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Phytoremediation potential and its methods- a review.

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Abstract

With the increase in the world's population and the subsequent increase in housing density, we are facing the problem of water, soil, and air pollution. On the other hand, the use of physical environmental purification methods is very expensive and can even cause environmental pollution. Phytoremediation is a cheap and accessible method that uses the potential of plants to remove or destroy dangerous contaminants from water, soil, and air. One of the major problems in Phytoremediation is that the process is time-consuming. This can be overcome by adding compounds such as nanoparticles in order to increase the speed. Special care must be given to using the correct doses of nanoparticles because they pass through cells and biological membranes, which may cause contaminations. Therefore, the use of appropriate doses of nanoparticles will eventually accelerate the phytoremediation process. The purpose of this study is to assess the recent discoveries in the Phytoremediation process and its methods.

Keywords: Phytoremediation , nanoparticles, heavy metals, municipal wastewater, industrial wastewater

1. Introduction

1.1. Environmental problems

Life is impossible without one of the most important natural resources, water. About 74% of our earth is water. Currently, the quality of water has decreased due to various pollutions and has made consumption and other uses very difficult, in other words, healthy water is one of the biggest concerns of the 28th century (Minh et al., 2016). It has become an increasingly scarce and highly valued resource. Rapid industrialization has caused the production and release of a significant amount of pollutants in water resources and has caused the increasing pollution of water resources [1]. Although the texture of the earth contains about 74% of surface water, but unfortunately only 1% of surface water is suitable for drinking. The discharge of sewage directly or indirectly into groundwater has increased significantly due to the increase in human population, the development of agricultural and industrial activities.

Water pollution happens due to the entry of many undesirable chemical compounds into water systems [2, 3]. With the increase in world population, especially in third world and developing countries, housing density has increased significantly, with very poor sewage systems in these houses [4]. Sewage causes significant damage to the environment, fisheries, tourism and drinking water sources. Preventing the pollution of surface water sources as the main sources of drinking water used by humans has a major contribution to the development of national and regional health. The increase in the use of heavy metals (HM) in industry and agriculture has caused serious concern about environmental pollution, and the high concentration of these heavy metals has caused serious damage to plants [5]. Increasing heavy metal pollution in the environment through agricultural land erosion, urban waste, rural activities, industrial activities and mining industries is a concern of the world, especially in developing countries [6].

1.2. Industrial wastewater

Wastewater treatment is very important in the world and a lot of money is spent in different countries to do this. Therefore, it is very important to use appropriate methods and technologies, according to the climatic and social conditions and the economic characteristics of the region. Basically, sewage is divided into two categories: urban and industrial. Industrial wastewater is very important due to the complexity of its 3 qualitative and quantitative characteristics. Wastewaters from industrial productions and factories, in addition to destroying natural resources, impose additional pressure on the planet's ecosystem. The quantity and quality of industrial wastewater according to the production process, the ease of access and cost of water supply and wastewater disposal, the type of raw material and production products, the level of supervision of the industrial unit's activity, the area of green space and grounds, the state of sanitary-welfare facilities, the existence of the system Recirculation and reuse rate changes [7, 8].

1.3. Urban sewage

The production of leachate is one of the consequences of waste burial operations in the cemetery, so that one of the most important issues in the design and operation of waste burial sites is the management of leachate. In cemeteries, the main pollution is due to the production of flammable gases and liquid leachate. When waste materials are placed in the burial ground, spontaneous physical, chemical and biological changes occur, such as decomposition of perishable organic materials in aerobic and anaerobic forms, oxidation, creating gas and releasing it into space, movement of liquids, dissolution and washing of organic materials and mineral by water and the movement of dissolved substances under the influence of the concentration gradient occurs in them. Materials are physically observed in three phases; solid phase (waste), liquid phase (leachate) and gas phase (biogas). The liquid phase is enriched by dissolved and suspended organic or mineral substances in the solid phase. Leachate or liquid phase is produced in different stages. Leachate is divided based on the type of process during which the leachate was formed and also according to the time of its production. The primary leachate is separated from the solid waste immediately after the waste is discharged in the landfill and as soon as the daily cover is established. In fact, their production time starts from the beginning of waste burial in burial cells and its origin is the initial moisture of solid waste materials [9-11].

Secondary leachate is caused by infiltration of rainwater, snow and surface runoff into the burial site. The moisture entering the burial site moves down under the influence of its own gravity and is absorbed by waste and materials in contact with them. Urban sewage contains almost all known chemical elements and all kinds of organic compounds, the reason for the presence of these substances is the daily use of salt, acid, alkaline compounds, synthetic organic substances, etc. The most important chemical characteristics of urban wastewater include organic and inorganic solids, nitrate, nitrite, ammonia, heavy metals, dissolved gases and the intensity of these pollutants in wastewater. Soluble and insoluble carbon hydrates (sugar and starch compounds), protein compounds, fats and oils, which are usually available in the form of emulsions, are among the main components

of municipal wastewater. Detergents, phosphates, and surfactants are also very important in urban wastewater [4, 12].

1.4. Heavy metals (HM)

According to the progress of industry, heavy metal pollution has become a serious issue and must be seriously addressed and demonstrated (Hajipour et al., 2023).In general, plants need two types of materials: organic materials and mineral materials. Almost half of the minerals needed by the plant are metal ions, which include: sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), Nickel (Ni) and Molybdenum (Mo). These ions are needed in different amounts for plants depending on how much they are needed for plant growth. Heavy metals with metallic characteristics (conductivity coefficient, cationic stability and 4 ligand properties) (and atomic number more than 24 are known. The term heavy metal has different definitions, but this term is mostly used in the field of environmental pollution.

Four characteristics are explained in the recognition of heavy metal groups, which are:

1. HM are relatively abundant in the earth's crust,
2. HM can be extracted and used,
3. HM are directly related to humans and the environment, and
4. HM are toxic to living organisms.

In another definition, heavy metals are described as do: metals that have a specific gravity greater than 6 grams per cubic centimeter. Most heavy metals are classified as toxic and available metals. According to the classifications, their concentration in the soil is between 8 and 84444 mg/kg changes. These metals cause serious and dangerous pollution to the environment due to their toxicity, stability and bioaccumulation properties [13-16].

2. Phytoremediation

The term phytoremediation is defined as the use of plants to remove or eliminate hazardous pollutants from water, soil, and air. Phytoremediation is derived from the Greek word Phyto, which refers to a plant, and the Latin suffix Remedium, which means treatment or restoration. The main reason for using this method is to collect pollutants and convert them into a suitable and extractable form (plant tissues). Compared to other physical and chemical methods of cleaning the environment, phytoremediation is more valuable and this method can also minimize environmental disturbances. The term phytoremediation provides a broader understanding of the importance of plants and their beneficial role in social and natural systems. Phytoremediation has been introduced and developed for the treatment of urban leachate, domestic and industrial wastewater, and remediation of polluted soils in the last three decades (Figure 1). Phytoremediation is not only recognized as an effective tool for improving water, soil and air quality, but also provides beauty and wildlife habitat [17-19]. Vegetation treatment systems are generally simple, affordable and have no harmful effects on the environment. The most important factor in the implementation of biological treatment systems is the selection of appropriate plant species, which must have unique characteristics such as high absorption of organic and inorganic pollutants, adaptation and proper growth in polluted environments, and easy and fast reproduction. The results of various researches have shown that even in one species, the amount of pollutant absorption is different from one species to another. Another feature of the plant for plant remediation is that the plant must tolerate the accumulation of metals with a high concentration in its organs. Plant remediation is also known as bioremediation, botanical bioremediation, and green remediation. The idea of using hyper accumulating plants, which have the ability to purify pollution, was first introduced It was proposed in 1989. Although there is a good image of phytoremediation, not many field studies have been conducted on this method and there is not enough information to support its commercialization and this is one of the reasons for the slow expansion of the plant [20].

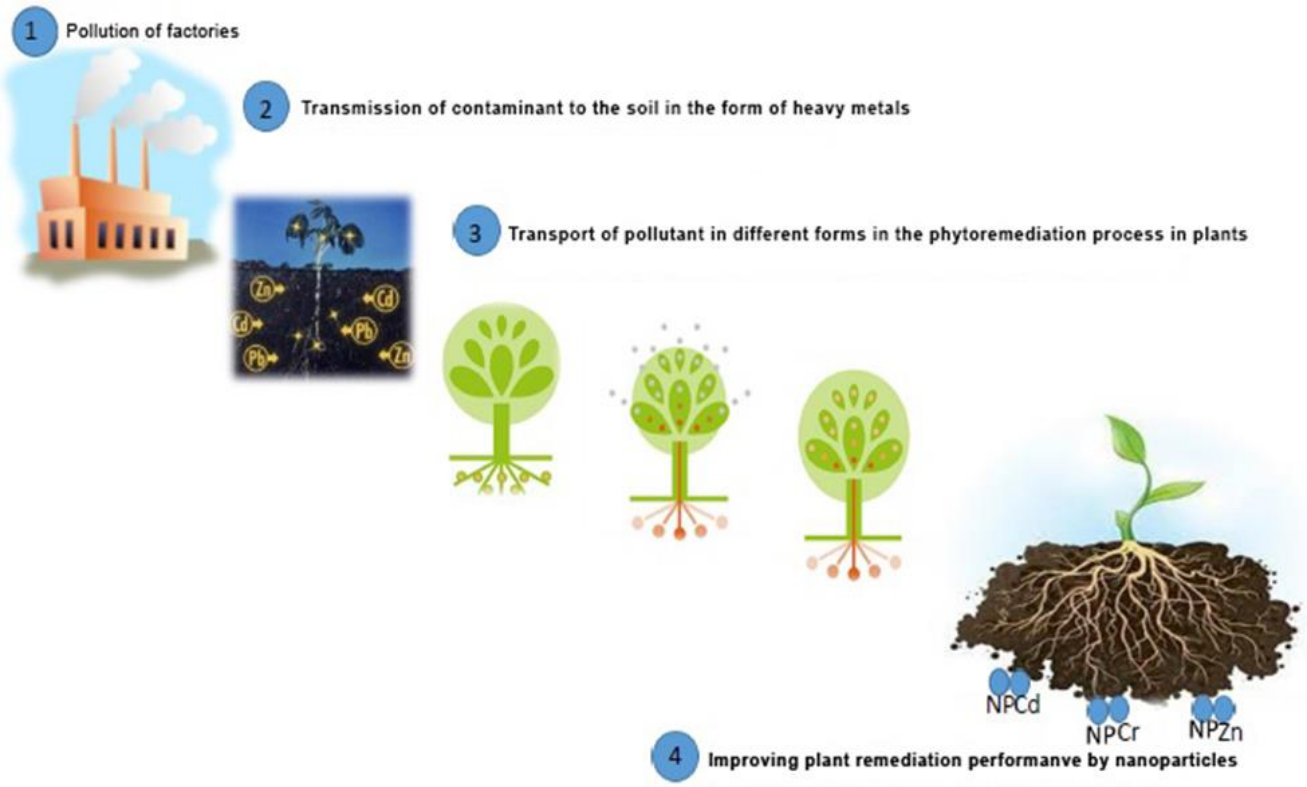

Figure 1: Overview of the phytoremediation process

2.1. Extraction of pollutants by plants (Phytoextraction)

This method consists of the absorption of pollutants by the roots of plants and their transfer to the plant, and by harvesting the plant, the pollutants are also removed. In this technology, the volume of waste materials is greatly reduced compared to the method of digging and transporting contaminated soil. The success and efficiency of this method depends on the amount of pollutants in the soil, the characteristics of the soil and the capacity of the plant to tolerate toxic concentrations of pollutants. The effective extraction of pollutants from the soil requires that plants absorb and transport toxic metals with high efficiency, store pollutants in their tissues in such a way that they can tolerate them, and also produce high biomass in their aerial organs. Of course, a plant that has all these characteristics is rare. In this context, special attention is paid to high-accumulating plants, these plants are able to extract metals from the soil up to 844 or 8444 times more than other plants and accumulate them in their tissues. In hyper-accumulating plants, genes encoding membrane transporters are more expressed. High concentration of metals do not create a toxic state for these plants. Hyper-accumulating plants have three characteristics that distinguish them from normal plants: very fast absorption of heavy metals, rapid transfer of materials from roots to aerial organs, and high ability to neutralize and store heavy metals [21-25].

2.2. Phytostabilization by plants

Stabilization by plants is the use of vegetation to trap soil pollutants, which is done by changing the chemical, physical and biological conditions of the soil. In this method, which is also known as Phytostabilization and in-place inactivation, the movement of pollutants in the soil and sediments through absorption and accumulation in the roots, complex formation, reduction of metal valence in the root area and Humification is prevented. In addition, vegetation reduces water and wind erosion. As a result, it prevents the spread of pollutants along with running water and dust. The advantages of this method include not needing to move the soil, being cheap, less destructive than other methods, helping to restore the ecosystem by renewing the vegetation, and not needing to destroy harmful substances [26-29].

2.3. Rhizofiltration

In this method, pollutants are absorbed from the soil solution in the root zone by biological or non-biological processes. Absorption, compression and transfer of pollutants are done depending on their type. Plant root exudates may absorb some metals. The first result of this method is the immobilization of pollutants, which is done by immobilizing or accumulating them in the plant. Then they remove the plant from the ground to remove the pollutants. The commercial application of this method faces problems due to the slow growth and limitation of metal absorption capacity by the tested plants. A suitable plant for filtering by roots must have roots with a high growth rate and be able to absorb toxic metals from the solution for a long time [21].

2.4. Rhizodegradation

Decomposition by roots refers to the breakdown of organic pollutants in the soil through bacterial activity. This method is also known as plant-assisted degradation, plant-assisted bioremediation, and plant-assisted biodegradation. The rhizosphere increases in the presence of these secretions and increases the intensity of biodegradation of pollutants. In this method, substances such as petroleum hydrocarbons, polycyclic aromatic hydrocarbons, benzene, toluene, ethylene benzene and herbicides such as atrazine are refined [30].

2.5. Phytovolatilization

This method consists of the absorption and transpiration of pollutants by plants and the release of these pollutants into the atmosphere through pollutant absorption, plant metabolism and transpiration. Some toxic metals such as selenium, arsenic, and mercury become volatile molecules after being filtered and enter the atmosphere. Previously, the role of microorganisms in volatilization of selenium was confirmed, but plants also have this ability. Due to the unique property of being a liquid at room temperature, mercury can easily turn into vapor. The most important advantage of this method is the transformation of pollutants into less toxic forms [30-33].

3. Management of residual plant biomass after phytoremediation of heavy metals

After each harvest from the contaminated area, a large amount of dangerous plant biomass rich in metal remains, which must be properly stored or destroyed in order to minimize environmental risks. In order to reduce the volume of metal-rich biomass, it should be burned and fermented or turned into gas. Residual materials that are rich in metals can be reprocessed to recover valuable metals such as zinc, copper, and gold, or they can be disposed of in a suitable location such as an environmentally safe isolated landfill accumulated [34-36].

4. Nanoparticles in phytoremediation

Nanoparticles (NPs) are considered as new millennium materials. Metal-based nanomaterials have been extensively researched recently. Materials with at least one dimension of 100 nm or less are classified as nanoparticles. They achieve some unique properties such as high performance and high reactivity due to their small size and large surface area. Some of the most important engineered nanoparticles in industrial, commercial and household use are: Ag, TiO_2, ZnO, SiO_2, CeO_2, Al_2O_3, Cu, Fe, carbon nanotubes and nano-clays. Inorganic ENPs can be divided into metal ENPs (mainly Ag, Cu, Fe), metal oxides (eg TiO_2, ZnO, CeO_2, Al_2O_3, Fe_2O_3, Fe_3O_3) and dots. Quantum split. (CdSe) is divided. Ag, TiO_2 and ZnO are the most common natural ENPs in commercial products.

Silica, titanium, alumina, iron and zinc oxides also dominate the global ENP market as components in paint, electronics, optics, cosmetics, energy and environmental applications, and catalysts [10, 26, 37]. Researchers found that silver nanoparticles can be used to reduce the transport and accumulation of heavy metals. Nickel, lead, cobalt and manganese stimulated the production of plant hormone in the treatment of corn stem obtained by inoculation of PGPR with MW water. Nano silver particles cause the production of GA and ABA phyto-

hormones in treated plants to help plants withstand stress and also increase the absorption of nutrients and water for better growth, but due to their small size, nanoparticles can be removed from cells and membranes, passes biologically and its excessive use can cause damage to humans and the environment, therefore, the application dose is very important [38-42].

5. Conclusion

Due to the increase in the world's population, especially in developing countries, the increase in housing density has caused an increase in pollution, especially heavy metals. Heavy metals have destructive and harmful effects for humans and the environment, and on the other hand, physical purification methods are very expensive and can themselves cause environmental pollution. Therefore, plants become more and more attractive to scientists, since the can easily remove contaminants from soil, thorough the process of phytoremediation. However, there are some disadvantages in the phytoremediation process itself, and one of them is the time that the plant takes to remove the pollutants. This problem can be overcome by using nanoparticles, but it is important to note that nanoparticles must be used in small sizes and standard doses in order to pass through biological membranes and help the plant in HM transport.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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