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# Phytoremediation, Effective Technology in the Removal of Nutrients and Heavy Metals in Wastewater by Slavonia Molesta, and Pistoia Stratiotes

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***Abstract***

*Many technologies are now utilized to remediate environmental contamination, and phytoremediation is an environmentally friendly technology poised to become one of the most important eco-friendly technologies employed by scientists in their study. Besides food and shelter, clean water is a requirement in human life. The primary sources of clean water are surface and subsurface water. However, due to fast population expansion and increased industrialization worldwide, many water sources are becoming contaminated. As a result, wastewater must be thoroughly treated before being discharged into the environment. Phytoremediation is a type of bioremediation that uses plants to remediate wastewater. Aquatic plants have the ability to absorb excess toxins such as organic and inorganic, heavy metals, and pharmaceutical pollutants found in agricultural, household, and industrial effluent. Salvinia molesta and Pistia stratiotes are two aquatic plants that have been widely employed in the treatment of agricultural, household, and industrial wastewater. The availability, durability in a hazardous environment, bioaccumulation potentials, invasive mechanism, and biomass potentials of these plants account for their widespread use. This review study examines the key functions and potentials of aquatic plants in wastewater remediation.*

*Keywords: phytoremediation, bioaccumulation potentials, invasive mechanism, biomass potentials, contaminants*

## 1. Introduction

Domestic sewage is undoubtedly the most hazardous organic effluent in the world in terms of the amounts produced and the locations affected. This is due to the fact that human waste is produced practically everywhere on Earth where people live. Domestic sewage is a prevalent pollutant as a result. The amount of sewage produced is likewise astounding; every day, up to 70 million m3 of residential sewage is produced in India alone. About 40 million m3 of this is released untreated into significant rivers and other water bodies [1].

In addition to food and shelter, clean water is a fundamental requirement for human survival. The main sources of clean water are surface and subsurface water. However, many water sources have become contaminated as a result of the world's fast population increase and industrial development. This is caused by manmade activities that continuously release organic and inorganic pollution into natural water sources [2].

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It is no secret that there is a serious pollution problem. Many researchers believe that if global warming exceeds 1.5 degrees Celsius, the impacts will be catastrophic. While it is tempting to just delegate responsibility to higher-ups in society, the unavoidable fact is that a collaborative effort is required to properly avert this approaching tragedy. It is not about making radical changes, but rather about gradually correcting poor behaviors and reinforcing good habits. True change frequently begins from the bottom and works its way up. Water pollution is one of the less-discussed contaminants. Currently, total removal of water is not always possible using standard wastewater treatment procedures. Because of this, purified water still contains a minor number of harmful pollutants. These residues may harm ecosystems owing to the poisonous nature of the pollutants, which can interfere with various cellular activities in plants. Alternative wastewater treatment techniques are necessary due to the negative impact of these toxins on human life and aquatic ecosystems. “Phytoremediation is a broad term that encompasses the use of plants to reduce contaminants in environmental media such as water, soil, and sediment [3]. Over the last ten years, research has demonstrated that the physiological, biological, and physiochemical behaviors of plants in an aquatic environment may be used to improve the processes of nutrient absorption from wastewater. Several researchers have looked at the processes by which aquatic plants absorb nutrients from wastewater systems. Free-floating aquatic weed Salvinia molesta has spread around the world, especially to Asia, Africa, Australia, Ceylon, and New Guinea. Due to its rapid development, adaptability, and productivity, this weed looks to have an advantage over the water hyacinth, which is the most troublesome weed in the world. Since several coordinated efforts to eradicate this plant using chemical, mechanical, and biological approaches have been ineffective, current focus has shifted to finding ways to make use of the weed in order to offset the expense of mechanically removing it [4]. The primary functions and potentials of aquatic plants in the phytoremediation of wastewater are assessed in this research. Additionally, it examined the effectiveness of molesta and Pistoia stratiotes plants in wastewater cleanup as well as potential future uses for the plants in phytoremediation research.

## 2. What is Wastewater, Exactly?

Any liquid waste or sewage that originates from residences, hospitals, industries, or any other facility that uses water in its facilities is referred to as wastewater. It is a byproduct of water consumption. As a result, anytime you tap on a faucet or use a toilet, the water you consume will ultimately make its way to the sea and other vast bodies of water. After treatment, this water is frequently dumped into a body of water. "Decrease in water quality can lead to increased treatment costs of potable and industrial process water [5]". "Surface water has been exploited for several purposes by humans. It serves as a source of potable water after treatment and as a source of domestic water without treatment particularly in rural areas in developing countries. It has been used for irrigation purposes by farmers, and fishermen get their occupation from harvesting fish in so many freshwater sources. It is used for swimming and also serves as centers for tourist attraction. Surface water, therefore, should be protected from pollution" [6]. Wastewater treatment's primary goal is to safeguard public health and stop environmental deterioration through the secure disposal of home and commercial wastewater produced during the usage of water. Water resources are limited in arid and semiarid parts of the world; hence one goal of the treatment of wastewater is to recycle sewage for use in agriculture [5]

*2.1 Contamination of water and habitats:* The most direct impact of wastewater on the ecosystem is when it leads to the pollution and destruction of natural ecosystems and the species that lives in them by exposing them to dangerous chemicals that would not be present in the normal run of things. Wastewater is a major source and carrier of illness. "Dichloromethane is a common groundwater contaminant which is a carcinogenic substance that can cause cancer and environmental problems" [3] According to a World Health Organization estimate, wastewater kills more than 3.4 million people every year. Aside from the pathogens carried by wastewater, the mix of human excreta, chemicals, and paints produces vapors that are not only nasty but also expose individuals to dangerous gases. Inhaling sewer gas poses a serious risk to health. "Recently, it has been shown that WW effluents contain emerging organic contaminants such as persistent organic pollutants (POPs), brominated flame retardants, perfluorinated compounds, and pharmaceuticals, which are not removed during the treatment process" [5].

*2.2 Deterioration of the soil:* Wastewater is frequently cleaned and recycled for cultivation. As if that wasn't awful enough, water purification methods aren't entirely successful. When wastewater is not adequately handled, chemicals that are hazardous to crops may make their way into the soil. Because of these compounds, the soil will produce fewer crops at a slower rate. Consider that these crops will ultimately be consumed which individuals. "Depuration of wastewater prior to its reuse is the most plausible option to prevent soil pollution by wastewater reuse. However, since wastewater represents a cheap source of water and fertilizer for farmers. By using these sorts of systems to treat wastewater, there may be a chance to combine sanitation with reuse as part of the program of comprehensive wastewater management, nutrient recycling, and the use of soil as a purifying system [7].

*2.3 Wastewater composition:* Heavy metals, pathogens, salts, toxic chemicals, oil and grease, sediments, nutrients, sludge, acids and bases, poisonous organic compounds, and organic and inorganic elements can all be found in wastewater. This effluent is hazardous to humans, animals, and the ecosystem as a whole. Globally, there is substantial concern over the presence, movement, and destiny of hazardous and persistent organic chemicals and heavy metals in water bodies [5]. It is poisonous, corrosive, reactive, acidic, and flammable. As a result, it must be treated before it may be reused or rerouted into the water supply.

*2.4 Consequences of wastewater on the aquatic environment:* "The release of raw and ill- treated wastewater onto water courses has both short- and long-term effect on the environment and human health" [5].Waterborne infections are becoming more prevalent due to the wastewater's impact on the water supply's quality [8]. Lakes and rivers are often the most vulnerable to the damaging impacts of wastewater. The concentration of harmful chemicals in wastewater disrupts aquatic habitats. When a big number of biodegradable compounds wind up in the water, organisms begin to break them down, requiring a huge amount of dissolved oxygen. Dissolved oxygen is essential for marine life to survive, and when it depletes, it can be lethal to marine species. Wastewater also contains oil and grease, which are more difficult to digest and can sit on the water's surface. This reduces the amount of light available to photosynthetic aquatic plants. It may also suffocate fish and become entangled in the feathers of birds. Heavy metals such as lead and mercury are hazardous to both people and animals. If a person drank or ate food from a polluted water source, they may experience major health consequences. The same is true for aquatic creatures and vegetation.

*2.5 Other negative wastewater characteristics:* Sludge created by wastewater treatment facilities must be disposed of properly, which is a huge concern [9]. "It is estimated that the projected wastewater from urban areas might cross 120,000 MLD by 2051 and rural areas will generate 50,000 MLD. Currently 884 million and an additional 2.5 billion people lack water sources and sanitation facilities" [8]. When untreated sewage is deposited, it is frequently warm or even hot, raising the temperature of the water and damaging the ecology. Because fish have cold blood, they rely on water to maintain their body temperature. Overheating the water can affect respiration, feeding, and movement. Furthermore, the concentration of oxygen in the water is affected by its temperature. Wastewater is more detrimental to the natural ecosystem where untreated water is dumped freely, causing numerous issues in regulating the difficulties of giving safe drinking water to rural and urban areas. Contaminants including Zn, Cu, Ni, and Cr constitute the most prevalent contaminants in industrial effluent [10]

Water contamination concerns are mostly caused by wastewater effluents, which create harmful algal blooms, encourage algae growth, raise purifying costs, pose health hazards to animals and humans, and cause extreme oxygen loss, all of which can induce changes in the population of freshwater environments. During the industrial period, humans introduced several harmful chemical and non-chemical compounds into the environment. Pollutants include toxic dyes, heavy metals, organic chemicals, and inorganic substances. Currently, standard wastewater treatment procedures are not always efficient in completely removing water pollutants. As a result, traces of these pollutants can still be present in treated water. Because of the hazardous nature of the pollutants, which can interfere with numerous cellular activities in plants, these residues may harm ecosystems. Given the dangers of these toxins to human existence and marine environments, alternate wastewater treatment procedures are necessary. For the elimination of organic and inorganic impurities, many traditional treatment procedures such as ion exchange, chemical precipitation, electrochemical treatment adsorption, reverse osmosis, and so on are utilized. However, the high energy requirements, carbon emissions, excess sludge discharge, and high maintenance costs pose significant challenges to these wastewater treatment technologies. As a result, environmentally friendly and low-cost remediation approaches are required for the long-term maintenance of clean water and aquatic ecosystems. Recent studies have found that aquatic plants have the capacity to remove both inorganic and organic pollutants. The phytoremediation strategy, a subset of bioremediation, uses plants to treat wastewater. It makes use of the abilities of the root system to absorb nutrients from wastewater. Plant species used for phytoremediation might accumulate a specific or broad spectrum of contaminants. Phytoremediation is more efficient and economical than conventional treatment methods.

## 3. A Major Source of Global Water Contamination

*3.1 Metropolitan wastewater:* Domestic sewage is often hazy, dilute solution including organic debris, human excrement, urine, soap, minerals, and unclean used-up home water. Domestic sewage is typically discharged into rivers, on the banks of which most municipalities are located. "Livestock wastewater, which is produced by livestock farms, refers to the total name of all excrement or residual excrement, urine, feed residue, washing wastewater, and wastewater generated during the life and production process of workers" [11]. Urban trash is the leading cause of water contamination. According to a recent analysis from the Water Pollution Research Laboratory in London, home sewage includes trace amounts of hazardous metals such as Cu, Cr, Zn, Mn, Pb, and Ni. Domestic sewage contains decomposable organic waste, which places an oxygen requirement on the receiving water bodies. Organic matter in sewage comprises amino acids, amides, fatty acids, esters, amino sugars, and other organic compounds.

*3.2 Industrial effluents:* The use of chemical-based pre-treatment processes of influent water to reduce the content of phosphorus and the biological oxygen demand of the wastewater has been promoted by public concern over the quality of wastewater released by sewage treatment facilities. [12]. Toxic chemicals and hazardous compounds found in industrial effluents include non-biodegradable pollutants, toxic acids aldehydes, ketones, amines, cyanides, metallic wastes, phenols plasticizers, , corrosive alkalis, dyes, biocides, suspended solids, oils, greases, radioactive wastes, and thermal pollutants. Chemical and drug companies, steel mills, oil refineries, fertilizer plants, pulp and paper, sugar, distilleries, textiles, soap and detergent, tanneries, and other sectors are major contributors to water pollution in India. Industrial effluents have badly contaminated certain Indian rivers and streams.

*3.3 Agricultural discharges:* Agricultural outflows such as both biodegradable and non-biodegradable pesticides, fertilizer, manure, slurry, animal and plant waste, soil erosion, and soil erosion consisting predominantly of inorganic elements are known to pollute water sources. The majority of the discharges that are added to the soil are rinsed off into water bodies by rainfall, irrigation, and drainage, where they significantly disrupt the marine ecosystem. Agricultural outflows are predicted to be three times greater than household sewage discharges.

*3.4 Fertilizers*: Because: heavy metals are non-biodegradable and accumulate at high quantities, they constitute a major threat to nature when they are exposed in excess, as in the case of industrial waste and fertilizers [13]. According to NCA, fertilizer application grew from 2.8 million metric tons in 1976 to 6.0 million metric tons in 1984 and 9.7 million tons in 1995. On the one hand, fertilizers increase agricultural productivity, but on the other, they disturb the overall natural aquatic ecology. India uses roughly 15-16 kilograms of fertilizer per acre, whereas the global average is 55 kg. In the Netherlands, fertilizer use is around 71 kg/ha. However, it isn't just the increased usage of fertilizers but also the increased output that has a negative impact on water and life forms.

*3.5 Detergents*: One of the main household chores that require a lot of water and detergent is doing the laundry at home. There are numerous miraculous cleaning detergents on the market right now. The many chemical ingredients that make up these laundry detergents include surfactants as well as builders, fillers, bleaching agents, enzymes, visual brighteners, anti-redisposition agents, fragrances, and color. [14] Detergents are created from surfactants (10-30%), builders (10-15%), and other chemicals and are used as cleaning agents. Because of their dual hydrocarbon and polar nature, surfactants, such as alkyl benzene sulphonates, dissolve partially in water and partly in organic solvents. As a sequestering agent, the builder is usually a sodium phosphate (polyphosphate) of the type Na3P3O10 or Na4P2O7. Surfactants and detergent builders both contribute to complicated water pollution concerns.

*3.6 Toxic metals*: Toxic metals enter aquatic systems as a result of industrial activities, residential sewage discharge, land run-off, street dust, engineering procedures, and the use of fossil fuels. Heavy metal residues such as Cd, Hg, Pb, As, Mn, Co, Fe, and Cr have been shown to harm aquatic ecosystems and public health.

*3.7 Silts:* "Municipal wastewaters are rich in carbon, nitrogen and phosphorus, it has large impacts on the environment" [15]. Silts are particles of soil/sand suspended in water. Siltation is the most common and harmful type of pollution, particularly in hillside streams with significant turbidity. These also impede the free movement of aquatic species, as well as the development and production of fish.

*3.8 Oils:* Numerous investigations have revealed that polycyclic aromatic hydrocarbons (PAHs), which are known to be powerful carcinogens, are pervasive pollutants in a range of matrices, including air, food, fly ash, soil, water, sediments, crude oil, and petrochemicals [14] . Oil pollutes marine water. Shipwrecks, loading and discharging of oil at the harbor, oil refining, and offshore oil industry all contribute to oil pollution. Every year, two million tons of old lubricating oil are introduced to coastal seas, according to estimates. Oil is released into the ocean after maritime incidents caused by collisions, fires, explosions, or grounding. The international release of oily pollutants from tank cleaning and unintentional spills severely damages marine water. In 1984, more than 90,000 liters of waste oil was collected from the Indira Dock basin alone. According to a recent study, around 20 billion tons of trash from enterprises, houses, farms, and municipalities end up in the sea each year.

*3.9 Thermal pollutants*: Water is used to cool several businesses. The warmed water that results is dumped into rivers, streams, or lakes. This results in water contamination. Calefaction is another term for thermal pollution (warming). Thermal pollutants in general comprise waste mostly from atomic, nuclear, and thermal power plants. Municipal sewage adds to thermal pollution as well. Electric utilities are the primary cause of thermal pollution in rivers and lakes. They also emit heat into the atmosphere, as do most industry enterprises and densely populated areas. Cooling has been the classic and still widely used way of removing waste heat from power plants.

## 4. The Impact of Heavy Metals on Aquatic Life

"The concentrations of heavy metals in the environment increase from year to year. Atmospheric deposition of Cd, Zn, and Pb has diffusely polluted the 700 km2 Camping area in Belgium and the Netherlands [16]. Fish is abundant in omega-3 fatty acids and protein, which the human body requires to keep healthy. However, potentially hazardous heavy metals are deposited into fish tissue and are passed to people when this afflicted fish is consumed. "Lead is one of the most abundant toxic metals that pose a serious threat to human beings, animals, and phytoplankton. In humans, it is absorbed directly into the blood stream and is stored in soft tissues, bones, and teeth (95% in bones and teeth [13]. Food of high grade only in an environment free of contamination and pollution can food for humans be produced. Fish are very important economically, yet they are greatly impacted by many substances, especially heavy metals, in various ways, either directly or indirectly. Mining has resulted in the destruction of 2.88 106 hectares of land in China alone, and an additional average of 46,700 ha of devastated land is created each year. Due to extreme pollution, these damaged fields are nearly entirely devoid of flora, which ultimately results in significant soil erosion and off-site contamination [16]. To reduce their influence on ecosystems, it is therefore imperative to clean up heavy metal-contaminated soils. Several studies have indicated that protracted heavy metal exposure increases mortality in juvenile fish and reduces adult breeding potential. The freshwater fish Labeo rohita is very important commercially since it is the most often eaten fish globally. As a result, it may be a useful model for studying the reactions to heavy metal contamination issues. Histopathological research on fish is an important and promising topic for understanding the structural organization that happens in organs as a result of environmental contaminants. These structural modifications differ depending on the body part, pollutant type, medium, and length of exposure.

The features of water quality also impact the histopathological manifestations of toxic effects. The structural reforms in the organs at the nano-cellular and organ levels cause changes in the function system.

## 5. Concept of Phytoremediation

The phrase phytoremediation is derived from the Latin words plant and cure. Phytoremediation is a low-cost, plant-based remediation method that makes use of plants' capacity to isolate elements and chemicals from their surroundings and metabolize diverse compounds in their tissues." Regarding cost, phytoremediation can cost as less as 5% of alternative clean-up methods" [16]. Phytoremediation is a new green strategy of detecting, degrading, and removing numerous sorts of contaminants from the environment. It refers to certain plants' natural capacity to bioaccumulate, digest, or render harmless pollutants in soil, water, or air. The primary targets for phytoremediation are harmful heavy metals and organic contaminants. Understanding of the molecular and cellular processes of phytoremediation has emerged since the late twentieth century, along with biological and technical solutions meant to enhance and improve phytoremediation. Furthermore, multiple field investigations demonstrated the viability of employing plants to clean up the environment. While the technique is really not new, current developments suggest that it is gaining popularity. Several methods are engaged in the removal of contaminants from water, particularly metal contaminants, in order to transform them into harmless molecules and therefore remove waste from water.

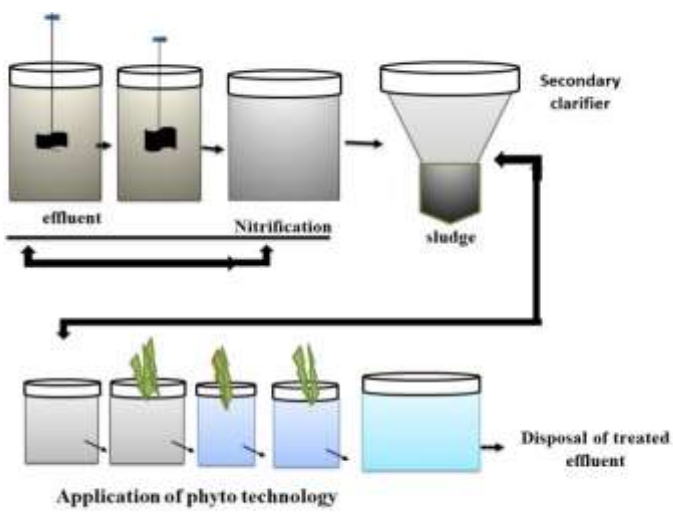


**Figure 1.** Mechanisms of phytoremediation

Phytoremediation basically refers to the use of plants and associated soil microbes to reduce the concentrations or toxic effects of contaminants in the environment. It can be used for the removal of heavy metals and radionuclides as well as for organic pollutants. Its novel, cost-effective, efficient, environmental and eco-friendly, in situ applicable and solar-driven remediation strategy" [16]. SHEFROLVR technology was developed in response to the urgent need for ways of treating home sewage that are affordable, easy to install and operate, work at very small to very large sizes, are clean-green, and are yet effective and efficient. It is a new technological advancement. It uses readily accessible aquatic, amphibious, and terrestrial weeds to treat wastewater in its primary, secondary, and tertiary stages in a single step [1].

*5.1 Phytoextraction/phytoaccumulation:* "Phytoextraction (also known as phytoaccumulation, Phyto absorption or Phyto sequestration) is the uptake of contaminants from soil or water by plant roots and their translocation to and accumulation in above-ground biomass such as shoots" [16]. Plants may collect heavy metals necessary for growth and development, such as Fe, Mg, Mo, Mn, Zn, Cu, and probably Ni. Furthermore, some of them have the ability to collect heavy metals with no recognized biological roles, such as Cd, Cr, Pb, Co, Ag, Se, and Hg. Plants require a balance between the intake of required metal ions to sustain growth and development and the capacity to better protect cellular activities and structures from excessive amounts of essential and non-essential metals for metal metabolism. Plants may resist heavy metal ions through an avoidance mechanism that primarily involves metal immobilization in root and cell walls. Robinson et al., 1994 explained that heavy metal tolerance is based on the sequestration of heavy metal ions in vacuoles, the binding of heavy metal ions by suitable ligands such as organic acids, proteins, and peptides, and the existence of enzymes that can operate at high levels of metallic ions The optimal plant for phytoextraction should possess the following characteristics: Be tolerant to high metal levels; have a quick growth rate; acquire high metal levels in its harvestable portions, have the ability to create a large amount of biomass; and have a dense root system.

*5.2 Phytodegradation:* Phytodegradation is the process by which plants break down organic pollutants without the aid of rhizosphere bacteria, using enzymes like dehalogenase and oxygenize [16]. It happens because of the plant's intrinsic ability to produce particular enzymes that assist in catalyzing and breaking down contaminants during natural metabolic activity, therefore incorporating them into the plant body and promoting development. Its effectiveness is dependent on synergistic interactions between plants, microorganisms, soil, and water. To boost microbial activity for decomposing carbon substrates, the plant offers surface space for bacteria to settle around the root and shoot. Plants play an important role not just enzymatically, but also mechanically in minimizing runoff by enabling compound adsorption on the root surface and promoting evapotranspiration

*5.3 Rhizo-filtration*: Unlike phytoextraction, plants in Phyto-filtration are cultivated in water to adsorb or absorb pollutants within water or from aqueous streams instead of in soil. Blastofilteration is regarded as the second era of wastewater treatment utilizing plants. Residues in wastewater are absorbed by root cells (rhizofiltration) or seedlings (blastofilteration). Phytofiltration begins with hydroponically growing plants until a significant root system develops, and then waste streams are added for the real treatment process. As the plants develop, they absorb these pollutants in the root, shoot, or both. After immersion, the plants are taken whole or merely the roots and discarded.

*5.4 Rhizo-degradation*: The plant root system harbors a variety of microorganisms such as bacteria, fungus, and yeast that break down organic materials in the soil around plant roots (called rhizosphere)." Rhizobacteria is a bacteria associated with the plant root zone, which plays an important role in contamination control and phytoremediation. Rhizobacteria are able to degrade organic compounds, enhance, and protect plant growth" [3]. Microorganisms degrade organic materials, some poisonous chemicals, solvents, and fuels, which can be harmful in nature, into simpler components for nourishment and energy. Plant roots produce chemicals that give food and sustenance for microorganisms while also promoting growth and metabolism. These microbes then devour and degrade the organic materials in the rhizosphere biodegradation is another term for this natural process.

*5.5 Phyto-stabilization*: Contaminants from the soil are ingested by the plant roots, which are subsequently transmitted to the aerial parts and lastly to the leaves, where they are converted into volatile form during metabolic processes and then transpired. This process of biomethylting metals such as Hg and Se into volatile form is contentious since it is unknown if releasing volatiles into the environment is safe. Plant management is also simplified in this method since no anthropogenic sources are required. It is a fantastic, practicable, cost-effective, green technology that uses metal-accumulating plants to remove harmful metals, pesticides, explosives, and radionuclides from soil and water. It also assures lower remedial costs, habitat restoration, and contaminant removal on-site rather than accumulating or being moved to another location for treatment. It is an effective method for accumulating heavy metals such as chromium, nickel, Cadmium, arsenic, lead, mercury, copper, and zinc, as well as radionuclides (Sr, Cs, and U) from the soil, water, and air. Most organic pollutants, including polycyclic aromatic hydrocarbons (PAHs) like benzopyrene, nitro aromatics like trinitrotoluene (TNT), and linear halogenated hydrocarbons like trichloroethylene (TCE), are highly toxic, teratogenic, and even carcinogenic, and are likely targets of phytoremediation.

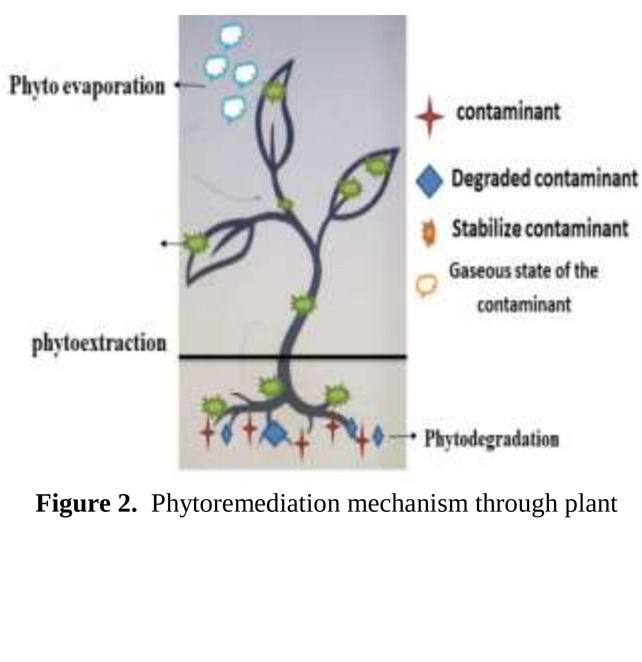


**Figure 2.** Phytoremediation mechanism through plant

## 6. The Function of Weeds Plants in Remediation of Contaminated Water

Aquatic plants are important in biological wastewater treatment systems because they may be employed for phytoremediation via hemofiltration, phytoextraction, phytovolatilization, phytodegradation, or Phyto transformation processes. Pollutant eradication is dependent on the period of exposure, the number of pollutants, ambient conditions (pH, temperature), and plant features (root system, species, etc.). However, it is worth mentioning that some aquatic plant species have been successfully used in the phytoremediation of wastewater. Aquatic plants such as free-floating plants (polyrhiza, Marsilea mutica, Azolla pinnata, Landoltia punctate, Pistia stratiotes, Salvinia molesta, Lemna, Spirodela, Eichhornia crassipes, and Riccia fluitans) and submerged crops are used in the method of phytoremediation, but this review will focus on Pistia stratiotes, Salvinia molesta

*6.1 Pistoia stratiotes*: The study aimed to assess the performance of Pistia stratiotes in a macrophytic wetland phase. Thirty young plants were grown in 1-2 plots in each of the 7 ponds, and their growth and productivity were assessed every 5 days. The plant's reproductive biology was also evaluated, and after 20 days, the plants were harvested, washed, and dried to calculate water content, nitrogen content, crude protein, and fat content. The removal efficiency of the wastewater was determined using general procedures given in the water analysis handbook Hach, 1997. The findings showed a great purifying effect on the nutritional content with BOD at 98% COD at 85.3%, and color at 90.6%, indicating that the wastewater was successfully treated. The study demonstrates the potential of Pistia stratiotes in wastewater treatment and its ability to improve water quality.

*6.2 Salvinia molesta*: Three experiments were used to examine the potential of S. molesta plants in the biological treatment of household wastewater. The study found that the quantity of plants impacts its efficacy in nutrient absorption during phytoremediation procedures. In other words, T1 eliminated 96.8% of the color, 91% of the BOD5, and 82.6% of the (COD). While T2 treatment systems reduced up to 88.6% (color), 87.1% (BOD5), and 81.1% (COD), T3 treatment systems reduced 85.5% (color), 86.1% (BOD5), and 68.3% (COD). In addition, pH values of 5.97-7.07, 6.29-7.19, and 6.17-7.42 were obtained from the T2, T1, and TS3 treatment systems, respectively. As a result, the treatment system with the greatest concentration of S. molesta (T1) performed better than the other two systems (T2 and T3). Additionally, collected S. molesta plants acquired during the phytoremediation method can be utilized as feedstock for biofuel generation. Furthermore, it fulfills the aims of sustainable development by utilizing green technology to lessen the threat of water contamination in natural water bodies.

## 7. Wastewater Contaminant and Its Effect on the Performance of Phytoremediation

It is worth noting that the performance of phytoremediation applications for industrial tertiary wastewater treatment, particularly nitrogen removal, is strongly reliant on tertiary wastewater effluent characteristics. The industrial wastewater contains a diverse set of pollutants that can be hazardous to aquatic macrophytes. Toxic pollutants in wastewater may impede plant development, affecting the efficacy of aquatic macrophytes in wastewater remediation. According to Clarke and Baldwin (2002), different species of aquatic macrophytes showed variable tolerance to ammonia concentrations, and they concluded that the efficiency of phytoremediation can be increased.

*7.1 Advantages of aquatic phytoremediation*: Ximénez-Embn et al., 2001 When compared to alternative treatment methods, green technologies have significant benefits for the decontamination of aquatic contaminated media Environmentally friendly and visually pleasing; Globally viable technology, Easy upkeep (supply and energy), Both on-site and off-site operations are offered. Inhibiting contaminant deployment to the environment or soil by in situ treatment; Appropriate for shallow depth polluted water to hydrologic regulation of groundwater; Periodic therapy versus ongoing treatment; many different forms of pollution can be handled at the same time; Produce biomass for green energy generation.

*7.2 Disadvantages of aquatic phytoremediation*: Phytoremediation like any other method has drawbacks that should be addressed before implementation. Biomass harvesting produces dangerous pollutants. Effective therapy takes a long period; Treatment for badly contaminated media is restricted. Restricted to low concentrations of contaminated sites, and limited to climatic growth conditions managing harvested biomass is essential. A few hyperaccumulator species have been introduced for aquatic media. Contaminants may spread as leaves fall. Most hyper-accumulator plants have restricted roots and develop slowly; most hyper-accumulator species uptake only a few elements. Contaminated biomass might reach the animal and human food chains

## 8. Conclusions

Phytoremediation is an exciting approach for removing or recovering surplus nutrients from contaminated water. The use of aquatic plants in wastewater phytoremediation is advantageous because they have a significant ability to absorb breakdown contaminants (nitrates, phosphates, heavy metals, and so on) from wastewater. As a result, it enhances effluent quality prior to release into natural bodies. Phytoremediation methods may also be used to recover nutrients from wastewater, such as nitrates and phosphate, which can then be utilized to make fertilizers, struvite, and food additives. Salvinia molesta and Pistia stratiotes are two aquatic plants that have been widely employed for the treatment of agricultural, household, and industrial wastewater. These plants are widely used because of their availability, resistance in a hazardous environment, bioaccumulation potentials, invasive mechanisms, and biomass potential. Furthermore, S. molesta and P. stratiotes contained a high concentration of biomass components, making them a viable alternative for bioenergy generation. Despite these two plants' outstanding potential, their entire potential has yet to be discovered. Further research on the plant's ability to remediate radioactive, nanoparticle, pharmaceutical, and polymer-based wastewater is required. However, research on these plants' thermodynamic efficiency index and resource pulse impacts is required in wastewater phytoremediation procedures.

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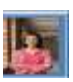

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