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Assessment of Bioremediation in Industrial Effluent Treatment and Environmental Safety

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ABSTRACT–*The industrial revolution, advancement in technology and population explosion are the reasons of contamination of bioresources. These industrial effluents have an adverse impact on water quality, soil flora and fauna and on aquatic ecosystem. Industrial discharge contains toxic and hazardous chemicals and organic compounds, which are detrimental to human health. Therefore proper treatment of industrial effluent is necessity before discharging into natural sources. There is a boom of technologies in effluent treatment plants but these technologies alone are not a sustainable way to achieve environmental goals. The conventional treatment methods have some drawbacks like production of harmful byproducts and large amount of sludge production. The bioremediation is a novel technology that uses microbial systems for the treatment of pollutants and attaining attention of environmentalists and researchers. Bioremediation can be boon to environment if used with amalgamation with conventional effluent treatment methods and new technologies. The objective of present review is to understand the role of microorganisms in bioremediation of different industrial effluents.*

Keywords: Bioremediation, Bioresources, Ecosystem, New Technologies.

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1. INTRODUCTION

The accumulation of organic pollutants and heavy metals in the environment is a threat to the flora and fauna. The discharge of inadequately treated Industrial effluent, use of pesticides in agriculture and improper management of sewage wastewater are the causes of contamination of bioresources. These organic pollutants are persistant in nature and pose a threat to human health and wildlife [1]. Therefore, it is the necessity to treat industrial effluent in a sustainable way so that the bio -resources can be saved. Bioremediation is considered as one of the safer, cleaner, ecofriendly technology for degradation of toxic organic compounds from industrial effluent. Bioremediation is attaining attention of researchers as it is a sustainable approach to save our bio-resources.

Bioremediation was first time applied on large scale for the bioremediation of Sun Oil pipeline spill at Ambler (Pennsylvania) in 1972 [2]. The sustainable approach of waste water treatment was first time invented by George M. Robinson at laboratory scale.

Reference [3] studied the Seasonal variation in Bacteriological Contamination of Groundwater and impact on Public health. They have taken samples from 17 different sites from Kangra District, Himachal Pradesh and they observed that industrial development in area, poor sanitation, agricultural practices and other anthropogenic activities are responsible for higher bacterial count in almost all samples. Dev and Bali et.al concluded in their research that best waste and industrial effluent practices should be taken. Bioremediation approaches can be boon for these kinds of polluted sites.

The conventional methods for the treatment of industrial effluent are not as efficient as the bioremediation technology because large amount of harmful by-products and toxic compounds are generated after conventional treatment of wastewater. Microorganisms have the potential to transform, mineralize and degrade toxic compounds into less toxic or harmless forms. Chemotaxis ,advanced omics ,biofilm formation, biostimulation , genetically modified microorganisms are the examples of bioremediation approaches which are used to enhance the metabolic capability of microorganisms [4] .The low cost , selectivity of microorganisms to specific pollutants or metals , less sludge generation ,high efficiency , possibility of metal recovery and no need of additional nutrients are some advantages of bioremediation process over conventional methods of wastewater treatment [5].

1.1 Role of bacteria in bioremediation of industrial waste water

Although all microorganisms have the potential of mineralization, immobilization and transformation of contaminants but bacteria play a significant role in bioremediation and sustainable treatment of industrial waste water. Next to glucosyl residues, the benzene is that the most generally distributed unit of chemical structure in environment, plenty of the aromatic compounds are responsible for contamination of bioresources. Bacteria have developed ways for getting energy from nearly each compound under aerobic or anaerobic conditions.

The Immobilized consortium of *Bacillus subtilis* , *Serratia marcescens* and *Enterobacter asburiae*has the potential to reduce the heavy metals , organic matter and chemical parameters from sugar mill effluent after treatment of six months. The biological oxygen demand(BOD) was 1090 mg/L before bioremediation process and after six month of biological treatment the BOD was 93 mg /L . the COD was 3260 mg/L before treatment and after six month of bioremediation process and 218 mg/L COD [6] .

The potential of cyanobacterial species in bioremediation of industrial effluents was observed and noticed that all four *cyanobacterial species: Oscillatoria species, Synechococcus sp., Nodularia sp. ,Nostoc sp., and Cyanothecesp* . were capable to degrade the contaminants from textile and pharmaceutical effluent .The pollutant reduction capability percentage of cyanobacterial species ranged between 69.5and 99.6 % [7] . Reference [8] conducted a study on the bioremediation of rubber processing industry wastewater by applying *Pseudomonas species*. They observed reduction in ammonia 71.3%, total solids 73% , BOD 72.1% , COD 79.4% and phosphate 68.8% after 15^{th} day of incubation.

The*Bacillus subtilis* and *Micrococcus luteus* are able to reduce BOD up to 87.2% of effluent generated from paper and pulp industry and an effective reduction in COD and lignin was observed [9] . *Pseudomonas putida* and *Acienetobactercalcoaceticus* have the potential to reduce COD up to 70-80% and are capable to degrade lignin content of pulp and Paper effluent [10] . The efficiency of soil microorganism for biological treatment of steel industrial wastewater was investigated and four microbial strains *Pseudomonas sps., Bacillus sps., Arthrobacter species* and *Micrococcus sps.*were isolated which were capable to reduce BOD and COD up to 95% [11] .

Bcterial strain*Pseudomonas flourescens* is capable fordecolourization of distillery effluent [12]. The carbon source is important factor for the decolourization of Melanoidins [13]. The Co- metabolism of microorganisms in the presence of abundant oxygen is responsible for the decolourization and degradation of Melanoidin polymers of distillery effluent. Refrence [14] isolated root associated rhizospheric bacterial communities of *Phragmites australis* grown on distillery effluent and they analysed 15 culturable bacterial species from rhizosphere soil of *P.*

australis by 16S rRNA gene sequencing.All the 15 bacteria were grown on post methanated distillery effulent by Chaturvedi et. al and a reduction in all the pollutants and BOD , COD was noticed . Approximately, 75.5 % colour reduction was observed. Microorganisms have the potential to remove the pollutants from wastewater.

A gram positive bacterial strain *Pseudomonas aeruginosa was* isolated from tannery effluent [15] . In the presence of excessive carbohydrate, *Pseudomonas aeruginosa* produces polyhydroxy butyrate (PHB). PHB is utilized by bacterium as an energy source. A maximum reduction (92.77%) of distillery spent wash was noticed when bacterium is used with a combination of PHB. While when treated separately then reduction was not as satisfactory as in combination.

Chromium contamination is a burning issue due to the high mobility and toxicity of Cr .It is present in the wastewater of leather tanning, textile, pigment and wood preservatives, metallurgical and metal finishing industries. *Bacillus cereus, B.subtilis , Pseudomonas flurorescens , E.coli, Achromobactereurydice, Desulfovibriodesulfuricans*and *D. vulgari*s are some bacterial strains which are studied by different researchers to analyse their CrO42 reduction potential. Three bacterial strains *Staphylococcus aureus , Pseudomonas aeruginosa and Escherichiacoli* were isolated from sludge of tannery industry and 60% biosorption of Cr can be achieved after biological treatment with these strains [16] .

1.2. Potential of fungal strains to degrade contaminants from industrial effluents -

Several fungal strains are capable to degrade and decolorize distillery waste water. The genera *Aspergillus* is attaracting the attention of researchers who are working on bioremediation of molasses based waste water [17]. Reference [18] reported potential to remove the colour from distillery effluent in a marine fungus, *Flavodon flavus* .But that fungus required high concentration of oxygen and sucrose. The fungal strain Aspergillus *fumigatus* is effective in decolourization of anaerobically treated distillery effulent [19]. The effective colour reduction is observed in diluted molasses distillery slop after the treatment with *Ganoderma lucidum* with addition of 2.5% glucose [20].The Pleurotus*sajor – caju*CCB020, a lignolytic fungus have the potential to biodegrade sugar cane vinasses. Approximately 82.8 % reduction in COD and 75.3% reduction in BOD and 99.2 % reduction in colour were observed [21] ..

Two fungal strains *Phanerochaetechrysosporium(* MTCC787)and *Trameteshirsuta(MTCC136)*were isolatedfrom soil and marine environment [22] . They applied these fungal strains for the bioremediation of paper and pulp industry effluent at laboratory scale andafter 21 days of biological treatment they obtained effective reduction in COD (chemical oxygen demand) that was 89.4% and colour reduction was 78.6%. The degradation of cellulose was observed throughout the study until the 15th day after which the degradation was stagnant.

*Phanerochaetesordida*is a species of wood-rotting fungus. The peroxidases are produced by the mycelium of *Phanerochaetesordida*which are capable to degrade 2, 3, 7, 8-TCDD/F [23]. The wastewater from tannery while treated with native fungus *Aspergillus niger* then 52-96 % reduction of toxic contaminants was obtained whereas non –native fungus *Aspergillus Flavus* was capable to reduce toxic substances upto 53-96% [24] . According to [24] that biologically treated water can be use for irrigation and aquacultural activities.

White rot fungi have extracellular enzymes like laccases and peroxidases and intracellular enzymes like cytochrome P450 system which make them effective biocatalyst to degrade a variety of xenobiotics. Reference [25] conducted an experiment to detect the ability of white rot- fungi to remove selected pharmaceuticals and toidentify degradation products of ibuprofen. They used four white rot fungi which were *Ganoderma lucidum* , *Phanerochaetechrysosporium* , *Irpexlacteus, Trametes versicolor* . They observed after 7 days of biological treatment at laboratory level that all the four fungi have ability to degrade ibuprofen while only *Trametes versicolor strain have the potential to degrade* clofibric(*91%) acid a*nd carbamazepine (58%). *Ganoderma lucidum is able to degrade* carbamazepine (47%) but could not degrade clofibric.

1.3. Role of algae in bioremediation of industrial effluent-

Microalgae are microscopic, unicellular and are capable of performing photosynthesis, they produces approximately half of the atmospheric oxygen and algae adsorbs greenhouse gas carbon dioxide to grow photoautotrophically. The use of microalgae for bioremediation is advantageous than bacteria and fungi because fungi and bacteria needs optimum conditions for growth and biological treatment process and nutrients while microalgae grow rapidly and algae has the ability to get energy and nutrients from contaminants like ammonium and nitrate phosphate[17] . Microalgae produces valuable products like ethanol, methane, livestock feed [26]. Algae have the potential to degrade contaminants from industrial effluent. Algae are a promising technology to promote environmentally sustainable effluent treatment, and carbon biosequestration; and it is a cost effective approach. It produces innovative products during the process of bioremediation like pigments, enzymes, sugars, and lipids).

The capability of *Spirogyra species* and *Oscillatoria species* for bioremediation of blue and red dyes were observed andnoticed that at pH 10 the adsorption by both species were maximum [27] . At pH 10, 78.29 % reduction in colour of blue dye was noticed after the bioremediation by *Spirogyra species*. *Oscillatoria species* have the potential to reduce the colour of blue dye up to 76.48% at pH 10. The*Spirogyra species* is more effective than *Oscillatoria species* for biodegradation and they concluded that both the algal species have the potential to remove blue and red dyes [27] .

The ability of microalgae to biodegrade effluent from textile industry was observed [28] and it was noticed in research that microalgae *Chlorella pyrenoidosa* , *Chlorella vulgaris* , *Oscillatoria tenuis* have the potential to degrade 30 azo dyes into simpler compounds [28] . They also observed that spent microalgae can be used to produce activated carbon and biochar.

The*Brevibacterium sp.* PDM-3 strain has the capability to degrade phenanthrene upto 93.92 % and can also degrade polyaromatic hydrocarbons like anthracene and fluorine [29]. Reference [40] observed that *Chlamydomonas reinhardtii*has the potential to degrade and adsorb prometryne which is an herbicide.

It was observed that *Scenedesmus quadricauda* , *Ankistrodesmusbraunii* are phenol resistant strains of green microalgae which have the capability to remove phenols upto 70 % from olive oil mill effluent after 5 days of treatment . These microalgae are efficient to remove phenols up to 50 % in dark and can be used in bioremediation of distillery wastewater [30] . It was observed that approximately , 54% decolourisation of spentwash can be achieved after 30 days treatment with *Oscillatoria boryana*[31][32].The colour of spent wash can be reduced up to 96% by *Oscillatoria* and 81% by *Lyngbya* strains . Maximum decolourisation of spent wash can be achieved with the use of consortium of *Lyngbya,Oscillatoria,Synechocystis*. *Oscillatoria boryana*BDV 92181 is a cynobacteria which utilizes melanoidins as carbon and nitrogen sources and able to decolourize melanoidin (0.1%w/v) up to 75% [31] . *Tetraselmis marina* is a microalga which has the capability to remove the mono-chloro phenols from the growth medium with higher efficiency as campared to p-chlorophenol. [33] . The most studied algal genra is *Chlorella* for the purpose of effluent treatment which has the potential to remove or degrade the pollutants. The waste water from ethanol and citric acid production is treated by *Chlorella vulgaris* and followed by *Lemnaminuscula treatment* .In first stage , 71.6% reduction in ammonium , 28 % reduction of phosphorus , 61% reduction in COD were noticed within 4 days [34] .

2. PHYTOREMEDIATION A SUSTAINABLE AND ECOFRIENDLY APPROACH TO SAVE BIORESOURCES

Phytoremediation is a bioremediation process that uses a variety of plants to remove, transfer, stabilize, or destroy pollutants in the soil and water sources. There are a number of advantages of phytoremediation as it is a ecofriendly and cost-effective technology. Natural plants and genetically modified plants have the potential to accumulate, adsorb and degrade pesticides,explosives, crude oil, and its derivatives, metals, solvents [35] . There are approximately 400 species from 45 plant families which can accumulate heavy metals 100 or 1000 times more than normal plants and therefore catogorize under hyperaccumulators [36] .

The potential of *Lemna minor*L wasanalyzedto degrade the textile effluent and observed that the 70% degradation can be achieved in the presence of sunlight in 20 days [37]. The absorption was maximum at 230 and 615 nm. The phytoremediation technology was studied for the effective removal of chromium from mines waste water. The*Eichhornia crassipes* was used forphytoremediation and 99.5 % reduction of Cr was noticed after 15 days of treatment. *Eichhornia crassipes* is capable to reduce biological oxygen demand (BOD) , chemical oxygen demand (COD) and TDS [38] .The ability of biosorption of toxic metals by *Cochlospermumgossypium* from industrial effluent was investigated . The maximum adsorption by *Cochlospermumgossypium* was noticed for Cd^{+2} (97%) and least biosorption was noticed for Zn^{+2} (34%). The ester ,amino , alcoholic , carbonyl , carboxylic , uronic , acetyl groups of biopolymer of *Cochlospermumgossypium* matrix interact with metal ions and forms complex compounds which is the reason of biosorption of metal ions by *Cochlospermumgossypium*[39] .

Leersiahexandraswartz is a perennial grass and it is a chromium rich plant. An experiment was conducted on industrial effluent to determine the metal adsorption capacity of Leersiahexandraswartz and effective results are obtained after treatment. A complete removal of chromium was observed and the reduction of nickel and copper was 89.3% and 93.8% respectively [40] .

The potential of *Typha domingensis*to accumulate heavy metals was studied .The samples of effluent were collected from industrial waste water pond El-Sadat city, Egypt and observed that the concentrations of Zn , Al, Fe, Pb were accumulated in roots of *Typha domingensis*[41] . The accumulation of metals in roots is common in aquatic plants [42] .

The phytoremediation of distillery waste water after bioremediation with microbial strain is an effective remedial measure. The bacterial strain Bacillus*thruringiensis (MTCC* 4714) bioremediation and plant species *Spirodelapolyrrhiza (*L.) Schliden for phytoremediation were used by [43] .A perennial herbaceous plant,Typha *angustifolia* is effective for the phytoremediation of waste water containing melanoidins, phenols and heavy metals. *Typha angustifolia* shows optimum tolerance for various heavy metals in the presence of phenols P(200- 400 mg /L) , melanoidin (3000 – 4000 Co – Pt) [44] .

Phytoremediation is cost effective, ecofriendly and aesthetic solution to remove heavy metals and toxic organic compounds from distillery waste.

3. ROLE OF TECHNOLOGY IN POLLUTION CONTROL

Many researchers are working on innovative and sustainable technologies which are boon for pollution control and environment. Dissolved Air Floatation (DAF) is an advanced technology and attaining attention of researchers and industrialists. DAF is used in SBR (Sequencing Batch Reactor) and MBBR (Moving Bed Biofilm Reactor) technologies as a clarifier. It is an effective and commonly used technology to reduce BOD, suspended Solids and fat from abattoir waste water. Reference [45] suggested that if flocculants and polymers were added in DAF then 32 – 90 % reduction in COD can be achieved. Some researchers suggested that electro coagulation (EC) technology is best option for the treatment of abattoir waste water [46].

Many researchers are also focusing their attention on the application of artificial intelligent to resolve the problem of pollution. MATLAB (Matrix Laboratory) is a ready to use software tool which is commonly used by environmentalists who are searching best solution to cope up with pollution. In beginning, the Artificial Intelligence technology was attaining attention to remove contaminants from waste water [47] but presently it is an emerging technology in the field of safe disposal of waste water and for characterisation of physico-chemical parameters. MLPNN (Multi-layer Perceptron Neural Network) and ANFIS (Adaptive Neuro fuzzy inference system) models are capable to provide accurate data of dye and copper removal efficiency by saw dust which was approximately similar to experimental results [48] . AI (Artificial Intelligence) while applied with conventional treatment methods then it is an innovative idea to reduce the contaminants from waste water and to keep an eye on ETPs (Effluent treatment Plant). The effective COD reduction was observed with reduced aeration period after using intelligent control system (ICS) with Sequencing batch biofilm reactor (SBBR) [49] . The fuzzy logic control systems (e.g. FNN and ANFIS) when used with biological wastewater treatment processes then better effluent quality can be achieved [50] [51] . Approximately 30% operation cost can be reduce after instalment of an ANFIS controller on a small scale WWTP to adjust aeration [52] . AI (Artificial Intelligence) is a best choice to use with ETPs of food processing industries for safe disposal of wastewater and to keep an eye on fluctuation of physicochemical parameters.

Genetically modified strains are not new phenomenon in the field of bioremediation but great success can be achieved if used with conventional effluent treatment plants. The Genetically modified strain was used to biodegrade 2, 4 –DNT and effective results were noticed [53]. The efficiency of genetically modified strain *Cupriavidusnecator*JMS34 to biodegrade PCBs and effective results were noticed [54] .

SBR (Sequencing Batch Reactor), MBBR (Moving Bed Biofilm Reactor), MBR (Membrane Bioreactor) are promising technologies in food processing effluent treatment while used with DAF. The efficiency of Advanced Oxidation Processes (AOPs) was observed to treat the dairy effluent [55] and an effective reduction of COD was noticed. As AOP is not a choice to degrade organic matter therefore AOPs are used with conventional effluent treatment technologies. It can be concluded that in the era of science and technology there is boom of pollution control technologies but there is need to choose the best technology on the basis of characterization of effluent. The amalgamation of conventional effluent treatment technologies with bioremediation and Artificial Intelligence can be a revolutionary step to achieve the sustainable treatment of waste water.

Microorganisms have a specific kind of mechanism to degrade or metabolize different kind of pollutants without producing any harmful chemical as a by-product. Therefore bioremediation is the best approach to sort out the problem of pollution caused by wastewater of different industries. It is a sustainable, eco-safe green technology to save bioresources. Moreover, the rate of degradation of pollutants can be enhanced by using bioremediation technology in amalgamation with conventional method of effluent treatment.

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