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Microbial bioremediation: Effective Strategy for Removal of Pollutants from Contaminated Industrial Water of Textile Mills Plants. An Overview

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ABSTRACT

Bioremediation is a process used to treat contaminated water by altering environmental conditions to stimulate growth of microorganisms and degrade the target pollutants. Microbial bioremediation uses microorganisms to break down contaminants by using them as a food source. These toxic compounds are metabolized by enzymes of microorganisms. The industrial water contaminated by heavy metals and other pollutants are common throughout the world. Many strategies are developed to encourage the degradation of pollutants from such affected sites. Bioremediation as one feasible way to be used**.** It is a technology that employs living microorganisms such as bacteria and fungi to remove harmful contaminants from the polluted environment. The basis of bioremediation is that microorganisms remove substances from the environment to carry out their growth and metabolism. The microorganisms used in this strategy can be both indigenous and non-indigenous. These microorganisms take part in the degradation, immobilization, and detoxification of various harmful chemical wastes and contaminants. Microorganisms which perform the function of bioremediation are known as bio-remediators or bio-reformers. The treatment of contaminated water by the conventional method is found to be unfeasible due to its high cost and generates secondary pollutants. Therefore, bioremediation is not effective only for the degradation of pollutants but it can also be used to clean unwanted substances in industrial water and raw materials form industrial waste through the biological activities of microorganisms. Microbial growth depends on several environmental factors such as pH, temperature, and nutrients. The practice bio-stimulation that involves the addition of nutrients to the contamination site enhances the growth of microbes that assist in bioremediation. One of the main nutrients is molasses, in Iraq we used a natural material (dates extracts) in bioremediation of industrial water of textile mills plants**.**

KEYWORDS: Bioremediation**,** bioreactors, industrial water, inorganic and organic pollutants.

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INTRODUCTION

Bioremediation is considered an eco-friendly, low-cost technology based on the degradation of pollutants by microbiological processes [1,2]. The pollution of water with toxic chemicals due to industrialization, is one of the global concerns for the sustainable development of human beings [3]. Therefore, the eradication of toxic organic and inorganic pollutants from the contaminated water is the need of global concern to advance the sustainable development with low environmental impact [4]. Biotechnology emerged an essential tool in this endeavor because it can provide new approaches such as bioremediation for understanding, managing, preserving and restoring the environment [5]. Bioremediation is a technology that employs living organisms such as bacteria and fungi to remove harmful contaminants and toxins from an environment [6,7]. It has also provided problem solving opportunities in this field by detoxifying industrial wastes/effluents, where in bacteria can be altered to produce certain enzymes that metabolize industrial waste components and also new pathways can be designed for the biodegradation of various wastes [8]. This reliable and eco-friendly approach has rapidly gained popularity in environmental research. Scientists have been successful in developing different bioremediation techniques to restore contaminated sites [9]. Therefore, bioremediation has emerged as a natural, economic, sustainable approach which can restore the contaminated water, with the help of biological agents like bacteria, fungi their enzymes [10].

Bioremediation depends on the living micro organisms to degrade the environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi to degrade or detoxify substances hazardous to human health and/or the environment [11]. So, it is an evolving green technology where microorganisms are grown in the presence of contaminated water to elevate the decomposition and/or removal of organic and inorganic pollutants [12]. The aim of this overview article was to give an idea about bioremediation, its strategies, factors affecting biodegradation processes, and advantages and disadvantages of bioremediation.

BASIS OF BIOREMEDIATION TECHNIQUES

Pollution is a threat to our health and damages the environment, affecting wildlife and the sustainability of our planet. Bioremediation can be tailored to the needs of the polluted site in question and the specific microbes needed to break down the pollutant are encouraged by selecting the limiting factor needed to promote their growth [13]. This tailoring may be further improved by using synthetic biology tools to pre-adapt microbes to the pollution in the environment to which they are to be added**.** Microorganisms are well known for their ability to break down a huge range of organic compounds and absorb inorganic substances. Currently, microbes are used to clean up pollution treatment in processes known as 'bioremediation'[14].

Bioremediation is not a new technique, but as the knowledge of the underlying microbial reactions grow, the ability to use them to our advantage increases. Bioremediation is a waste management technique that includes the use of living organisms to eradicate or neutralize pollutants from a contaminated site [15]. Bioremediation is a treatment techniques that uses naturally occurring organisms to break down harmful materials into less toxic or non-toxic materials. Frequently, bioremediation requires fewer resources and less energy than conventional technology, and has technical and cost advantages, although it can often take more time to carry out than traditional methods [16].

Bioremediation is based on the idea that all organisms remove substances from the environment to carry out growth and metabolism. Bacteria and fungi are found to be very good at degrading complex molecules and incorporating the breakdown products into their metabolism [17]. The resultant metabolic wastes that they produce are generally safe and some-how recycled into other organisms. Fungi, especially yeasts, are good at digesting complex organic compounds that are normally not degraded by other organisms [18]. Bioremediation does not involve only the degradation of pollutants but also, at times it is sufficient to remove the pollutant from the environment without degrading it. Bacteria in particular take up large amounts of metals and minerals to ensure adequate resources for binary fission [19].

MICROBIAL BIOREMEDIATION PROCESSES

The bioremediation process is a biological process that stimulates helpful microbes to use harmful contaminants as their source of food and energy. Certain microorganisms eat toxic chemicals, digesting them and eliminating through changing their composition into harmless compounds [20]. Some contaminated water conditions already have the right counter-microbes. Here, human intervention can speed up the natural remediation by boosting microbial action. Generally, bioremediation occurs naturally, without the use of any chemical catalysts, when biological agents come into contact with the contaminants. However, it is necessary to create the ideal environmental conditions to facilitate and expedite the bioremediation process [21]. The conditions include the nutrients, right temperature, pressure, pH, and moisture. In microbial bioremediation, the microbes secrete enzymes to break the contaminants into smaller pieces, which they then consume. As a byproduct of the digestion process, they release water, carbon dioxide, and amino acids [22]. Microorganisms are involved through their enzymatic pathways act as biocatalysts and facilitate the progress of biochemical reactions that degrade the desired pollutant. The reason for rate of degradation is affected due to bacteria and pollutants do not contact each other. Certain enzymes produced by microorganisms attack hydro-carbons molecules, causing degradation [23].

The degradation of pollutants on having sufficient microorganisms for degradation through the metabolic pathways (series of steps by which degradation occurs). Fortunately, nature has evolved many microorganisms to do this job. Throughout the world there are different types of microorganisms that are known to degrade organic and inorganic compounds [24]. If microorganisms are not present in a system they can be added to promote bioremediation. The added microorganisms can be culture grown from other contaminated areas or they can be genetically engineered to degrade pollutants. However, even when these microbes are present, degradation of hydrocarbons can take place only if all other basic requirements of the microbes are mental conditions [25]. Microorganisms will adapt and grow at extreme conditions in water, with an excess of oxygen and in anaerobic conditions, with the presence of hazardous compounds or on any waste stream. The main requirements are an energy source and a carbon source. These microorganisms because of their adaptability and other biological systems can be used to degrade or remediate environ- mental hazards [26].

FACTORS REQUIRED FOR BIOREMEDIATION

The factors that directly impact on bioremediation are energy sources (electron donors), electron acceptors, nutrients, pH, temperature, and inhibitory substrates or metabolites [27].

Microbial growth and activity are readily affected by different factors. The control and optimization of bioremediation processes is a complex system of many factors. These factors include:

1- The existence of a microbial population capable of degrading the pollutants.

2- The availability of contaminants to the microbial population.

3- The environmental requirements.

ENVIRONMENTAL REQUIREMENTS

Although the microorganisms are present in contaminated water, they cannot necessarily be there in the strength required for bioremediation of the site. So, their growth and activity must be stimulated. Microbial growth and activity are readily affected by pH, temperature and moisture. Although microorganisms have been also isolated in extreme conditions, most of them grow optimally over a narrow range, so that it is important to achieve optimal conditions [28]. The bio-stimulation usually involves the addition of nutrients and oxygen to help indigenous microorganisms. These nutrients are the basic building blocks of life and allow microbes to create the necessary enzymes to break down the contaminants. Carbon is the most basic element of living forms and is needed in greater quantities than other elements [29]. Generally, the molasses as carbon source, is added to the contaminated water. In our country (Iraq) we used dates extract (locally called ibis) as carbon source. If the water has too much acid it is possible to rinse the pH by adding lime. Temperature affects biochemical reactions rates and the rates of many of them become double for every 10°C rise in temperature [30]. Above a certain temperature, however, the cells die. The amount of available oxygen will determine whether the system is aerobic or anaerobic. Hydrocarbons are readily degraded under aerobic conditions, whereas chlorinated compounds are degraded only in anaerobic ones [31]. In situ bioremediation techniques have been successfully used to treat chlorinated solvents, dyes, heavy metals, and hydrocarbons polluted sites. Notably, the status of electron acceptor, moisture content, nutrient availability, pH and temperature are amongst the important environmental conditions that need to be suitable for a successful in situ bioremediation to be achieved [32]. Unlike *ex situ* bioremediation techniques, soil porosity strongly influences the application of in situ bioremediation to any polluted site.

The advantages of microbial bioremediation

The major benefits of bioremediation are completely natural processes with almost no harmful side effects, and carried out *in situ* for most applications with no dangerous transport. Quick turnaround time to water and soil useful. It is a natural process, it takes a little time, as an acceptable waste treatment process for contaminated material such as water [33]. Microorganisms able to degrade the contaminant and increase in numbers when the contaminant is present. The residues for the treatment are usually harmless product. So, the main advantages of microbial bioremediation are:

1- A natural process is accepted by the public as waste treatment method for contaminated material such as soil. Microorganisms capable of degrading the contaminant, increase in numbers and produce harmless products. The residues for the treatment are normally harmless products such as carbon dioxide, water, and cell biomass.

2- Complete destruction process, employed for the complete destruction of a wide variation of contaminants. Many toxic pollutants can be transformed to non-toxic products. Bioremediation can be performed on site treatment, without causing a major disturbance of normal activities.

3- An **economic process,** it is cost effective in comparison to other methods that are used for removal of hazardous pollutants.

The disadvantages and limitations of microbial bioremediation

The main disadvantage of bioremediation technology is restricted to biodegradable compounds. Further, researchers have revealed that sometimes the new product developed after biodegradation may be more toxic to the environment than the initial compound. Also, the major constraint of bioremediation is that not all compounds are biodegradable and this limits the bioremediation process. Lastly, this process is time-consuming, especially for ex-situ bioremediation, which requires excavation [34]. In some cases, if at all the material is biodegradable, its downstream processing and degradation further generate some toxic material [35].There are several limitations to bioremediation, such as:

1- Bioremediation is limited to biodegradable compounds.

2- This method is prone to rapid and complete degradation.

3- Products of biodegradation may be more lasting or toxic than the parent compound.

Usually, the removal of pollutants by organisms is not a benevolent gesture. Rather, it is a strategy for survival. Most bioremediation organisms do their job under environmental conditions that suit their needs. Consequently, some type of environmental modification is needed to encourage the organisms to degrade or take up the pollutant at an acceptable rate. In many instances the microorganisms must be presented with low levels of the pollutants over a period of time. This induces the microorganisms to produce the metabolic pathways needed to digest the pollutant. When using bacteria and fungi, it is usually necessary to add fertilizer or oxygen to the material containing the pollutant. This can be disruptive to other organisms.

Microorganisms and pollutants (Tables 1&2)

Bacteria and fungi are typical prime bioremediators [36]. The application of bioremediation as a biotechnological process involving microorganisms for solving and removing dangers of many pollutants through biodegradation from the environment. These microorganisms can survive in varied and extremely high pollutants. Some bacteria exhibit a chemo tactic response, where they can sense the contaminant and move towards it, thereby, leading to bioremediation. Similarly, Several fungi, involved in this process, grow their filament in the contamination site [37]. Heavy metals cannot be destroyed biologically (no degradation, changes occur in the nuclear structure of the element), but only transformed from one oxidation state or organic complex to another. Besides, bacteria are also efficient in heavy metals bioremediation [38]. Microorganisms have developed the capabilities to protect themselves from heavy metal toxicity by various mechanisms, such as adsorption, uptake, methylation, oxidation and reduction. Microorganism's uptake heavy metals actively (bioaccumulation) and /or passively (adsorption). Microbial methylation plays an important role in heavy metals bioremediation, because methylated compounds are frequently volatile. For example, Mercury, Hg (II) can be bio-methylated by a number of different bacterial species.

Table 1: The most dominate microorganisms in the involvement of textile dyes bioremediation.

Microorganisms	Compounds
Bacillus spp. ETL-2012, *Pseudomonas aeruginosa* and *Bacillus pumilus* HKG212	Textile Dye, Sulfonated di-azo dye
Bacillus firmus, *Bacillus macerans*, *Staphylococcus aureus* and *Klebsiella oxytoca*	Vat dyes, Textile effluents
Micrococcus luteus, *Listeria denitrificans* and *Nocardia atlantica*	Textile Azo Dyes
B. subtilis strain NAP1, NAP2, NAP4	Oil-based based paints
Myrothecium roridum IM 6482	industrial dyes
Pycnoporus sanguineous, *Phanerochaete chrysosporium* and *Trametes trogii*	Industrial dyes
Penicillium ochrochloron	Industrial dyes
Exiguobacterium indicum, *Exiguobacterium aurantiacums*, *Bacillus cereus* and *Acinetobacter baumanii*	Azo dyes effluents

Table 2: The microorganisms serve for utilizing heavy metals.

Microorganisms	Compounds
Saccharomyces cerevisiae	Heavy metals, lead, mercury and nickel
Cunninghamella elegans	Heavy metals
Pseudomonas fluorescens and *P. aeruginosa*	Textile Azo Dyes Fe 2+, Zn2+, Pb2+, Mn2+ and Cu2
Lysinibacillus sphaericus CBAM 5	cobalt, copper, chromium and lead
Microbacterium profundi strain Shh49T	Fe
Aspergillus versicolor, *A. fumigatus*, *Paecilomyces* sp., *Paecilomyces* sp.,*Terichoderma* sp., *Microsporum* sp., and *Cladosporium* sp.	cadmium
Geobacter spp.	Fe (III), U (VI)
Bacillus safensis (JX126862) strain (PB-5 and RSA-4)	Cadmium
Pseudomonas aeruginosa and *Aeromonas* sp.	U, Cu, Ni, Cr
Aerococcus sp. and *Rhodopseudomonas palustris*	Pb, Cr, Cd

CONCLUSIONS

Biodegradation is very fruitful and attractive option to remediating, cleaning, managing and recovering technique for solving polluted environment through microbial activity. Microbial bioremediation is the most effective, economical, eco-friendly management tool to manage the polluted environment. Bioremediation is highly involved in degradation, eradication, immobilization, or detoxification diverse chemical wastes and physical hazardous materials from the surrounding through the all-inclusive and action of microorganisms. The main principle is degrading and converting pollutants to less toxic forms. All bioremediation techniques have its own advantage and disadvantage because it has its own specific applications. It is a powerful tool available to clean up contaminated industrial water and it occurs when there are availability of microorganisms that can biodegrade the given contaminants and the necessary nutrient Microbial bioremediation is a technology that employs living organisms such as bacteria and fungi to remove harmful pollutants and toxins from the contaminated environment. Regardless of which aspect of bioremediation that is used, this technology offers an efficient and cost effective way to treat contaminated water. Nonetheless, microorganisms can be used to treat wide range of pollutants in a controlled manner. Consequently, cost of remediation apparently is not the major factor that should determine the bioremediation technique to be applied to any polluted site. All bioremediation techniques have its own advantage and disadvantage because it has its own specific applications.

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