Bioremediation: A strategic alternative for treatment of textile effluent

[1]Patel Feni and [1]Marjadi Darshan
[1]Shree Ramkrishna Institute of Computer Education & Applied Science,Surat
Email: fenipatel.5349@gmail.com , darshworld@gmail.com

Abstract— **The textile industry, which is one of the largest consumers of water in the world, produces wastewater comprising various recalcitrant agents such as dyes, sizing agents and dying aids Strong colour of the textile waste water is the most serious problem of the textile waste effluent. The disposal of these wastes and their Dyes may significantly affect photosynthetic activity in aquatic habitat and damage to the environment. It is retards biological activity by reducing the light penetration and also causes metal toxicity to both aquatic and terrestrial life. It also leads to toxicity of fish and mammals and Major problem is that Dyes having higher stability under sunlight and resistance to microbial attack. Therefore, care should be taken when releasing these types of wastewater into the environment. For solving these now a Days novel approach based on bioremediation using bacteria is widely used. In which natural biota and the microbial consortia have been used and found that it is more effective. Bioremediation is the cost effective process and their end products are also non-hazardous. For these purpose mostly, bacterial culture was used widely.**

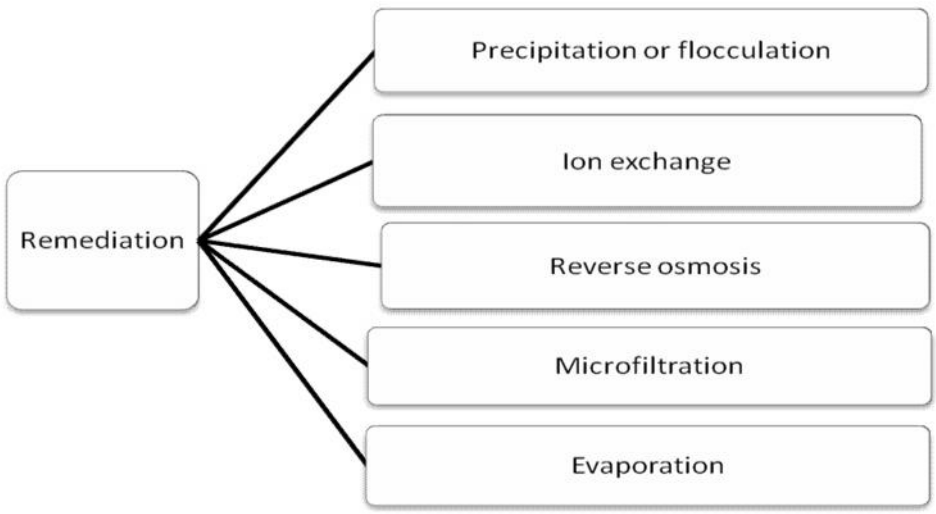
Keywords-Bioremediation; Dyes; Genetically modified organism's; Heavy metals; Pollution

I. INTRODUCTION

Bioremediation constitutes the use of natural biota and their processes for pollution reduction; it is a cost effective process and the end products are non-hazardous [1]. Bioremediation is an integrated management of polluted ecosystem where different microorganisms are employed which catalyze the natural processes in the polluted or in the contaminated aquatic or terrestrial ecosystem [2].Textile is one of the largest industries and results in water pollution contributed by untreated effluent discharge, which contains high concentrations of consumed metal based dyes, phenol, aromatic amines etc. The discharge of textile effluent alters the Biological Oxygen Demand (BOD), Chemical OxygenDemand (COD), Total Organic Carbon(TOC), suspended solids, salinity, colour, a wide range of pH (5–12) and the recalcitrance of organic compounds, suchas azo dyes and gives the rivers intense colouration [3].

Major problem in textile is that dyeing industry effluent alters the color and quality of the water bodies has been proved to be hazardous to aquatic ecosystem and it reduces the sunlight penetration which is essential for photosynthesis, it leads to toxicity of fish and mammals. They also inhibit the activity and growth of microorganisms [4]. Dyes having higher stability under sunlight and resistance to microbial attack and temperature were identified [5]. Many dyes were known as carcinogens, such as benzidine and other aromatic components all of which might be reformed as a result of microbial metabolism. It has been already well documented that azo and nitro-compounds were reduced in the sediment and intestinal environment, resulting in the regeneration of the parent toxic amines this compound was not readily removed by typical microbial based waste treatment processes. The highest rates of toxicity were observed for basic, diazo and direct dyes [6]. Decolorization and degradation of dyes by mixed as well as pure cultures of bacteria and fungi have been studied under aerobic and anaerobic conditions. In most studies, the microbial consortia have been used and found that more effective than pure cultures [7].

Figure 1. Conventional method approaches to reduce heavy metal contamination in water.



Conventional method having some disadvantages that chemical used to remediate heavy metal or dyes which is present in textile raw effluent, that Increased aquatic toxicity, Increased sludge production, Increased filamentous growth, Decreased sludge settle ability, Decreased sludge dewatering characteristics, Increased cost of treatment [8].

Due to the inherent drawbacks of physical, chemical and photochemical approaches to dye and metal removal, the use of biological methods for the treatment of textile wastewaters has received attention as a more cost effective alternative [9].

Bioremediation use the bacteria, fungi and enzymes to degrade environmental pollutants. Bioremediation is a natural process and is therefore perceived by the public as an acceptable waste treatment process for contaminated material such as soil or water. The residues after the treatment are usually harmless products and include carbon dioxide, water, and cell biomass. Theoretically, bioremediation is useful for the complete destruction of a wide variety of contaminants. This eliminates the chance of future liability associated with treatment and disposal of contaminated material. Instead of transferring contaminants from one environmental medium to another, for example, from land to water or air, the complete destruction of target pollutants is possible by using bacteria. This also eliminates the need to transport quantities of waste off site and the potential threats to human health and the environment that can arise during transportation. Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste [10].

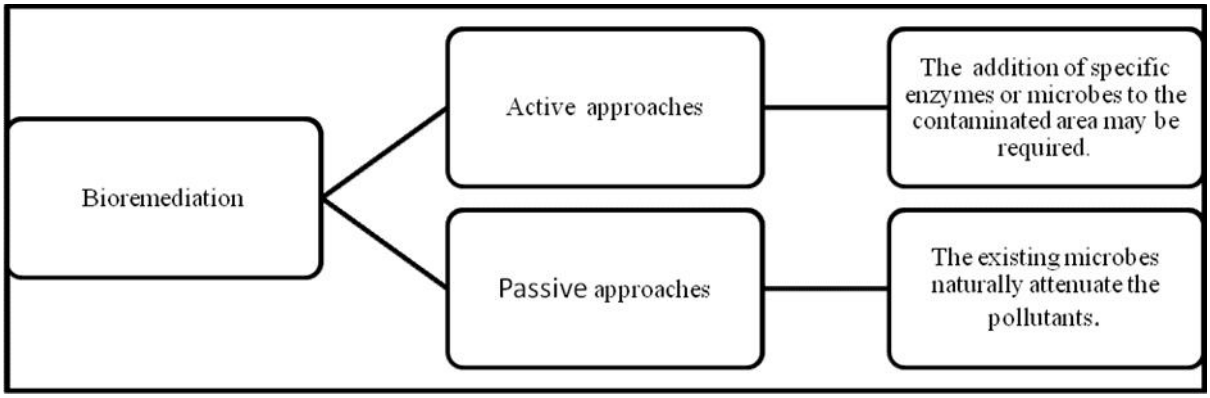
TABLE I. ENVIROMENTAL CONDITION AFFECTING MICROBIAL ACTIVITY

Parameters	Condition Required For Microbial Activity
Soil moisture	25–28% of water holding capacity
Soil Ph	5.5–8.8
Oxygen content	Aerobic, minimum air-filled pore space of 10%
Nutrient content	N and p for microbial growth
Temperature (°C)	15–45
Heavy metals	Total content 2000 ppm
Contaminants	Not too toxic
Type of soil	Low clay or silt content

II. MECHANISM OF BIOREMEDIATION

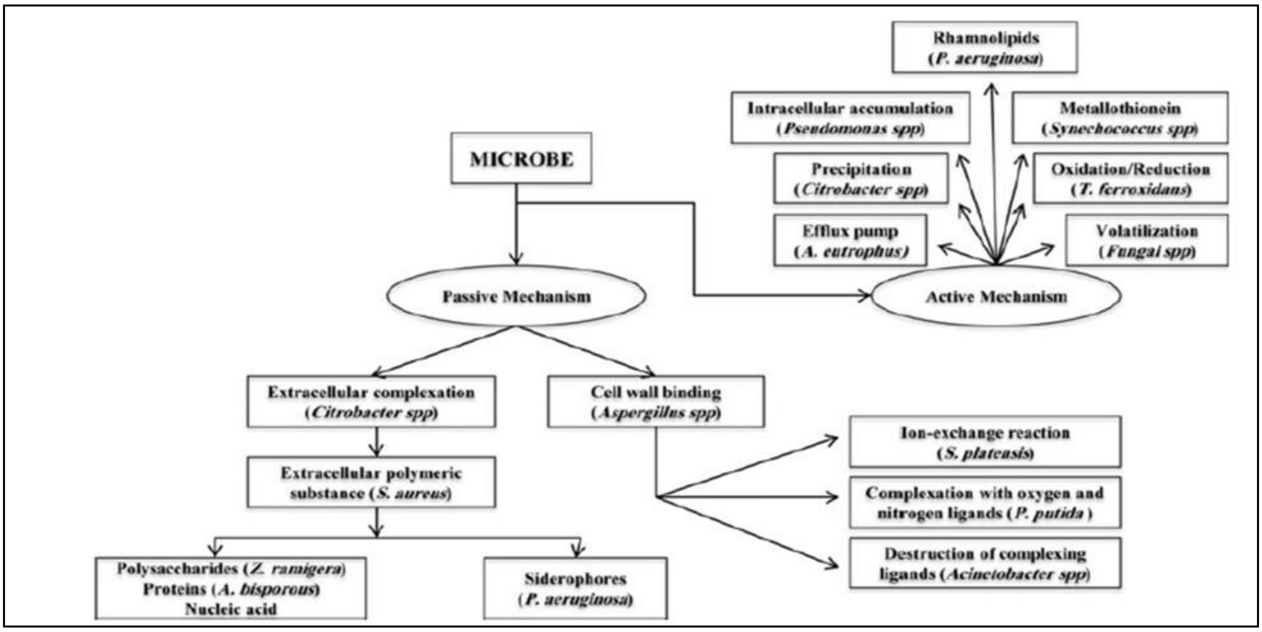
The mechanism by which metal ions bind to the cell surface include, electrostatic interaction, vanderwaals forces, redox interaction, extracellular precipitation, and combination process [11]. The negatively charge groups (carboxyl, hydroxyl, and phosphoryl) of the bacterial cell wall absorb metal cations, which are then retained by mineral nucleation [12]. Bacteria are responsible for the stabilization of wastes coming into a treatment plant. Many of these bacteria form floc particles or clusters of bacteria that break down waste. The floc particles also serve as sites on which waste can be absorbed and broken down later. In addition, filamentous bacteria form trichomes or filaments. These chains of bacteria provide a backbone for the floc particles, allowing the particles to grow in size and withstand the shearing action in the treatment process. When filamentous bacteria are present in excessive numbers or length, they often cause solid/liquid separation or settle ability problems. *B. cereus* performed well because they are nutritionally versatile and carries an efficient enzymatic system for the cleavage of azo bonds, which cause rapid decolourization of different azo dyes and thus they are able to biodegrade many natural and synthetic organic compounds. Azo dyes are the largest group of dyes. More than 3000 different varieties of azo dyes are extensively used in the textile, paper, food, cosmetics and pharmaceutical industries [13]. Azo dyes are characterized by the presence of one or more azo groups – N = N -, which are responsible for their colouration and when such a bond is broken the compound loses its colour. They are the largest and most versatile class of dye, but have structural properties that are not easily degradable under natural conditions and are not typically removed from water by conventional waste water system.

Figure 2. Approaches to reduce contamination in water.



Microbial decolouration can occur via biosorption, enzymatic degradation or a combination of both [14]. The uptake or accumulation of chemicals by microbial mass has been termed as biosorption. It was mainly taking place in the cell wall, where as the mechanism includes adsorption and absorption will differ according to the biomass type [15]. Biosorption mechanism for metal removal has been studied extensively using various species of live and inactivated biomass of bacteria, algae, fungi or yeast [16].

Figure 3. General Heavy metal sorption mechanism Operating in various microbes.

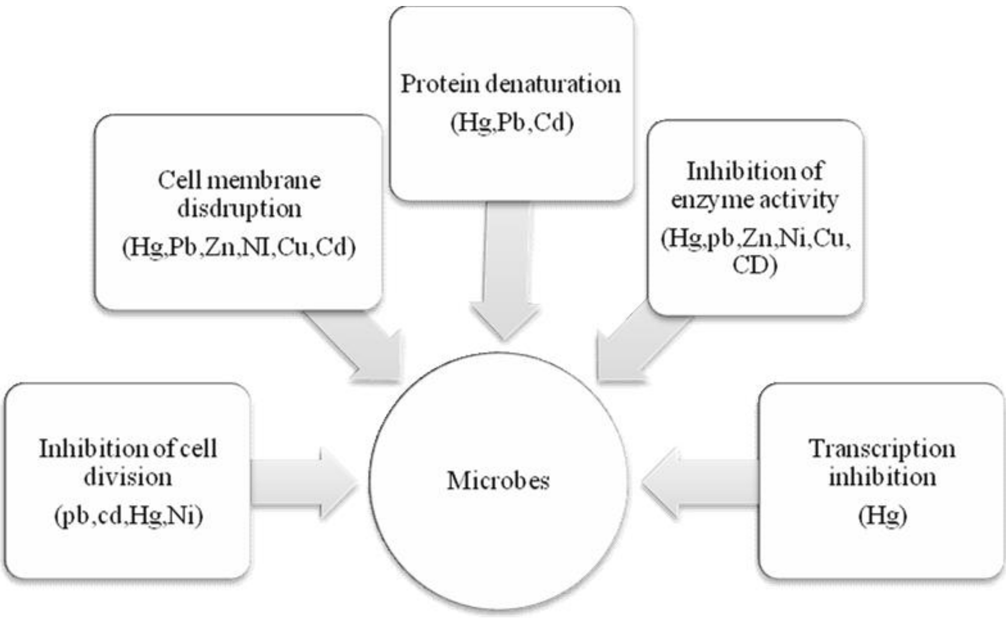


(after ,[8])

III. HEAVY METAL TOXICITY MECHANISM TO MICROBES

Organisms respond to heavy metal stress using different defense systems shown in fig.2 . Such as exclusion, compartmentalization, formation of complexes and synthesis of binding proteins, like phytochelatins (PCs).

Figure 4. Different defence systems of microbes to toxic metal .



IV. GENETIC ENGINEERING FOR METAL REMEDIATION

There are several developments in GEMs which overcome the limits of using wild type microbes. Microbes are confined to aerobic catabolic and co-metabolic pathways and therefore cannot be applied to anaerobic environment. GEMs are developed by inserting genes for oxygenases make it possible to use them in anaerobic environmental conditions. Application of GEMs based remediation of xenobiotics is in the fore front due to eco-friendly and human friendly approaches. Bioremediation using GEO is a relatively cheap, environmentally-friendly and socially acceptable technology which can eliminate waste permanently [17], [18].

Genetic engineering allows introduction of desired traits into cells to metal clean up techniques, and this approach has already been used to construct cells for the bioremediation of mercury. The recombinant *staphylococcus xylosus* and *staphylococcus carnosus* , had gained Ni^{2} and Cd^{2} binding capacity and suggested that they could be used in bioremediation of heavy metals [19]. *E. coli* strain that accumulated Ni^{2} by introducing the nixA gene from *helicobacter pylori* into *E. coli* JM 109 that expressed a glutathione S-transferase pea metallothioneine fusion protein [20]. The recombinant *Escherichia coli* strain accumulated four times more nikel than the wild type. Metal resistant R. eutropha isolate , engineered to produce metallothionein accumulated more Cd^{2} than its wild type and offered tobacco plants some protection form Cd^{2} when inoculated into contaminated soil [21]. Nickel (Ni) is possibly the most recalcitrant pollutant and can be accumulated by the GE *Escherichia coli* SE5000 strain from an aqueous solution [22]. Arsenic (As) is a very toxic metal which can be found in nature [23]. GM bacteria expressing the ArsR gene can promote the bioaccumulation of as when present in contaminated water [24].

V. BIOREMEDIATION THROUGH BIODEGRADATION

Waste water sample collected form the effluent treatment plant (ETP)of textile industries, from the printing and dyeing mills, or in some case Heavy metal solution prepared in laboratory and used as sample. This raw effluent was treated with different bacteria.

Bacteria were isolated directly from the textile raw effluent or from the soil at nearby areas of textile industry. Mostly bacteria that used for study is *Bacillus cereus*, *Bacillus subtilis* [25], *Escherichia coli* [26], *Pseudomonas aeruginosa* [27]. Dye degrading isolates were identified on the basis of morphological and biochemical tests according to Bergey's Manual of Systematic Bacteriology [28].

Dyes and heavy metal: Reactive azo dyes used in some research are, Reactive Orange – M2R (m = 493 nm), Reactive Blue – M58 (m= 572 nm), Reactive Yellow – M4G (m = 413 nm) and Reactive Black - B (m = 574 nm) [26]. In some, Crystal violet (λ_{max}523 nm) [25] , in some , Cr(VI) bioremediation [27] and in some article , reactive torquoise blue, disperse yellow, reactive orange H3R, cibacron red P4B and cibacron black PSG dyes are used for experiment.

TABLE II. OTHER MICROORGANISM THAT ARE UASED FOR BIOREMEDIATION

Microorganism and Source	**Process, Conditions and Enzymes**	**Effluent, % Colour, COD, BOD removal, Toxicity**	**References**
Bacillus cereus isolated from site dye Contaminated	Adsorption and degradation; 30 ◦C, Lac, azoreductase	Real textile effluent, 100% colour	[29]
Escherichia coli and *Legionella sp.*	Degradation	Textile wastewater, 86% COD, 92% TOC	[30]
Candida tropicalis	Adsorption and degradation; room temperature	Textile wastewater, 100% colour, 70% COD, 76% BOD	[31]
Consortium of Pseudomonas sp. and Aspergillus ochraceus	Adsorption and degradation	Effluent containing reactive and disperse textile dyes, 77% colour	[29]
Consortium of *Pseudomonas sp.* and *Pseudomonas sp.*	Degradation; pH 7, 30 ◦C, 48 h; Lac, azoreductase	Effluent with reactive azo dyes, 100% colour, 78% COD, 80% BOD. Reducing toxicity at least 30%	[32]
Sludge from a treatment plant	Adsorption and degradation; 25 ◦C, pH 2–11	Effluents containing Reactive Red 120, 99% colour> 88%COD	[33]
Aspergillusfumigatus isolated from mildewing rice straw	Degradation; pH 3, 150 rpm, 30 ◦C, 72 h	Effluents of a printworks utilizing reactive textile dyes, 100% colour	[34]

VI. CONCLUSION AND DISCCUSION

Several researchers have demonstrated the possibility of utilizing micro-organisms for biotreatment of textile wastewater. Microbiological methods are quite simple to use and the cost of operation is low. South Asian countries are experiencing severe environmental problems due to rapid industrialisation. This phenomenon is very common where the polluting industries such as textile dyeing, leather tanning, paper and pulp processing, and sugar manufacturing thrive as clusters. Among these the textile industries are large industrial consumers of waters as well as producers of wastewater [35].

Various parameter like, the pH of the effluent alters the physico-chemical properties of water which in turn adversely affects the aquatic life, plant and humans. High temperature decreases the solubility of gases in water, which is ultimately expressed as high BOD/ COD. Sediment rate is drastically increased because of the high value of TDS, which reduces light penetration into water, and ultimately decreases photosynthesis. The decrease in photosynthetic rate reduces the dissolved oxygen level of wastewater, which results in decreased purification of wastewater by micro-organisms [36]. High chloride contents are harmful for agricultural crops [37].

The isolation of different micro-organisms from the effluent sample collected from the textile industries indicates natural adaptation of micro-organisms to survive in the presence of toxic chemicals and dyes. A strain of bacterium *Bacillus subtilis* ETL-2211 with strong decolourising ability was isolated from textile effluent to decolourise the textile azo dye Crystal violet (100 mg L^{-1}) within 24 h in aerobic and static conditions. Some study indicated that bacterial species *Bacillus cereus* isolated from the dyewaste effluents have potential to decolourize dyes to varying degrees. Bacterial capable of dye decolourization have been reported.

Like dyes reactive torquoise blue, disperse yellow, reactive orange H3R, cibacron red P4B and cibacron black PSG in which degree of decolorization is obtained 65.33, 88.33, 35, 23, 32% respectively by *Bacillus cereus* [38]. *Pseudomonas sp.* show the capacity to the maximum metal removal by 80.16% at 10 mg/l of Cr (VI) through after 72 hours and remove 78% at 25 mg/l of Cr (VI) [39]. Decolourization of azo dye Reactive Yellow – M4G by *Escherichia coli* was 20%.Decolourization of azo dye Reactive Black - B by *Escherichia coli* was 30%, Decolourization of Reactive Blue - MR by *Escherichia coli* was 60% [26].

A Recombinant DNA and RNA technology is a promising method for the preparation of genetically modified organism able to combat environmental pollutants for successful bioremediation [40]. Genetically engineered microbes are an advanced technology that has attracted public attention when employed in cleaning up toxic waste and heavy metals from contaminated sites [41], [42]. DNA shuffling is a powerful mutagenesis technique that can create new enzymetic activity [43] and Bio-catalysts with higher degradation rates for heavy metals [44].

REFERENCES

[1] Ahmedna, M., W.F. Marshall, A.A. Husseiny, R.M. Rao and Goktepe , "The use of nutshell carbons in drinking water filters for removal of trace metals", *Water Res*., vol.38(4), pp.1064-1068, 2004.

[2] ISKANDAR, I.K. AND ADRIANO, D.C., "Remediation of soils contaminated with metals-A review of current practices in the USA", In: Remediation of soils contaminated with metals (eds. A. Iskandar and D.C. Adriano), Science Reviews, Northwood, UK, pp. 1-16, 1997.

[3] Savin II, Butnaru R.,"Wastewater characteristics in textile finishing mills", EnvironEng Manage J, vol.7, pp. 859–64, 2008.

[4] P. Rajendran, P. Gunasekaran, MJP Publishers, pp. 138-159, 2006.

[5] K. Schliephake, D.E. MainwarinG, G.T. Lonergan, I.K. Jones, W.I. Baker Enzyme MicrobTechnol, vol. 27, pp. 100-107, 2000.

[6] Chang, JO-Shu Chou, Chien, Chen, Shan-Yu, Process Biochem, vol. 36, pp.757-763, 2001.

[7] R.C. Kuhad, N. Sood, K.K. Tripathi, A. Singh, O.P. Ward, AdvApplMicrobiol , vol. 56, pp. 185-213,2004.

[8] P. Rajendran,j muthukrishnan & P. Gunasekaran, "microbes in heavy metal remediation", Indian journal of experimental biology, vol.41, pp. 935-944,2003.

[9] Olukanni OD, Osuntoki AA, Gbenle GO, "Textile effluent biodegradation potentials of textile effluent-adapted and non-adapted bacteria", Afr J Biotechnol, vol. 5, pp. 1980, 2006.

[10] Vidali, M., "Bioremediation An overview", Pure Appl. Chem., Vol. 73, No.7, pp. 1163- 1172, 2001.

[11] wase J and forsterC, "inbiosorbents for metals ions", Bristol , vol. 1, 1997.

[12] Blanco A., "immobilization of nonviable cynobacteria and their use for heavy metal adsorption from water in environmental biotechnology & cleaner bioprocesses", edited by oluguinEJ .sanchez E (Philadelphia, taylor& AMP. francis), pp. 135, 2000.

[13] Maximo, C., M.T.P. Amorim and M. Costa Ferreira, " Biotransformation of industrial reactive azo dye by Geotrichum sp." Enzyme and Microbial Technology, vol. 32, pp.145-151, 2003.

[14] Wu Y, Li T, Yang L. "Mechanisms of removing pollutants from aqueous solutionsby microorganisms and their aggregates: a review", BioresourTechnol, vol. 107, pp. 10–8, 2012.

[15] N. Ali, L.G. Ikramullah, A. Hameed, S. Ahmed, World J Microbiol Biotechnol, vol. 24, pp. 1099-1105, 2008.

[16] Vasudevan P, padmavathyV,tewari N &dhingra SC , "Biosorption of heavy metal ions", J sci Indus res, pp. 60 -120, 2001.

[17] Eapen S, Singh S, D'Souza S, "Advances in development of transgenic plants for remediation of xenobiotic pollutants", Biotechnol Adv, vol. 25, pp. 442–451 , 2007.

[18] Doty SL, "Enhancing phytoremediation through the use of transgenics and endophytes", New Phytol, vol. 179, pp. 318–333, 2008.

[19] Patel J, Zhang Q, Michael R *et al*, "Genetic engineering of Caulobacter crescentus for removal of cadmium from water", Appl Biochem Biotechnol, vol. 160, pp. 232–243, 2010.

[20] Zhao XW, Zhou MH, Li QB *et al*, "Simultaneous mercury bioaccumulation and cell propagation by genetically engineered Escherichia coli", Process Biochem, vol. 40, pp. 1611–1616, 2005.

[21] Kiyono M, Pan-Hou H , "Genetic engineering of bacteria for environmental remediation of mercury" , J Health Sci, vol. 52, pp. 199–204, 2006.

[22] Fulkerson JF, Garner RM, Mobley HLT , "Conserved residues and motifs in the nixA protein of Helicobacter pylori are critical for the high affinity transport of nickel ions", J Biol Chem, vol. 273, pp. 235–241, 1998.

[23] Jackson BP, Seaman JC, Bertsch PM, " Fate of arsenic compounds in poultry litter upon land application", Chemosphere, vol. 65, pp. 2028–2034, 2006.

[24] Kostal JRY, Wu CH, Mulchandani A *et al*, "Enhanced arsenic accumulation in engineered bacterial cells expressing ArsR", Appl Environ Microbiol, vol. 70, pp. 4582–4587, 2004.

[25] Shah MP, Patel KA, Nair SS, Darji AM, "Potential Effect of Two Bacillus spp on Decolorization of Azo dye", J Bioremed Biodeg, vol. 4, pp. 199, 2013.

[26] N. Sriram, D. Reetha and P. Saranraj , "Biological Degradation of Reactive Dyes by Using Bacteria Isolated from Dye Effluent Contaminated Soil", Middle-East Journal of Scientific Research, vol. 17 (12), pp. 1695-1700, 2013.

[27] Deepali , "Bioremediation of Chromium (Vi) from Textile Industry's Effluent and Contaminated Soil Using *Pseudomonas putida"* , Iranica Journal of Energy & Environment, vol. 2 (1), pp. 24-31, 2011.

[28] Sneath PHA, Mair NS, Sharpe ME, Holf JG, "Bergey's Manual of Systematic Bacteriology", Williams and Wilkins, Baltimore, USA., 1984.

[29] Kadam AA, Telke AA, Jagtap SS, Govindwar SP., "Decolorization of adsorbed textile dyes by developed consortium of Pseudomonas sp. SUK1 and Aspergillus ochraceus NCIM-1146 under solid state fermentation", J Hazard Mater, vol. 189, pp. 486–94, 2011.

[30] Cao Y, Hu Y, Sun J, Hou B., " Explore various co-substrates for simultaneous electricity generation and Congo red degradation in air-cathode single-chamber microbial fuel cell", Bioelectrochemistry , vol. 79, pp. 71–6, 2010.

[31] Charumathi D, Das N., " Packed bed column studies for the removal of synthetic dyes from textile wastewater using immobilised dead C. tropicalis", Desalination, vol. 285, pp. 22–30, 2012.

[32] Jadhav JP, Kalyani DC, Telke AA, Phugare SS, Govindwar SP., "Evaluation of the efficacy of a bacterial consortium for the removal of color, reduction of heavy metals and toxicity from textile dye effluent", BioresourTechnol, vol. 101, pp. 165–73, 2010.

[33] Klepacz SA, Ledakowicz SJ, Pazdzior K, Ledakowicz S., "Application of anoxic fixed film and aerobic CSTR bioreactor in treatment of nanofiltration concentrte of real textile wastewater", Chem Papers, vol. 64, pp. 230–6, 2010.

[34] Jin XC, Liu GQ, Xu ZH, Tao WY., "Decolorization of a dye industry effluent by Aspergillus fumigates XC6", Appl Microbiol Biotechnol, vol.74, pp. 239–43, 2007.

[35] Tyagi OD, Mehra M., "A textbook of environmental chemistry", New Delhi, India: Anmol Publications., 1990.

[36] Kim HT, " Soil reaction. In: Environmental soil science", USA: Marcel Dekker Inc., pp. 149, 1994.

[37] Coughlin MF, Kinkle BK, Tepper A, Bishop PL., "Characterization of aerobic azo dye degrading bacteria and their activity in biofilms", Water Sci Technol, vol. 36, pp. 215–20, 1997.

[38] Ola, I. O.1,2*, Akintokun, A. K.1, Akpan, I.1, Omomowo, I. O.1 and Areo, V. O.1., "Aerobic decolourization of two reactive azo dyes under varying carbon and nitrogen source by *Bacillus cereus"*, African Journal of Biotechnology, Vol. 9(5), pp. 672-677, 2010.

[39] Sethuraman, P. and N. Balasubramanian,, " Removal of Cr(VI) from aqueous solution using Bacillus subtilis, Pseudomonas aeruginosa and Enterobacter cloacae", Intl. J. Engineering Sci. Technol., vol. 2(6): pp. 1811-1825, 2010.

[40] Lovley DR, "Cleaning up with genomics: applying molecular biology to bioremediation", Nature Rev/Microbiol, vol. 1, pp. 35–44, 2010.

[41] Shukla KP, Singh NK, Sharma S, "Bioremediation: developments, current practices and perspective", Genet Eng Biotechnol J, vol. 3, pp. 1–20, 2010.

[42] Liu S, Zhang F, Chen J *et al* , "Arsenic removal from con taminated soil via biovolatilization by genetically engineered bacteria under laboratory conditions", J Environ Sci, vol. 23, pp. 1544–1550, 2011.

[43] Stemmer WPC, " Rapid evolution of a protein in vitro by DNA shuffling", Nature 370, pp. 389–391, 1994.

[44] Canada KA, Iwashita S, Shim H et al, "Directed evolution Of toluene ortho-monooxygenase for enhanced 1-naphthol synthesis and chlorinated ethene degradation", J Bacteriol, vol. 184, pp. 344–349, 2002.