *Scytonema* sp., *Anabaena* sp., *Calothrix braunii*,
Actinomycetes	*Actinomyces*, *Streptomyces*
Vesicular arbuscular mycorrhiza	*Glomus fasciculatum*

8.7 Phosphate Fertilizers Use in Agriculture and the Environmental Impacts:

The population of the world is increasing continuously, with which the need for food also increasing. Due to which there is more pressure in the agriculture sector and excessive use of fertilizers has started, continuous use of fertilizers is generating environmental problems. Use of chemical fertilizers on regular basis has become a costly affair and also environmentally undesirable.

Plants utilize very small amounts of phosphatic fertilizers that are applied and the rest (70-80%) is rapidly converted into insoluble complexes in the soil [22]. large amount of P applied as fertilizer enters in to the immobile pools through precipitation reaction with highly reactive Al^{3+} and Fe^{3+} in acidic and Ca^{2+} in calcareous or normal soils.

Efficiency of P fertilizer throughout the world is around 10-25% and concentration of bioavailable P in soil is very low reaching the level of 1.0 mg kg^{-1} soil. The addition of RP will increase total soil P with the potential to replenish labile P and plant available P [23].

8.8 Rock Phosphate:

In recent years the possibility of practical use of rock phosphate as fertilizer has received significant interest in India, it is estimated that about 260 million tons of rock phosphate (RP) deposits are available and this material provides a cheap source of phosphate fertilizer for crop production.

The optimal development of crops demands a high and often costly input of P fertilizers. Current concepts in sustainability involve application of alternative strategies based on the use of less expensive natural sources of plant nutrients. Natural phosphate rocks have been recognized as a valuable alternative for P fertilizers [24].

The beneficial effect of rock phosphate has made this material an attractive component for management in agriculture. Phosphate rocks are the biggest reserves of phosphorus. Direct application of RP would minimize pollution and decreases the cost of chemical fertilizer. The use of rock phosphate as phosphate fertilizer and its solubilization by microbes and become available for plants.

Therefore natural rock phosphates have been recognized as a valuable alternative source for P fertilizer, especially for acidic soils. The P released from directly applied ground RP is often too low to provide sufficient P for crop uptake. Low-technology alternatives to the energy intensive and costly methods of conventional P fertilizer production have been proposed including enhancing plant and microbiological mechanisms that promote RP solubilization [25].

8.9 Solubilization of Rock Phosphate:

Rock phosphate may originate from igneous, sedimentary, metamorphic and biogenic sources, with sedimentary being the most widespread. Forms of apatite, the primary P bearing mineral in RP, include Fluor apatite, hydroxyapatite, carbonate-hydroxyapatite, and francolite. In general, high carbonate-substituted forms of apatite (francolite) will solubilize more readily than pure forms of Fluor apatite, releasing more P for plant use. In addition to RP source, the major influences on RP solubility are soil properties, crop species and management practices. These factors have various influences on the equilibrium of the dissolution reaction of a given apatite mineral [26]. A simplified dissolution equation is shown in Equation 1.

$$\mathbf{Ca_{10}F_2(PO_4)_6 + 12H^+ \rightarrow 10Ca^{2+} + 6H_2PO_4^- + 2F^-} \qquad \mathbf{(1)}$$

The lower the soil pH, the more available the P from RP becomes. Moreover, since apatite dissolution releases Ca^{2+}, soils high in calcium do not support RP dissolution, in accordance with the mass action law.

The dissolution of RP will be favoured if Ca^{2+} is removed from soil solution. One traditional method used to increasing P availability is the acidulation of RP with small amounts of H_2SO_4 or H_3PO_4 to produce partially acidulated RP [27]. Rock phosphate has been found to have high P contents of nearly 28-30%, it cannot be used directly as fertilizer owing to limited solubility and subsequent release of P that can be taken up by the plants. The particle size, chemical properties and mineralogical nature of phosphate rocks in accordance with the important soil properties need to be considered to assess the suitability and efficacy of the phosphate rocks in releasing the phosphates in forms which are considerably plant available [28]. Rock phosphate can be converted Phosphorus to plant available forms by utilizing them in the preparation of composts due to the prevalent low pH environment during the process of composting which in turn can also improve the nutritional value of the compost. Since farmyard manure and conventionally prepared traditional composts contain very small amount of nutrients (generally), particularly P, compost enriched with rock phosphate can be effectively used as a potential alternative for sustaining the soil quality [29].

8.10 Mechanisms of Phosphorus Solubilization:

The global cycling of insoluble inorganic and organic soil phosphates is attributed to microorganisms. Phosphate solubilizing microorganisms can improve the concentration of phosphorus by solubilization of organic and inorganic phosphates.

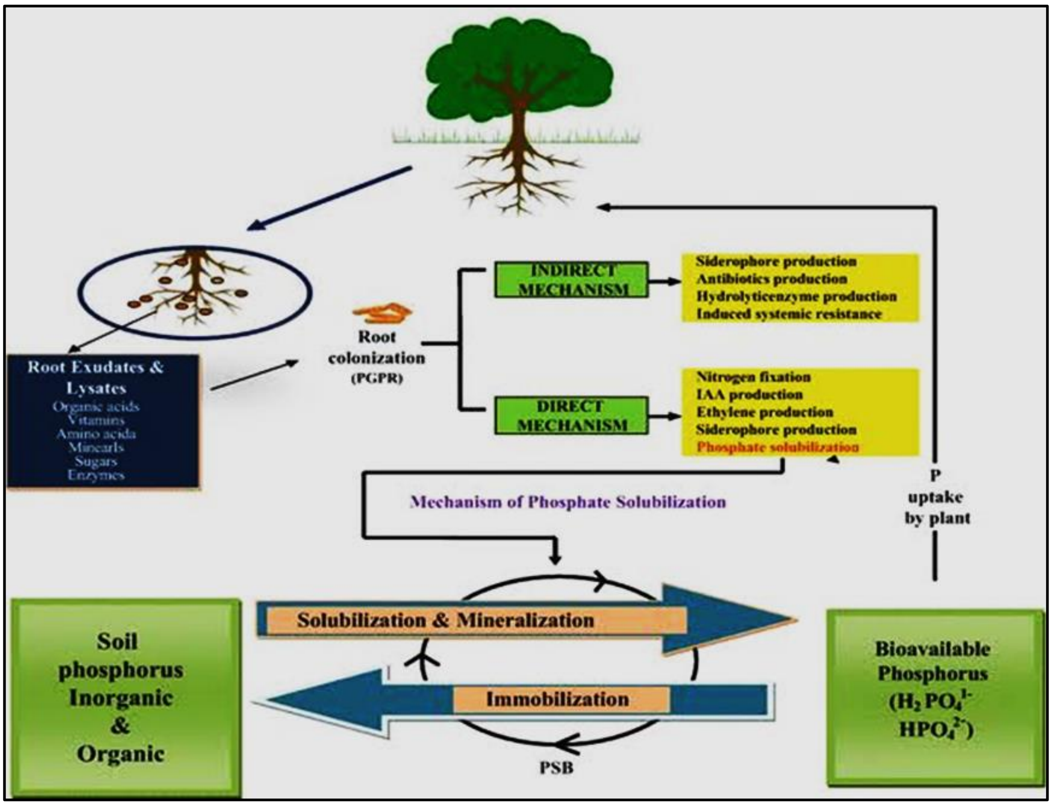

Figure 8.1: Functional Diversity of Phosphate Solubilizing Microorganisms [Adapted from Khan et al. (2013)]

Organic acids play a key role and responsible for solubilization of organic and inorganic phosphate. Apart from this, inorganic acids such as sulphuric, nitric and carbonic acids produced by microorganisms have been reported to solubilize inorganic phosphate.

8.10.1 H^+ Excretion:

Proton extrusion and organic acid production are the two important mechanisms for phosphate solubilization as it decreases the pH of the media which renders solubilization of inorganic phosphate.

Microbial excretion of H^+ occurs in response to the assimilation of cations, primarily related to N source. It is a well-known bacterial phenomenon that H^+ is excreted in exchange for NH_4^+. RP is solubilized when using an NH_4^+ rather than a NO_3^- source of N. In the same study, it was found that pH was generally lower and titratable acidity higher, when NH_4^+ was used. Verity of N sources and found that ammonium sulphate promoted the most RP solubilization for bacterial and fungal species [30].

8.10.2 Chelation:

In addition to pH reduction, organic acid anions can solubilize RP through chelation reactions. Chelation involves the formation of two or more coordinate bonds between an anionic or polar molecule and a cation, resulting in a ring structure complex. That organic acid anions, with oxygen containing hydroxyl and carboxyl groups, have the ability to form stable complexes with cations such as Ca^{2+}, Fe^{2+}, Fe^{3+}, and Al^{3+}, that are often bound with phosphate in poorly forms [31]. The formation of complexes between chelator and cations such as Al^{3+} and Ca^{2+} depends on the number and kind of functional groups involved as well as the specification. Acids with an increased number of carboxyl groups are more effective at solubilizing RP.

8.10.3 Organic Acid Production:

Phosphate solubilizing microorganisms has a potential to convert insoluble form of phosphorus into soluble forms for healthy plant growth. Consequently, PSMs application has increased tremendously in agriculture. PSMs are known to produce organic acids in varying concentrations and types. Commonly reported organic acids produced by microorganisms include gluconic acid, citric acid and oxalic acids. The production of organic acid was the major mechanism involved in the solubilization of rock phosphate by the PSMs but other mechanisms might be involved. In vitro conditions, the growth medium has decreased as a result of the release of organic acids by PSMs [32].

The export of organic acid anions by microbes can occur by an H^+ transport system, causing acidification of the extra cellular solution. Organic acid production, consequently the pH change and reduction potential are thought to be responsible for the dissolution of tricalcium phosphate in the culture medium. Plants most commonly produce citric acid, oxalic acid and malic acid. Organic acids either directly dissolve mineral phosphates as a result of anion exchange reactions or chelate iron, aluminium and calcium (Ca) ions associated with phosphate generating soluble monobasic ($H_2PO_4^-$) and dibasic (HPO_4^{2-}) ions [33].

(Di- Calcium phosphate) $$CaHPO_4 + H^+ \leftrightarrow H_2PO_4^{-1} + Ca^{+2}$$

(Hydroxyapatite) $$Ca_5(PO_4)_3(OH) + 4H^+ \leftrightarrow 3HPO_4^{-2} + 5Ca^{+2} + H_2O$$

In acidic soils, the presence of organic acids propitiates the formation of complexes with Al and Fe ions, which in turn facilitates the dissolution of these minerals.

If Fe^{3+} and Al^{3+} are sequestered via chelation with organic anions the following reactions proceed to the right.

(Strengite) $$FePO_4.2H_2O \leftrightarrow HPO_4^{-2} + \text{chelate-}(Fe^{3+})\ OH^- + H_2O$$

(Variscite) $$AlPO_4.2H_2O \leftrightarrow HPO_4^{-2} + \text{chelate-}(Al^{3+})\ OH^- + H_2O$$

The ability of PSMs to solubilize P complexes has been attributed to the process of acidification, chelation, exchange reactions and production of organic acids.

8.10.4 Ligand Exchange Reactions:

Through ligand exchange reactions organic acid anions can mobilize P from the phosphate anions that are adsorbed to crystalline Fe $(OH)_3$ and Al $(OH)_3$ surfaces by chelating metal ions associated with bound P. These ligand exchange reactions where hydroxide ions replace phosphate, causes decrease in the pH and P binding capacity of Fe and Al and consequently release P. In a study using four soils of varying pH, $CaCO_3$ and organic C contents, all soils more P was mobilized when citrate was added than when the soil, was subjected to a wide range of pH changes.

This study showed that the phosphorus was fixed due to ligand exchange between the citrate and the P absorbed to iron and aluminium ion sites rather than dissolution from Ca-P precipitates.

8.11 Mineralization of Organic P:

Soil enzymes like phosphatase (acid and alkaline) have an important role to play in the transformation of organic form of P into different inorganic forms for increasing the plant uptake, particularly when the availability of P tends to limit plant growth and its productivity. The activities of important soil enzymes like dehydrogenase and phosphatases (both acid, alkaline or neutral) are considered as important factors for regulation of the rate of mineralization of organic P in soil, and also is a conclusive determinant for P deficiency. The mixed cultures of PSMs are most effective in mineralizing organic phosphate. Phytates account for a large component of the organic P, some 20-50 % of the total soil organic P. yet appear to be only poorly utilized by plants [34].

8.12 Designing of Medium:

8.12.1 Agricultural Wastes as Raw Materials of Medium:

The Synthetic media cost increases very rapidly these days. It is only used for lab purposes. But in the field application, synthetic media is not compatible. So this problem can be solved by agricultural waste media. Agricultural wastes contain lots of organic components. They increase the fertility of soil and soil quality. Agricultural wastes and organic wastes are highly nutritious and found all types of nutrients for microbial and plant growth.

For this property of agricultural wastes can be used as microbial growth media. They are cost effective and we easily get the agricultural wastes left after crop harvesting. Their use does not cause any kind of environmental pollutions. Agricultural wastes contain organic components that increase the water holding capacity in the soil. Agricultural waste media can be used in the place of synthetic media or chemical media due to the presence of excessive nutrients in it.

Sugarcane bagasse contain high amount of sugar and other essential nutrients, which are mostly used in making agricultural wastes media. The process of photosynthesis in sugarcane plant is very fast and their dry matter per hectare is approximately 60 tones. Sugarcane is used by many industries to make products.

After which a large amount of sugarcane waste is obtained as sugarcane bagasse. In which there is still a lot of nutrients left. So that it is used in making media [35].

Rice straw represents an important crop product in India. About 10 million tons of rice straw was produced every year from the rice fields. Using rice straw as agricultural media for agriculture production is one of the proposed practical uses. The use of compacted rice straw as organic media in open field production is a new approach. Rice straw pulp contain good source of N and C [36].

8.13 Effect of Phosphate Solubilizing Microorganisms on Crops:

Microorganisms have enormous potential in providing soil P for plant growth. The phosphate solubilizing bacteria as inoculants simultaneously increases P uptake by the plant and crop yield. These PSMs effect directly and indirectly on plant growth. Direct effects include the increased solubilization and uptake of nutrients or production of plant growth regulators, while the indirect effects include suppression of pathogens and producing metal binding molecules, known as siderophores. In most bacteria, mineral phosphate dissolving capacity has been shown to be due the production of organic acids.

The chemical messengers by producing hormones, which are effective at very low concentration. They are synthesized in one part of the plant and are transported to another location and affect a plants ability to respond to its environment. Phosphate solubilizing bacteria assist in good supply of nutrients to plants, improve soil structure and also help in the bio accumulation or microbial leaching of inorganic compounds [37]. The plant microbe interaction by PSMs in the rhizosphere play a vital role in transformation pathways, mobilization of nutrients and solubilization processes of nutrients from limited nutrient pool and subsequently uptake of essential nutrients by plants to realize their genetic potential.

8.14 Application of PSB in Crop Production:

Phosphate solubilizing microorganisms play an important role in enhancement of growth and yield of crop plants by providing them phosphorus, which is otherwise unavailable to plants. These microorganisms can directly or indirectly affect the plant growth.

Considerable success was acclaimed in increased yield and quality of crops due to increased phosphate uptake by inoculating seeds with efficient phosphate solubilizers. Statistically significant increase in yield of the order of 5 to 10% has been recorded in about 30% of large number of inoculation experiments with phosphate solubilizing Microorganisms [38]. PSMs are environmental friendly they reduce environmental problems and maintain soil health.

They produce many types of organic acids and secondary metabolites which mineralize plants. PSMs increase bioactivity in rhizospheric regions of soil, which affect plant productivity and crop yield. Increasing soil microbial activities, bioavailability of P in a bioactive soil was remarkably enhanced.

Such a phenomenon inspires the application of a similar principle on the bio activation of relatively nonreactive rock phosphate. The fact that certain soil microorganisms are capable of solubilizing relatively insoluble phosphatic compounds has opened the possibility for inducing microbial solubilization of phosphates in soil.

The phosphate solubilizing microorganisms onto rock phosphate or reacting the rock phosphate with a liquid culture supernatant may be considered a better means to overcome the low solubility problems of rock phosphate. Such an approach may eliminate factors inhibiting a successful interaction between phosphate solubilizing microorganisms and rock phosphate under field conditions. This approach will also make the production of single soluble phosphate possible without the use of chemical acidulation.

8.15 Field Inoculation in Combination with PSM and Application of RP:

The microorganisms have enormous potential in providing soil P for plant growth. Combined application of rock phosphate and PSMs has produced mixed results on plant growth responses, which were perhaps attributed to differences in microbial strains and soils. There are some species of microorganisms which have the potential to mineralize and solubilize organic and inorganic phosphorus in soils.

The genera *Pseudomonas, Bacillus* and *Rhizobium* are among the most powerful phosphate solubilizers. Phosphorus solubilizing activity is proved by the ability of microbes to release metabolites such as organic acids. These organic acids chelate the cations bound to phosphates and thereby resulting in the conversion of the later to soluble forms.

Combine inoculation of PSMs, RP and agricultural wastes as raw materials give better uptake of both native P from the soil and P coming from the phosphatic rock and enhance plant growth by solublizing P from different fractions of soil. Since not many reports are available on the use of RP with PSMs as fertilizer, which is a cheap, consistent and environment friendly source of phosphate fertilizer, this is an attempt to isolate efficient phosphate solubilizers and inoculating them in the field with RP amended soils to increase the P levels [39].

8.16 Concluding Remarks and Future Perspectives:

Phosphate-solubilizing microbes (PSM) play an important role in P supply to plants. Their use as a biofertilizers can help in reducing dependence on chemical phosphatic fertilizers. Biofertilizers are the formulations containing viable microbial cells that are applied to soil for growth promotion of plants through direct or indirect mechanisms. They are usually prepared as carrier based inoculants containing effective microorganisms.

They settle in plant roots actively and promote plant growth by increasing nutrient uptake from rhizospheric soil. Phosphate solubilizing microbes are more significant because they are the natural source of fertilizers that improve the efficiency of soils and plants. PSMs have a great potential for phosphorus management and disease suppression in P deficient soils. Therefore, the use of environmentally friendly microorganisms is needed for plant growth promotion and disease control in sustainable agriculture.

As a result, the concept of eco-friendly agriculture is getting to be a new field of interest to diminish the harmful outcomes of commercialized farming presently being experienced.

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9. Role of Microorganism in Bioremediation of Chlorpyrifos Pesticides in Contaminated Soil

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Abstract:

In the modern agriculture technology extensive use of pesticides for increase in crop production but due to its persistence nature in the environment, it is leading various toxic effects in human animals and plants. Chlorpyrifos is commonly used organophosphate pesticide for agriculture. The repeated uses of chlorpyrifos disturb the microbial biodiversity in the soil and associated with potential health risks factors.

Here, we discuss the toxicity level of chlorpyrifos and their association environment pollution and method applicable for degradation of pesticides contamination in the soil.

Microorganism that have excellent capacity to degrade pesticides compound in laboratory condition, generally failed to remediate in the natural condition. To explore the chlorpyrifos degrading bacteria for bioremediation, the present review will significantly increase our knowledge towards degradation of chlorpyrifos and will provide the chlorpyrifos degrading bacteria to remediate chlorpyrifos contaminated site.

Keywords:

Bioremediation, Chlorpyrifos, pesticides.

9.1 Introduction:

In modern agriculture practices, the extensive use of pesticides for pest control is common practice in India. Currently, among the various groups of pesticides that are used to control pests, organophosphorus pesticides form the major and most widely used group that accounts for more than 36% of the total world market.

But due to its accumulation nature into the environment it is associated with various health hazards, hence, its degradation is very important. The organophosphorus pesticides (OP) are all esters of phosphoric acid and due to their high efficiency widely used in agriculture (Fulekar and Geetha, 2008).

The continuous and excessive uses of organophosphorus pesticides have caused serious impact on the soil fertility. Soils contaminated with pesticides have attracted high attention because it impacts human health and environmental pollution (Laxmi *et al.,* 2009). The organophosphate chlorpyrifos has been widely used pesticides in agriculture for the purpose of pest control. However, because of its toxicity and persistence nature in environment, the degradation of chlorpyrifos from contaminated sites of soil and water has become an argent requirement. Hence microbial bioremediation is much promising approach to overcome the pesticide pollution that can surely solve the pesticide contamination of soils.

9.2 Types of Pesticides:

On the basis of chemical composition pesticides are classified into the followings types-

- **Organochlorine-** Organochlorine pesticides are insecticides and due to toxic and persistent nature in the environmental it is not used nowadays. It includes- DDT, HCH, chlordane, and toxaphene.
- **Organophosphorus-** Organophosphates are a diverse group of chemicals and mostly insecticides in nature. They affect the acetylcholine enzyme that regulates a neurotransmitter in nervous system. An example of organophosphates includes- Malathion, parathion, diazinon, fenthion, dichlorvos, chlorpyrifos and ethion.
- **Carbamates-** The carbamate pesticides also affect the nervous system by disrupting an enzyme that regulates the neurotransmitter but the enzyme activities are usually reversible. An example of carbamates includes followings- Thiobencarb, propoxur, molinate, disulfiram, pyridostigmine.
- **Pyrethrin and pyrethroids-** These are a synthetic version of pyrethrin, also called naturally occurring pesticide. They synthesized from chrysanthemums flower. It includes- Allethrin, resmethrin, permethrin, cyfluthrin or esfenvalerate.

9.2.1 Chlorpyrifos Pesticides Structure:

Chlorpyrifos (CPS) [O, O-diethyl O-(3, 5, 6-trichloro-2-pyridyl) phosphorothioate)] is one of the most widely used organophosphate pesticides in agriculture worldwide, but its extensive use has led to the contamination of various soil and water systems.

The half-life of CPS generally ranges between 10 and 120 days in soil but can be up to 1 year depending on abiotic factors such as temperature, moisture, pH, etc. It acts by acetyl cholinesterase inhibition on the nervous system of insects.

There is also a growing concern of widespread contamination of the environment leading to potential risks to non-target organism because of its entry in the food chain and undesirable health issues to humans that include persistent developmental disorders, reproductive defects, endocrine disruptions, nervous system disorders, and immune system abnormalities.

Microbial bioremediation is considered to be one of the most reliable and cost effective approach for the removal of CPS from the environment; however, little is known about the soil bacterial diversity that degrades CPS.

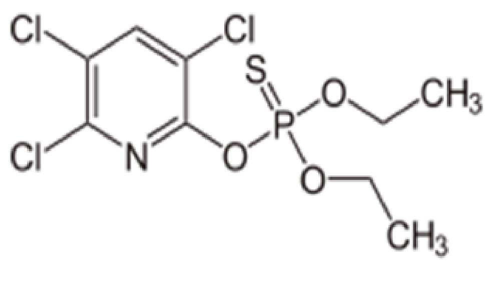

Figure 9.1: Structure of Chlorpyrifos (IUPAC name-*O, O*-Diethyl *O*-(3, 5, 6-trichloropyridin-2yl) phosphorothioate.

9.2.2 Harmful Effect of Chlorpyrifos:

a. In human chlorpyrifos pesticides interfere the action of acetylcholinesterase enzymes there by disturbing the human central nervous system. These neurological effects are associated with elevated risks for children as their brains and nervous systems develop.

b. The immediate effect of low-dose exposure showing symptoms headaches, agitation, inability to concentrate, weakness, tiredness, nausea, diarrhoea and blurred vision and high dose cause the respiratory paralysis and death.
c. Recent studies suggest the adverse effect of chlorpyrifos is also associated with reduced birth size, endocrine disruption, lung and prostate cancer in human.
d. Several studies also shown that reduced birth size, endocrine disruption, lung and prostate cancer
e. The adverse effect of chlorpyrifos exposure in anima, fish, amphibians, birds, reptiles was reported**.**

9.2.3 Persistence of Chlorpyrifos Pesticides in Soil:

Soil productivity is directly or indirectly influence by the pesticides. Pesticides are toxic substances and tend to persist for longer periods in soil due to the chemical residues are rapidly metabolized or diluted in living growing system as compared to soil. Chlorpyrifos half-life in soil is usually between 60 and 120 days.

While persistent pesticides have toxic and harmful effects on soil micro flora and contaminate environment. Chlorpyrifos is less persistence in soil and absorbed by soil particle. The persistency of pesticides in soil is affected by many factors including volatility, chemical structure, solubility in water, method of formulation and application.

9.2.4 Bioremediation:

Bioremediation is a method that uses naturally occurring microorganisms to modify harmful and toxic substances to nontoxic compounds. Also, increased public awareness and concern has prompted the researchers to address ways to detoxify/remove these organic compounds/ pollutants from the natural environment. Remedial strategies require reliable methods to identify and observe contamination, as well as effective procedures to eliminate the pollutant from environment. Traditional physio-chemical remediation strategies such as soil excavation, transport to a reclamation site etc. employed to remediate contaminated sites are inefficient, costly and may also lead to the formation of toxic intermediates and the need for specialized equipment.

Therefore, the bioremediation process has become environment-friendly strategy for removal of pesticides from contaminated site. To date, there are several reports of successful use of bioremediation for the treatment of site is contaminated with different pesticide.

Different techniques were used for bioremediation process it includes-

a. **In situ bioremediation-** In this technique following methods included- Bioventing, biosparging, bio augmentation.
b. **Ex situ bioremediation-** For ex situ bioremediation process land farming, composting, bioreactors were employed.

9.2.5 Microorganism Used for Chlorpyrifos Bioremediation:

Several studies have shown that the microorganism used for degradation of chlorpyrifos. The important role of microorganism in chlorpyrifos degradation pathway is the metabolism and mineralization of 3, 5, 6-trichloro-2-pyrinidinol (TCP) and 3, 5, 6-trichloro-2-methoxypyridine (TMP) metabolites which are toxic intermediates in chlorpyrifos degradation. The previous studies have reported the chlorpyrifos degrading microorganism including *Alcaligenes faecalis* (Yang *et al.,* 2005), *Pseudomonas* sp. (Feng *et al.,* 1997), *Streptomyces sp*. HP-11(Supreeth *et al.,* 2016), Enterobacter Strain B-14 (Singh *et al.*, 2004), *Providencia stuartii (*Rani *et al.,* 2008) Flavobacterium sp. ATCC27551.

Recently, the degradation of chlorpyrifos by fungi in soil has been studied by many researchers including *Trichoderma viride* and *Aspergillus Niger (*Hussain *et al.,* 2007*).* The mixed culture of fungi is also have capacity to degrade chlorpyrifos (Singh *et al*., 2004).

9.3 Conclusion:

Chlorpyrifos organophosphorus pesticides are a highly acutely and chronically toxic to insects, mammals, and other animals. The chlorpyrifos degrading bacteria would be screened for their ability to degrade chlorpyrifos as the sources of carbon and energy.

The characterization of chlorpyrifos degrading bacteria will not only provide strains for degradation of chlorpyrifos pesticides but may also provide some novel species.

Microbial bioremediation is effective and safe technique for chlorpyrifos removal in contaminated soil.

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10. Solid Waste Management

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Abstract:

Globally, with the growing population, the waste generation rates are increasing exponentially which poses a significant challenge in solid waste management. In 2016 nearly 2.01 billion tons of solid waste were generated, which equates to a carbon footprint per person per day is 0.74 kilograms. Due to rapid population growth and urbanization, it is anticipated to increase by 3.40 billion tons by 2050. This poses a significant environmental and emerging issue in India. Lack of appropriate SVM facility poses a significant challenge especially in highlands due to increased urbanization, remoteness, harsh climate topographical configuration increasing urbanization. Waste can be categorized as paper, plastic, metal. Solid waste management should be an eco-friendly process of collection, transport, storage and safe disposal of waste. It includes planning, organizing, and administration along with technical, legal, and financial support. Further, it also involves major activities starting from generation, followed by storage, collection, transport, processing, and safe disposal. Methods adopted must align with the principles including economy, aesthetics energy, and conservation.

Eligible MSW treatment methods are sanitary landfills, incinerators, dumpsites, waste open burning, recycling sites, composting plants, transfer stations, and anaerobic digesters. Environmental pollution and outbreak of vector-borne diseases result when the Municipal solid waste (MSW) is not managed properly. A wide range of economic, administrative, and social problems associated with SVM could be effectively managed by the implementation

of Legislation and regulations. Adoption of new approaches in SWM ensures that it is comprehensive, organized, and cost-effective, create wealth, and protects public health. Managing and reducing waste can be guided by the 5 R's principle: Refuse, Reuse, Reduce, Repurpose, and Recycle. This principle advises that recycling should be a last option.

10.1 Introduction:

Among the environmental issues, solid waste management has become a significant concern, mainly due to the rapid rise in the urban population, constituting 31.6% in a population of 1.210 million[1]. Annually .3 billion municipal solid waste (MSW) is generated which is expected to rise to about 2.2 billion tons by 2025[2]. The need for effective waste management arises as it increases proportionally to population and income.[3]. Due to the rapid rate of urbanization the municipalities face an extra burden in environmental and socio-economic leading to the depletion of natural resources. [4]. The per capita waste generated in India increases exponentially (0.26 kg/day to 0.85 kg/day)[4]. according to the central pollution control board (CPCB)[4].

Existing lines of evidence suggest that Municipal solid waste (MSW) disposed of without proper treatment results in the emission of greenhouse gases leading to land, water, and air pollution[5]. Currently, single-use plastics have become a global threat although they are biodegradable and less harmful[6]. In cities generation of plastics could lead to drainage choking in monsoons leading to flooding. Also, these micro plastics can cause disturbance in aquatic life leading to pollution of rivers and oceans leading to global warming, and ingenious extinction of species[7]. Plastic waste generated spans 300 million tonnes of which only 9% is generated plastic is recycled while the remaining reaches the ocean.

Generation of hazardous waste in cities from hospitals and industries premature death and breathing problems[8] Although India has emerged as a recycling market where the recycling is not done as prescribed[9]. Health issues originate due to improper municipal solid waste management in landfills attracts rodents, mosquitoes, scavengers, etc. The primary factor to consider for efficient solid waste management is the place where solid waste is produced. To have successful solid waste management, solid waste generation is the most crucial factor to consider. The amount of garbage produced varies between nations based on public awareness, culture, and management. Additionally, it was shown that the generation of garbage was related to the nation's economic situation [10]. Existing evidence suggests that in comparison to the developing countries the generation of waste by the developed countries is comparatively higher

The quantity of garbage produced by Asian and African nations varies from 0.21 to 0.37 tonnes per capita per year [10], whereas the European nations produce 0.38 to 0.64 tonnes per capita per year (Intergovernmental Panel on Climate Change [IPCC], 2006) Example Japan and Hong Kong, which have greater GDPs than India and Vietnam, were found to produce more solid garbage. Table 10.1. The handling of MSWs at landfills attracts insects, and rats and mosquitoes can have negative health effects.

Table 10.1: Waste generation in a few Asian countries, as measured by the GDP.

Country	GDP (PPP) per capita estimated for 2007 (USD)	Waste generation (kg/capita/day)
Hong Kong	37 385	2.25
Japan	33 010	1.1
Singapore	31 165	1.1
Taiwan	31 040	0.667
South Korea	23 331	1.0
Malaysia	12 702	0.5-0.8
Thailand	9426	1.1
China	8854	0.8
Philip pines	5409	0.3-0.7
Indonesia	5096	0.8-1.0
Sri Lanka	5047	0.2-0.9

Country	GDP (PPP) per capita estimated for 2007 (USD)	Waste generation (kg/capita/day)
India	3794	0.3-0.6
Vietnam	3502	0.55
Lao PDR	2260	0.7
Nepal	1760	0.2-0.5

10.2 The Necessity of Solid Waste Management:

- Due to the rapid rise in population and increased urbanization significant increase in solid waste is observed which hampers the development of city or village [11]
- The major threats that arise due to solid waste is a health issues and bad odor.
- In India more than 1000 tonnes of solid waste is generated which is treated by landfilling which harms the land and marine environment [10].

SWM must be ensured with proper facility for segregation, collection, transport, and treatment of waste. This in turn reduces the transmittance and origin of diseases and reduces odor thereby improving the aesthetics of the city. SWM must be executed with eco-friendly approaches to achieve needful.

10.2.1 Characteristics of Solid Waste:

Solid waste consists of inefficacious or unwanted material that are often generated by human activities in commercial, residential, or industrial areas[12]. It is usually categorized in three ways, according to its-

Contents	organic material, metal, glass, plastic, paper etc
Origin	domestic, construction, industrial, commercial or institutional
Hazard potential	non-toxin, toxic, flammable, infectious, radioactive, etc

Further, solid waste is divided into two types- Non-municipal and Municipal solid wastes. Non-Solid Municipal Waste is a product that is produced along with the generation of Solid Waste (NMSW)[12].

Waste from the mining, farming, and industrial sectors is included. Municipal solid waste (MSW), also called garbage and rubbish, is produced by individuals, families, businesses, and institutions (like hospitals and schools)[12]. It may include electrical and electronic waste, biodegradable waste such as food scraps, and composite waste such as clothing, construction and demolition debris (CnD), hazardous waste (chemicals, paints, and spray), and medical waste (hypodermic needles, syringes, scalpels, medicines, tissue, and organs)[13]. Hazardous waste causes immediate danger when exposed to individuals or the environment. These materials are either toxic, ignitable, reactive, corrosive, radioactive, or infectious and originate from chemical production, manufacturing, hospitals, and other industrial activities[13]. Common household hazardous waste includes bleaches and cleaning products, pesticides, batteries, paints, electronics, and pharmaceuticals. On the other hand, the concern about electronic waste is escalating day by day. E-waste such as computer equipment, televisions, telephones, smartphones, and refrigerators contain various harmful elements like mercury, lead, and cadmium[14].

Globally, the rate of production of municipal solid garbage has reached 2.01 billion tonnes annually[15]. At least 33% of the entire trash generated from that is handled in an unsustainable and severe manner. The range of daily waste production per person worldwide is between 0.11 and 4.54 kilos, with an average of 0.74 kilogrammes[16]. High-income nations contribute around 34% (683 million tonnes) of the garbage produced globally, although having only about 16% of the global population. With urbanisation and population expansion, it is predicted that garbage production would rise exponentially until 2050, when it will reach 3.40 billion tonnes[16]. There is a link between waste production and income. In low- and middle-income countries, daily garbage production is expected to increase by 40%, whereas in high-income ones, it will increases by 19% by 2050[16].

India has experienced a sharp increase in rubbish production over the past few years. Everyday garbage production has increased by 1.3 percent annually to 450 grams per person[17]. Over the past few years, garbage generation in India has been rising quickly.

The amount of waste produced per person each day has climbed by 1.3 percent annually to 450 grams[18]. By 2031, urban India is anticipated to reach 4,50,132 tonnes of rubbish per day and 11,95,000 tonnes per day by 2050, according to the Task Force on Garbage to Energy's 2014 report[19].

10.2.2 Solid Waste Management Practice:

Waste management refers to the processes and actions involved in managing waste, from its inception to its disposal[20]. Solid waste management is generally regarded as a discipline that focuses on the controlled generation, storage, collection, transportation, recycling, treatment & disposal of solid wastes in a manner that best addresses a range of public health, environmental protection, aesthetic, practical, financial, engineering, city and regional planning, geography, administrative, legal and other environmental deliberation[21].

Solid waste management aims to minimize and eliminate detrimental effects of waste products on the environment and human health in order to encourage economic growth, a healthy environment, and a higher standard of living[3].

Poor management and Improper disposal of solid waste creates unsanitary conditions and breeding ground for vectors-borne diseases like West Nile virus, Lymphatic Filariasis, Onchocerciasis, Chagas, Leishmaniosis, Schistosomiasis, Yellow Fever, and Leishmaniosis [22]. Biomedical waste (infectious waste) is a serious threat to human health if not handled in a scientific and discriminate manner[22]. Open dumps or in improper landfills create serious negative impacts on the environment like soil and water bodies contamination creates loss of biodiversity; it releases dangerous gasses and leachates like methane, due to microbial decomposition, which contribute to climate change and air pollution. Improper waste management harms public health, hurts the environment and climate, and hinders economic growth[22].

10.2.3 Hierarchy of Solid Waste Management:

Waste management hierarchy is the guidelines that rank various waste management options based on relative desirability to achieve an economically efficient and environmentally friendly waste management practice[23]. The standard hierarchy of waste management consists of five important steps in the form of an inverted pyramid; Prevention, Reuse, Recycling, Recovery and Disposal[23].

The most effective and environmentally preferred methodology in the hierarchy is **Prevention** which aims to reduce or totally prevent waste generation at the source[18]. This includes redesigning products, reducing packaging and toxicity, particularly at manufacturing by implementing eco-friendly materials such as organic cotton and bamboo. The second-best option is **Reuse**[23]. In addition to preventing, reusing scrap can have benefits in reducing waste. The third phase in the hierarchy of waste management is recycling because it requires more energy and resources to produce the end product[23]. Recycling reduces the demand for resources and the amount of waste that needs to be disposed of by landfilling. It involves segregating and sorting wastes and then processing them into raw materials. **Recovery** is usually ranked fourth in the hierarchy[23]. It includes conversion of non-recyclable waste materials into fuel, electricity or heat through various physical-chemical processes. This method reduces the toxicity and volume of waste by producing renewable energy sources such as biofuels which reduce carbon emission and fossil fuel dependency. Disposal, ranked lowest in hierarchy, entails disposing of wastes in or on the earth's mantle. Disposal is the least desirable method because it affects health and the environment[24].

10.2.4 Components of Solid Waste Management:

Sustainable, efficient and reliable management of solid waste can be broken down into five components to ensure minimization of its impact on social and human health, economy and environment[24].

10.2.5 Collection and Transport:

The first step towards solid waste management is collection and transport of waste from its source to transfer station. About three-quarters of the overall waste management budget goes toward this labour-intensive process[25]. Enclosed and compact trucks, with capacity up to 30 cubic meters, are used for waste collection from densely populated cities. These collection vehicles travel to a transfer station, where garbage from various cars is collected in a tractor-trailer unit that is much larger. These trailers then transport roughly 76 cubic metres of garbage to a local facility for processing or disposal. Tons of trash can be handled daily by large transfer stations.

10.2.6 Separation and Recycle:

Separation, recovery, and reuse of economically valuable components from solid waste is called recycling[3]. Separation of waste is accomplished either at the source or at a central processing unit. It is usually carried out by individual citizens who separately place recyclables and non-recyclables waste at the curb for collection[26]. Centralized mechanical processing plants can also separate recyclable materials from garbage. However, recyclables recovered from such facilities lost quality due to the contamination with broken glass and moist garbage. Hence, for best practice, separation should be done by individuals[27]. A centralised material recycling facility, or MRF, processes recyclables. An electromagnetic separator removes tin and steel cans, and a vibrating screen separates shattered glass from the remaining components[27].

Then, an air classifier separates lighter glass containers from heavier plastic and aluminium containers, and at last, eddy-current separators separate aluminium from plastic. Whereas paper materials are stored by hands. Broken glass that has been recovered can be used as cullet for producing glass and in asphalt pavement. Cans made of scrap steel may be baled and transported to steel mills[27]. Aluminium has the highest value as a recyclable resource despite being one of the smallest parts of municipal solid trash, which can be reused by smelters[28].

Due to different polymeric materials, recycling of plastic is challenging. Mixed thermoplastics, however, are utilised to create inferior goods like "plastic timber.[6]" Recovered papers can be sent to paper and tissue mills. Rubber can be shredded and remodelled by vulcanization. In asphalt paving, shredded rubber can be used as an addition and as artificial turf. Discarded tires can be employed in recreational structures like swings for children in tire playgrounds[29].

10.3 Composting:

Composting is an eco-friendly and biological method of treating municipal solid waste which offers recycling and processing of both garbage and sewage sludge[29]. Under carefully controlled conditions, organic waste is allowed to decompose by microbes, which reduces their volume by around 50 percent. Humus or compost, the stabilised end result, has a texture and smell similar to soil and can be used as mulch.

The process includes isolation of decomposable materials from refuse, shredding or pulverizing with rotary shredders and hammer mills for a uniform mass of material and digestion of pulverized by enclosed mechanical facility or the open windrow method[30]. Windrows refers to the long and low mounds of refuse. Relatively, Open windrow composting requires large land areas and manual aeration, whereas mechanical composting systems employ closed digesters that mix and aerate the shredded waste with rotating vanes, reducing land requirement by about 85 percent[30]. Compost goes through the process of drying, screening, and granulating before it can be used as a mulch.

10.3.1 Energy Recovery through Waste Treatment:

Energy recovery, often known as waste-to-energy, is the process of converting non-recyclable trash into useful power or heat, or fuel, using a number of different techniques, such as combustion, pyrolysis, anaerobic digestion, gasification, and landfill gas recovery[31]. Often referred to as trash to energy, this process. These methods generate new sources of renewable energy, reducing carbon emission and methane production from landfills. Usually, Waste-to-energy plants either employ mass burn or refuse-derived fuel systems to operate, to generate electricity or steam[32]. The fact that differentiates both is the prior treatment or preparation. The mass burn method uses all refuse whereas combustible wastes are first separated from non-combustibles (metal and glass) in a refuse-derived fuel system before burning[32].The heat released from the combustion chamber converts water to steam, which is then converted into electricity by a turbine generator. The remaining ash is collected, filtered by a highly-efficient baghouse filter for removal of metal scrap and disposed into landfills. Apart from aerobic digestion or composting, compostable materials are treated anaerobically, to utilize the methane gas which is used as a fuel for ovens, water heaters, homes, automobiles, kilns, turbines, etc.[33]. MSW is often converted into a combustible gas by gasification, which utilizes an additional reactant and a high temperature (up to 1000°C). Gasification and pyrolysis both resemble burning, however it is conducted without oxygen. Recovered gasses can be utilized with different energy technology[33]. Greater volume reduction and self-sustaining processing of waste are provided by both the processes, that's why it is used for hazardous and infectious biomedical waste treatment[34]. Chemical, thermal, and biological treatments of hazardous waste prior to disposal is crucial.

Ignorance and mismanagement may harm public health and the environment[35]. Chemical methods like ion precipitation, exchange, oxidation-reduction, and neutralization; thermal methods like multiple-hearth furnace, fluidized-bed incinerator, and rotary kiln; biological methods like fluidised bed bioreactors for ethanol and cellulose production, hydrolysis for organic acid recovery should be employed to reduce toxicity, recovery and disposal of hazardous solid wastes.

E-waste management basically relies on recycling and repurposing. Another class of contagious waste is biomedical and hospital waste, which are detoxified and recovered generally by autoclaving, plasma processing, gasification, microwaving, ultraviolet and Cobalt-60 produced gamma rays[36].

10.3.2 Disposal of Waste:

In order to reduce the impact of waste on the environment, completely waste material and by-products are finally disposed of after MSW treatment. Incineration and landfills are the most widely used disposal methods for MSW management[27].

10.3.3 Incineration:

Controlled Incineration involves combustion of waste at very high temperatures (800–1100 degrees Celsius), it is a dry oxidation process[37]. However, modern waste management approaches consider incineration as a process of energy recovery and waste treatment. Modern incinerators are equipped with extensive emissions control equipment such as electrostatic precipitators that separate the fly ash and acid gas, fabric baghouse filters, and gaseous by-products before they end up in the atmosphere[37]. After secondary treatment, fly typically, bottom ash and ash are combined and dumped in landfills. Incinerators are particularly equipped for hazardous and biomedical waste disposal[38]. Double-chambered incinerators are used for pathological waste and rotary Kilns are used on heat resistant chemicals and genotoxic waste. Incineration is an expensive method and produces potentially dangerous dioxin (human carcinogens) emissions. The incineration process should be strictly controlled and efficiently executed so that the dioxin does not exceed the norm[39].

10.3.4 Landfills:

Landfilling is the primary method for disposal of waste. Proper waste management system adopts three types of landfills; Sanitary Landfills or MSW Landfills for municipal waste disposal; Hazardous Waste landfills; and Monofils, designated for single type of waste (e.g., construction waste)[40].

A landfill is a limited part of a site that is used to disperse waste in thin and compact layers. Multilayer approach is used to maximize depth up to whereas the compacted waste only takes up roughly a fifth of its original volume, it measures 3 meters (10 feet). To eliminate odor, wind-borne litter, pest and rodent problems, a layer of soil is deposited over the litter at the end of daily operations. Creating the final cap with a topsoil layer on completed landfill may support vegetative growth. Despite landfill being a simple concept, proper management is important, otherwise it will create public health concerns and negative impacts on the environment. Landfills cause soil water and air pollution[40]. Harmful emissions like benzene, toluene, ethylbenzene and xylene isomers and landfill leachate are potential dangers and adverse effects of landfilling that could harm human health.

10.3.5 Strategy for Sustainable Solid Waste Management:

Waste management is important for developing countries and cities to be sustainable and livable, but it remains a challenge for many. Waste management is a complex process that costs between 20% and 50% of the municipal budget[27]. An efficient, sustainable and socially responsible system is essential to conduct this important municipal function.

Confirming the correct application of the waste hierarchy across industries, private companies and households requires a comprehensive strategy with effective horizontal collaboration between local, regional, state councils and national levels, as well as local and vertical collaboration[27]. Financial investment, knowledge and technical expertise are all essential for the implementation and success of an effective waste management policy.

There are various practical problems associated with MSW management. Finding appropriate applications and suitable markets is the most strenuous problem with the recyclables.

Recycling alone won't the growing issue of managing and dumping solid waste[27]. There will always be room for solid residue that has no value. High transportation cost and competition with inorganic chemical fertilizer, generally reduce the agricultural demand for digested manure[27]. Improved infrastructure, closed dumps, treatment facilities and waste sorting, and the construction or refurbishment of landfills with bins, dumpsters, truck and transfer stations are the first steps towards sustainable MSW management. Long-term planning of tax and fee structures and concrete policies for the sphere of municipal waste management, and coordinated institutions will help governments improve waste cost control and recovery.

Public involvement and a change in behavior are necessary for a functional waste system. About 15–20% of the waste produced in most developing nations is collected, sorted, and recycled by informal workers in developing countries [27].Safe working conditions, educational opportunities, a social safety net and child labour restrictions will promote waste management practice at the individual and social level. Advancement of environmentally sound waste treatment and disposal technologies is required.

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11. Bioremediation

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Key Concepts:

After completing this chapter, you will be able to:

- Understand the concept of bioremediation.
- Discuss how selection of microorganisms is done and how biodegradation is done using natural and modified microbes.
- Details about techniques used in bioremediations.
- List of different pollutants which can be brake down using bioremediation.

11.1 Introduction:

Absorption and degradation of the xenobiotic present in the environment with the help of microorganisms is called biodegradation. The focused pollutants are metals and radionuclides which make the site unsuitable for the living organism to flourish. The microorganisms used for bioremediation are either genetically modified or selected from nature. Bioremediation can either be carried out in situ, which is at the site of contamination itself, or ex-situ, which is located away from the site. The selection of technic depends on the range of factors like type, concentration, or characteristics of pollutants. Microbus utilizes contaminants as a source of food and energy and converts them into simple elements which are harmless to the environment. The optimum condition for the growth of microorganisms should be fulfilled for proper growth, which is provided by adding amendments like molasses, vegetable oil, or gases. Which thereby accelerates the bioremediation process. The various factors involved in bioremediation are an energy source, nutrition, pH, temperature, oxygen content, characteristics of contaminant, etc. The advantage of bioremediation includes its being cost-effective and fewer harmful by-products.

Some disadvantage like the growth of microbes is not controlled resulting in toxic by-products, providing optimal condition for the growth of microbes In situ is of major concern, also the process take long time as compare to other remediation technique. Bioremediation can be classification into three phytoremediation, bacteria remediation and mycoremediation. Examples of bioremediation are contaminated soil, oil spill, ground water, crime scene clean up.

11.1.1 Definition:

Bioremediation is a branch of biotechnology that employs the use of living organism like microbes and bacteria in the removal of contaminants, pollutants and toxins from soil, water and other environments. (Cory Mitchell).

Bioremediation is a waste management technique that includes the Living Organism living organisms to eradicate or neutralise pollutants from a contaminated site. Bioremediation is a treatment technique that uses naturally occurring organisms to break down harmful material into less toxic or non-toxic material.

11.2 Selection of Microbes:

Microorganisms can grow at temperature below 0°C to extreme heat. The microbes are adaptive to new environment and their biological system made them suitable for remediation process. Carbon is the main requirement for microbial activity. The native microorganisms can stimulate by providing resources to grow and proliferate the process is called as bio-stimulation. It also increases the rate of degradation.

Microbes break down pollutants via there inherent metabolic processes with or without slight pathway modification. By using genetic engineering and transgenic technics specially designed microbes can be used at the site which can degrade the pollutants more efficiently. Naturally occurring microbes can degrade hydrocarbons, polychlorinated compounds, polyromantic hydrocarbons, radionuclides and metals. Aerobic microorganisms used for bioremediation are *Pseudomonas, Acinetobacter, Sphingomonas, and Mycobacterium* etc. They degrade pesticides, hydrocarbons, alkanes and polyromantic compounds. Anaerobic bacteria are not used frequently as aerobic bacteria.

11.2.1 Biodegradable Pollutants:

Pollutants which can be degrade by bioremediation are –

- Pesticides
- Agrochemicals
- Non- chlorinated pesticides and herbicides
- Organic halogens
- Inorganic metals (lead, chromium, mercury)
- Gases (ozone, nitrogen dioxides, sulphur dioxide)
- Petroleum hydrocarbons
- Radionuclides
- Dyes
- Plastics explosive and sludge.

Soil gets polluted by various industrial and agricultural activities due to deposition of heavy metals, chemical spillers or pesticide usage. It can be clean by bio stimulation or addition of microbes to the site of contamination. Air gets polluted by industrial emission carrying volatile compounds, dust particles, toxic gases etc. Bio filtration is used for cleaning industrial gases by passing polluted air over a microbial culture medium.

That degrades contaminants into co2, water or salts. Bio filtration is the only biodegradable technique currently available to remediate air born pollutants. Water is treated by aerobic and aerobic strains of bacteria. That degrades pollutants and organic matter present in waste water.

11.2.2 Factor Responsible for Bioremediation Process:

- Temperature.
- Moisture.
- Electron acceptors.
- Cost.
- Nutrients.

- pH.
- Soil density, permeability, texture etc.
- Size of contaminated area.
- Concentration of contaminants.
- Properties of pollutants.

11.2.3 Bioremediation Techniques:

Bioremediation can be generally classified as in-situ, intrinsic and ex-situ.

Table showing classification of bioremediation technique-

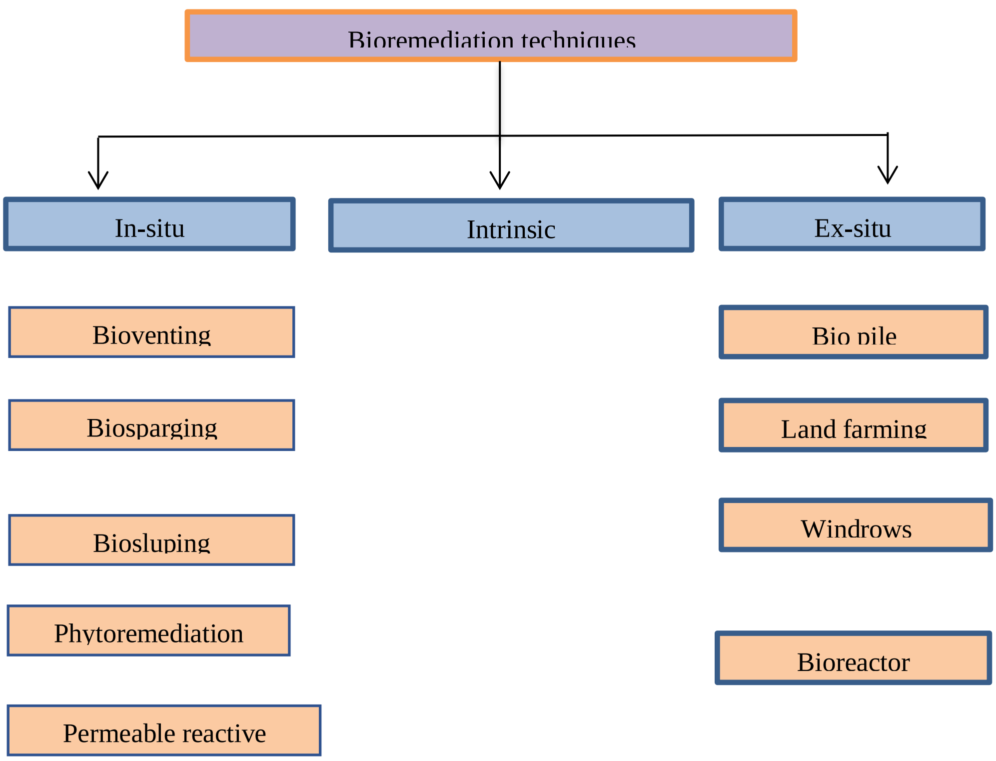

Figure 11.1: Classification of Bioremediation Technique

11.2.4 In-situ bioremediation:

In in-situ techniques contaminants are treated at the site only it does not require excavation from the site. It is less costly than ex-situ as no equipment is required on site.

The major concern is to increases efficiency of microbes by providing optimum conditions (nutrient, pH, moisture content, temperature) for growth of microorganism. Soil porosity and texture play important role in in-situ technique.

A. Different technique classified under in-situ technique are-

a. **Bioventing-** In this technique airflow of oxygen is pass to unsaturated zone to stimulate the activity of indigenous microorganism. Nutrients and water is also added to soil to enhance bioremediation. It is used in diesel polluted soil, hydrocarbons polluted site, reduction of chlorinated compounds under aerobic condition. Permeability of soil enhances the biodegradation process.
b. **Biosparging-** here air is injected to soil subsurface to stimulate microbial growth. Which help in movement of pollutant from saturated zone to unsaturated zone in turn promote biodegradation? It depends upon soil permeability and pollutant biodegradability. It is used in remediation of benzene, petroleum products, toluene, xylene, etc.
c. **Bio slurping-** Here a light non-aqueous phase liquids (LNAPLs) is pumped to soil surface by upward movement. Which in turn help in increasing the permeability of oxygen and hence increase the microbial activity. It is used for volatile and semi volatile compounds remediation at saturated and unsaturated zone. Here main concern is soil moisture which decreases air permeability in turn oxygen transfer rate.
d. **Phytoremediation-** In this technique plants are used for biodegradation of pollutants. Plants can breakdown, remove, accumulate or convert pollutants into non-toxic compounds present at the site. Hundreds of plant species are identified as accumulators of pollutants e.g., Hemp, alfalfa, Indian mustard, water hyacinth, corn, sunflower, tobacco etc. used for remediation of metals (As, Cu, Pb, Zn, Cd) gasoline, ethers etc. recombinant DNA technology is used to produce transgenic plants which increase metabolism and degradation of heavy metal.

11.2.5 Type of Phytoremediation Are:

- **Phytostabilization-** secretion from roots of the plant precipitates the toxins and made them less available.

- **Phytotransformation-** plant uptake the pollutants and transform it into another product.
- **Phyrovolatilization-** plant evaporate the volatile pollutants by transpiration process.
- **Phytoextraction-** direct uptake of pollutants and concentration of pollutants in plant tissue followed by removal of plant from the site.
- **Phytostimulation-** enhancing the process of degradation in rhizosphere.

11.2.6 Advantages of Phytoremediation:

- It's easy to observe plants growth and changes.
- It's cost effective.
- Doesn't cause any harm to environment.
- It is helpful in extraction of metals by phytomining.
- Helpful at the site where excavation is not possible.
- Prevention of erosion and leaching of metal.

11.2.7 Limitations of Phytoremediation:

- Long time is required as compare to other remediation techniques.
- Pollutant concentration, toxicity tolerance.
- Accumulated toxins can be transferred to food chain.

Permeable reactive barrier (PRB): It include precipitation, degradation and sorption of pollutants. It is in-situ technique used for remediation of heavy metal and chlorinated compounds. It is physical method where a permanent or semi-permanent reactive barrier (medium) is submerged in polluted groundwater where pollutants are trapped and undergo series of reactions in turn clean the water.

11.2.8 Advantages of In-Situ Technique:

- It is done at the site so no extra affords required for excavation and transportation.
- Less costly.

- Native microorganisms are only used most of the time so no laboratory expense is included.
- No disturbance to soil.
- No sophisticated equipment is required.

11.2.9 Limitations of In-Situ Technique:

- Providing optimal condition on site is a difficult task.
- Soil texture, porosity, permeability and environmental conditions are limiting factors in in-situ technique.

Intrinsic bioremediation-

it is a type of natural in-situ technique where no extra affords is applied for bioremediation. It totally depends on aerobic and anaerobic microorganisms to biodegrade the pollutants. It is observed in biodegradation of saturated and unsaturated hydrocarbon. It is passive form of remediation and is less expensive as compare to other bioremediation process. Intrinsic approach is limited as it takes a long time to eradicate pollutants and it is limited to some xenobiotic compounds only.

A. Different naturally occurring bioremediation processes are-

- **Bio stimulation-** In this process indigenous microorganism is provided with additional nutrients which enhances biodegradation.
- **Bio augmentation-**In this process exogamic microorganism are added which capable of detoxifying the contaminants, mostly genetically modified microbes are used.
- **Natural attenuation-**Here biodegradation is totally depended upon the indigenous microbes without any human intervention other than monitoring.

11.3 Ex-Situ Bioremediation:

Ex-situ means off site i.e., taking the contaminants to other site or treating it elsewhere. The contaminated soil can be treating in bioreactors where microorganisms can grow in control condition like pH, temperature and nutrient supply.

Bio pile, land farming or windrowing is used other than bioreactor in ex-situ bioremediation. Exogamic microbes, nutrients, water, air supply is provider to contaminated soil which enhances biodegradation process.

A. Different technique classified under ex-situ are:

a. Bio pile:

It's an ex-situ technique where contaminated soil is mixed with soil containing microbes. Nutrients, moisture, heat, nutrients, oxygen and pH can be controlled to increase biodegradation process.

It is useful in cold environment and to treat low molecular weight volatile pollutants like petroleum pollutants, halogenated volatile organic compounds and pesticides. In this technique aeration is provided thru proper air supply system which increases the oxygen supply and hence microbial activity.

b. Land farming:

In this technique contaminated soil, sludge are incorporate into soil surface and tiled or turn over which provide aeration and thus increases the biodegradation process. Land farming may be in-situ or ex-situ depends up on depth of pollutant in the soil.

If the pollutant is present at depth of <1m below the ground then it is treated with in-situ techniques. If pollutants are present below >1.7 m then ex-situ techniques are used.it is useful in oil sludge and petrol refinery waste treatment. Inorganic contaminants can’t be treated with this technique.

c. Windrows:

Here polluted soil is rotated periodically which in turn increases the aeration and nutritional supply for microbes and accelerate the bioremediation process. This is most cost-effective technique for bioremediation.

Contaminated soil is piled up into small hill which is periodically turned upside down which increases oxygen concentration, nutrient and other amendments are also added during turning process.

d. Bioreactor:

Bioreactors are large vessels in which raw material are treated to form different products. Polluted soil or slurry can be treated using bioreactor.

Bioreactors are designed according to the mode of operation like batch, fed batch or continuous.

Bioreactor provide controlled environment for microbial growth hence increases biodegradation process.

11.3.1 Advantages of Ex-Situ Technique:

- Less laborious
- Less expensive
- Result is faster as compare to in-situ.
- It's easy to control the growth condition for microorganisms.
- Preliminary assessment of site is not required.
- Use for wide range of contaminants.
- Large volume can be handled easily.

11.3.2 Disadvantages of Ex-Situ Technique:

- It is not possible to perform ex-situ under the building, in city, and crowded area.
- It disrupts soil texture and structure.
- Not applicable for heavy metals.
- Required large area for treatment thus site size is main constrain.
- Only aerobic biodegradable contaminants can be treated.
- Hard to provide optimum conditions for microbes to grow.

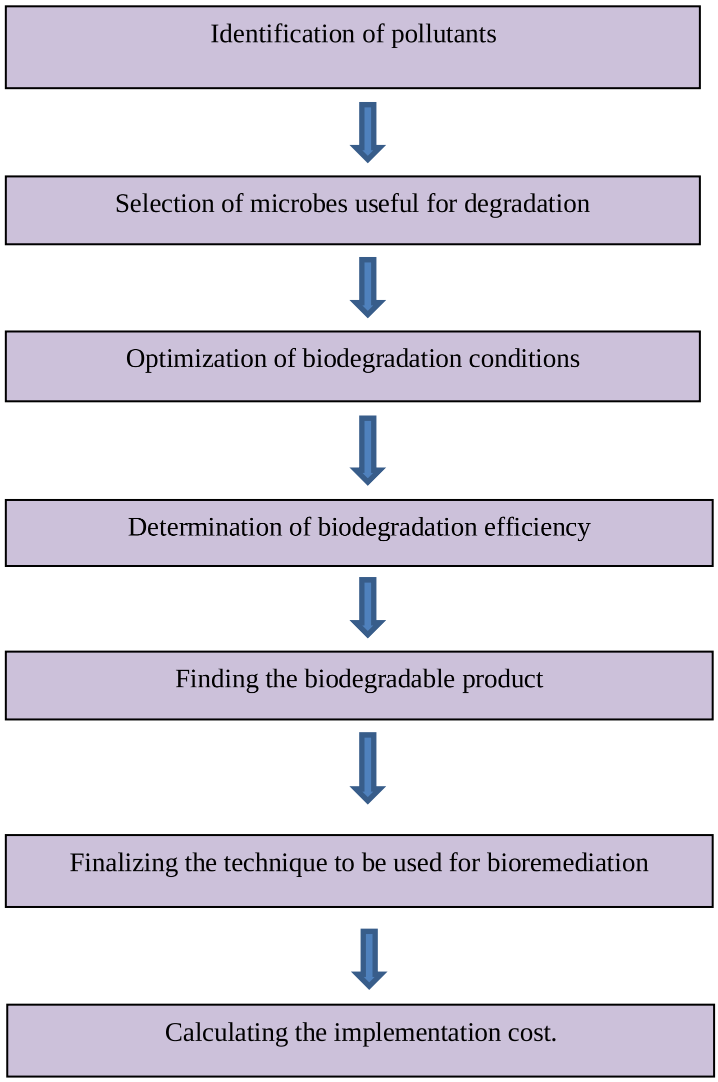

Figure 11.2: Steps for Bioremediation using Microbes

Advantages and Limitations of Bioremediation:

11.3.3 Advantages of Bioremediation:

- It is often be carried out on site.
- It does not require too much of sophisticated equipment.
- Bioremediation is less expensive.

- End product is safe to the environment.

11.3.4 Limitations of Bioremediation:

- Bioremediation is limited to only biodegradable compounds.
- Bioremediation take longer time than other treatment options.
- Research and development are requiring engineering microbes that are not naturally present in environment.

11.3.5 Applications of Bioremediation:

- **Waste water and industrial effluent treatment-**bioremediation is sustainable method accepted worldwide over expensive chemical method in sewage treatment plant and effluent treatment plant. Microorganisms are seeming to be effective in biodegradation of pollutants to less toxic substance which make waste water suitable for disposal or for further use.
- **Control of air pollution-** air filters were developed using microbes immobilized on inert material when polluted air come in contact with microbes undergoes biodegradation.it is useful for absorption of toxins released from industries. It is effective detoxification method and also helps in volume reduction. Phylloremidiation is also known for reduction of air pollutants like particulate matters, ozone, nitrogen dioxides, sulphur dioxide and volatile organic compounds. Phylloremidiation is a bioremediation method where plant leaves and microbes associated with leaves adsorbs air pollutants and degrades it.
- **Soil and land treatment:-**Bio slurping, bio venting, bio sparing, phytoremediation are various methods used for efficient bioremediation of toxic pollutants from soil. Bio remediation is effective for biodegradation of petroleum hydrocarbons, heavy metals and agricultural pesticides which is a major concern for health and environment.
- **Solid waste management-** bioremediation of solid waste can be done by windrow composting; here microorganisms were sprayed on the windrows of solid waste which is then converted into manure. This manure there by used in agriculture practices.

11.4 Conclusion:

Bioremediation is a natural remediation process for removal of toxic pollutants from the site. It is mainly classified in to in-situ and ex-situ, as compare to ex-situ technique in-situ is less costly as it does not required excavation of pollutants, installation of big equipment or laboratory cost. Process of bioremediation involves analysis of pollutants, finding right microbes for biodegradation, standardising the process and its pilot scale implementation. Selection of technique depends up on pollutant concentration, depth, type, location of site, performance and human habitation.

11.4.1 Questions for Review:

- Define bioremediation.
- Describe different type of bioremediations techniques. What are the criteria for selection of technique?
- Discuss the strategy to be followed for efficient bioremediation.
- What are the limitations and advantages of bioremediation?
- Discuss selection of microbes for effective biodegradation.
- What are the different applications of bioremediation?
- Discuss the factors responsible for bioremediation.

11.4.2 Questions for Discussion:

- Make a list of different pollutants can be effectively treated by using bioremediation.
- Discuss how efficiency of microbes can be increase for effective biodegradation. Using naturally occurring microbes and increasing its efficiency or using genetically modified microbes is preferred?
- Give your review on statement-"phytoremediation is the future of bioremediation".

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