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(Review Article)

Evaluation of the efficiency of *Nerium oleander L.* in the phytoremediation of soil pollutants heavy metal

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Abstract

The oleander plant is considered one of the promising plants in soil treatment techniques (Phytoremediation). Due to its high tolerance to environmental stress and pollution, the plant absorbs pollutants, especially heavy metals and chemical compounds, from the soil through its roots, then transports or fixes them within its tissues. The root zone also contributes to this process. (Rhizosphere) in promoting the activity of microorganisms that help break down some organic pollutants. Therefore, the use of the plant *Nerium oleander L.* is a sustainable environmental approach to reduce pollutant concentrations and improve soil properties in pollution-affected environments. This supports environmental protection and human health.

Keywords: Soil Bioremediation; *Nerium Oleander L.* Plant; Heavy Metals; Environmental Protection

1. Introduction

Heavy metal pollution is a form of environmental pollution caused by human industrial or agricultural activities. In recent years, scientists have focused on studying heavy metals, including their presence in the environment, biological effects, and their relationship to human health. Food is considered a primary source of human exposure to these elements [1].

Almost every human activity that leads to the deterioration or destruction of the natural environment constitutes pollution, and environmental pollution is not a new phenomenon; it remains the biggest problem facing humanity. In 2015, pollution caused 9 million premature deaths, which is more than three times the number of deaths caused by malaria, AIDS, and tuberculosis combined [2]. Apart from earthquakes, erosion, and other natural disasters that tend to damage the soil, the main sources of soil pollution are industrial and domestic waste. Some soil pollutants include heavy metals, hydrocarbons, organic and inorganic solvents, open dumping, waste burning, and inadequate landfills. These factors combined cause soil pollution, and when these pollutants penetrate the soil, they prevent nutrient absorption by plants and affect plant metabolism, leading to reduced crop yields [3]. Apart from a few cases where heavy metal levels are naturally high in the soil, the vast majority of pollution with these elements is caused by human-induced inputs [4]. The term phytoremediation refers to the process of removing pollutants from the environment using plants that can tolerate and accumulate them. This technology can be applied to both organic and inorganic pollutants found in soil, water, and air [5]. This technique was preferred over other physical and chemical methods because they damage the soil and eliminate biological activity, including beneficial microbes such as nitrogen-fixing bacteria, fungi, and other microorganisms [6]. Plants absorb pollutants from soil, water, or sediment via their roots and transport them to their aboveground biomass, where they accumulate in shoots or other parts [7].

Nerium oleander L. is a perennial shrub from the Apocynaceae family. Apocynaceae, native to the Mediterranean region, grows as an ornamental plant of high aesthetic value. This plant is salt- and drought-tolerant and can live in soils contaminated with heavy metals, thanks to its strength and ability to withstand various stresses. It is one of those plants

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that play a key role in reducing the concentration of pollutants in nature because of its lance-shaped leaves, high cuticle thickness, and strong root system [8].

Plant growth and treatment efficiency can be enhanced by adding factors that increase the likelihood of oxidation-reduction in the soil, such as chemicals, organic fertilisers, plant growth regulators, and amino acids, with the possibility of utilising genetic and biological engineering methods [9.10,11].

2. *Nerium oleander* L. Plant

Oleander is an ornamental shrub belonging to the Apocynaceae family. Apocynaceae, an evergreen family, grows to 2 to 4 meters tall and is native to the Mediterranean basin. It generally thrives in warm regions and can tolerate high temperatures. The leaves are lanceolate, leathery, and dark green to greyish green, with distinctive light-yellow veins. The flowers are in terminal clusters, white, pink, or dark red, with five petals. The fruit is a narrow pod containing numerous silky-hairy seeds [12]. This medicinal plant contains a mixture of highly toxic glycosides, which are used in the preparation of heart medications [13]. It was found that the oleander plant can collect heavy elements on its leaf surface, mainly from aerial sources and via its roots [14]. This plant plays a key role in reducing heavy metal levels in the environment due to its complex morphological and physical characteristics [8]. The removal and bioaccumulation factors reflect the plant's ability to eliminate heavy elements such as lead and cadmium [15]. *Nerium oleander L.* is a preferred plant in phytotherapy for several reasons, including: its widespread use in urban areas as an ornamental plant; its perennial nature; its ease of cultivation and low maintenance costs; its resistance to pollution and drought; and its demonstrated ability to bioaccumulate various minerals [16]. It is one of the most important plant species proposed as a good indicator of bioaccumulation [17]. Furthermore, oleander can survive in soil contaminated with heavy metals due to its strong accumulation behaviour [18]. The plant contains many secondary metabolites such as flavonols, steroids, and polyphenols, which give oleander an advantage in tolerating heavy metal stress [19]. Several previous studies have examined the oleander plant's ability to remove heavy metals [20].male [21] In a study conducted to evaluate the ability of oleander as a tool for monitoring pollutants and removing and accumulating heavy metals in the air and soil of cities where pollutant concentrations are high within the plant's biomass, researchers concluded that it is a suitable candidate as a biomonitoring tool for heavy metal pollution in densely populated areas and for reducing pollution within cities. The study further explained that [22] In an experiment conducted to employ phytoremediation techniques for soil irrigated with wastewater, the oleander and cattail plants were used. Catharanthus roseus Regular monthly analyses were conducted on the leaves and roots of both plants. Accordingly, the researcher concluded that oleander exhibited the highest efficiency in removing pollutants, accumulating lead at 19.61 mg/kg in its roots, significantly exceeding the concentration of 11.40 mg/kg in the control plant [23]. In a study conducted to evaluate the efficiency of the oleander plant, Nerium oleander and the shrubby ena plant Lantana camara in the phytoremediation of soils transported from a designated landfill area with a high pollution level and treated with compound fertiliser NPK was used to promote biomass growth in both plants and to accumulate higher concentrations of heavy elements. The results indicated that both plants showed good phytoremediation and heavy metal accumulation capabilities [24]. In a study evaluating the effect of phytoremediation using oleander to reduce soil pollution from lead, cadmium, and other heavy metals, the researchers concluded that lead accumulated in the roots, while cadmium and zinc concentrated in the oleander's aerial parts. The study confirmed that [25]. In a study evaluating the efficiency of oleander in removing heavy metals from wastewater following a 65-day outdoor toxicity test, this study revealed that oleander can tolerate and efficiently treat various concentrations of trace elements [26]. In an experiment conducted to assess oleander's ability to accumulate in urban areas, researchers concluded that oleander can be used as a monitoring plant for areas exposed to heavy metal pollution, as it can accumulate heavy metals present in polluted air.

2.1. Plant treatment Phytoremediation

The term phytoremediation refers to the process of removing pollutants from the environment using plants characterised by their ability to withstand and accumulate pollutants. This technology can be applied to both organic and inorganic pollutants found in water, soil, and air [5]. Phytoremediation is an environmentally friendly, inexpensive technique that relies on sunlight as an energy source and is effective in removing organic and inorganic pollutants, especially compared to other techniques that are expensive and ineffective [27]. Depending on soil characteristics, plant species, and the type of heavy metal, some plants can be used effectively and safely to treat contaminated soil [28,29,30].

Figure 1 *Nerium oleander* L. plant

2.2. Environmental pollution Environmental pollution

Pollution is defined as any change that occurs to the physical, chemical, and biological properties of the components of the environment, air, water, and soil, and this pollution results in varying degrees of harm to human, animal, and plant life in general [31]. Pollution sources are either natural, with no human intervention, such as volcanic activity, which emits gases, vapours, and accompanying dust particles. Sometimes, natural pollutants result from organic decomposition processes that produce ammonia, hydrogen sulfide, and other gases, as well as from forest fires that emit large quantities of smoke and gases. Or they may be unnatural (industrial) sources generated by human activity, such as urban waste (garbage and refuse), transportation emissions, and the accumulation of chemical fertilisers and pesticides in the environment [2].

The indiscriminate and excessive use of fuels extracted from underground sources, coal, smelting and mining operations, various means of transportation, waste, petroleum derivatives, dust, and other pollutants is one of the sources of environmental pollution [5]. Similarly, the general misuse of pesticides causes many problems for both plants and animals and leads to soil degradation [7]. Soil plays a vital role in plant growth and life. It is the medium in which all aspects of agricultural production occur, as it is the natural habitat for many microorganisms, worms, and insects. Soil is of paramount importance as the physical medium that supports plants, in which roots grow, penetrate, and absorb the water and salts that the plant needs for growth and development. Furthermore, soil provides the various environmental conditions necessary for plant growth, including moisture, aeration, nutrients, and others [13].

Soil is exposed to the accumulation of external materials, increasing the concentration of one of its natural components and, in turn, altering its physical and chemical composition. These materials are called soil pollutants and may include pesticides, chemical fertilisers, acid rain, waste, and many other substances that ultimately degrade soil properties and pose a threat to various living organisms [32].

2.3. Heavy elements

Heavy elements, also known as heavy metals, are defined as those with a density more than five times that of water (5 mg/cm3). They have negative effects on human, animal, and plant health. Examples include lead, cadmium, mercury, copper, zinc, and arsenic. Caesium is one of the most dangerous toxic substances. It pollutes soil, water, and air, causing severe damage to humans, animals, and plants [3]. Agricultural soil is exposed to heavy metal pollution. These elements mix with soil, depleting its fertility. They kill the bacteria responsible for decomposing organic matter and fixing nitrogen. Plants absorb these elements if present in soil or water. The metals then reach humans through the food chain. Protecting soil from pollution and degradation is imperative due to its connection to human health [33].

2.4. Sources

Soil becomes contaminated with heavy metals from many sources, including natural sources and some resulting from human activity, called industrial sources because most of them are due to industrial activity [4].

2.4.1. Natural sources

Heavy elements are abundant in nature and are released through various cycles. These geochemicals influence the environment, as heavy elements exist in varying concentrations despite their scarcity. Specifically, physical, chemical, and biological weathering of the Earth's crust releases some of these components from parent rocks. As a result, heavy elements dissolve in water during the water cycle, either through rocks or through soils that contain elements such as mercury, lead, zinc, nickel, cadmium, and others [25].

Natural pollution can occur underground due to reactions of sulfur minerals with oxidising agents. Such reactions can be activated by the presence of nitrates, which can come from many sources. Therefore, these elements are naturally present in soil as part of its composition [32].

2.4.2. Sources resulting from human activity

Sources resulting from human activity include the following:

- Extracting minerals from mines and the resulting waste becomes a source of pollution in the surrounding lands.
- Sewage and industrial wastewater: All types of sludge contain high concentrations of toxic elements, but industrial wastewater sludge contains inorganic pollutants in much higher concentrations than sewage sludge. Zinc is considered one of the most significant pollutants. Zn, Ni, Cu, and Cd are among the most important elements that cause problems in agricultural production when sludge is added to the soil.
- Disposing of solid and toxic waste: Household, factory, and hospital waste can lead to soil pollution with micro- and heavy metals. Disposing of it, whether by dumping or burying it in the soil, leads to soil contamination and its transfer to groundwater [34].

2.5. Heavy metals and their harmful effects on the environment and plants:

Heavy metals are among the most dangerous inorganic pollutants that have significantly contaminated the environment, especially since the beginning of the massive industrial revolution and the increase in industrial activities across various sectors. The environment has been greatly affected, including changes in chemical and physical properties that have negatively impacted the lives of living organisms [27]. Heavy metals are divided into two categories. The first is called essential trace elements, which plants need in small concentrations. A deficiency of these elements affects some vital processes in the plant. When the concentrations of these elements exceed the critical limit, symptoms of toxicity appear. These include copper. The first category consists of essential elements such as Cu , chromium (Cr), iron (Fe), manganese (Mn), magnesium (Mg), zinc (Zn), nickel (Ni), cobalt (Co), calcium (Ca), and silicon (Si). The second category comprises non-essential heavy metals, which are not required by plants and are toxic at any concentration. These include lead (Pb), cadmium (Cd), mercury (Hg), and silver (Ag) [34]. Heavy metals are among the most dangerous pollutants because they do not decompose and can accumulate in the tissues of living organisms as they are transferred through the food chain after entering the soil from various agricultural and industrial sources [24]. It has no beneficial role in biological systems and is dangerous to the health of humans, animals, and plants [35].

2.6. The danger of heavy metals to humans

Most heavy metals share many physical properties, but their chemical reactions differ. This applies to their environmental effects as well. Some of these elements (mercury, lead, cadmium) are hazardous to public health, while others (chromium, iron, copper) have effects limited to workplaces where prolonged exposure occurs. These are less dangerous than other elements, such as lead, which has become increasingly prevalent in recent times and is now found in abundance in water, air, and food. Many heavy metals are essential for life, even in very small amounts, but they become toxic when their concentration in the body reaches high levels, at which point they can interfere with cell growth and the digestive system [36]. Human exposure to these elements has increased due to their excessive use in daily life, leading to their widespread presence in most countries, especially in industry. Heavy metals, which pollute both soil and water, are extremely dangerous because of their persistence in the environment and their carcinogenicity to living organisms, including humans. They cannot be biologically broken down but transform from one complex organic compound to another [37]. He explained [38]. The use of sludge or sewage water in agriculture increases the concentration of major and heavy elements in the soil. These heavy elements are toxic to humans and animals when present in large quantities.

The use of industrial waste and solid residues for irrigation purposes increases the concentration of heavy metals in soil and, subsequently, in cultivated crops, posing a risk to human health as these substances become toxic to plants and cause damage [39,40,41].

Recommendations

- A well-thought-out plan was developed to reduce various pollutants, including heavy metals, by cultivating super-accumulating plants with high biomass, both within and outside cities.
- Encouraging the cultivation of oleander in Iraq, as it is one of the plants most suitable for Iraq's environmental conditions.

3. Conclusion

Oleander (Nerium oleander L.) is an effective plant species used in phytoremediation techniques to reduce environmental pollution, particularly heavy metal soil contamination. Thanks to its high tolerance to harsh environmental conditions, such as drought and pollution, this plant can absorb and accumulate heavy metals through its roots and store them in various plant tissues.

The morphological and physiological characteristics of oleander, including its robust roots and thick leaves, enhance its ability to survive in polluted environments and help reduce pollutant concentrations in the soil. Furthermore, the root zone surrounding the plant plays a crucial role in stimulating microbial activity that helps break down some pollutants. Therefore, oleander can be considered a promising and sustainable biological tool for environmental remediation. Cultivating it in polluted areas can improve soil quality, reduce the spread of toxic elements in the environment, and protect human health and the ecosystem.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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