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Micro Biotechnology Tools for Wastewater Treatment and Organic Solids Reduction

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Abstract

Bio-solids contain organic materials and fertilizing elements that are important for the preservation of soil fertility. Nevertheless, treated sewage, and bio-solids include a wide range of pathogens which are transmitted directly or indirectly to the atmosphere and infect humans. The wastewater treatment can be done by the process of bioremediation. Bioremediation is the use of microorganisms to deplete or reduce the hazardous waste levels on the polluted sites. There are several uses for bio-treatment systems, such as water, soil, sludge and streams for the cleaning of polluted sites. Rapid industrialization, urban planning, intensive agricultural activities and other human activities in all sectors of agriculture have led to land degradation, environmental pollution and a decrease in the crop productivity. Human activities have increased the pressure on the natural resources, making it a source of countless pollutants. Many technologies were developed, but more often these processes produce additional, environment-friendly pollutants again. One of the most important strategies for removing organic pollutants from wastewater in wastewater treatment plants is the biodegradation of contaminants or pollutants by harnessing the micro-organisms present in the active sludge. This strategy however is constrained by the absence of successful removal of many contaminants. This method was tested with promising results for cleaning wastewater, but failures were also recorded, in particular during the scale-up.

Key words: Bioremediation, Environmental pollution, Land degradation, Wastewater treatment, Organic pollutants, Pathogens

Introduction

Industries need clean water sources while producing enormous amounts of pollutants polluted by various toxic compounds at the same time. Such a situation has in the past existed only in the developed world, with high demand for clean water and wastewater generation, but now, as a result of increasing industrialization, is now also rising in the developing countries. In recent years, for example, China has produced more than 20 billion m^3/year of waste water, one of the world's fast-growing industrial nations [1].

Waste effluent produced from a treatment plant is classified as treated or untreated wastewater. The treated sewage is divided into domestic sewage, hospital drains and industrial waste waters according to its source. Domestic waste consists of a complex mixture of water, organic and inorganic elements and a wide array of pathogenic bacteria, viruses and parasites. The sewage from hospitals and medical centers requires the washing of laboratories and of other buildings and contains sewage and wastewater [2]. The most important components in these waste products are the antibiotics, disinfectants and antibiotic-resistant bacteria (due to their major hospital use).

Bioremediation is a method which is used to purify polluted soil and water through beneficial microbiological agents such as plants, fungi or bacteria. It is characterized by the use of biological processes as the removal, attenuation or transformation of the contaminating or polluting substances. The aquatic ecosystems, affected by the point or useless sources of pollution, are the first and most significantly affected ecosystems in any region. Pollution sources arise if the pollutant is released directly into the waterway. Municipal and industrial wastewater effluents; river drainage and leachate from the solid waste disposal sites; river drain from industrial sites; river drainage from industrial sites; vessel discharge are the common pollution sources. Non-point sources include water flow from agricultural land and olive groves, urban rivers from waste fields, etc. Not only marine species but also the terrestrial animals and birds are affected by the water pollution. Contaminated water destroys aquatic life more seriously and reduces its reproductive capacity. In the final analysis, water is unsafe for food or household use, even a threat to human health in severe cases. Waste disposal also has environmental and financial costs that can be minimized through the use of sustainable remediators [3]. Seeding polluted residues with the qualified micro-flora that can kill the dangerous waste is typically practiced in most of the treatments to speed up the bioremediation cycle. The microorganisms inoculated either occur naturally or are ready to attack the target waste within the laboratory.

Industrial wastewater is the unwanted industrial wastewater such as the chemical, electrochemical, electronic, petrochemical, food production and manufacturing industries. The wastewater is linked to high dissolved metal (heavy metal) concentrations and may include the domestic sewage, but domestic wastewater does not constitute the main component [4].

During wastewater treatment, the waste that is produced is the solid, semi-solid or liquid residue. The term bio-solids recently replaced the term sewage sludge. Bio-solids contain sewage sludge that has been treated with advanced methods, including aerobic and anaerobic therapy, heat treatment or lime treatment. Depending upon their origin (human, vegetable or animal), and the treatment process they are undertaking (physical, chemical or biological, anaerobic or aerobic treatment, alkaline lime treatment etc.), the specific characteristics of the bio-solids vary [5]. Biosolids are important to soil and plants for organic and inorganic materials.

This needs to provide a large quantity of clean water for commercial activities increases the challenges that the human beings are facing to provide the increasing population with the same clean water. Due to the fact that the freshwater supply is restricted in the southern and the west states of the United States in particular, the reuse of both domestic and industrial wastewater continues to be the longest possible solution for that problem, particularly for the countries with limited rainfall patterns, such as North Africa, the North and the Middle East [6].

In order to remove or reduce the concentrations of toxins to acceptable levels before their re-use or release in the environment, polluted wastewater requires treatment. As pollutant-disclosure legislation throughout the world is being tightened with the growing awareness of its effects on human health and the environment. This leads to the implementation of the approaches to increase the performance of industrial wastewater treatment plants. A typical industrial treatment plant can be illustrated in Fig. 1. The first step involves treating organic and/or inorganic pollutants physically and chemically, followed by the secondary treatment (removal of organic pollutants). This secondary treatment results in the backwash effluent production, concentrate sludge and the membrane. If the discharge conditions are met, backwash effluents may be discharged or transferred to a nearby sewage treatment plant. The products of physicochemical and biological treatment are subjected to the purification and disinfection before reuse, depending on the type of contamination [7].

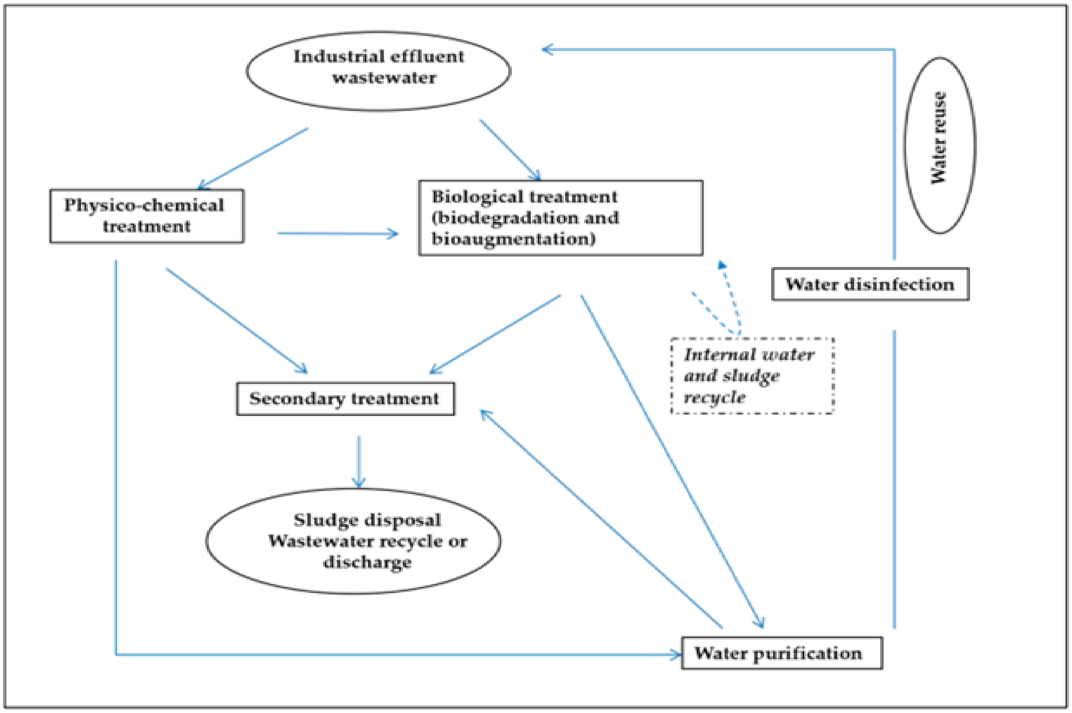

Fig.1: Generic flow of industrial wastewater treatment plan (adapted and modified form).

Approaches such as advanced oxidation, Nanofiltration, ROF (reverse osmosis filtration) and activated carbon filtration in physico-chemical therapy are useful in the removal of contaminants, which remain expensive, especially when treated on an overall scale [8]. However, some of these methods contain environmental toxic by-products.

1. Role of microbes in Bioremediation process:

In order to protect the human health and the environment, microbial bio-remediation can cost-effectively and quickly destroy or re-mobilize the pollutants. Work is being conducted at a number of facilities to improve bioremediation using exogenous microbes or genetically engineered microbes. The microbial bio-remediation program, which is successful, cost effective, is dependent on the hydro-geological conditions, contaminants, and microbial ecology. Contaminants are used as the nutrients or energy sources in every bioremediation phase. Bioremediation activity is induced by the microbes with additional nutrients (nitrogen and phosphorus), electron acceptors (oxygen), and substrate (methane, phenol and toluene) [9]. Some of the common microorganisms used for remediation are the species of "*Acromobacter, Alcaligenes, Arthrobacter, Bacillus, Cínetobactor, Corneybacterium, Flavobacterium* and *Mycobacterium*, etc. Lactic acid bacteria-*Lactobacillus plantarum, L. casei, Streptococcus lacti, Rhodopseudomonas palustrus* and *Rhodobacter spaeroid* are the main species involved in the successful waste water treatment [10].

2. Importance of sewage treatment:

With the rapid growth of communities and cities, human waste has tremendously increased. Many pathogenic microorganisms have originated in the sewage, including bacteria, viruses and protozoa parasites. Poor sanitation and drinking water pollution have resulted in the death of over 2000 children each day worldwide under the age of five [11]. So the extent of ecological degradation due to the untreated sewage is required in the environment for sewage management. The selection of a suitable technique of treatment and disposal of treated sewage therefore requires an assessment of the environmental and agricultural consequences of the effluent.

The world's production of bio-solids is estimated to be 20×10^9 tons per year. As such, the sewage sludge management has been a vital global environmental issue. In the Middle East, however, it cannot be implemented in the management and disposal of sewage lots to follow a realistic, economic or appropriate method. The current practice is either reuse or direct disposal at sea for agricultural purposes.

The waste treatment program is a multi-phase method for the collection, before disposal and reuse for agriculture in order to remove the organic matter, heavy metals, causative agents of disease and other contaminants. The treatment degree varies from the simple processes such as individual septic tanks (IST), oxidation ponds, stabilization ponds, primary and secondary processes (advanced method or tertiary process) of highly polluted waste to polishing processes for the removal of the trace concentrations remaining following major treatments [12]. Depending on the water source and its applicability (Fig. 2), the final application of sewage treatment systems is achieved. The following can be defined as the common sewage treatment processes.

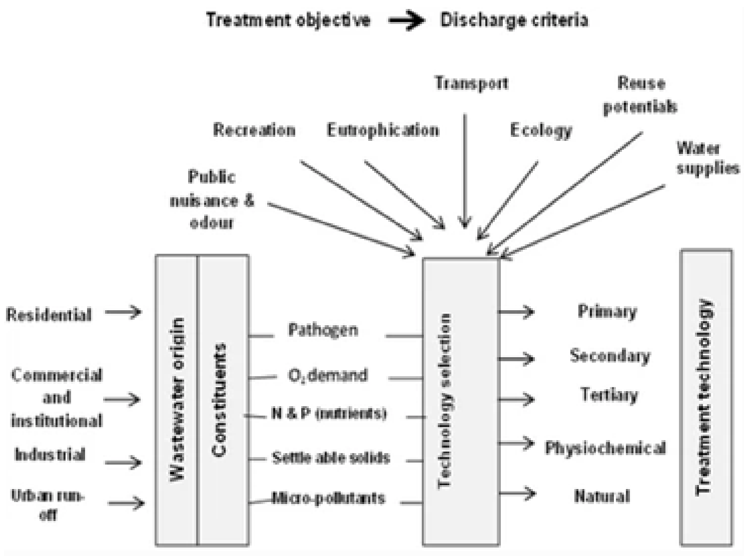

Fig.2: Treatment technology selection in relation to the origin of the sewage.

3. Bio-augmentation to remove recalcitrant pollutants in industrial wastewater:

The sludge, released in the wastewater, includes natural microorganisms that are biodegradable to a wide range of contaminants. This resistance is due to the several factors: high toxicity, low water solubility, low bio-availability and low bio-degradability. Microbial metabolic enzymes may not use any compounds as substrates effectively. The chemical structures of some pollutants may be so complex that the consortia of various microorganisms may need to biodegrade them or not all necessary microorganisms may be present in the environment simultaneously. Recalcitrant compounds may in many instances be new and therefore not adapted to use them as a substratum by the microorganisms. The major benefit of the bio-augmentation is that treatment can be customized to a particular pollutant that is environmentally dominant. This method is therefore appealing in order to address both the growing number of emerging contaminants and the high concentration of pollutants [13]. In the past ten years, various studies have concentrated on exploring the renewable wastewater bio-enhancement approaches and primarily on the recalcitrant molecules. Below are examples of the use of bio-augmentation from early 2000s up to the present to eliminate toxins from the industrial wastewater (table 1).

Table 1: Examples of bio-augmentation of industrial wastewaters for the remediation of important organic compounds.

Pollutant	Set Up	Medium for Bio-augmentation	Bio-augmented Bacteria
Phenol (PH) and Naphthalene (NAP) along with carbazole (CA), dibenzofuran (DBF), and dibenzothiophene	BR (column of 10 × 50 cm)	Coking wastewater from a treatment plant	*Immobilized phenol-utilizing Arthrobacter sp.*
Naphthalene	MBR (8 L)	Coal gasification wastewater	*Streptomyces sp.*
Mixture of phenol, pyridine, quinoline, naphthalene and carbazole	A sequential system of anaerobic reactor (4.9 L), anoxic reactor, A2 (4.5 L), and an oxic MBR (9L). MBR (9.0 L)	Coking wastewater	Consortium of 6 bacteria containing *Panacoccus denitrificans* and 5 strains of *Pseudomonas sp.*
Phenol	Biological contact oxidation reactor (BCOR)	Coal gasification wastewater	Mixture of phenol-degrading bacteria

Conclusion

In the last few decades in the Middle East countries the reuse of sewage-treated effluent and bio-solids for the agricultural purposes has increased significantly. Such countries face a significant shortage of water resources and are not accessible in the tertiary wastewater treatment plants. The treatment of wastewater and bio-fuels is rich in nitrogen and phosphate that would enhance the growth of plant and soil. Nevertheless, there is also a wide range of pathogens, which poses a potential risk to humans and animals. Bio-augmentation is an effective technique in wastewater to eliminate the recalcitrant contaminants. This method has been successful in the laboratory work, but there are still some challenges, in particular in terms of increasing these processes. The extraction from groundwater of chlorinated compounds by *Dehalococcoides* bacteria was effective using bio-augmentation in the real-world conditions till date..

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