igMinRESEARCH A BioMed & Engineering Journal
Focusing on Biology, Medicine and Engineering disciplines
ENGINEERING ISSN 2995-8067
Materials Science

Article Information

Submitted: December 16, 2024
Approved: January 03, 2025
Published: January 06, 2025

How to cite this article: Kalimoldina LM, Kuanganovna AS, Satzhankyzy ZG, Shaikhova ZE, Sapina SG. Utilising Phytoremediation in Green Technologies: Exploring Natural Means of Environmental Clean-up. IgMin Res. January 06, 2025; 3(1): 005-008. IgMin ID: igmin276; DOI: 10.61927/igmin276; Available at: igmin.link/p276

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Keywords: Phytoremediation; Pollutants; Paulownia; Environment; Technology; Heavy metals; Soil

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Research Article

Utilising Phytoremediation in Green Technologies: Exploring Natural Means of Environmental Clean-up

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Abstract

Recently, environmental pollution has acquired the character of a global environmental threat, the current situation causes concern for the authorities, scientists, and the public and the need to develop simple and sufficiently effective technologies for the return to nature of elements that have been reformed in the course of economic processes and thus become pollutants.

Traditionally used physical and chemical methods are effective, but very expensive and may cause additional load on ecosystems. Existing outdated technologies and equipment for wastewater treatment need to be replaced with new ones.

Phytoremediation is a set of methods for treating wastewater, soil and atmospheric air with the help of green plants. Due to differences in plant physiology, not all plants can collect heavy metals or organic pollutants. Even varieties of the same species can accumulate pollutants.

The work aims to investigate natural means of cleaning the environment by phytoremediation.

Several field trials confirmed the possibility of using the Paulownia plant for cleaning the air environment of Almaty city. The results of the study showed that the fast-growing Paulownia tree in areas with heavy metal-contaminated cadmium, lead, arsenic and antimony polluted and disturbed soils can be rehabilitated or reclaimed.

All advantages and limitations of the phytoremediation method were investigated and experimentally demonstrated. The obtained research results confirm the prospects of the phytoremediation method for reducing environmental impact on contaminated soils.

Introduction

Phytoremediation technologies use plants to clean up environments contaminated with hazardous pollutants. This process can be effective in removing heavy metals, pesticides, and other harmful substances from soil and water. Phytoremediation provides an environmentally friendly and sustainable way to control pollution but requires careful planning and implementation to achieve the best results [1,2].

Phytoremediation technologies use living plants to clean up soil, air and water contaminated with hazardous pollutants. It is defined as 'the use of green plants and associated microorganisms, along with appropriate soil improvement and agronomic practices to contain, remove or neutralise toxic environmental pollutants' (Table 1). The term is a mixture of the Greek words phyto (plant) and the Latin text medicium (restoring balance) [3,4]. Although phytoremediation is attractive because of its cost, it has not been demonstrated to remediate any serious environmental problems to the extent that the contaminated space has been remediated [5-7].

Table 1: Natural environmental cleaners.

Plant names	Annual growth	Height of a 3-year-old tree	Maximum height of an adult tree
Paulownia	3-5 m	10,5-15,5 m	15-20 m
Hybrid willow	1,5-4 m	7,5-12 m	15-25 m
Black poplar	2,5-3,5 m	9-12 m	20-25 m
Delta poplar	2,5-3,5 m	9-12 m	20-30 m
Texas red oak	2-2,5 m	7.5-9 m	15-20 m
Red Eucalyptus	2-2,5 m	6-9 m	10-15 m
Weeping willow	1,5-2,5 m	4,5-9 m	15-20 m

Phytoremediation can be applied to contaminated soil or static aquatic environments. This technology is increasingly being investigated and applied to sites with soils contaminated with heavy metals such as cadmium, lead, aluminium, arsenic and antimony. These metals can cause oxidative stress in plants, disrupt cell membrane integrity, interfere with nutrient uptake, inhibit photosynthesis and reduce chlorophyll [8,9].

The principle of phytoremediation is that the plant affects the environment in different ways:

Rhizofiltration: The roots suck up water and chemical elements necessary for plant life.

Phytoextraction: Accumulation of hazardous pollutants (e.g. heavy metals) in the plant body.

Phytostabilisation: Conversion of chemical compounds to a less mobile and active form (reduces the risk of spreading contaminants).

Phytodegradation: Degradation by plants and symbiotic microorganisms of the organic part of the pollution.

Phytostimulation: Stimulation of the development of symbiotic microorganisms taking part in the cleaning process [6,10,11].

Research materials and methods

The study of plants that purify the natural environment using phytoremediation methods includes the following steps:

- Selection of plants with a high capacity to absorb and accumulate pollutants. For example, algae can be used to clean ponds.
- Preparing the soil before planting the plants is important. This may include adding organic matter and fertiliser to help create favourable conditions for plant growth and phytoremediation capacity (Tables 2,3).

Table 2: Characteristics of the samples.

№ sample	Depth, cm	Acidity, pH	Humus, %	CO_2, %	Mobile forms, mg/kg	
					P_2O_5	K_2O
Soil sample №1	0-20	7.6	2.44	5.84	21	310
Soil sample №2	0-20	8.0	1.8	2.36	15	313.6

Table 3: Effect of soil medium on plant growth.

Soil pH	Impact on plant life
> 8,3	Too alkaline an environment for most plants
7,5	The availability of iron (Fe) is becoming problematic.
7,2	6.8 to 7.2 - almost neutral 6.0 to 7.5 - acceptable for most plants
7,0	
6,8	
6,0	
5,5	Reduction of soil microbial activity
<4,6	An environment that is too acidic for most plants

- Once the soil is prepared, the plants are planted and require regular care. This includes providing them with the right amount of water and light, as well as protection from pests;
- It is important to continuously monitor the level of contamination and the condition of the plants. This allows the effectiveness of phytoremediation to be evaluated. - Soil and water testing can help determine how well plants absorb pollutants;
- Plants can be harvested after the phytoremediation process has been completed [8,12,13].

Biomonitoring is an essential element of the study.

The object of research was the fast-growing Pavlovnia. The choice of the object was justified by the ecological characteristics of the plant. It was found that for precipitation there is an excess of heavy metal content compared to the MAC standards accepted for soils. Fresh sediments are the most contaminated, but during the five-year storage period, the content of cadmium, lead, copper, zinc and chromium in them decreased by 4.9-17.4 times [9,14]. The species specificity of Pavlovnia species in terms of growth rate, biomass accumulation and heavy metal accumulation on soil substrates based on sewage sludge solids was also established. These results emphasise the importance of plant breeding studies for anthropogenic soils (Figure 1).

Results and discussion

Several field trials confirmed the feasibility of using Pavlovnia for environmental treatment.

From the above data, it can be seen that the characteristics of the samples are identical.

Thus, at pH 6.0-7.5 is a favourable environment accordingly.

Phytoremediation is proposed as a cost-effective plant-based approach to environmental remediation that utilises the ability of plants to concentrate elements and compounds from the environment and remove toxins from various compounds. The concentrating effect results from the ability of some plants, called hyperaccumulators, to bioaccumulate chemicals [15,16]. The remediation effect is quite different. Toxic heavy metals cannot be degraded, but organic pollutants can be and usually are the main targets for phytoremediation.

The effect of copper sulphate in the aqueous medium in the presence of reducing agent ascorbic acid and stabiliser gelatin was investigated. To determine the optimal conditions, the influence of various factors on the antibacterial activity of copper was studied: concentrations of the reagents used, pH values of the medium, and the effect of temperature on the

ISSN 2995-8067 DOI: 10.61927/igmin276

Figure 1: Stages of Pavlovnia growth.

reduction of copper ions. To improve the acid resistance of soils containing copper sulphate based on ascorbic acid, a simple and environmentally safe method of obtaining concentrated (about 0.01 mol/l) in suspended particles is proposed. The treated soils were examined on a spectrophotometer with a wavelength from 0.2 to 0.9 (Figures 2,3).

From the tabulated data, it is evident that with increasing concentration of copper sulphate the optical density of the sample increases.

Based on Tables 4,5, the optimum condition for plant growth is a concentration of about 0.3 mol/l of solution.

From the above, bioaccumulation of pollutants, especially metals, in plants can affect consumer products and requires safe disposal of affected plant material.

Figure 2: Study of solution samples.

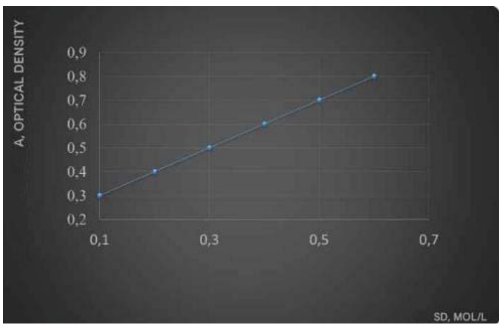

Figure 3: Effect of copper sulphate concentration on optical density.

Table 4: Variation of optical density with the concentration of $CuSO_4$ solution.

$C_{CuSO4,}$ mol/l	0,1	0,15	0,3	0,4	0,5	0,6	0,7
AU	0,3	0,4	0,5	0,6	0,7	0,8	0,9

Table 5: Concentration of initial substances.

№	The initial concentration of the substance, mol/L		
	Gelatin	$CuSO_4$	$C_6H_8O_6$
1	0.05	0.1	0.05
2	0.1	0.15	0.1
3	0.2	0.3	0.3
4	0.05	0.4	0.1
5	0.1	0.5	0.1
6	0.2	0.6	0.1
7	0.3	0.7	0.2

Conclusion

When heavy metals are absorbed, sometimes the metal binds to soil organic matter, making it unavailable for extraction by the plant.

Several plant- or algae-mediated processes are tested in environmental problems: for example, chromium is toxic to most higher plants at concentrations above 100 μM/kg/1 by dry weight. To simplify the implementation of photo-screening in the field, standard methods have been developed to extract a portion of the tree trunk for laboratory analysis of sites and to reduce the cost of cleaning up contaminated sites.

Thus, the advantages and limitations of the method are:

- The cost of phytoremediation is lower than the cost of traditional processes;
- Preserves topsoil, maintaining soil fertility;
- Improves soil health, crop yields and plant phyto-chemicals;

- Use of plants also reduces erosion and leaching of metals in the soil.

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Regularity: Monthly
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Publication Time: 14 Days
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