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PHYTOREMEDIATION OF CADMIUM AND CHROMIUM CONTAMINATED SOILS BY *CYPERUS ROTUNDUS*. L

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***Abstract**: Toxic trace elements are increasing in all compartments of the biosphere including air, water and soil, as a result of anthropogenic processes. Environmental heavy metal pollution is mainly of anthropogenic origin and results from activities such as fossil fuels, vehicular emissions, industrial emissions, landfill leachates, fertilizers, sewage and municipal wastes. Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them. Cyperus rotundus is a perennial plant, commonly known as coco-grass or nut grass. A pot experiment was conducted using Cyperus rotundus for the removal of chromium and cadmium contaminated soils. In the experimental period Cyperus accumulated chromium and cadmium in their plant body. Bioconcentration factor was calculated. The BCF of cadmium was 44.18 and the BCF of chromium was 4.42. Based on BCF values the grass species was a good accumulator of cadmium and chromium and the grass species was recommended for remediation of cadmium and chromium contaminated soils.*

***Key words**: Phytoremediation, Heavy metals, Bioconcentration factor, Cyperus rotundus.*

I. Introduction

Human activities such as mining, transport, agriculture, waste disposal and military actions frequently release these inorganic pollutants in high and toxic concentrations. Environmental heavy metal pollution is mainly of anthropogenic origin and results from activities such as fossil fuels, vehicular emissions, industrial emissions, landfill leachates, fertilizers, sewage and municipal wastes [1]. Heavy metal pollution causes potential ecological risk. Metals like Cadmium (Cd), Lead (Pb), Zinc (Zn) and Chromium (Cr) when present in high concentrations in soil exert potential toxic effects on overall growth and metabolism of plants [2], and bioaccumulation of such toxic metals in the plants poses a risk to human and animal health. Heavy metal pollution has become one of the most serious environmental problems today [3]. Metals are natural components in soil. Contamination has resulted from industrial activities such as mining and smelting of metalliferous ores, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticide application, and generation of municipal waste. Phytoremediation describes the treatment of environmental problems through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere. The term Phytoremediation ("phyto" meaning plant, and the Latin suffix "remedium" meaning to clean or restore) refers to a diverse collection of plant-based technologies that use either naturally occurring or genetically engineered plants for cleaning contaminated environments [4,5]. Phytoremediation is clean, simple, cost effective, non-environmentally disruptive [6]) green technology and most importantly, its by-products can find a range of other uses [7, 8].

At metals contaminated sites, plants are used either to stabilize or remove the metals from the soil and ground water through mechanisms such as Phytoextraction, Rhizofiltration, and Phytostabilisation [9]. Five main subgroups of Phytoremediation have been identified: Phytoextraction: plants remove metals from the soil and concentrate them in the harvestable parts of plants [10]. Phytodegradation: plants and associated microbes degrade organic pollutants [11]. Rhizofiltration: plant roots absorb metals from waste streams [12]. Phytostabilisation: plants reduce the mobility and bioavailability of pollutants in the environment either by immobilization or by prevention of migration [13, 14]. Phytovolatilisation: volatilization of pollutants into the atmosphere via plants [15, 16].

Phytoremediation processes: A range of processes mediated by plants or algae are useful in treating environmental problems:

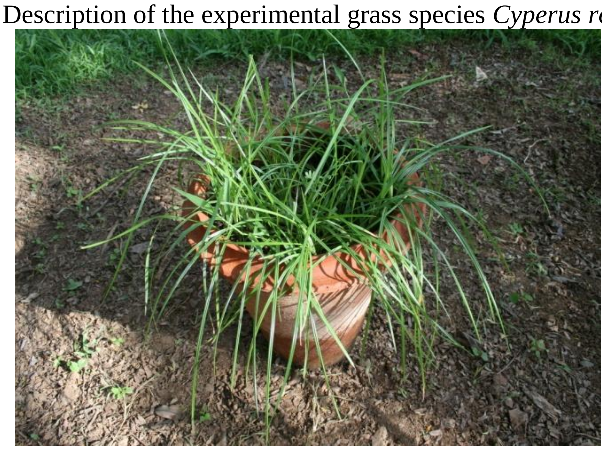
- **Phytoextraction** — uptake and concentration of substances from the environment into the plant biomass.
- **Phytostabilisation** — reducing the mobility of substances in the environment, for example, by limiting the leaching of substances from the soil.
- **Phytotransfermation —** chemical modification of environmental substances as a direct result of plant metabolism, often resulting in their inactivation, degradation (Phytodegradation), or immobilization (Phytostabilisation).
- **Phytostimulation** — enhancement of soil microbial activity for the degradation of contaminants, typically by organisms that associate with roots. This process is also known as rhizosphere degradation.
- **Phytovolatilisation** — removal of substances from soil or water with release into the air, sometimes as a result of phytotransfermation to more volatile and/or less polluting substances.
- **Rhizofiltration** — filtering water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots.

The plants absorb contaminants through the root system and store them in the root biomass and/or transport them up into the stems and/or leaves. A living plant may continue to absorb contaminants until it is harvested. After harvest, a lower level of the contaminant will remain in the soil, so the growth/harvest cycle must usually be repeated through several crops to achieve a significant cleanup. After the process, the cleaned soil can support other vegetation. The main advantage of Phytoextraction is environmental friendliness. Traditional methods that are used for cleaning up heavy metal-contaminated soil disrupt soil structure and reduce soil productivity, whereas Phytoextraction can clean up the soil without causing any kind of harm to soil quality. Another benefit of Phytoextraction is that it is less expensive than any other clean-up process. Phytoremediation should be viewed as a long-term remediation solution because many cropping cycles may be needed over several years to reduce metals to acceptable regulatory levels. This new remediation technology is competitive, and may be superior to existing conventional technologies at sites where Phytoremediation is applicable. [17].

Mine reclamation and biogeochemical prospecting depends upon right selection of plant species and sampling. The selection of heavy metal tolerant species is a reliable tool to achieve success in Phytoremediation. 163 plant taxa belonging to 45 families are found to be metal tolerant and are capable of growing on elevated concentrations of toxic metals. The use of metal tolerant species and their metal indicator and accumulation is a function of immense use for biogeochemical prospecting [18, 19]. Plants and humans require adequate amounts of micronutrients like iron and zinc [20], but accumulation of an excess or uptake of non-essential metals like cadmium or lead can be extremely harmful. As a plant- based technology, the success of Phytoextraction is inherently dependent upon proper plant selection. As previously discussed, plants used for Phytoextraction must be fast growing and have the ability to accumulate large quantities of environmentally important metal contaminants in their shoot tissue [21, 22, 23, 24],. High concentrations of heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including physiological and biochemical processes, inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants [25, 26].

II. Methodology

Description of the experimental grass species *Cyperus rotundus*, L.



Systematic classification:

Kingdom : Plantae (Angiosperms, Monocots, Commelinids)
Order : Poales
Family : Cyperaceae
Genus : *Cyperus*
Species : *rotundus*

Binomial name: *Cyperus rotundus* L.

Cyperus rotundus commonly known as coco-grass, purple nut sedge, red nut sedge, etc., is a species of sedge belongs to Cyperaceae, native to Africa, southern and central Europe and southern Asia. [27].The word Cyperus derives from the Greek 'kuperos' and rotundus is from Latin, meaning 'round'. The names "nut grass" and "nut sedge" are derived from its tubers, that somewhat resemble nuts, although botanically they have nothing to do with nuts. *Cyperus rotundus* is a perennial plant that may reach a height of up to 55 inches. The root system of a young plant initially forms white, fleshy rhizomes. Some rhizomes grow upward in the soil, and then form a bulb-like structure from which new shoots and roots grow, and from the new roots, new rhizomes grow. Other rhizomes grow horizontally or downward, and form dark reddish-brown tubers or chains of tubers.

Cyperus rotundus is one of the most invasive weeds known, having spread out to a worldwide distribution in tropical and temperate regions. The plant has several medicinal uses. The decoction of the roots and tubers are excellent antidote to all poisons. The root is often used for developing high memory. This herb also harmonizes the liver, spleen, and pancreas. The grass is anthelminthic, anti-fungal, anti-parasitic, anti-rheumatic, antispasmodic, aphrodisiac and astringent. It cures dyspepsia, vomiting, indigestion, thirst, worm troubles, cough, bronchitis, dysuria, and poisonus affections. It is used as an insect repellent, for perfuming clothing. [28].

The seedlings of the plants were selected from the vicinity of Acharya Nagarjuna University. Plants were grown in pots filled with five kgs of garden soil. The seedlings were collected from the uncontaminated soils. All the selected seedlings were of uniform size and free of any disease symptoms. The heavy metals selected for the study were Cadmium and Chromium. The uptake was estimated for every 20 days for a total period of 60 days, in total plant. In addition a control blank set of experimental pots was also maintained. The heavy metals were dissolved in distilled water to prepare stock solution of 1000 ppm for each metal. The calibration curves for each heavy metal were also prepared. A blank reading was also taken to incorporate necessary correction factor. The heavy metal solution of 5mg/L was prepared from the stock and administered to the grass species and care was taken to avoid leaching of water from the pots. The metal uptake was estimated once in every 20 days. The sample plants were removed from the pots and washed under a stream of water and then with distilled water. The collected plants were air dried, then placed in a dehydrator for 2-3 days and then oven dried for four hours at 100 ºc. The dried samples of the plant were powdered and stored in polyethylene bags. The powdered samples were subjected to acid digestion. 1gm of the powdered plant material were weighed in separate digestion flasks and digested with HNO3 and HCl in the ratio of 3:1. The digestion on hot plate at 110ºc for 3-4 hours or continued till a clean solution was obtained. After filtering with Whatman No. 42 filter paper the filtrate was analyzed for the metal contents in AAS.

III. Results And Discussion

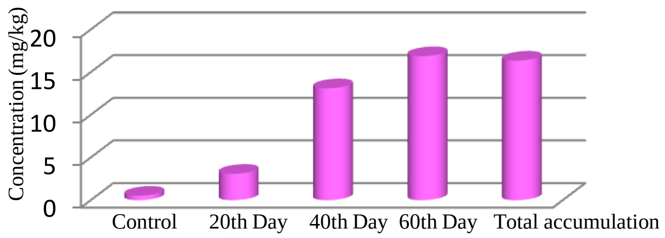
Phytoremediation is one of the promising methods for reclamation of soils contaminated with toxic metals [29]. Metal concentrations in plants vary with plant species [30, 31, 32, 33]. Plant uptake of heavy metals from soil occurs either passively with the mass flow of water into the roots, or through active transports, and crosses the plasma membrane of root epidermal cells. Under normal growing conditions, plants can potentially accumulate some metal ions in order of magnitude greater than the surrounding medium [34, 35].

Accumulation of Cadmium (mg/kg biomass) in *Cyperus rotundus* during the experimental period

Cyperus rotundus has accumulated 16.35 mg/kg of cadmium in 60 days the initial concentration was 0.52 mg/kg. Cyperus has accumulated 3.09, 13.11 and 16.87 mg/kg by 20th, 40th and 60th days respectively. The accumulation levels of cadmium in *Cyperus rotundus* was a good accumulator of cadmium.

Table 1: Accumulation of Cadmium (mg/kg biomass) in *Cyperus rotundus* during the experimental period

Plant part	Control	20th day	40th day	60th day	Total Accumulation
Total Accumulation	0.52±0.15	3.09±0.19	13.11±0.08	16.87±0.19	16.35



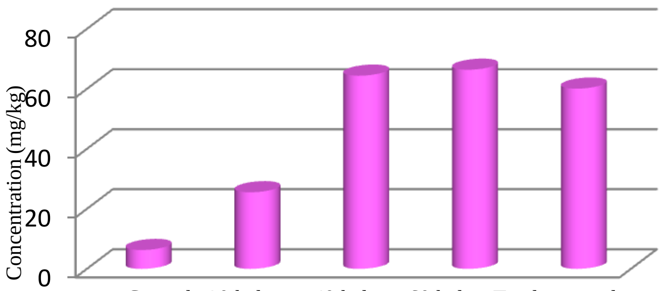
Accumulation of Cadmium in ***Cyperus rotundus*** during the experimental period

Accumulation of Chromium (mg/kg biomass) in *Cyperus rotundus* during the experimental period

The chromium concentration was 6.28 mg/kg at the beginning of the experiment. There was a substantial accumulation in 40 days (64.4 mg/kg). The accumulation increased to 25.53 mg/kg in first 20 days and later to 64.4 mg/kg by 40th day. The increase of accumulation was less from 40th day to 60th day (only 1.98 mg/kg i.e. from 64.4 to 66.38 mg/kg). The total accumulation of chromium in 60 days was 60.1 mg/kg which reveal that *Cyperus* was a good accumulator of chromium. This Cyperus species can be recommended to specially remediate cadmium contaminated soils.

Table 2: Accumulation of Chromium (mg/kg biomass) in *Cyperus rotundus* during the experimental period

Plant part	Control	20th day	40th day	60th day	Total accumulation
Total accumulation	6.28±0.15	25.53±0.19	64.4±0.08	66.38±0.18	60.1



Accumulation of Chromium in ***Cyperus rotundus*** during the experimental period

Bioconcentration factor:

Heavy metals are currently of much environmental concern. They are harmful to humans, animals and tend to bioaccumulate in the food chain. According to Ghosh and Singh [29] phyto-extraction is a process to remove the contamination from soil without destroying soil structure and fertility [36]. A plant's ability to accumulate metals from soils can be estimated using the BCF, which is defined as the ratio of metal concentration in the roots to that in soil. The Bioconcentration Factor (BCF) of metals was used to determine the quantity of heavy metal absorbed by the plant from the soil. This is an index of the ability of the plant to accumulate a particular metal with respect to its concentration in the soil and is calculated using the formula:

$$BCF = \frac{\text{Metal concentration in plant tissue (whole plant/ portal)}}{\text{Initial concentration of metal in substrate (soil)}}$$

The higher the BCF value the more suitable is the plant for Phytoextraction. Yoon *et al*., 2006 [36]. In the present study *Cyperus rotundus* highly absorb chromium than cadmium. Bioconcentration factor calculated using soil initial concentration. Cadmium background concentration was 0.37 and chromium background concentration was 13.58. The BCF of cadmium was 44.18 and the BCF of chromium was 4.42. Based on BCF values these grass species was a good accumulator of cadmium and chromium.

IV. Summary and conclusions

The contamination of heavy metals to the environment, i.e., soil, water, plant and air is of great concern due to its potential impact on human and animal health. Cheaper and effective technologies are needed to protect the precious natural resources and biological lives. Substantial efforts have been made in identifying plant species and their mechanisms of uptake and hyper accumulation of heavy metals in the last decade. A pot experiment was conducted using Cyperus rotundus for the removal of chromium and cadmium contaminated soils. In the experimental period Cyperus accumulated chromium and cadmium in their plant body. Based on BCF values the grass species was a good accumulator of cadmium and chromium and the grass species was recommended for remediation of cadmium and chromium contaminated soils.

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