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NEWSLETTER

ON

APPLICATION OF BIOTECHNOLOGY IN INDUSTRIAL WASTE TREATMENT

DESKU ENVIS RP, UNIVERSITY OF KALYANI, NADIA, WEST BENGAL

Email: desku-env@nic.in, Phone: +91-33-25828750

Website:http://www.deskuenvis.nic.in

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EDITORIAL

Wastes are unwanted or the inevitable by-product of any anthropogenic activity. Waste generation is increasing day by day due to increase in population and uncontrolled urbanization and it has been the major cause of environmental pollution. After industrial revolution, it transformed rural areas into industrialized and urban ones and brought a huge problem by producing a huge amount of industrial waste from different industries such as mills, mining operations, power plants etc. Now days, environmental pollution from industrial wastes are one of the most alarming global problems, which needs proper disposal and management in sustainable way for our future protection. It should be decomposed or managed efficiently to keep ourselves and our environment safe.

Among the various industrial waste management technologies, the advanced biological and environmental engineering process are the most effective sustainable waste treatment and degradation techniques, where major portion of the waste can be transformed into safe valuable products.

In this newsletter both the articles describe, how can waste will be managed through biotechnological process.

Prof. Kausik Mondal
Dr. Subhankar Kumar Sarkar

IN THIS ISSUE:

Sustainable Industrial Waste Management

Santanu Chowdhury[1] and A. C. Samal[2]

[1]Dept. of Environmental Science, Asutosh College, Kolkata. West Bengal. India.

[2]Dept. of Environmental Science, University of Kalyani,West Bengal. India.

Introduction

Waste is the inevitable by-product of any anthropogenic activity. Waste generation is increasing day by day due to increase in population and uncontrolled urbanization and it has been the major cause of environmental pollution [1-3]. Industries, mining operations, power plants, tanneries, paper mills, pharmaceutical industries etc. generates large quantity of waste products[4-7]. Mainly three types of wastes are produced from industries - solid, liquid and gaseous. Components of industrial waste include various metal ions, anions, organic chemicals, Persistent organic pollutants (POPs), hazardous waste and gaseous pollutants [8-9]. In India, there are 36,165nos. of hazardous waste generating industries, generating 62,32,507MetricTonnes of hazardous wastes every year (CPCB report, 2009). Management of industrial solid waste is becoming a challenge due to its varying quality and increasing quantity [10-11]. The environmental health hazards is generally associated with poor waste management and disposal. It is very important as well as challenging to manage waste in an environmentally sustainable manner. It is high time that we use technologies which not only recycle waste but also convert them to some form of valuable products. Reuse is not the only way to reduce waste; it can also be reduced by adopting a preventive approach. Among the new technologies, waste treatment and degradation using biological organisms has attracted the most attention. Biotechnology finds many applications in the fields of treatment of waste by biological methods and disposal of solid wastes by composting technique using environmental engineering [12-15].

Types and Categories of Industrial wastes

Industrial waste is the waste produced by industrial operations which includes any substance which is considered useless during the manufacturing process. It also included by-products such as chemicals, paper, metals and hazardous materials. Industrial waste is manufacturing waste from a wide range of different processes, such as sludge, product residues, kiln dust, slags, and ashes. The composition of waste may be differentdue to variation of raw materials, , the operational procedure or different manufacturing procedure, and the nature of the product (fig.1) . The different categories of wastes are inorganic fractions, organic fractions, biodegradable fractions, non-biodegradable substances, be recyclable products, etc. Thermal power plants in India generates maximum industrial solid waste as fly ash, the integrated Iron and Steel industries producing blast furnace slag and steel melting slag, non-ferrous industries like aluminium, zinc and copper producing red mud and tailings, Crude press mud produced from sugar industries, lime is produced from paper and pulp industry, and gypsum can be a byproduct of fertilizer and fertilizer and associatedindustries. The main treatment concerns for industrial waste is the efficient management of the liquid waste products. The properties of liquid waste may alter with the compositionof raw material and processes used. It can be acedic or alkaline, organic and inorganic, suspended or dissolved., or it can contain inextricable organic or inorganic fractions. .

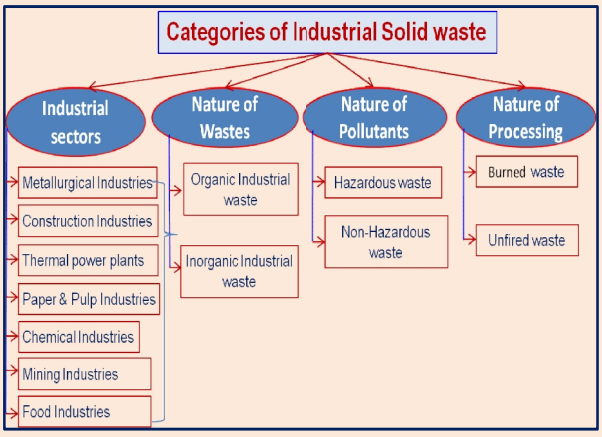

Fig.1 Categories of Industrial Solid wastes

Waste disposal rules and regulations

Management of different wastes (solid, hazardous, medical, electronic etc) is a very challenging issue now. It is estimated that 78% of sewage generated in India remains untreated (down to earth, 2018). Industrial activity israpidly increasing in India over past few decades. With the expanding industrial

development the industrial activities, the requirement of for keepinga balance between development and protection of natural environment is also increasing. Environment (Protection) Act, 1986 have powered the Central Government to regulate all forms of waste disposal and management. In our country, India the waste management is governed by Ministry of Environment, Forest and Climate Change (MoEF& CC) who work together with State and Central Pollution Control Board to set up various regulations and standards for waste disposal. A number of rules and regulations implemented time to time by the government of India for protection of environment and sustainable development, i.e. Solid Waste Management Rules, 2016; E E-Waste Rules 2016 (Amendment Rules, 2018); Plastic Waste Management Rules, 2016 (amended, 2021 & 2022); Bio-medical Waste (Management & Handling) Rules, 1998; Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 etc.

Process & design of Effluent Treatment Plant(ETP)

ETP (Effluent Treatment Plant) is a process design for treating the industrial waste water for its reuse or safe disposal to the environment (fig.2).

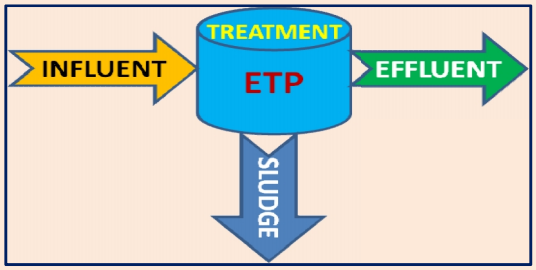

Fig. 2 Stages of ETP

The design and size of the ETP depends upon various factors like Quantity, quality and type of the industrial discharge, Land availability, economic feasibility of ETP construction, operation & maintenance cost, Quality of wastewater to be treated, Flow rate and type of chemical and biological treatment to be used. The general Flow diagram of a typical ETP of an industry shown in below figure.

Different process of Industrial waste management

The 4 most effective methods of industrial waste management are Segregation, Landfill, Composting and Recycling. The industrial wastes are generally managed and treatments through Physical, Chemical and biological processes. The biological treatment using biotechnological tools is the most effective, economic, and environmental sustainable process for industrial waste management (fig.3).

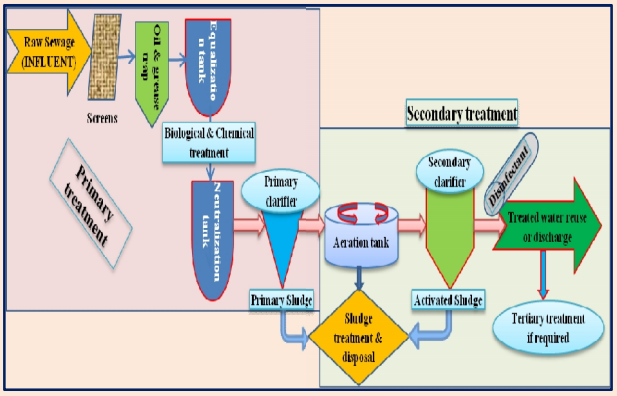

Fig.3 Flow diagram of Industrial treatment plant

Application of Biotechnology in Industrial Waste Management

Application of biotechnology in waste management is very importance in view of its economic and environmental benefits. Using microorganism in the treatment of industrial wastes open news direction to waste management. Some of the biotechnological process includes activated sludge process, bioremediation, biofiltration, biosorption, bioreactior, bioleaching, composting, phytoremediation etc.

Bioremediation of Heavy metals

Industries like tannery, paint and pigment, fertilizer, electroplating is a major source of heavy metal contaminants. Environmental pollution by heavy metals has become a serious threat to living organisms in an ecosystem. Many environmental and physiological problems are caused by heavy metal contamination from industrial effluents. Bioaccumulation and bio magnification in the food chain increased the toxic effects of these contaminants.

However, a large number of industries are generating massive pollution to our natural environment. Many organisms are in the verge of extinction due to the contaminants produced by anthropogenic activities. Heavy metals are the most potential contaminants in terms of detrimental effect on environment as well as on all living organism including us. Heavy metal contamination from industrial waste has become a serious issue due to their toxicity which can be enhanced due to biomagnification through the food chain. The Waste containing heavy and

toxic metal with non-biodegradable nature is a serious threat to all living beings.

So, it is very necessary to develop new, cost effective and ecofriendly technology for the remediation of heavy metal pollution from industrial sources. Bioremediation of heavy metal using Recent research shows that microorganism like *Pseudomonas*, *Rhodococcus*, *Alcaligenes*, *Sphingomonas*, and *Mycobacterium etc* can be used effectively for bioremediation of heavy metals.

Biofilm can also be used as a bioremediation agent and biological stabilization agent for heavy metals. Endophytic microorganism possesses metal bioabsorption capacities and can be used to reduce metal toxicity. Research shows that naturally occurring microorganisms like algae, fungus, bacteria and plants are more efficient, environmental friendly and cost effective than conventional waste treatment methods[16].

Bioremediation of xenobiotic compounds

Xenobiotic compound are often accumulated in the living organisms and causes serious toxic effect. Industrial waste products containing xenobiotic compounds are becoming a serious cause of concern in recent times due to its non biodegradable properties. Waste produced from pharmaceutical and chemical industries are the major source of xenobiotic compound. Many other industries like Polyethylene, pulp and paper, paint, fabric, pesticide etc. are also produced the xenobiotics. Variety of organic non-biodegradable compounds produced from pharmaceutical and dye industries.

Table 1: Microbes involve in remediate of xenobiotic compounds

Xenobiotic compounds	Microbes (Reference)
PCB	*RhodococcusRHA1 [18]*
Benzene	*Dechloromonas sp. [19]*
Napthalene	*Pseudomonas putida [20]*
Endosulfan compounds	*Mycobacterium sp. [21]*
Endosulphate compounds	*Arthrobacter sp. [22]*
Vinylchloride	*Dehalococcoides sp. [23]*
Pyrene	*MycobacteriumPYR-1 [24]*

Bio-engineered microbial degradation can be used to degrade these toxic and hazourdous xenobiotic compounds. Bacteria can be very useful for fixation of different kinds of xenobiotic compounds (**Table 1**). Research shows that cyanobacteria, methanogecic and different aerobic and aneaerobic bacteria can be applied for the degradation of xenobiotic compounds. Microbial organisms have great potential for treating xenobiotic contaminated soil and water from industrial waste [17].

Bioremediation of organic industrial effluents

Industrial effuents are the major source of anthropogenic organic compounds in the natural environment. Paper pulp, food manufacturing, t industries generates huge amount of organic waste materials. Bioremediation is a waste management approach that utilizes microorganisms, plants or their enzymes to degrade/detoxify the organic and inorganic pollutants such as phenols, chlorophenols, petroleum hydrocarbons, polychlorinated biphenyls, organic solvents, azo dyes, pesticides, recalcitrant compounds, and toxic metals from contaminated soils and wastewaters. There has been an increasing concern regarding the release of various hazardous chemicals along with industrial wastes, which are considered as highly toxic for the environment and living beings. Some of these chemicals are listed as "priority pollutants" by the USEPA and other environmental pollution control agencies. Biotechnological innovation for organic waste degradation and pollution control can show us the path of sustainable industrial waste management [25].

Green technology

Green technology has become an important concern for every industry. Especially in textile dyeing factories, there is much use of water, energy, and chemicals. This can cause significant water and air pollution problems. Biodegradation methods such as fungal decolourization, microbial degradation, adsorption by (living or dead) microbial biomass and bioremediation systems are commonly applied to the treatment of industrial effluents because many microorganisms such as bacteria, yeasts, alges and fungi are able to accumulate and degrade different pollutants.

The combined reduction–biological treatment system for the decolorization of non-biodegradable textile dye waste water was an effective process[26]. In this treatment system, a bisulfite-catalyzed sodium borohydride

reduction followed by activated sludge technique was used in order to remove the color at ambient temperature and pressure. A bench-scale experimental comparison of this technique with other reported combined chemical–biological methods showed higher efficiency & lower cost for the new technique [27].

Conclusion:

Now a days, environmental pollution from industrial wastes are one of the most alarming global problems which needs proper disposal and management in sustainable way for our future protection. Among the various industrial waste management technologies, the advanced biological and environmental engineering process are the most effective sustainable waste treatment and degradation techniques, where major portion of the waste can be transformed into safe valuable products.

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Biotechnological applications in Industrial Waste management

Anusaya Mallick[1]* and Kausik Mondal[1, 2]
[1] ENVIS RP on Environmental Biotechnology, University of Kalyani, West Bengal
[2]Department of Zooloy, University of Kalyani, West Bengal: 741 235, India.

Introduction

After industrial revolution, it transformed rural areas into industrialised and urban ones and brought a huge problem by producing a huge amount of industrial waste from different industries such as mills, mining operations, power plants etc. It produces three kinds of wastes - solid, liquid and gas such as chemicals, ashes, industrial effluent, carbon dioxide, sulphur dioxide etc , which threats to our environment. It should be decomposed or managed efficiently to keep ourselves and our environment safe. In this article we discuss the the types of industrial waste and its management through biotechnological process.

Biotechnological processes are used for industrial waste treatments such as wastewater treatment, agricultural waste treatment, pesticide treatment, mining treatments etc. This technology can be also utilized for the production of biogas and hydrogen as new energy resources.

There are many sectors of industrial manufacturing that produce waste, including various types of factories (fig.1).

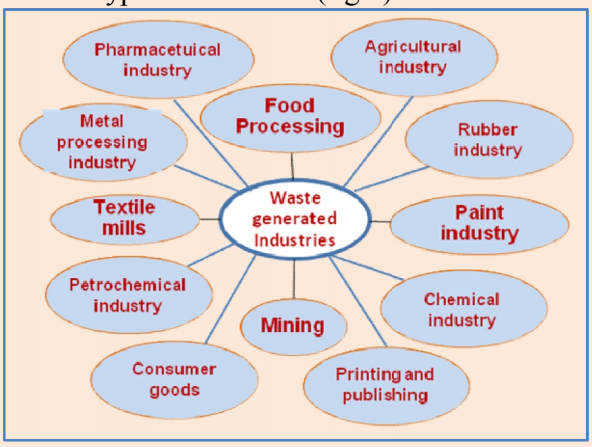

Fig. 1: Types of Waste generated Industries

Types of Industrial Waste

Wastes produced from different factories after the manufacturing of desired products. Based on products the industrial wastes can be categorized into biodegradable and non-biodegradable (fig. 2).

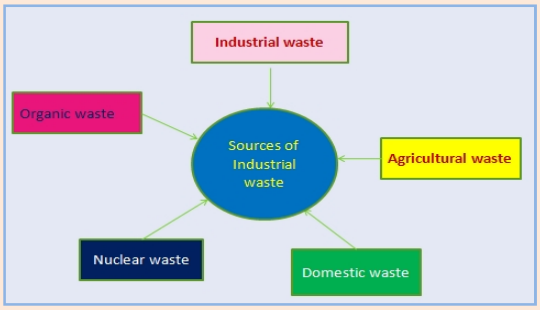

Fig. 2: Sources of industrial waste

a. Biodegradable Industrial Waste

Those industrial wastes which can be broken down or decomposed to non-toxic substances in nature with time by the action of micro-organisms such as certain bacteria are called biodegradable wastes(fig. 3).

The biodegradable wastes are generated from food processing industries, dairy, textile mills, slaughterhouses, etc decomposes naturally and transform into harmless non-toxic form in due time. Management of these biodegradable wastes can be done at low cost and easily.

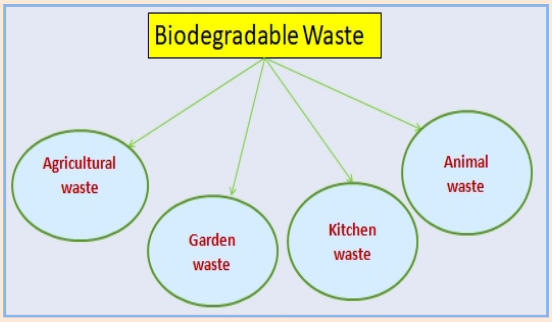

Fig. 3: Types of biodegradable wastes

b. Non-Biodegradable Industrial Waste

The industrial waste materials which cannot be further decomposed via the action of the microorganisms or harmless substances in nature are called non-biodegradable industrial waste, viz. plastics, fly ash, synthetic fibres, gypsum, silver foil, glass objects, radioactive wastes, etc (fig.4). The major nonbiodegradable wastes are generated from petrochemical industries, iron and steel plants, fertilizer industries, chemical, drugs, and dyes industries. The nonbiodegradable materials remains in the environment for years without any damage and harm to the ecosystem. The harmful substances absorbed are retained in the living organisms through respiration, intake of food or drink, or even by direct absorption through the skin. These types of wastes are difficult to manage and very toxic in nature.

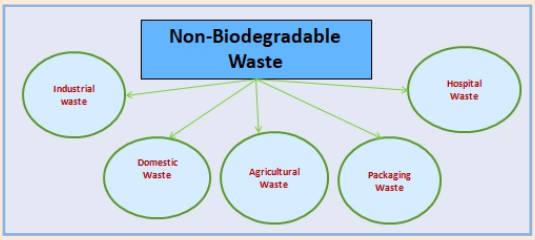

Fig. 4: Types of non-biodegradable wastes

Application of Biotech in Industrial waste management

a. Waste water treatment

Biotechnology finds application fields in the treatment of wastewaters by biological methods. The methods based on biotechnology in wastewater treatment are activated sludge, trickling filters, oxidation ponds, biofilters and anaerobic treatment.

- **Activated sludge**

An activated sludge wastewater treatment system has at least four components; an aeration tank,

- **Trickling filters**

Trickling filters have been used to treat wastewater since the 1890s. The name is something of a misnomer since no filtration takes place.

- **Anaerobic treatment**

The anaerobic process comprises a series of interdependent phases.

b. Bioremediation

Bioremediation is a sustainable strategy that utilizes the metabolic potential of microorganisms to clean-up contaminated environment. It uses living systems especially microorganisms to catalyze the degradation of wastes without disruption of the environment. It achieves decomposition of contaminant or immobilization by exploiting the existing metabolic potential of microorganisms with novel catabolic functions derived from selection or by introduction of genes encoding such functions. The goal of bioremediation is to transform organic pollutants into harmless metabolites or mineralize the pollutants to carbon dioxide and water [1]. Bioremediation techniques are typically more economical than thermal and physicchemical remediation such as incineration [2].

- **Bioremediation of pesticides**

The waste generated by the pesticide industry has become an emerging environmental problem due to the present inadequate waste treatment technology. Some active members of microbial consortiums involved in biodegradation process. These microorganisms include: *Acinethobacter, Actinobacter, Acaligenes, Arthrobacter, Bacillins, Berijerinckia, Flavobacterium, Methylosinus, Mycrobacterium, Mycococcus, Nitrosomonas, Nocardia, Penicillium, Phanerochaete, Pseudomonas, Rhizoctomia, Serratio, Trametes* and *Xanthobacter.*

- **Bioremediation of Heavy Metals**

Heavy metals are considered one of the most common and hazardous pollutants in industrial effluents that might cause serious problems to the sewage network pipelines. The deleterious effects of heavy metals on biological processes are complex and generally related to species, solubility and concentration of the metal and the characteristics of the influent, such as pH, as well as presence and concentration of other cations and/or molecules and suspended solids[3]. Different conventional bio-adsorbents e.g. algae, fungi, bacteria, agricultural wastes effectively used as an eco-friendly and low cost material for bioremediation of pollutants[4]. Some species of *Aspergillus, Pseudomonas, Sporophyticus, Bacillus, Phanerochaete,* etc., have been reported as efficient heavymetal accumulator. The application of microorganisms towards toxic heavy metals remover is very important for reclamation of polluted sites [5]. *Pseudomonas putida* MHF 7109 was isolated from cow dung microflora as potential benzene degrader and its ability to degrade benzene, toluene, and o-xylene (BTX) at various concentrations was evaluated[6,7].

Table-3: Bioremediation of heavy metals by different bacteria

Name of the species	Removal of elements
Bascillus sp.	Cd, Cu, Zn[8,9]
Cellulosmicrobium cellulans	Cr [10]
Pseudomonas aeruginosa	Cd, Pb, Fe, Cu, U, Ra, Ni, Ag [11,12]
Aspergillus fumigates	Ur[13]
Aspergillus niger	Cd, Zn, Th, Ur, Ag, Cu[9,14]
Beta vulgaris	Cd, Ni,Cr, Hg [9]
Micrococus roseus	Cd[15]
Escherichia coli	Zn & V [16]
Oedogonium rivulare	Cr, Ni, Zn, Fe, Mn Cu, Pb, Cd & Co [10]
Trichoderma Viride, Humicola Insolens	Hg [17]

Genetically engineered bacteria for remediation of heavy metals.	
E. coli strain	As ArsR [18]
E .coli strain	Cd^{2+} [19]
Methylococcus capsulatus	Cr^{6+} [20]
P. putida strain	Cr [21]
Ralstonia eutropha CH34, *Deinococcus radiodurans*	$Cd^{2+,}$ Hg[22,23]
E. coli strain	Hg [24]
E. coli JM109	Hg [25]
Pseudomonas K-62	Hg [26]
Achromobacter sp. AO22	Hg [27]
P. fluorescens 4F39	Ni [28,29]

Source: Singh, (2014)[30]

- **Bioremediation of Rubber Waste**

There are about 12% constitute of rubber found in solid wastes. A rubber can neither degrade easily nor recycled due to its physical composition [31]. The effects of microorganisms on rubber and related products, change in their physical, chemical and mechanical properties and leads to the degradation of the products, but on the other hand, can prove to be an excellent method of rubber waste disposal. It has been recognized that only a few species of bacteria can cause degradation of rubber, mainly *Pseudomonas* sp. and the *Actinomycetes* species from the genus *Streptomyces*[32]. Tire is composed of synthetic polymers and high grade of black carbon is also there[33].The reason behind this black carbon is to increase the strength of that rubber or tire [34]. A major environmental problem arises due to rubber, because on burning it gives a large number of toxic fumes along with carbon monoxide [35]. Even after that the use of rubber is increasing day by day, of which maximum rubber comes from vehicles i.e. 65% [36]. The toxic chemicals like zinc oxides inhibit the growth of sulfur oxidizing and other naturally occurring bacteria, which leads slow natural degradation of rubber [37]. Through bioremediation process different microorganisms can effectively degrade the the rubber industry wastes [38,39,40].

- **Bioremediation of textile waste**

Textile industry occupy the second largest industrial sector in India. Textile industries utilize large volumes of water and diverse chemicals for wet processing [41,42].

- **Bioremediation of Agricultural Waste**

The agricultural industry produces a large amount of wastes of human, livestock, and crops byproducts, i.e. approximately 38 billion metric tons of organic waste worldwide every year. This includes animal waste as well as food residual waste. Animal wastes from farms may include bedding material and also wash down water. The food harvesting and production industry generates crop residuals, as well as pre- and postconsumer food wastes. There is a need to find ways to deal with these wastes other than by sending them to landfills.

In recent much attention has been given to develop low-input and efficient technologies like vermicomposting, to convert such nutrient rich organic wastes into value-added products for sustainable land practices. Here microorganism helps in degradation of organic matter and earth warm drives the process and conditioning to the substrate and altering the biological activity[43].

Several epigeic earthworms, e.g., *Eisenia fetida* (Savigny), *Perionyx excavatus* (Perrier), *Perionyx sansibaricus* (Perrier), and *Eudrilus eugeniae* have been identified as detritus feeder and can be used potentially to minimize the anthropogenic waste from different source[44].

- **Bioremediation of petrochemical waste**

Petroleum is the major source of energy and it is composed of hundreds or thousands of aliphatic, branched and aromatic hydrocarbons. It is used in various industries and in our daily life. The petrochemical industry is one such major source of hazardous waste producer during its processing. These wastes are often released in the environment (whether accidentally or due to human activities) is a main cause of soil pollution. Soil contaminated with petroleum has a serious hazard to human health. In long term, this pollution affects the environment.

Although in the natural environments they are readily degraded by indigenous microbial communities, these processes are very time consuming. Various physical and chemical applications like mechanical burying, evaporation, dispersion and washing are currently employed to remediate the problems caused by PAHs pollution. However, these forms of treatments are either expensive or can lead to incomplete decomposition of contaminants[45].

The microorganisms to detoxify or remove pollutants owing to their diverse metabolic

capabilities is an evolving method for the removal and degradation of many environmental pollutants including the products of petroleum industry[46].

Case study on Industrial waste treatment

❖ Bioremediation of soil contaminated with petroleum hydrocarbons in the Borhola oil fields, Assam, India.

The effects of aeration, nutrients (i.e. nitrogen and phosphorus) and inoculation of extraneous microbial consortia on the bioremediation process were applied. The beneficial effects of these parameters on the bioremediation rate were realised equally in laboratory and field pilot tests. The field tests revealed that up to 75% of the hydrocarbon contaminants were degraded within 1 year, indicating the feasibility of developing a bioremediation protocol. The computer simulations model indicated that due to the high initial contaminant concentrations, the bioremediation process was restricted mostly to the macropores of the system within the period of 1 year and had not penetrated into the soil aggregates sufficiently.

(Source:https://www.sciencedirect.com/science/article/abs/pii/S1093019102000291)

❖ Bioremediation of oil spill site in Gujarat oil field in India (Western India)

In June 2008 there was accidental oil spill near city of Gujarat due to crude oil trunk line rapture. Crude oil was spread in large area in farm land. This trunk pipeline was being used for transportation of crude oil from oil producing field to the Gujarat Refinery in Baroda City of India. Oil Company also immediately stop pumping and barricaded the oil spill site and also prevented the spread of crude oil. The Oil company recovered substantial amount of crude oil accumulated in low lying area at spill site. Then the ONGC & TERI Biotech Ltd with joint venture applied the bioremediation technology to recover the oil spill area.

(Source:http://www.otbl.co.in/Bioremediation.php

Conclusion:

Biotechnology in industrial waste treatment and bioremediation examines the primary waste streams, including air, water, soils, sediments and explores specific treatment methodologies for industrial and environmental contaminants. The observations and successful field applications compiled in biotechnology in industrial waste treatment and bioremediation make it an excellent reference for understanding, evaluating, developing, and operating efficient and costeffective treatment systems.

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FORTHCOMING EVENTS

Event	Date	Place & Correspondence
International Conference on Blue Biotechnology and Biodiversity ICBBB	December 09-10, 2022	United Kingdom https://waset.org/blue-biotechnology-and-biodiversity-conference-in-december-2022-in-london
International Conference on Advances in Energy and Environmental Biotechnology ICAEEB	December 30-31, 2022	Paris, France https://waset.org/advances-in-energy-and-environmental-biotechnology-conference-in-december-2022-in-paris
International Conference on Environment, Agriculture and Biotechnology (ICEABT)	06th Jan 2023	Ooty, India http://academicsconference.com/Conference/26856/ICEABT/
International Conference on Agriculture, Food and Biotechnology ICAFB on	January 06-08, 2023	Ho Chi Minh City, Vietnam http://www.icafb.org/
International Conference on Algal Biotechnology and Bioprocesses ICAB	January 28-29, 2023	Dubai, United Arab Emirates https://waset.org/algal-biotechnology-and-bioprocesses-conference-in-january-2023-in-dubai

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