ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

A Systematic Review on Phytoremediation of Cadmium-Contaminated Soils: Identifying Hyperaccumulator Plants, Assessing Soil Quality, Analyzing Contamination Sources and Determining Health Risks

[1*]Carl Andrei Estrada; [2]Clouie May Amatorio; [3]Ryan Cacacho; [4]Jeryl Joselin Morales; [5]Melmar Camacho; [6]Cristopher Parmis
Civil and Allied Department, Technological University of the Philippines – Taguig, Taguig City

Corresponding Author: [1*]Carl Andrei Estrada

Abstract:- Cadmium is a highly toxic heavy metal found in soils due to various anthropogenic and natural sources, posing significant environmental and health risks. This systematic review aimed to identify plant species that can effectively accumulate cadmium, assess soil quality and contamination sources in cadmium-affected areas, and evaluate potential health risks within affected communities. Relevant studies and articles were methodically selected from databases such as PubMed, Science Direct, Google Scholar, Research Gate, and Zendy, following Prisma Guidelines. The reviewed studies, both local and international, were published after 2000. The review found that several plant species can accumulate high levels of cadmium, with Athyrium wardii (Hook.) (Makino) achieving a 55% removal rate, Linum usitatissimum L. (Flax) achieving 32-49% removal, and T. caerulescens (Alpine Pennycress) achieving 19-36% removal. These plants showed the highest cadmium concentrations in their roots, followed by stems and leaves. Anthropogenic sources of cadmium in farm soil include agricultural activities and emissions from fuel combustion, with petrochemical industries significantly contributing through oil and gas flares, leading to elevated levels of nickel and cadmium. The review highlighted that higher cadmium accumulation poses substantial health risks, with risk concentrations higher in agricultural lands than in urban areas, implying a higher carcinogenic risk for people in these regions.

Keywords:- *Anthropogenic,Carcinogenic, Cadmium-Contaminated Areas, Health Risks, Hyperaccumulator.*

I. INTRODUCTION

Environmental pollution due to heavy metals has emerged as a global concern with the rise of urbanization and industrial development. The detrimental impact of high levels of heavy metals, particularly nonessential ones like Cadmium (Cd) and Lead (Pb), on human health and water quality is a pressing issue. Essential metals essential for body metabolism include Iron (Fe), Copper (Cu), Zinc (Zn), Selenium (Se), and Nickel (Ni), while heavy metals lack specific roles in the body and pose risks due to their non-biodegradability and physiological effects. Phytoremediation, a process that utilizes plants and soil-related microbes to mitigate pollutant concentrations in the environment, offers a sustainable and effective solution for heavy metal contamination in soil, ultimately enhancing food safety and human health Nouri, H., & Hashempour, Y. (2021). Cadmium (Cd) pollution in the soil is increasing due to the use of agrochemicals, particularly phosphatic fertilizers, which are significant sources of Cd contamination (Gray et al., 1999; Loganathan et al., 2003; Tijani et al., 2008; Zeng et al., 2007). Organic fertilizers like farmyard manure also contribute to Cd pollution (Alloway, 1995).

In unpolluted soils, cadmium (Cd) is found at concentrations of 0.01 to 1 mg/kg, with a global average of 0.36 mg/kg. Cd is highly mobile in the environment and can be released from soil into groundwater more quickly than other heavy metals. It can also easily transfer from soil to plants, entering the food chain [Raza, A. et al., 2020]. Recognized as a food contaminant since 1972, high Cd levels can lead to renal failure, bone demineralization, and increased cancer risk. Cd accumulates in the human body with age, particularly in the kidneys and liver. While Cd-contaminated food is the primary exposure source for the general population, smokers, Cd industry workers, and those with high environmental exposure face greater risks (Kubier, Wilkin, & Pichler, 2019).

Cd (II) is a highly toxic, soil-persistent, primary heavy metal contaminant , relatively easily absorbed by plant roots by which it can contaminate the food chain and consequently bioaccumulate in the human body, expressing its toxic effects. There are several factors that can affect uptake of Cd by plants, pH is one of the most prominent ones since adsorptive capacity of soils for Cd triples for

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

each pH unit increase within the interval 4–7(Ali et al., 2020) Cd is relatively water soluble under acidic conditions, with limited solubility in carbonate forms (CdCO3) and neutral solubility in alkaline soils (Shiyu et al., 2020) Besides pH, other soil factors can also affect Cd solubility, such as organic matter content, cation exchange capacity and concentration of other cations. Organic matter bounds Cd and converts it into an organically bound fraction, reducing its bioavailability.(Chen et al., 2010)

II. METHODOLOGY

The study aimed to systematically review Cadmium (Cd) concentrations in polluted soil that used phytoremediation for cleaning. The research period spanned from 2005 to 2020, with a focus on the uptake of cadmium by various plants in contaminated soil. The research uses the PRISMA guidelines

➢ *Data Sources*

The existing studies were searched using Following PRISMA guidelines, relevant studies were systematically selected from four widely recognized databases: PubMed (5), ScienceDirect (13), Google Scholar (76), ResearchGate (5), and Zendy (1).

➢ *Inclusion and Exclusion*

- *Inclusion*:

Both local and international studies, Cadmium as the heavy metal, Phytoremediation in soil, English articles or studies translated to English, articles published after 2000, articles that uses plants with cadmium accumulation properties, articles that discuss health factors and practices that affect the contamination.

- *Exclusion:*

Articles that discuss other heavy metals except cadmium, phytoremediation of plants in water, non-english articles, articles published before 2000.

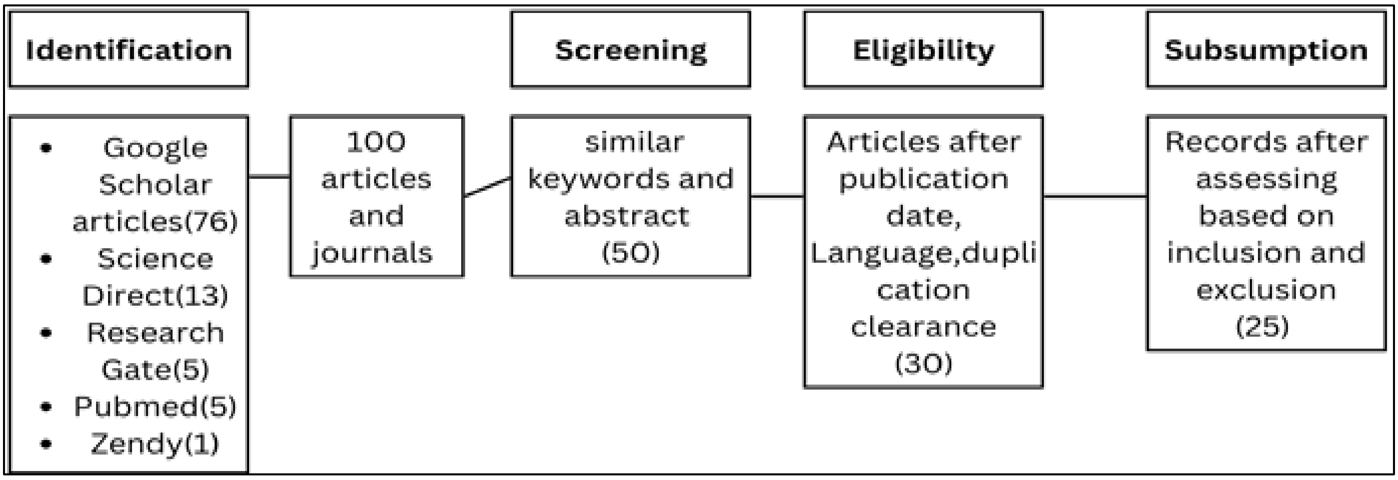

Fig 1 Framework

➢ *Data Extraction*

This systematic review provides an overview of the phytoremediation abilities of various plants in cadmium-contaminated areas. A total of 25 journal articles were evaluated. For the analysis, the following data were collected from each retrieved article: author and publication year, scientific name of the plants, types of area/location, soil quality in the area, source of contamination, and the potential health risks to the community.

III. RESULTS AND DISCUSSION

Table 1 Phytoremediating Plants with its Percent removal and Translocation Factor

Plants with scientific name	Type of area	Soil quality	Contamination Sources	Percent removal	Translocation factor		Reference
Hibiscus cannabinus L (Kenaf)	Agricultural Land	**pH**: Typically between 6.0 and 8.0 **Organic Matter**: 2% to 5% **N**: 0.1% to 0.5% **P**: 10 to 30 mg/kg	Wastewater irrigation	8.50 - 14.43%	Shoot: Root:	0.36 mg/kg and 0.87 mg/kg	(Shehata et al., 2019)
Zea mays L. (corn/maize)	Agricultural field	**pH**: 6.42 **Organic Matter**: 1.63%	Contamination Spiking	0.70 %	Root Shoo:	35.14 - 2.30 mg/kg and 15.73 - 0.84 mg/kg	(H. Zhang et al.,2009b)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

Athyrium wardii (Hook.) (Makino)	Mining area	**pH** 6.5 **Organic matter:** 3.8%	Metal mining activities and industrial waste	55%	Roots	0.11 mg kg-1	(S. J. Zhang et al., 2013)
Boehmeria nivea (China grass)	Paddy field	**pH**: 4.83 **Organic matter:** 3.41% **N**: 113.1 mg kg−1 **P**: 10.5 mg kg−1 **K**: 65.1 mg kg−1	Wastewater irrigation	9.7%	Bast: Stems Leaves	54.55mg/kg ^-1 27.37 m/kg^-1 16.57 mg kg^-1	(She et al., 2011)
Linum usitatissimum L. (Flax)	Agricultural research station	**pH:** 7.8 **Electrical Conductivity (EC):** 1.46 **Total Organic Carbon** 1.22 **N:** 2.46 **P:**41.2	Contamination Spiking	32% - 49%	Roots	74 mg/kg	(ARC), Egypt.
Phragmites australis (Common Reed)	Agricultural field	**pH:** 6.4 **Electrical Conductivity (EC):** 0.012 dSm^{-1} **Total Organic Carbon:** 3.02 g kg^{-1} **N:** 0.22 g kg^{-1} **P:** 0.12 g kg^{-1}	Contamination Spiking	4.5 %	Root Shoot	1.4 mg/kg 0.05 mg/kg	(Hechmi et al., 2013)
Lolium perenne L. (perennial ryegrass)	Farmland	**pH:** 5.05-9.70 **SOM** (%): 1.08-2.54 **P** (%): 0.03-0.07 **N**(%):0.049-0.096 **K** (%): 0.062-0.081	Smelter	5.9-22.7%	Shoots	0.1-13.6 mg/kg	(Xiao et al., 2019)
T.caerulescens (Alpine Pennycress)	Cultivated fields	**pH**: 6.9 **Organic Matter (O.M.):** 5.2% **P**: 265 mg/kg **K**: 295 mg/kg **N:** 0.096%	Smelter	19-36%	Shoots	937 to1456 mg kg	(Wang et al., 2006)
Juncus subsecundus (Finger rush)	constructed wetlands for the treatment of stormwater	**pH**: 6.4 **EC**: 0.012 dS/m **Total organic carbon:** 3.2 g/kg **N:** 0.22 g/kg **P**: 0.12 g/kg	Contamination Spiking	0.5 -0.02%	Shoot Root	338-29 mg/kg and 330- 26 mg/kg	(Zhang et al., 2012)
Conocarpus Erectus (Buttonwood mangrove)	Botanical garden	**pH**: 8.1 **Organic Matter**: 0.53% **Electrical Conductivity (EC)**: 2.5 dS/m **Cation Exchange Capacity (CEC)**: 23.8 cmolc/kg	Anthropogenic sources	0.25%-0.03%	Root to shoot	0.36–0.89 mg/kg	(Tauqeer et al., 2019)

Table1: The Phytoremediation potential of various plants grown in different Types of Area with varying Soil Qualities and Contamination Sources. This study also compares the percent removal and translocation factors (TF) of each plants

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

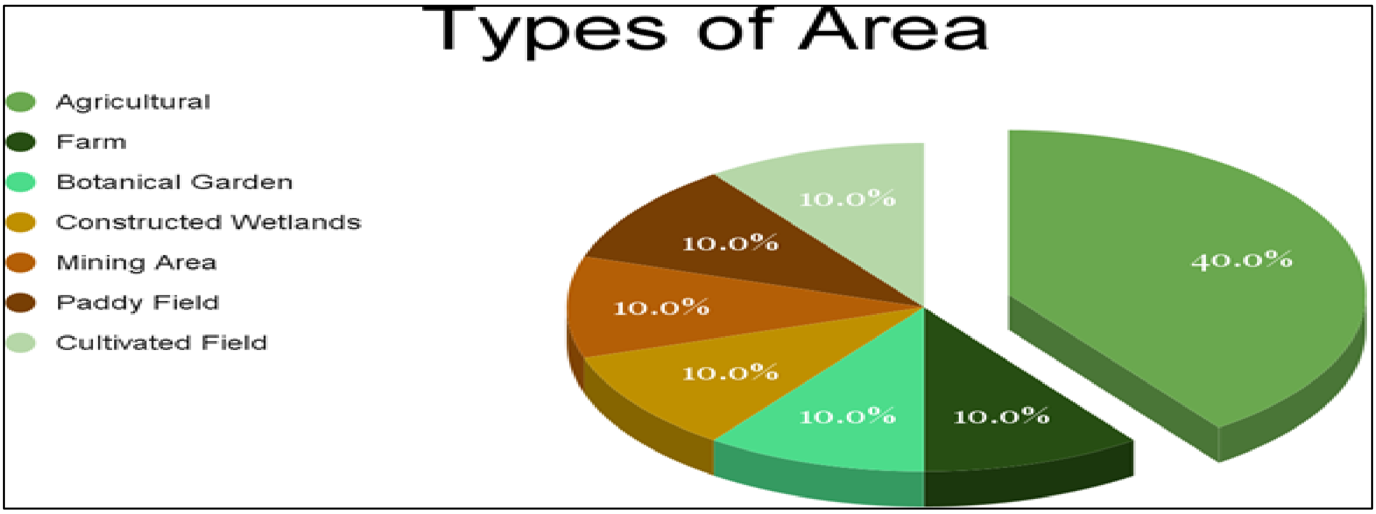

Fig 1 Phytoremediative Plants are often Found in Agricultural Areas

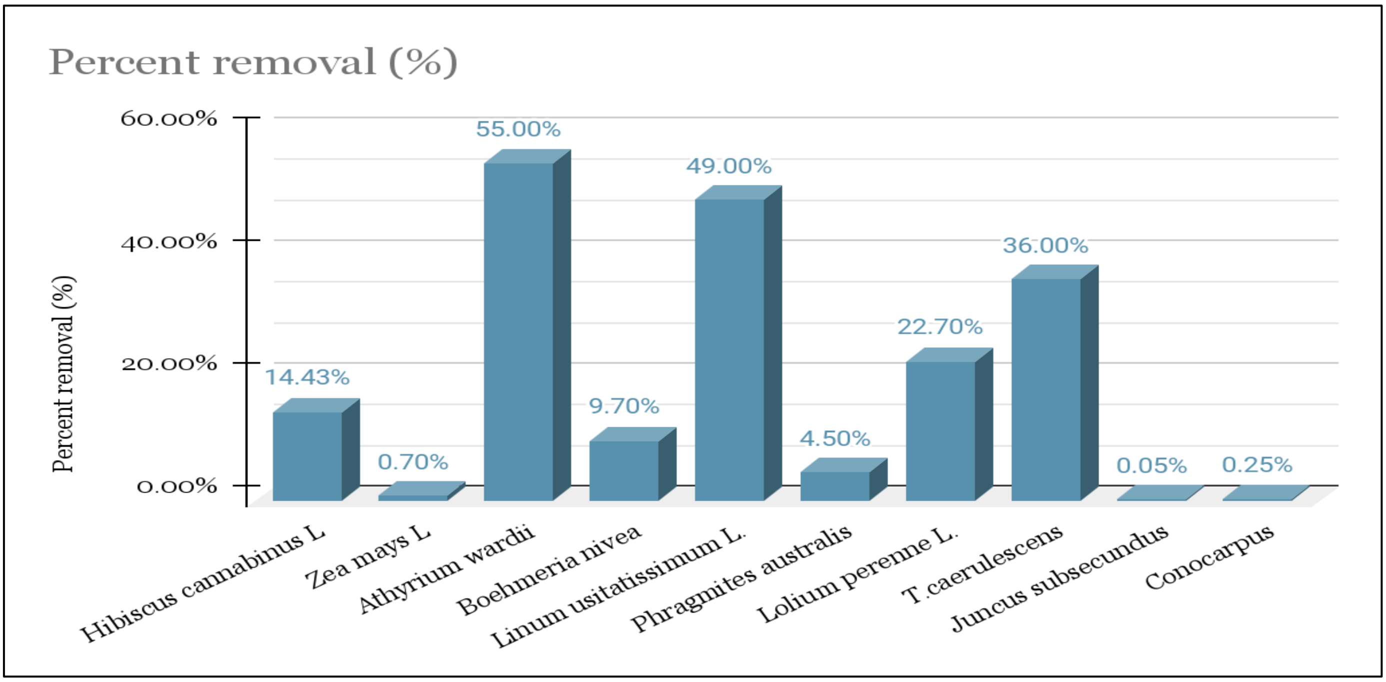

Fig 2 The Figure Illustrates the Percent Removal of Cadmium by Various Plants Studied for their Phytoremediation Potential.

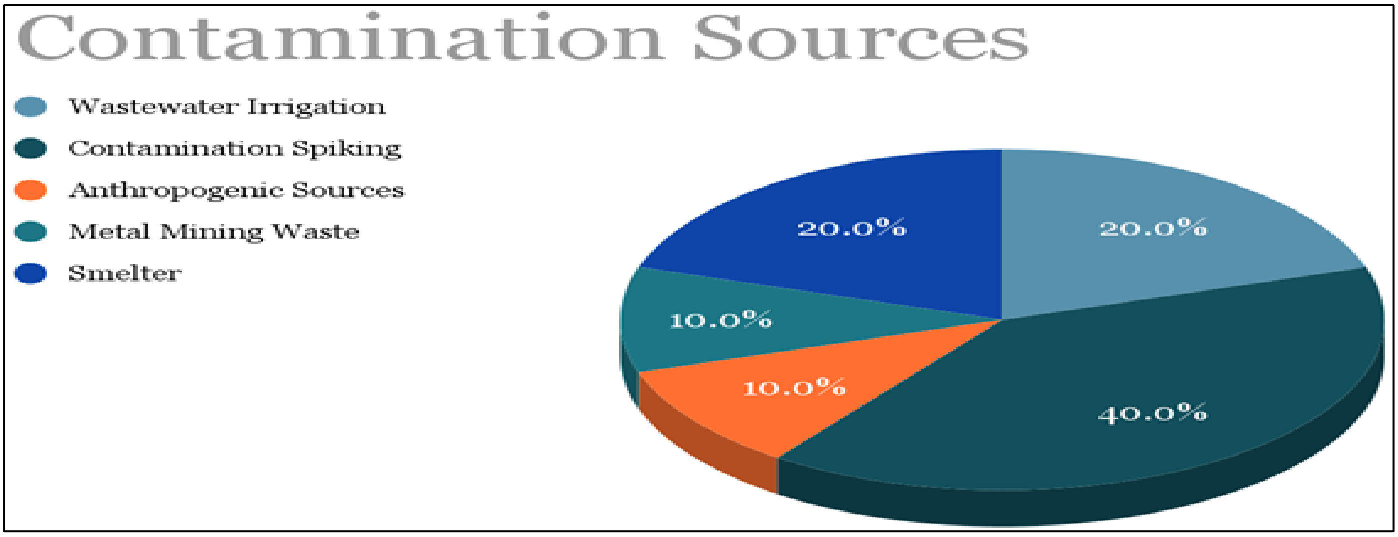

Fig 3 The Figure Provides a Visual Representation of the Various Contamination Sources Contributing to Soil Pollution.

Table 2 Health Risk Assessment of Cadmium Exposure to Humans

Source	Body Part/Organ	Disease	Description	Amount of Cadmium before symptoms appear
Haswell-Elkins, M., Imray, P., Satarug, S., Moore, M. R., & O'Dea, K. (2006). *Urinary excretion of cadmium among Torres Strait Islanders (Australia) at risk of elevated dietary exposure through traditional foods. Journal of Exposure Science & Environmental Epidemiology, 17(4), 372–377.*	Kidney	Diabetic Nephropathy	Renal damage characterized by proximal tubule dysfunction, potentiate the effects of diabetes in kidney.	Cadmium in Urine: 1-1.99μg
Schutte, R., Nawrot, T. S., Richart, T., Thijs, L., Vanderschueren, D., Kuznetsova, T., … Staessen, J. A. (2008). *Bone Resorption and Environmental Exposure to Cadmium in Women: A Population Study. Environmental Health Perspectives, 116(6), 777–783.*	Bones	Osteoporosis	Decreased bone density through hypercalciuria resulting from renal tubular dysfunction.	Cadmium in Blood: 5.7-9.8nmol/day Cadmium in Urine: 6.5-8.5nmol/day
Messner, B., Knoflach, M., Seubert, A., Ritsch, A., Pfaller, K., Henderson, B., … Bernhard, D. (2009). *Cadmium Is a Novel and Independent Risk Factor for Early Atherosclerosis Mechanisms and In Vivo Relevance. Arteriosclerosis, Thrombosis, and Vascular Biology, 29(9), 1392–1398.*	Cardiovascular System	Atherosclerosis	Cadmium exposure starts/worsens atherosclerosis by harming endothelial cells and boosting plaque formation	Cadmium in Blood:>15μmol/L

Table2: The table shows human organs affected by cadmium exposure, along with associated diseases, short description about the disease, and amount of cadmium that trigger the symptoms.

IV. DISCUSSION

This paper delves into the potential of various plants to effectively accumulate cadmium, examining soil quality in cadmium-contaminated areas and analyzing contamination sources from different practices.

- *Potential of Plants for Phytoremediation of Cadmium-Contaminated Soils*

Several plants have demonstrated potential in phytoremediating cadmium-contaminated soil, including *Hibiscus cannabinus L., Zea mays L., Athyrium wardii, Boehmeria nivea, Linum usitatissimum L., Phragmites australis, Lolium perenne L., Thlaspi caerulescens, Juncus subsecundus,* and *Conocarpus erectus.* Figure 2 illustrates the percentage removal of cadmium by each plant, with *Athyrium wardii* achieving the highest removal rate of 55.00%, making it a highly effective option for phytoremediation. In contrast, *Juncus subsecundus* has the lowest removal rate at 0.05%, suggesting it is less effective in cadmium accumulation. These findings underscore the importance of selecting the most efficient plants for phytoremediation to improve soil quality and mitigate contamination.

- *Soil Quality*

Soil pH is a critical factor that influences various aspects of soil quality, particularly in the context of cadmium (Cd) contamination. Soil pH significantly affects the solubility and availability of essential nutrients, which are crucial for plant growth and the success of phytoremediation. The presence and levels of organic matter, electrical conductivity, phosphorus, nitrogen, and organic carbon in soil are vital for enhancing soil quality and supporting the growth and effectiveness of phytoremediation plants. These soil properties create a conducive environment for phytoremediation, improving soil health and facilitating the removal of contaminants. Organic matter, in particular, enhances soil structure, increases nutrient availability, and supports the microbial community essential for phytoremediation processes (Paul, 2014).

Soil pH also affects the formation of soil aggregates, which are crucial for maintaining good soil structure. Aggregated soil has improved aeration, water infiltration, and root penetration (Bronick & Lal, 2005). In very acidic ($pH < 5.5$) or very alkaline soils ($pH > 8.5$), soil particles can disperse, leading to poor structure and increased erosion risk. Maintaining a neutral to slightly acidic pH helps in stabilizing soil aggregates, thereby improving soil physical properties (Lal, 2004).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

In mining areas, where *Athyrium wardii* is prevalent, the soil typically has a pH of around 6.5. This slightly acidic pH level is conducive to the bioavailability of cadmium (Zhang et al., 2013). It ensures that the plant can effectively uptake cadmium without experiencing phytotoxicity. Additionally, these soils have moderate moisture levels and an organic matter content of 3.8%. Organic matter enhances soil structure, nutrient availability, and microbial activity, all of which support the phytoremediation process (Brady & Weil, 2008).

Constructed wetlands designed for stormwater treatment provide a controlled environment for phytoremediation efforts. The soil pH in these wetlands, at 6.4, is slightly acidic, favorable for the uptake of cadmium by *Juncus subsecundus* (Zhang et al., 2012). This pH level supports the solubility and bioavailability of cadmium, facilitating its absorption by the plant. Additionally, the soil has an electrical conductivity (EC) of 0.012 dS/m, indicating low salinity levels, which are conducive to the growth and health of *Juncus subsecundus*.

The soil in these constructed wetlands also contains 3.2 g/kg of total organic carbon, 0.22 g/kg of total nitrogen, and 0.12 g/kg of total phosphorus. These nutrient levels support plant growth and enhance the phytoremediation process by promoting healthy root development and microbial activity (Brady & Weil, 2008). Organic carbon and nitrogen are particularly important for sustaining the plant's metabolic processes and overall vigor, which are crucial for effective phytoremediation.

Despite the relatively low cadmium removal efficiency of *Juncus subsecundus*, ranging from 0.5% to 0.02%, the plant's ability to accumulate cadmium in its biomass is noteworthy. Cadmium concentrations in the shoots and roots of *Juncus subsecundus* are reported to be between 338-29 mg/kg and 330-26 mg/kg, respectively. This accumulation suggests that while the overall removal percentage is low, the plant effectively sequesters cadmium within its tissues, thus reducing the bioavailability of the metal in the soil.

➢ *Type of Areas*

Phytoremediation, the use of plants to remove, transfer, stabilize, or destroy contaminants in soil and water, has gained significant attention as an eco-friendly and cost-effective remediation strategy. While phytoremediation can be applied in various contexts, agricultural areas are particularly prevalent as sites for these interventions, as shown in Figure 1. This discussion explores the reasons behind this trend and its implications for environmental management.

Agricultural lands are often subjected to extensive use of agrochemicals, including pesticides, herbicides, and fertilizers, which can lead to the accumulation of various contaminants in the soil. Moreover, irrigation practices and the use of biosolids can introduce heavy metals and other pollutants into agricultural soils. The need to address these contaminants makes agricultural lands prime candidates for phytoremediation (Pulford, 2003).

Agricultural areas typically offer large expanses of open land that are readily available for planting phytoremediating species. Unlike urban or industrial areas, which might be limited by space and infrastructure, agricultural lands can be more easily repurposed for remediation projects. Additionally, the soil in these areas is already managed for plant growth, making it more suitable for introducing phytoremediation species (McGrath & Zhao, 2003).

➢ *Source of Contamination*

In figure 3, it has become evident that contamination spiking is the predominant source of contaminants. This section explores the implications of this finding, the reasons behind the frequent use of contamination spiking in scientific studies, and its impact on the validity and applicability of our results.

Contamination spiking, the deliberate addition of contaminants to soil in a controlled environment, is widely used in scientific research for several reasons. Primarily, it allows researchers to establish precise, reproducible contamination levels, facilitating the study of pollutant behavior and the effectiveness of remediation techniques under controlled conditions (Fussell & Corbet, 1992)

contamination spiking has been instrumental in evaluating the efficiency of various plants in remediating specific contaminants. By creating known contamination levels, assessing the uptake, translocation, and transformation mechanisms of different phytoremediating species. This approach is essential for identifying hyperaccumulators and optimizing phytoremediation strategies (Pivetz, 2001).

The predominance of contamination spiking in the data reflects its utility in providing controlled, reproducible, and safe experimental conditions. While this approach has facilitated significant advancements in our understanding of phytoremediation, it is essential to complement spiking experiments with field studies to ensure the robustness and applicability of our findings. By integrating laboratory and field data, we can develop more effective and sustainable remediation strategies for contaminated soils (Fussell & Corbet, 1992b).

➢ *Health Risks*

The health risk assessment of cadmium contamination highlights significant threats to multiple organ systems. For the kidneys, cadmium levels in urine between 1-1.99 μg/day can lead to diabetic nephropathy, marked by proximal tubule dysfunction. Regarding bone health, cadmium exposure results in osteoporosis and decreased bone density through hypercalciuria, manifesting renal tubular dysfunction when blood cadmium levels reach 5-7.9 nmol/day and urinary cadmium levels reach 6.5-8.5 nmol/day. Additionally, the cardiovascular system is at risk, with atherosclerosis and its associated endothelial damage and plaque formation occurring when blood cadmium levels exceed 15 μmol/L. These findings underscore the critical need for monitoring and mitigating cadmium exposure to protect human health.

V. CONCLUSION

Based on the results presented in the graphs and tables of the systematic review on phytoremediation of cadmium-contaminated soils, several concrete conclusions can be drawn. The review highlights the significant potential of various plant species in removing cadmium from contaminated soils. For instance, plants like Athyrium wardii demonstrated a remarkable 55% removal efficiency, indicating their effectiveness in phytoremediation efforts. Other species, such as Hibiscus cannabinus and Zea mays, also showed notable cadmium removal percentages, reinforcing the viability of using these plants in agricultural and mining areas. The translocation factors of the studied plants varied, with some species exhibiting higher capabilities to transport cadmium from roots to shoots, a crucial characteristic for the effectiveness of phytoremediation. The health risk assessment indicates that cadmium exposure poses significant threats to human health, particularly affecting the kidneys and liver, and even low levels of cadmium in urine can lead to serious health issues, such as diabetic nephropathy. This underscores the importance of addressing cadmium contamination in soils to mitigate health risks to local communities. The review identifies various anthropogenic sources of cadmium, including agricultural practices, industrial activities, and urban runoff, with agricultural lands showing a higher prevalence of cadmium, suggesting the need for more stringent monitoring and remediation efforts in these areas. The findings advocate for further research into the long-term effects of phytoremediation and the potential for integrating these plant species into sustainable agricultural practices, as well as exploring the genetic and physiological traits of hyperaccumulator plants to enhance the efficiency of phytoremediation strategies. In conclusion, the systematic review provides compelling evidence for the effectiveness of specific plant species in remediating cadmium-contaminated soils, highlights the associated health risks, and emphasizes the need for continued research and practical applications in phytoremediation efforts to safeguard environmental and public health.

REFERENCES

[1]. Ackland, M. L., & Liu, Y. (2010). Strategies for enhancing the phytoremediation of cadmium-contaminated agricultural soils by Solanum nigrum L.

[2]. Azizi, M., Faz, A., Zornoza, R., Martinez-Martinez, S., & Acosta, J. A. (2023). Phytoremediation of cadmium by native plants grown on mining soil.

[3]. Dhaliwal, S. S., Sharma, V., Kaur, J., Shukla, A. K., Singh, J., & P. (2022). Cadmium phytoremediation potential of Brassica genotypes grown in Cd spiked Loamy sand soils: Accumulation and tolerance

[4]. Farid, M., Ali, S., Shakoor, M. B., & Hannan, F. (2013). EDTA Assisted Phytoremediation of Cadmium, Lead and Zinc.

[5]. Farid, M. (2015). Citric acid assisted phytoremediation of cadmium by Brassica napus L.

[6]. Hamzah, A., Hapsari, R. I., & Wisnubroto, E. I. (2016). Phytoremediation of cadmium-contaminated agricultural land using indigenous plants.

[7]. Haswell-Elkins, M., Imray, P., Satarug, S., Moore, M. R., & O'Dea, K. (2006). Urinary excretion of cadmium among Torres Strait Islanders (Australia) at risk of elevated dietary exposure through traditional foods. Journal of Exposure Science & Environmental Epidemiology, 17(4), 372–377.

[8]. Hechmi, N., Aissa, N. B., Abdenaceur, H., & Jedidi, N. (2013). Evaluating the phytoremediation potential of Phragmites australis grown in pentachlorophenol and cadmium co-contaminated soils. *Environmental Science and Pollution Research International*, *21*(2), 1304–1313. https://doi.org/10.1007/s11356-013-1997-y

[9]. Huang, R., Dong, M., Mao, P., Zhuang, P., Paz-Ferreiro, J., Li, Y., & Y., Hu, X., Netherway, P., & Li, Z.(2020). Evaluation of phytoremediation potential of five Cd (hyper) accumulators in two Cd contaminated soils

[10]. Kumar, P., & Fulekar, M. H. (2021). Cadmium phytoremediation potential of Deenanath grass (Pennisetum pedicellatum) and the assessment of bacterial communities in the rhizospheric soil.

[11]. Lisha, Z., Lijin, L., Ming'an, l., Jin, W., Yi, T., Guochao, S., Dong, L., Hui, X., Xun, W., Huifen, Z., Wei R. (2019). Phytoremediation potential of Pterocypsela laciniata as a cadmium hyperaccumulator

[12]. Messner, B., Knoflach, M., Seubert, A., Ritsch, A., Pfaller, K., Henderson, B., … Bernhard, D. (2009). Cadmium Is a Novel and Independent Risk Factor for Early Atherosclerosis Mechanisms and In Vivo Relevance. Arteriosclerosis, Thrombosis, and Vascular Biology, 29(9), 1392–1398.

[13]. Mojiri, A., Aziz, H. A., Zahed, M. A., Aziz, S. Q., & Selamat, M. R. B. (2013). Phytoremediation of Heavy Metals from Urban Waste Leachate by Southern Cattail (Typha domingensis).

[14]. Mojiri, A. (2011). The Potential of Corn (Zea mays) for Phytoremediation of Soil Contaminated with Cadmium and Lead.

[15]. Nahvi, H., Torabian, S., Hashemi, S. A., & Payam, H. (2024). Alnus glutinosa (Alder) sapling as a phytoremediator for cadmium in contaminated soil of industrial park.

[16]. Njoku, K. L., & Nwani, S. O. (2022). Phytoremediation of heavy metals contaminated soil samples obtained from mechanic workshop and dumpsite using Amaranthus spinosus.

[17]. Putri, M. P., & Moersidik, S. S. (2021). Effectiveness of typha latifolia for phytoremediation of cadmium in acid mine drainage.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL1800

[18]. Ramana, S., Tripathi, A. K., Kumar, A., Dey, P., Saha, J. K., & Patra, A. K. (2021). Evaluation of Furcraea foetida (L.)Haw. for phytoremediation of cadmium contaminated soils.

[19]. Schutte, R., Nawrot, T. S., Richart, T., Thijs, L., Vanderschueren, D., Kuznetsova, T., … Staessen, J. A. (2008). Bone Resorption and Environmental Exposure to Cadmium in Women: A Population Study. Environmental Health Perspectives, 116(6), 777–783.

[20]. Sewalem, N., Elfeky, S., & El-Shintinawy F.(2014). Phytoremediation of Lead and Cadmium Contaminated Soils using Sunflower Plant.

[21]. Shehata, S. M., Badawy, R. K., & Aboulsoud, Y. I. E. (2019b). Phytoremediation of some heavy metals in contaminated soil. *Bulletin of the National Research Centre/Bulletin of the National Research Center*, *43*(1). https://doi.org/10.1186/s42269-019-0214-7

[22]. She, W., Jie, Y., Xing, H., Luo, Z., Kang, W., Huang, M., & Zhu, S. (2011). Absorption and accumulation of cadmium by ramie (Boehmeria nivea) cultivars: A field study. *Acta Agriculturæ Scandinavica. Section B, Soil and Plant Science*, *61*(7), 641–647. https://doi.org/10.1080/09064710.2010.537678

[23]. Sun, T., Song, Y., Ji, P., Ackland, M. L., & Liu, Y. (2010). Strategies for enhancing the phytoremediation of cadmium-contaminated agricultural soils by *Solanum nigrum L.*

[24]. Tauqeer, H. M., Ur-Rahman, M., Hussain, S., Abbas, F., & Iqbal, M. (2019). The potential of an energy crop “Conocarpus erectus” for lead phytoextraction and phytostabilization of chromium, nickel, and cadmium: An excellent option for the management of multi-metal contaminated soils. *Ecotoxicology and Environmental Safety*, *173*, 273–284. https://doi.org/10.1016/j.ecoenv.2019.01.119

[25]. Udousoro, I., & Essien, M. (2015). Transfer of metals from soil to Cucumis sativus fruit and possible health risk assessment under actual field conditions.

[26]. Wang, A. S., Angle, J. S., Chaney, R. L., Delorme, T. A., & Reeves, R. D. (2006). Soil pH Effects on Uptake of Cd and Zn by Thlaspi caerulescens. *Plant and Soil*, *281*(1–2), 325–337. https://doi.org/10.1007/s11104-005-4642-9

[27]. Waseem, M., Khilji, S. A., Tariq, S., Jamal, A., Alomrani, S. O., & Javed, T. (2023). Phytoremediation of heavy metals from industrially contaminated soil using sunflower (Helianthus annuus L.) by inoculation of two indigenous bacteria.

[28]. Wei, S., & Qi-Xing Zhou (2006). Phytoremediation of cadmium-contaminated soils by Rorippa globosa using two-phase planting.

[29]. Wei, S., Zhou, Q., & Koval, P. V. (2006). Flowering stage characteristics of cadmium hyperaccumulator Solanum nigrum L. and their significance to phytoremediation

[30]. Xiao, R., Ali, A., Wang, P., Li, R., Tian, X., & Zhang, Z. (2019). Comparison of the feasibility of different washing solutions for combined soil washing and phytoremediation for the detoxification of cadmium (Cd) and zinc (Zn) in contaminated soil. *Chemosphere*, *230*, 510–518. https://doi.org/10.1016/j.chemosphere.2019.05.121

[31]. Yuko, N., Junta, Y., Takashi, K. (2005). Potential of Thlaspi caerulescens for Cadmium Phytoremediation : Comparison of Two Representative Soil Types in Japan under Different Planting Frequencies

[32]. Zakaria, Z., Zulkafflee, N. S., Redzuan, N. S., Jinap, S., Ismail, M. R., Praveena, S. M., Tóth, G., & Abdull Razis, A. F.(2021). Understanding Potential Heavy Metal Contamination, Absorption, Translocation and Accumulation in Rice and Human Health Risks.

[33]. Zhang, H., Dang, Z., Zheng, L. C., & Yi, X. Y. (2009b). Remediation of soil co-contaminated with pyrene and cadmium by growing maize (Zea mays L.). *International Journal of Environmental Science and Technology*, *6*(2), 249–258. https://doi.org/10.1007/bf03327629

[34]. Zhang, S. J., Li, T. X., Huang, H. G., Zhang, X. Z., Yu, H. Y., Zheng, Z. C., Wang, Y. D., Zou, T. J., Hao, X. Q., & Pu, Y. (2013). Phytoremediation of cadmium using plant species of Athyrium wardii (Hook.). *International Journal of Environmental Science and Technology*, *11*(3), 757–764. https://doi.org/10.1007/s13762-013-0384-z

[35]. Zhang, Z., Rengel, Z., Chang, H., Meney, K., Pantelic, L., & Tomanovic, R. (2012). Phytoremediation potential of Juncus subsecundus in soils contaminated with cadmium and polynuclear aromatic hydrocarbons (PAHs). *Geoderma*, *175–176*, 1–8. https://doi.org/10.1016/j.geoderma.2012.01.020