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Phytoremediation Potentials of some Selected Tropical Plants in Aquatic and semi-aquatic environments in Hadejia-Nguru wetlands of North Eastern Nigeria

Mohammed Inusa Nguru [1] Sani Abba Nasidi [2] Karagama Kolo Geidam [3] Mubarak Abdullahi [4]
Abubakar Liman [5]
[1,2] School of sciences Department of Science Laboratory Technology Mai Idris Alooma Polytechnic Geidam
[3,5] School of Environmental Studies Department of Surveying and Geoinformatics Mai Idris Alooma Polytechnic Geidam Yobe State.
[4]Department of Biological Science Adamawa State College of Education, Hong P.M.B. 2237 Yola
Corresponding author: inmuhammad1970@gmail.com

Abstract

By cultivating green plants that can withstand and/or eliminate contaminating elements, phytoremediation techniques improve the reduction of unwanted effects and restoration of polluted ecosystems, such as soils and waters, recovering the soil and its functions. The primary cause of the rise in heavy metal concentrations in various ecosystems has been human activity. The rise in potentially hazardous elements (PTEs) in the Hadejia-Jama'are river basin is ascribed to ingredients in agro allied products like fertilizers,pesticides,herbicides and other manufactured goods like paints and batteries. Mining operations as well as industrial, municipal, and household waste, are significant contributors of PTE contamination in the environment. There are currently around 15 million people living in the Hadejia River Basin (HRB) and theirlives are largely dependent on the water resources in the basin. The climates of the basin are mostly semi-arid and partially humid. The field of phytoremediation has gained popularity over the last 10 years as a plant -based remediation technique with the potential to be inexpensive, environmentally friendly, and low -impact. Water hyacinths (Eichornia crassipes), Poplar (Populus spp), alfalfa (medicago sativa), kentucky bluegrass (Poa pratensis), Scirpus spp., coontail (Ceratophyllum demersum L.), American pondweed (potamogeton nodsus), and the emergent common arrowhead (Sagittaria latifolia) are a few common examples of plants used in phytoremediation. In order to identify tropical aquatic plants, this work conducts a systematic assessment of previous research.

Keywords: *Phytoremediation,Tropical, Plants, Aquatic, Hadejia-Nguru, wetlands*

Introduction

Acute demands for food, water, energy, lumber, and other ecosystem services follow exponential human population increase putting stress on the environment and natural resources. The environment is becoming seriously contaminated by heavy metals (HMs), metalloids, radionuclides, organic compounds, agrochemicals, and oil spills as a result of human activities such as agricultural intensification methods, rapid urbanization, and industrialization (Kafle, Arjun, 2022;)

Due to ignorance, lack of vision, negligence, or the high expense of waste removal and treatment, contamination from research trials, industries, military operations, and agricultural practices is progressively affecting land, surface waters, and ground water worldwide. (Uera, 2007). One of the main issues facing our civilization today is the remediation of soil and water pollution in order to maintain ecosystem processes and functioning. Numerous physical, chemical and biological techniques have been used to clean up environmental contamination but their uses are restricted because of their high cost and labour requirements, potential safety issues, and ecological risks (Ali et al., 2013).

An alternative method that is becoming more and more accepted and used is phytoremediation, which has the potential to be an effective method(Kafle, Arjun, 2022). A remarkable technique called phytoremediation employs plants to purify polluted soil, water, and air. In essence, some plants may absorb, break down, or even make innocuous a variety of contaminants, including pesticides, heavy metals, solvents, and petroleum chemicals.

When compared to conventional clean up techniques, this natural process is frequently more economical and environmentally friendly. It can be used to clean up contaminated locations such as landfills or former industrial regions (Adebayo et. al. 2022). Moreover, phytoremediation offers additional ecological advantages by enhancing biodiversity and soil quality. It's a potent illustration of using nature to address environmental issues. By cultivating green plants that can withstand and/or eliminate contaminating elements, phytoremediation techniques improves the reduction of unwanted effects and restoration of polluted ecosystems, such as soils and waters, recovering the soil and its functions. (Oyedeji, 2022).

Using phytoremediation procedures might involve either artificially cultivating specific plant species or allowing plants to grow naturally in the contaminated soil. The majority of traditional metal remediation techniques, such as pollutant leaching vitrification, electro kinetic treatment, excavation, and off- side treatment is proven to be costly, reduce soil fertility, and have detrimental long-term effects on the ecosystem.

On the other hand, phytoremediation uses plants to lessen, eliminate, break down or immobilize pollutants in the environment. (Nenman, Daniel Victor, 2023). The field of phytoremediation has gained popularity over the last 10 years as a plant -based remediation technique with the potential to be inexpensive, environmentally friendly, and low-impact.

Sources of water pollution in Hadejia-jama'are river basin

There are currently around 15 million people living in the Hadejia River basin (HRB), and their lives are largely dependent on the water resources in the basin. The climates of the basin are mostly semi-arid and partially humid (Sobowale et al. 2010)

However, it was determined that the primary cause of the growing disparity between the freshwater resources supply and demand was the combined effect of both natural and man- made factors, including desert encroachment, rainfed and irrigation agriculture, population growth, and water quality degradation brought on by pollution (Goes 2001).

The scope of the basin's surface water resource availability problems has not been completely recognized, despite the obvious problems with the area's water resources. (Goes 2001).

This is demonstrated by the dearth of long-term water resources management policies and the insufficient study on the availability of water resources (Umar & Ankidawa 2016). In fact, balancing water supply and demand in the face of climate change and population growth is one of the region's biggest problems.The primary cause of the rise in heavy metal concentrations in many environments has been human activity .The rise in potentially toxic elements (PTEs) in the HadejiaJama'are river basin is ascribed to ingredients in agroallied products like fertilizers, pesticides, herbicides, and other manufactured goods like paints and batteries.Other sources of PTE are mining activities, industrial, municipal and domestic wastes act as important sources of PTE pollution to the environment (Bako, 2023).

Increased use of natural resources due to urbanization, industry, and agriculture results in wastewater with a high nutrient load that must be removed before disposing of the land or water. This leads to serious ecological and public health issues. (Singh, 2010).

Around the world, mining, processing, and smelting operations have contaminated soil and water supplies with heavy metals. Geochemical weathering processes on metallurgical wastes and by-products start the process of transferring heavy metals from contaminated areas and dispersing them into nearby soils, streams, and ground water . (Arathi, 2021).

The second oldest and most important industry in the world after farming, mining is a major economic endeavor in many parts of the world, including northern Nigeria. Mining is a major source of wealth for economic development in many nations, increasing GDP and foreign exchange earnings. (Kahangwa, 2021).

Notwithstanding their contributions to the growth of the national economies, they are also linked to adverse environmental effects. One of the main sources of heavy metals in many parts of the world is mining activities, which also contributes to air, water, and soil contamination. Heavy metals (Pb, Cr, Cd, Cu, As, Mn, Ni, Zn, and Hg) are the primary environmental contaminants in places where precious metals are mined.(Kahangwa, 2021).Heavy metals are a group of metallic chemical elements that have relatively high densities, atomic weights, and atomic numbers.When present in excess, heavy metals—a collection of elements having a density of 6g/cm3—become hazardous. At low quantities, these elements provide vital nutrients needed by plants and animals. The ecological degradation of the Hadejia-jama'are Komodugu Yobe basin has gotten worse in recent years (Garba, S. T., and Barminas, J.T., 2010).

Cadmium (Cd), mercury (Hg), lead (Pb), arsenic (As), zinc (Zn), copper (Cu), nickel (Ni), and chromium (Cr) are examples of common heavy metals and metalloids. They pose a harm to the ecosystem because they are persistent in the soil for a long time and cannot be broken down by any biological or physical activity. Heavy metals are separated into essential and non-essential categories. Cu, Fe, Mn, Ni, and Zn are among the essential ones; plants need trace levels of these for physiological and biochemical functions. Pb, Cd, As, and Hg are examples of non-essential heavy metals that are extremely poisonous and have no recognized purpose in plants. They have a detrimental impact on a number of physiological and biochemical functions in crop plants and are a significant source of pollution to the environment. Through crops, they enter the human body and build up there. (Yan, 2020).

Because heavy metals have a propensity to bioaccumulate in plants and animals, bioconcentrate in the food chain, and target particular biological organs, they are poisonous. Certain metals, such Fe, Mn, Zn, and Cu, are necessary for plants and animals to grow and develop properly in trace amounts, but when they are present in excess, they can harm aquatic life and endanger human health (Bayero et. Al. 2020). Plant species, diversity, metal solubility, and translocation all affect the accumulation of heavy metals in plants. (Nedjimi, 2021).

Water hyacinths (Eichornia crassipes), poplar trees (Populus spp.), alfalfa (Medicago sativa), Kentucky bluegrass (Poa pratensis), scirpus spp., coontail (Ceratophyllum demersum L.), American pondweed (Potamogeton nodsus), and the emergent common arrowhead (Sagittaria latifolia) are a few common examples of plants used in phytoremediation. (Paz-alberto, 2013). Uera et al. (2007) carried out a study to evaluate the potential of a few chosen tropical plants as EtBr phytoremediators.

EtBr was extracted from laboratory wastes using a variety of plants, including tomato (Solanum lycopersicum), mustard (Brassica alba), vetiver grass (Viteveria zizanioides), cogon grass (Imperata cylindrical), carabao grass (Paspalum conjugatum), and talahib (Saccharum spontaneum).

Individual plastic bags containing 10% EtBr-stained agarose gel were used to sow the six tropical plants. For 30 days, the plants were let to settle and develop in the soil. Before and after soil treatment, the amount of ethidium bromide in the soil and test plants was measured. An ultraviolet visible spectrophotometer was used to measure the amount of ethidium bromide present in the plants and soils.

The ability of the tropical plants to absorb the EtBr from the soils varied significantly ($p < 0.001$), according to their findings. The maximum uptake of EtBr was recorded by mustard (1.4 ± 0.12 μg·kg−1), followed by tomato and vetiver grass (1.0 ± 0.23 and 0.7 ± 0.17 μg·kg−1 EtBr, respectively). The least quantity of EtBr was absorbed by cogon grass, talahib, and carabao grass (0.2 ± 0.6 μg·kg−1). The amount of ethidium bromide in the mustard-planted soil decreased by 10.7%. Tomato came next, with an average decrease of 8.1%. Vegetable grass-planted soils only yielded a 5.6% reduction. The lowest decrease in EtBr level, 1.52%, was seen in soils planted to cogon grass, talahib, and carabao grass (Table Uera

Table 1. levels of EtBr in soils and relative reduction of EtBr in soils after 30 days (Source)Paz alberto 2013

Plants (Treatments)	Intial level of soil (μg.kg^{-1})	Final Level in soil (μg.kg^{-1})	Percent reduction in soil
Tomato	19.7	18.1±0.17	8.12b
Mustard	19.7	17.6±0.23	10.66a
Vetiver grass	19.7	18.6±0.23	5.58b
Talahib	19.7	19.4±0.15	1.52c
Carabao grass	19.7	19.4±0.20	1.52c
Cogon grass	19.7	19.4±0.21	1.52c

Mechanisms of phytoremediation

The mechanism of the Phyto technique in phytoremediation can be divided into distinct categories (Table 2below)Rhizodegradation,Phytostabilization,rhizofiltration,phytoevaporation/volatilization,phytodesalination,phytodegradation/transformation, phytoaccumulation/extraction, and Phyto hydraulics. Various detoxification processes, including accumulation, translocation, degradation, excretion and volatilization, occur when a plant absorbs a toxin. The pollutants undergo change, fragmentation, and /or deposition within the plant tissue during the break down process. (Khan, Shaista, 2023).

Table 2. Different mechanisms of phytoremediation. (Khan, Shaista 2023)

Phytoremediation type	Contaminant nature	Medium	Mechanism	Scope of application
Phytoextraction/ phytoaccumulation	Inorganics	Soil, water	Hyperaccumulation	Moderately polluted sites
Rhizodegradation/ phytostimulation	organics	soil	Breakdown inside the rhizosphere through metabolic processes	Polycyclic aromatic hydrocarbon (PAH) contaminants
phytostabilization	Inorganics	Soil	immobilization	Mining contamination
Phytovolatilization/ phytoevaporation	Organic/inorganic	Soil, water	volatilization	Volatile contaminants
Rhizofiltration	Organic/Inorganics	Water	Rhizosphere accumulation	Waste water
Phytodegradation/ phytotransformation	Complex organics	Water/soil	Breakdown inside the plant through metabolic processes	Soil and water contamination
Phytodesalination	Organics/inorganic	Soil water	Na hyperaccumulation	Sodic soil and water
Phytohydraulics	Organics/inorganics	Ground water	Uptake, sequestering and degradation of ground water contaminants	Shallow contaminated sites

According to (Khan, Shaista, 2023) Various type of phytoremediation methods exists. It is a reliable green technology which help in the mitigation and reversing the effects of human activities on the environment. (Babanlungu, Z.A., Oguh, E. E., Esomonu, I., and Audu, I., 2021).

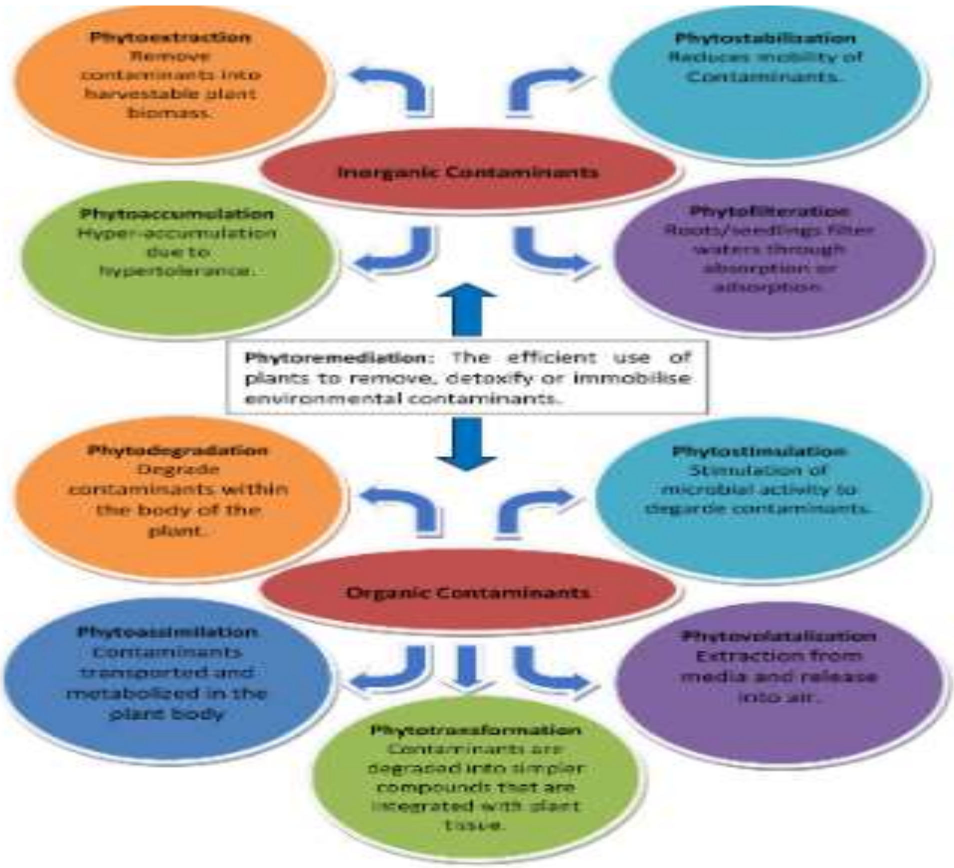

Figure 1 Various processes involved in phytoremediation of contaminants in aquatic environment. (Ali, 2020)

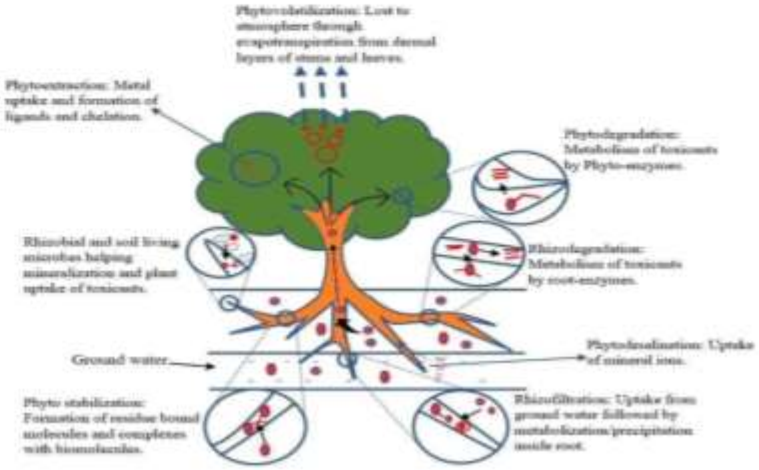

Figure 2 Phytoremediation processes and their associated functions (Kafle, Arjun, 2022)

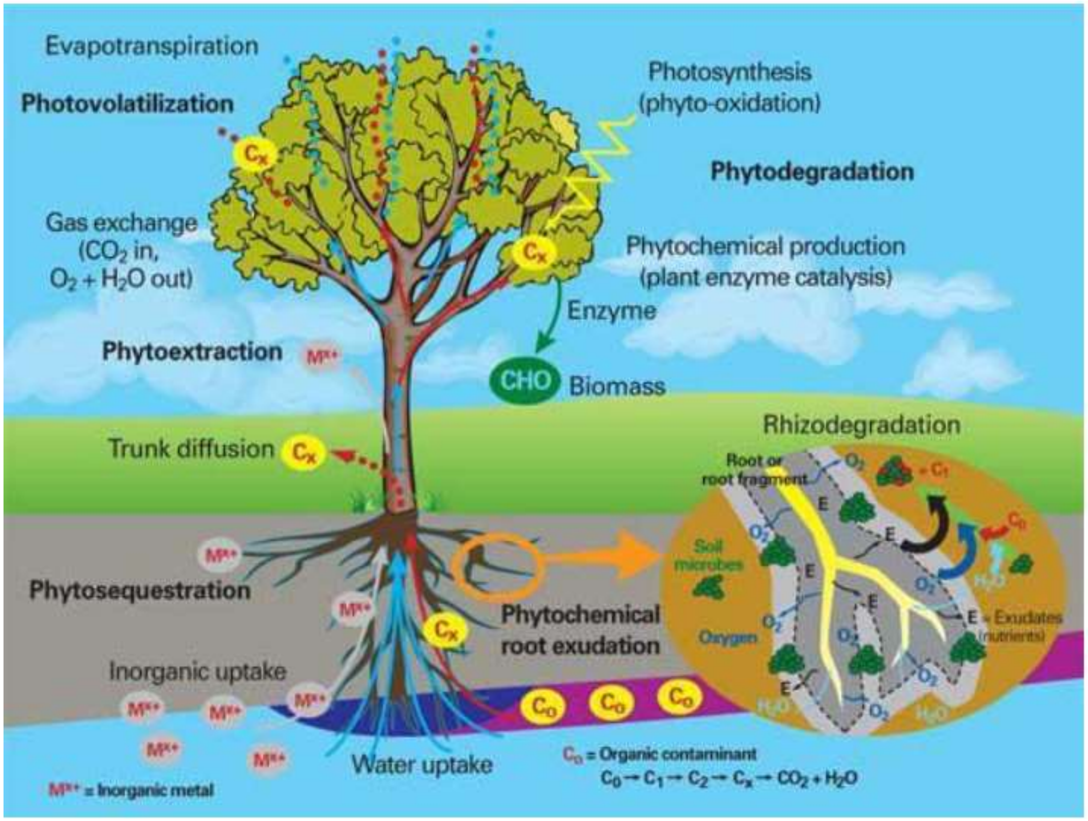

Figure 3. Mechanisms of phytoremediation (Oyedeji A. A., 2022)

Using green plants and related microbiota to clean contaminated soil and ground water in-situ is known as phytoremediation, a plant-based bioremediation technique. It has recently gained widespread acceptance as a method of cleaning up polluted soils and water. Due to the high expense of many other soil remediation techniques and the aim to employ a "green" sustainable procedure, the method is becoming more and more popular. (Abdullahi, U, 2016).

The main factors contributing to the method's acceptance are its long-term applicability, cost effectiveness, and aesthetic benefits. A specific polluted site may need a combination of treatments to provide the best remediation for the current circumstances. Because of their flexibility to a variety of settings and frequently rapid growth rates, tropical climates are home to a vast diversity of plant species with potential for bioremediation. Some tropical plant species that are wellknown for their capacity for bioremediation include the following

Some selected plants with phytoremediation potentials.

For phytoremediation, choosing the right plant species is essential.
In order to immobilize heavy metals, stabilize soil structure, and stop erosion, the selected plant should have deep root systems and be tolerant of heavy metal circumstances.

Another feature is the ability to produce a lot of biomass and develop quickly to create a vegetative cover in a particular area. (Nenman, Daniel Victor, 2023).

For cleanup, some plant species from the following genera can be used: Acer, Arundo, Astragalus, Betula, Brassica, Cannabis, Castor, Eucalyptus, Helianthus, Jatropha, Linum, Miscanthus, Phalaris, Pisum, Populus, Quercus, Ricinus, Robinia, Salix, Sarcocornia, Sorghum, Zea mays, and many more. They should be able to thrive under less ideal edaphic circumstances, such as water content, PH, and salinity. Such plant species need to be disease and pathogen resistant and have a deep root system. The best method for sustained phytoremediation of contaminated soils has been identified as the employment of naturally colonizing, commercially valuable, and perennial plants that are inedible to cattle (Jatropha, Miscanthus giganteus, and Ricinus communis) (Hauptvogl, 2020).

Figure 4. Characteristics of the ideal plants for phytoremediation (Khan, Shaista, 2023).

A species of flowering plant belonging to the Euphorbiaceae spurge family is the castor oil plant (Ricinus communis).
It is a perennial shrub that grows quickly and suckeringly, reaching the size of a small tree.
Potential applications for the plant include phytoremediation of polluted environments.
its potential as an energy crop and to clean up areas contaminated by mine tailings that contain high levels of Cu, Zn, Mn, Pb, and Cd.
Its power to accumulate metal ions and its ability to grow in highly polluted soil have garnered special interest. (Yashim, Zakka Israila, 2016).

1. Vetiver grass, also known as Chrysopogon zizanioides, is well known for its capacity to stabilize soil, stop erosion, and absorb contaminants including pesticides and heavy metals. It works well for phytoremediation in contaminated soil because of its deep root system, which can reach several meters below the surface.

2. The water hyacinth (*Eichhornia crassipes*) is a plant that effectively removes contaminants from water bodies, while being regarded as an invasive species in many areas due to its fast growth. It helps to improve the quality of water by absorbing organic contaminants, nutrients, and heavy metals.

3. Brassica juncea, or Indian mustard: Indian mustard is a South Asian native that is well-known for storing heavy metals including zinc, cadmium, and lead in its tissues. It is frequently

used to clean up contaminated soils in phytoremediation projects.

4.The Indian subcontinent is home to the multipurpose tree known as Moringa (*Moringa oleifera*), which is well-known for its capacity to purify water. Proteins in its seeds have the ability to coagulate suspended particles, causing them to sink to the bottom and clearing turbid and polluted water.

5.The potential of sunflowers (*Helianthus annuus)* to remove heavy metals from soil, including uranium, lead, and arsenic, is well known. They are useful for phytoremediation of contaminated locations because they acquire these metals in their tissues.

The annual herbaceous plant known as kenaf (*Hibiscus cannabinus* L.) is a member of the Malvaceae family. It is distinguished for its high biomass, quick development, and adaptability to various environmental circumstances. Biomaterials are manufactured from its fibers. Textiles and the paper industry both use its pulp. Since it doesn't get into the food chain, there should be no danger to the environment or human health.

The ability of the Senna occidentalis plant to eliminate contaminants from waste soil contaminated by different heavy metals was investigated in Makurdi, Benue state, Nigeria. Senna occidentalis was able to absorb all of the heavy metals under investigation (Cd, Cu, Ni, Pb, and Zn) when the appropriate soil amendments were applied. (Juliana, Ogbodo O, 2019).

The process by which contaminants are absorbed by plants through their roots, then translocated and accreted in their aboveground portions, is known as phytoextraction or phytoaccumulation. This process is typically followed by the harvesting and ultimate disposal of the plant's biomass (Figure 2). Other names for phytoextraction include phytosequestration and phytoabsorption. Since their structures are typically not further altered or changed within the plant system, the process applies to metals (Cd, Ag, Cu, Cr, Co, Mo, Hg, Pb, Mn, Ni, and Zn), radionuclides (137Cs, 90Sr, 238U, and 234U), metalloids (Sb and As), non-metals (Se), and certain organic substances (primarily hydrocarbons).

Bako et al., (2023) investigates the potential of ruderal plants for cleaning up toxic metal-contaminated places in the city of Kaduna. Because they exhibit above-grown biomass with a bioconcentration factor >1, ten plant species—*Salix leadermanii*, *Ceruanapra tensis*, *Polygonum lanigerum*, *Physalis angulata polygonum limbatum*, *Cymbopogon giganteum*, *Heliotropium indicum*, *Croton lobatus*, *Hyppoethes cancellata*, and *Mimosa pigra*—have been identified as CU phytoextractors (Bako, 2023).

Although phytoremediation is a potential method for addressing pollution issues, the technology is still in its infancy. Extensive research is required to examine plant species, habitat, and the rate at which different contaminants convert. Appropriate plants must have a strong bond with problematic contaminants. Combining the traits of several genes is necessary to create a viable phytoremediation solution in the future. Phytoremediation is separated into several categories, including phytoextraction, phytostabilization, and phytotransformation, based on the diverse roles that plants play. phytovolatilization and rhizoremediation. Numerous plant species have been effectively used to remove both organic and inorganic contaminants from soil and water. For instance, the Brassica family (Indian Mustard & Broccoli) absorbs heavy metals like cadmium, chromium, nickel, and zinc; poplars eliminate and metabolize polychlorinated biphenyls (PCBs), 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and trichloroethylene (TCE).

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