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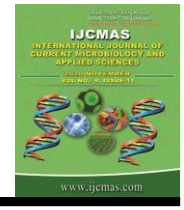

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Bioremediation of Textile and Tannery Effluents – An Overview

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Water is considered to be one of the essential resources for the survival of living beings. The vital resource is exposed to toxic pollutant due to the untreated industrial discharge from tannery, textile and other industries. Effluents discharged from the tannery and textile industries contains an ample of heavy metals and other toxic azo dyes which affects the living beings including aquatic and terrestrial flora and fauna. The removal of this toxic compounds from the water bodies has become a challenge to the human society. Various treatments are used for the removal of these toxic compounds but due to its undesirable features such as partial removal, higher maintenance cost these methods are considered as ineffective process. Microbes remain as a promising candidate in bioremediation which effectively degrade the xenobiotic component such as hexavalent chromium and toxic azo dyes completely from the environmental bodies. This review concentrates on the tannery and textile effluents and the general treatment methods used for the remediation of the effluents from these sectors.

Introduction

Environmental pollution is the major problem caused by the anthropogenic activities where, human pollute the biological system in several ways. Evolution of various types of industries contributes significant growth economically to the country on the other hand, these industries release ample of waste into the environment in the form of liquid and solid matter. Among various industries, tanneries and textile industries play a vital role in the discharging large amount of waste in the form of effluent. The waste material of these industries includes organic and inorganic constituents, which are highly toxic, carcinogenic and mutagenic in nature. This industrial discharge disturbs the aquatic system which deteriorations the eminence of the aquatic bodies. These wastes contain more amounts of heavy metals and complex azo dyes thus greatly affect the physic-chemical properties of soil and water. Due to adverse environmental impacts the effluents released from tanneries and textile industries are given much importance during treatment process. Removal of waste from effluents is considered to be an essential process before letting out the effluent. Common issues arouse due to the improper sewage treatment and its disposal into the environment includes soil and water pollution, diseases, obnoxious odour, fire hazards etc., (Sarker *et al.,* 2013). Various physical and chemical methods were introduced for the removal of the xenobiotic components from the industrial effluents. Adsorption, membrane filtration, ion exchange, and chemical reduction are some of the methods used for the cleaning up the industrial discharge. Due to high-cost instrumental set up, less efficiency and complicated operational procedures these techniques were found to be inefficient methods. The environment gets highly polluted through increased population, industrialization and various undesirable activities. Though, many techniques are available for the removal and/or recovery of xenobiotics from the tannery and textile effluents, none of the method showed complete removal of these foreign substance from the effluents. This complexity urges the industries to design and construct an effective treatment method for the removal of the xenobiotics. To overcome these complications, a novel technique was introduced, which encompasses microorganism either the contribution of individual organism or as a consortium. Since this method involves living organism it is referred as Biological treatment method. This microbial treatment was found to be efficient with low-cost substrate and easy and faster degradation of heavy metals and other carcinogenic dyes present in the effluent. Microbes like Algae, fungi, and bacteria were highly studied in the removal of toxic materials from the runoff.

Tannery and its major pollutants

Tanning

Tanning is one of the ancient processes involved in the leather tanning industries. In this process, the animal products are protected from decomposing and transferred into usable products. India holds third place in leather production and export. Leather industries are considered to be one of the greatest contributors to economy of leather. More than 3000 tanneries are installed in the various parts of the countries which broadly includes Tamilnadu, West Bengal, Uttar Pradesh, Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Punjab (Chaudhary *et al.,* 2017). Vast disposal of the effluents from the tannery industries converted the agricultural land to infertile field (Mohan and Devi, 2015). The waste disposed from the tannery depends upon the leather process taking place in the tannery. These effluents normally contain abundant amount of chromium, sulfates, acids, dyes, ammonium, oils and other organic substances (Hasegawa *et al.,* 2011).

Chromium

Chromium (Cr) is a lustrous and hard chemical element. Due to its hardness and stability chromium takes an important role in many processing industries despite its toxicity (Panda and Sarkar, 2012). Cr salt is highly used in the tannery industries in processing the animal products after reaction, the Cr salt is converted into two different forms namely trivalent (III) and hexavalent chromium (VI). The toxicity of the former is very lesser when compared with the later form. Hexavalent chromium (Cr (VI)) is reported to be one of the toxic metals which has the ability to dissolve in the water and penetrate into the living cells and get interconnected with the essential cellular molecules such as proteins and nucleic acids (Samrithi and Usha, 2012). It is also stated that, when these toxic meals get in contact with human beings it results in various toxic effects in human system. Respiratory disorders such as itching, irritation, swelling, allergies are some of the respiratory disorders that occurs due to the Cr(VI) exposure. Lung cancer, renal disorder, epidermal disorders are some of the adverse effects of Cr(VI) exposure. Apart from these cellular toxicities, the impact of Cr on DNA was reported where the toxicity affects the gene and cause mutation (Farag and Zaki, 2010; Samrithi and Usha, 2012).

Sulfides

Sulfides are inorganic anions of sulfides; these inorganic substances are abundantly found in the tannery effluents. Exposure to these compounds in low concentration causes dizziness, tired, headache and it also leads to disorder in the central nervous system. Whereas, exposure to sulfides in higher concentration leads to the death. The higher concentration of Sulfide for human consumption is 250 mg/L and lower concentration was determined as 0.025 and 0.25 µg/L in clean potable water (Midha and Dey, 2008; Balasubramanian and Pugalenthi, 2000).

Other tannery pollutants

Apart from these major tannery pollutants, there are many pollutants which are reported to be a part in the tannery effluent. Azo dyes, cadmium, cobalt, copper, selenium, mercury, arsenic, lead are few heavy metals present in the tannery effluents. These metals are reported to cause severe and adverse effects to human beings when exposed to larger time. Few are generally considered as beneficially metal which enhances the growth of terrestrial and aquatic plants. On the other hand, presence of these beneficially metals like copper in higher concentration turn as toxic metals which inhibits the regular growth of plant. But other metals such as lead, arsenic, cadmium are considered to be toxic element for both plants and animals. Cadmium which is not an essential element when present in the soil with varying pH acts as a toxic metal and hinders the growth of animals and plants. These metals are also responsible for bone disorder when it gets in contact with the human and animals in water as contaminant.

Textile effluents and its contaminants

Colorants are elements that are capable of transmitting its nature to the compounding substance. Generally, these colorants are highly used in industries such as textile, tannery, paint, cosmetics, food, pharmaceutic industries. These compounds are normally used alone as a coloring agent or combined with the intensifiers which enhances the color of the dye. Colorants are generally used for enhancing the visual characterization of the compound which in turn plays an essential role in determining the value of the compound in the global market. In general, colorants are classified into two major categories i.e., Natural colorant and synthetic colorant. Natural colorants are pigments extracted from natural sources such as plants and animals. Synthetic colorants are coloring substances manufactured chemically in the laboratories or in industries with low-cost products. Azo dyes are the major cheap colorant used for coloring the materials. These dyes are generally considered as synthetic dyes that act as a substitute for natural dyes due to its cost, synthesis and processing time. Apart from vast advantages like stability, intensity, durability these azo dyes possess negative role in the environmental aspect. Due to the presence of strong azo bond in it these dyes are extremely hard for dissociating in the environmental conditions. Thus, these compounds when discharged in the effluent remains in the soil and the aquatic bodies as such and create adverse effects to the aquatic and terrestrial living organisms. Accumulation of azo dye in the environmental bodies makes them unfit for the regular activities such as irrigation, consumption and domestic usage.

Dyeing

Dyes in textile and other coloring industries use synthetic colorants due to its easy and low-cost availability. These are generally derived from coal tar and petroleum-based intermediates. These dyes basically called as chromophores and they contain electrons responsible for intensifying the color called auxochromes. Chromophores are generally, azo (-NON-), carbonyl (-COO), methine, carboxy (-COO)group. The chemical structure and common name of the azo dyes are listed in the table 1. These azo dyes are classified into various types based on the azo linkage present in the chemical structure namely monoazo (Z-N=N-W), diazo (-N=N-), trisazo, polyazo, and azoic. These dyes are the major synthetic chromatic substance which are used in several dyeing industries.

Table.1 Structure and common name of few azo dyes

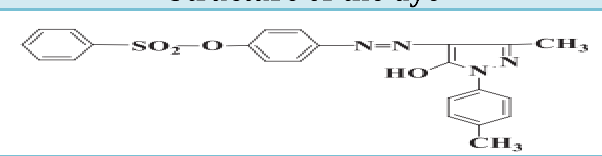
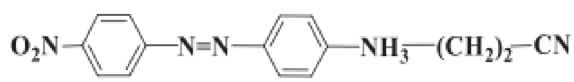
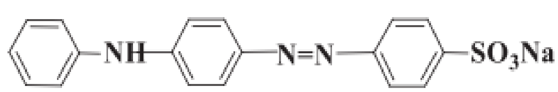
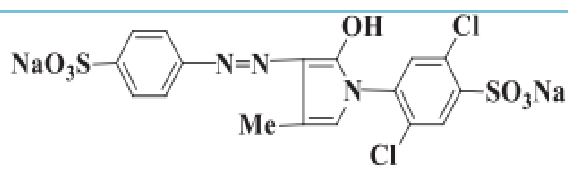
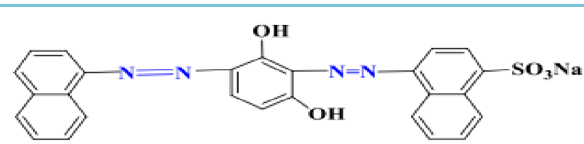
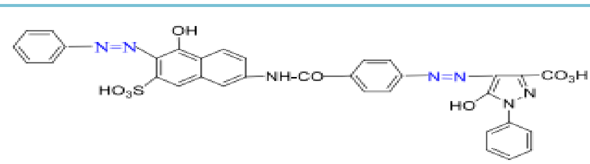
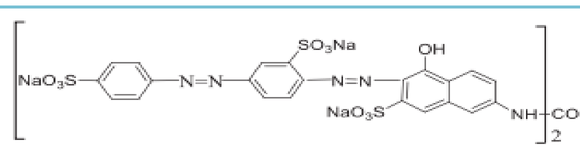
S.No	Structure of the dye	Name of the dye
1.		Yellow basic dye
2.		Orange dye
3.		Orange IV
4.		Yellow dye
5.		Brown dye
6.		Orange direct dye
7.		Direct red dye

Table.2 Decolorization of Synthetic Dyes by Bacterial Consortium

Sl. No	Consortium	Microbial Composition	Dye	Reference
1	HM-4	*Bacillus cereus* BN-7 *Pseudomonas putida* BN-4 *Pseudomonas fluorescens* BN-5 *Stenotrophomonas acidaminiphilia* BN-3	Acid Red-88 Acid Red-119 Reactive Red-120 Acid Blue-113 Acid Brown-100	Khehra *et al.*, (2005)
2	JW-2	*Paenibacillus polymyxa* *Micrococcus luteus* *Micrococcus* sp.	Reactive Violet 5R	Moosvi *et al.*, (2007)
6	GR	*Proteus vulgaris* *Micrococcus glutamicus*	Scarlet R	Saratale *et al.*, (2009)
7	SDM	*Providencia* sp. SDS *Pseudomonas aeruginosa* BCH	Red HE3B	Phugare *et al.*, (2011)
8	PVN-5	Unknown	Direct Red 28 Direct Blue 8	Hemapriya and Vijayanand. (2013)
8	TVU-AO64	Halophilic bacterial consortium	Acid orange	Vijayanand *et al.*, (2017)

Table.3 Dye Decolorization by Pure Cultures of Gram +ve Bacterial Isolates

Bacteria	Dye	Reference
Bacillus gordonae	Tectilon Blue 4R-01	Walker and Weatherley (2000)
Clostridium perfringens	Bromophenol Blue	Kim *et al.*, (2002)
***Kerstersia* sp. strain VKY_1**	Sulphonated dye	Vijaykumar *et al.*, (2007)
Bacillus firmus	Mono azo dye	Arora *et al.*, (2007)
***Bacillus cereus* strain DCII**	Anthraquinone dye	Deng *et al.*, (2008)
***Bacillus subtilis* HM**	Fast Red	Mabrouk and Yusef (2008)
Bacillus thuringiensis	Acid Red-119	Dave and Dave (2009)
***Bacillus* sp. TVU-M4**	Methyl Orange	Shyamala *et al.*, (2014)

Table.4 Dye Decolorization by Pure Cultures of Gram -ve Bacterial Isolates

Bacteria	Dye	Reference
Xenophilus azovorans	Carboxy Orange II	Blumel *et al.*, (2002)
Aeromonas hydrophilia	Acid Orange-7, Acid Red-106	Chen *et al.*, (2003)
Escherichia coli	Reactive Red-21	Chang *et al.*, (2004)
***Kocuria rosea* MTCC 1532**	Malachite Green	Parshetti *et al.*, (2006)
Pseudomonas desmolyticum	Direct Blue-6	Kalme *et al.*, (2007)
Vibrio harveyi	Acid Black-210	Ozdemir *et al.*, (2008)
***Pseudomonas* sp. SUK-1**	Reactive Red-22	Kalyani *et al.*, (2009)
***Klebsiella* sp.**	Orange 3R	Ponraj *et al.*, (2011)
***Enterobacter* sp. VP-64**	Crystal violet	Hemapriya and Vijayanand (2014)
***Escherichia coli* AK-12**	Evan's blue	Aswinkumar *et al.*, (2017)

Treatment methods used in bioremediation of the effluents

Treating the effluents from the waste water industries involved the three different methods namely physical, chemical and biological treatment methods. Sometimes, a combination of two methods is used for the treatment procedure

Physio-chemical treatment methods

Physical methods involved the usage of physical features such as coagulation (Sengil *et al.*, 2009), sedimentation (Song *et al.*, 2000), filtration (Tiglyene *et al.*, 2008), flotation (Murugananthan *et al.*, 2004), precipitation, adsorption (Physical, chemical and ionic) (Kabir and Ogbeide, 2009). Tannery waste are treated using a noval approach called as electrochemical oxidation process in which the effluent treated with two systems such as electrolytic and physicochemical systems (El-Sheikh *et al.*, 2011).

A newer approach was initiated which includes nanoparticle adsorption and magnetic separation of Cr from the waste water. A research study carried out by Jing *et al.*, 2005proved that the removal of chromium from tannery waste is possible by use of maghemite nanoparticles. When using maghemite as adsorbent, maximum adsorption of Cr was achieved at pH 2.5. Using Hydrogen peroxide (H_2O_2), hypochlorites of calcium and sodium aids in the recovery of chromium from the tannery effluents. Hydrogen peroxide showed a remarkable chromium recovery from the waste water. Nearly 98% of the chromium can be recovered and re-used. Due to these agents, the oxidation of chromium(III) to chromium(VI) can be reduced greatly and make a reduction in environmental pollution (Ali awan *et al.*, 2003).

Biological methods of effluent treatment

Biological method of effluent treatment is an important as easy procedure where, the treatment process is carried out using biological substance such as microorganisms which widely included bacteria and fungi. It is considered to be the most advantageous process with less undesirable features when compared with the other techniques. Remediation process is carried out by microbes using two different mechanisms namely aerobic and anaerobic methods. Bioremediation is one of the famous methods for the treatment of tannery waste. It has been implemented successfully in many countries. Biological treatment methods are cost effective than physico – chemical methods. Numerous microorganisms possess the capability of breaking of these pollutants to obtain energy and nutrients for their growth (Metcalf and Eddy, 2003). Biological methods of textile effluent treatment are mediated by both bacterial consortium (Table 1) and pure cultures of bacterial isolates (gram positive and gram negative) (Table 2 and 3).

Most of the microorganisms are capable of reducing the hexavalent chromium [Cr(VI)] to trivalent chromium [Cr (III)]. So, Bioremediation plays an essential role in the removal of toxicity from Cr(VI). Certain MOs (Example: Pseudomonas sp) possess an enzyme called "chromium reduction" thus actively reduces Cr (VI) to Cr (III) (Arellano *et al.*, 2004; Middleton *et al.*, 2003)**.** Sarker *et al.*, (2013) revealed that certain microorganisms like bacteria, possess the ability of reducing Cr(VI) to Cr(III) either in the presence or absence of oxygen. Those organisms are referred as chromium reducing bacteria [CRB]. Anaerobic process employs anerobic bacteria which grows in the absence of oxygen that generally requires prolonged time for remediation process. This feature remains as a disadvantage of the anaerobic process. The treatment system also gives a bad odor during reaction time. On the other hand, aerobic treatment is carried out using aerobic bacteria which requires oxygen for their steady growth. This treatment process is considered to be an effective process when compared with anaerobic treatment.

Activated sludge treatment is highly used for bioremediation using biological method. But this method is been considered as one of the expensive process both operational and maintenance wise (Midha and Dey, 2008). In general, tannery and other industrial effluents are reported for its degradation and remediation using microorganism. Several organisms such as Bacillus sp., Pseudomonas sp., E. coli, Flavobacterium sp., are reported for its efficacy in degrading the complex metals and other xenobiotics present in the effluent.

In conclusion the bioremediation has become a topic of interest to researchers all over the world due to its ability in degrading the challenging complex molecules in lesser incubation time with low-cost substrate and cheaper maintenance features. Newer bioremediation procedures are been introduced day by day to increase the degradation efficacy of the microbes against heavy metals and other pollutants released from the industries. Compared with chemical and other physical remediation treatment, biological treatment process results in the complete removal of the pollutant which physical and chemical process fail or achieve by consuming expensive mechanical and other resources.

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