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Assessment of Biodrainage Potential of Existing Plant Species Along the Sewage Drains of Vedapatti Drainage Stretch, Coimbatore, Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The proper disposal of manufacturing and consumer waste, including sewage sludge, is one of the numerous environmental issues facing today's society. In addition to posing serious health concerns to humans, anthropogenic activities are a major source of environmental pollution and can result in an overabundance of pollutants entering the terrestrial ecosystem. The goal of the current study was to determine how existing tree and plant species near sewage drains were affected by the bioaccumulation of carcinogenic metals (Cd, Ni, Co, and Cr) together with other

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heavy metals. These heavy metals found in the sewage are hazardous to the health of both people and the environment. To further understand how well these plant species adapted to the metal-contaminated soil, many biological parameters, including stomatal density, leaf length, leaf area index, and stress hormone levels, were investigated. For every species included in the study, soil samples were taken near the sewer drains and the rhizosphere. The plant species' leaves and roots (where feasible) were also harvested. To check for metal buildup in the wood, various tree species had their trunks harvested. All of these samples go through an acid digestion process using an aquaregia combination. Following digestion, the samples are examined using Microwave Plasma Atomic Emission Spectroscopy (MP-AES) for the presence of heavy metals. In this study, we briefly address the findings on the accumulation of heavy metals by certain plant species.

Keywords: Sewage; heavy metals; carcinogens; bio drainage; pollution.

1. INTRODUCTION

Heavy metal contamination in urban environments is a significant problem since it may end up hurting people through the food chain. Elements with densities higher than 5.0 g/cm^3 are referred to as heavy metals, and they contain both necessary elements and metals and metalloids that are linked to pollution and toxicity. Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Lead (Pb), and Zinc (Zn) are the heavy metal pollutants that are most frequently found. Metals are organic elements of soil. Zn, Cu, Mn, Ni, and Co are a few of these metals that are essential micronutrients for plant growth, but Cd, Pb, and Hg have uncertain biological functions. When released into surface waters, they have the potential to concentrate and move up the food chain. They have the capacity to dissolve in wastewaters [1].

Leaded paint and gasoline, mine tailings, land fertilizer application, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, petrochemical spillage, and atmospheric deposition are just a few of the ways that the accumulation of heavy metals and metalloids can contaminate soils [2].

Heavy metal contamination in the environment has increased due to the expansion of urbanization and industrialization over the past few decades, posing a serious threat to ecosystems and public health. Sewage discharge stands out as a significant contributor to heavy metal pollution among the numerous sources because of the variety of toxins it contains [3-5]. Concerns related to the potential bioaccumulation of heavy metals in plants have been raised due to the close proximity of sewage treatment facilities to agricultural lands and water bodies. These metals could then enter the food chain and have an effect on human health. As persistent pollutants, heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and chromium (Cr) are known for their toxic effects on living things. Plants are essential for the cycling of heavy metals since they are the principal producers in terrestrial ecosystems. These metals can be absorbed, accumulated, and translocate into their tissues by these organisms, which can have negative effects on the environment and human health.

The foundation of the world's food production is agriculture, which provides the food on which humanity depends. However, in our rapidly urbanizing world, agricultural lands are coming closer and closer to cities, exposing them to a variety of environmental stressors, the most significant of which is sewage contamination. Sustainable agriculture is faced with a variety of problems due to the release of sewage into the environment, which is frequently filled with a complicated mixture of toxins.

Coimbatore is the second-largest industrial hub in Tamil Nadu and is a city with a rapid population growth. Unorganized metal-based industries are widely dispersed throughout Coimbatore. Textile, dyeing, electroplating, motor and pump sets, foundries, and metal casting are some of the important businesses. According to [6], the Coimbatore district is home to roughly 4500 textile businesses, 1200 electroplating businesses, 300 dyeing businesses, and 100 foundries.

Metals, while essential in trace amounts, become toxic when concentrations exceed the body's tolerance levels. Arsenic, copper, iron, and nickel, vital at low levels, are harmful in excess. They accumulate in crucial organs like the heart, brain, kidney, bone, and liver, disrupting functions. Environmental exposure and occupational contact lead to metal toxicity, causing severe health issues and even mortality. The body's intricate mechanisms for handling metals can be overwhelmed, leading to adverse effects. Understanding this delicate balance is vital for preventing heavy metal-related morbidity and mortality. Hence this study aims at exploring the bio drainage potential of plant species along the sewage drains for heavy metals.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area consisted of a sewage stretch starting from Vedapatti village panchayat (western region of the Coimbatore city) to Poosaaripalayam village to the east. The sewage consisted of many number of plants grown naturally. The sewage contains both black water and grey water from around thousands of residents. The area also has one machinery production unit and one LED spare parts assemble unit. Total distance covered for the study was 6.0 Kms 11.0068ºN 76.9047ºE to 11.003512ºN, 76.924416ºE.

2.2 Collection of Sewage Water Samples

Once high sewage drainage areas were identified, samples of the sewage water along with sediments were collected at six sites divided equally with one kilometre interval along the drainage system. This step was crucial to understand the composition of the sewage water, including the presence of heavy metals. The sampling collection site was also selected based on the abundance growth of plant species.

2.3 Identification of Trees and Shrubs Grown Along the Sewage Drain Proximity

The specific trees and shrubs that were grown along the sewage affected areas were surveyed and identified. The plants those that were naturally grown or intentionally planted in these locations were included. The physiological characters of the trees and plants were measured to study the impact of heavy metals accumulation in the plant species.

2.4 Plant Sample Collection

Once the plants were identified, leaf samples of the trees and shrubs were collected, preferably matured leaves over fresh leaves.

2.5 Sample Preparation

The plant samples collected were dried in a hot air oven at a specific temperature of 105º Celsius. The dried samples were typically left in the oven until they reached a constant weight, indicating that all moisture has been removed. Once the samples were completely dry, they were macerated into a fine powder using a pestle and mortar which increases the surface area of the sample, making it easier for the subsequent digestion process to happen. After obtaining the powdered samples, the samples were subjected to digestion with aqua regia. Aqua regia is a highly corrosive mixture of concentrated hydrochloric acid (HCl) and nitric acid (HNO_3) with the ratio of 3:1.

The powdered sample was placed in conical flask with glass funnel placed inside, and 20ml of aqua regia was added. The mixture was then kept on a hot sand bath for digestion. The heat produced by the sand bath accelerated the digestion process and helped in the break down the sample, releasing the heavy metals bound within the plant material. The digestion was continued until the sample changed into a colourless or pale yellow liquid. This color change indicated that the sample has been effectively digested, and the heavy metals are released into the solution. Once digestion is complete, the digested sample is allowed to cool. After cooling, it is carefully diluted with Milli-Q water to a known volume, typically 100 mL. This dilution ensures that the heavy metal concentrations are within the detection range of the MP-AES instrument and that the sample is at a suitable concentration for analysis.

To remove undigested material, the diluted sample was filtered through Whatman No. 42 filter paper. Filtration ensure that the solution fed into the MP-AES instrument is free from particulate matter that could clog the instrument or interfere with the analysis. The filtrate contained the dissolved heavy metals in a clear liquid form, ready for spectroscopic analysis.

2.6 Determination of Heavy Metals in MP-AES (Make: Agilent 4210 MP-AES)

The prepared samples were fed into the instrument. The instrument was then standardized using a set of 23 analyte standards to calibrate its wavelength settings. After the wavelength calibration process is completed, the prepared plant samples were fed into the instrument. The sample introduction system of the MP-AES will transport the prepared sample solutions to the atomization and excitation chamber. The sample is atomized and excited using a high-frequency microwave energy and the excited atoms emit characteristic wavelengths of light, and the instrument measures the intensity of these emissions for each element present in the sample. The intensity of the emission lines is directly proportional to the concentration of the elements.

As the MP-AES analyzes each sample, it records the emission intensities for the specific wavelengths associated with the elements of interest. These intensity measurements are then used to calculate the concentration of each element in the sample. The instrument's software typically allows for real-time data collection, visualization, and storage of results. It can also perform any necessary data processing, such as background correction and baseline subtraction.

3. RESULTS AND DISCUSSION

Table 1 and Table 2 denoted that there is abundant growth of plants like *Acalypha indica, Ricinus communis, and Datura metal*. In spite of the fact that sewage water is the only source of irrigation, we may infer from visual examination that these plants have not displayed any physiological damage. Despite being few in number, tree species *like Azadirachta indica, Melingtonia hortensis, Pongamia pinnata, Tamarindus indica, and Ficus benghalensis* are included in this study because they have endured in this sewage-irrigated environment for a considerable amount of time. Even though *Nerium oleander* does not appear to have naturally grown in these drains, it appears that residents placed it there for decoration. This plant is included in the study because it appears to have adapted effectively to the sewage water.

Tables 3 and 4 showed that the pH and EC of both sewage and soil samples varies throughout the study area. The EC (Electrical Conductivity) test measures the soil's electrical conductivity and provides information on the amount of soluble salts present in the soil. The soil's electrical conductivity increased with the amount of soluble salts present.

Table 1. Identification of plant species along the poosaripalayam sewage drains

S. No.	Common Name	Scientific Name	Number of species
1	Neem	*Azadirachta indica*	22
2	Maramalli	*Melingtonia hortensis*	3
3	Pungam	*Pongamia pinnata*	15
4	Tamarind	*Tamarindus indica*	5
5	Banyan tree	*Ficus benghalensis*	1
6	Kuppaimeni	*Acalypha indica*	Abundance
7	Castor	*Ricinus communis*	Abundance
8	Oomathai	*Datura metal*	Abundance
9	Kaatu aamanakku	*Jatropha curcas*	17
10	Nerium	*Nerium oleander*	25
11	Vana tulsi	*Ocimum gratissimum*	5

Table 2. Trees and shrub species identified and their coordinates along the poosaripalayam sewage drains

Site No	Co-ordinates	Species identified
S1	11.006810ºN, 76.904007ºE	Castor, Nerium species, Neem
S2	11.003539ºN, 76.909676ºE	Pungam ,Castor,Vana tulasi, Jatropha
S3	11.004171ºN, 76.911170ºE	Maramalli, pungam, Tamarind, neem
S4	11.004423ºN, 76.916499 ºE	Pungam, Castor, datura, Tamarind
S5	11.004121ºN, 76.920048ºE	Tamarind, Castor, datura
S6	11.003512ºN, 76.920048ºE	Kuppaimeni, castor, jatropha, banyan

Table 3. Assesment of pH and EC (dS m^{-1}) of soil samples collected along the poosaripalayam sewage drains

Sampling site	pH	EC (dS m^{-1})
S1	7.17	0.40
S2	7.08	0.47
S3	6.54	0.73
S4	8.09	2.16
S5	7.25	1.15
S6	6.15	0.98

Table 4. Assesment of pH and EC (dS m^{-1}) of sewage samples collected along the poosaripalayam sewage drains

Sampling site	pH	EC (dS m^{-1})
S1	6.04	1.67
S2	7.69	2.33
S3	7.20	1.78
S4	7.08	1.60
S5	9.09	1.98
S6	7.65	1.27

High concentrations of soluble salts in the soil can be poisonous to plants and have an adverse effect on water uptake. In addition, low amounts of soluble salts may indicate insufficient soil fertility, which may potentially have an effect on plant growth. As with most of the parameters in the soil, it's critical to maintain a healthy EC since too much of these nutrients, especially Na and Mg, can be harmful to the health of the soil. Therefore, the range of ideal soil EC values is 1.10 to 5.70 deciSiemens per meter (dS m^{-1}). When EC levels are too low or too high, it means that there aren't enough nutrients available. Here, the soil and sewage have pH levels that are practically neutral, neither acidic nor alkaline, making the environment optimal for plant development. The only conclusion we can draw is that the soil includes some salts like Na and Mg but is contaminated with some heavy metals because the EC of the soil is below the acceptable limit. As a result, we can infer that the soil has some potential to conduct electricity.

Tables 5 and 6 showed Metals including Fe, Cu, Mo, Mn, and Ni were abundant in the soil and sewage samples collected in this area. All of them are regarded as plant nutrients. So let's concentrate on heavy metals that could be dangerous and are present in reasonable amounts, like Pb, Cr, and Cd. Although [7,8] and [9] have previously reported that micronutrients like Zn, Mn, and Fe to distribute well in the profile, [10] observed greater movement of metals in sewage affected light textured soils than in heavy textured soils. Higher build-up was observed in surface than lower layers with the exception of Cd. It should be noted that the accumulation of heavy metals like Cr, Ni, and Pb calls for ongoing monitoring and appropriate action before they become harmful. These heavy metal concentrations are in the following order of Pb>Cr>Cd.

Fe and Cu were present in high concentrations in soil samples from S2 (111.4 mg kg^{-1}) and 56.4 mg kg^{-1}). This can be because there are meat markets close by those locations. The existence of an LED assembly unit and a machinery unit nearby may be the cause of the greatest levels of Pb (147.2 mg kg^{-1} and 50.01 mg kg^{-1} in S4 and S3, respectively) and Ni (105.6 mg kg^{-1} and 21.8 mg kg^{-1} in S5 and S6, respectively). Although the amount of Pb and Ni is below the permitted limit, there is cause for considerable worry.

Plant species that are excellent in accumulating both Pb and Cr include *Nerium oleander, Jatropha curcas, and Ricinus communis*. If you take into account the biomass, all five of the tree species included in this study—*Azadirachta indica, Melingtonia hortensis, Pongamia pinnata, Tamarindus indica, and Ficus benhalensis*—are great at accumulating Pb,Cr, and Cd. Tree species can accumulate more metals since they have longer lifespans than other plant and shrub species. From the observations recorded it is inferred that, *Ricinus communis* appeared to have spread widely and has accumulated nearly all the metals without showing any physical deformation.

Table 5. Assessment of heavy metal concentration of soil samples along the poosaripalayam sewage drains

S. No.	Sampling site	Cd (mg kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Mo (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})
1	S1	1.8	3.1	42	91.3	1.3	25.12	5.0	24.2	2.1
2	S2	0.8	2.7	56.17	111.4	0.5	0.3	21.1	0.41	0.5
3	S3	1.5	25.6	17.9	18.6	51.6	1.12	18.0	50.01	1.2
4	S4	1.12	0.6	111.74	45.3	7.8	0.5	16.01	147.2	0.71
5	S5	0.9	14	41.02	56.0	13.0	0.8	105.6	26.0	0.1
6	S6	0.87	15.8	37.2	81.2	0.01	52.1	21.8	31.5	-

Table 6. Assessment of heavy metal concentration of sewage samples along the poosaripalayam sewage drains

S. No.	Sampling site	Cd (mg L^{-1})	Cr (mg L^{-1})	Cu (mg L^{-1})	Fe (mg L^{-1})	Mn (mg L^{-1})	Mo (mg L^{-1})	Ni (mg L^{-1})	Pb (mg L^{-1})	Zn (mg L^{-1})
1	S1	0.7	3.7	3.0	39.2	0.5	9.8	8.9	3.1	0.5
2	S2	0.7	9.1	11.12	23.8	0.32	5.6	5.6	3.0	-
3	S3	0.5	-	4.5	0.56	0.4	92.1	9.1	13	3.1
4	S4	0.1	2.3	10.2	12.6	0.65	2.3	2.36	9.8	-
5	S5	0.8	3.8	21.3	58.9	-	54.2	5.16	0.6	0.2
6	S6	0.7	6.5	5.6	0.01	-	3.2	14.2	21.9	-

Table 7. Bioaccumulation of heavy metals in the plant samples along the sewage drains

S. No.	Sampling site	Cd (mg kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Mo (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Zn (mg kg^{-1})
1	*Azadirachta indica*	0.96	1.51	0.64	2.16	9.57	1.55	6.19	4.16	2.64
2	*Melingtonia hortensis*	1.71	9.66	1.96	4.92	7.49	2.67	2.86	-	1.17
3	*Pongamia pinnata*	3.25	4.94	0.81	9.75	5.27	3.79	6.32	7.69	4.98
4	*Tamarindus indica*	2.85	7.21	2.95	4.36	2.16	1.45	-	4.5	7.64
5	*Ficus benhalensis*	4.68	6.83	1.91	3.24	0.59	0.94	4.26	9.34	5.79
6	*Acalypha indica*	-	15.31	0.64	14.60	0.17	0.05	17.81	5.27	0.25
7	*Ricinus communis*	2.18	0.36	1.64	0.36	5.12	0.66	7.56	6.84	9.16
8	*Datura metal*	0.35	11.27	2.56	0.61	0.64	15.1	10.51	5.86	6.97
9	*Jatropha curcas*	-	2.59	4.98	0.23	0.99	11.8	9.47	8.74	6.59
10	*Nerium oleander*	-	16.5	1.26	0.84	0.65	1.27	22.39	11.85	0.37
11	*Ocimum gratissimum*	-	-	3.55	-	2.19	-	12.94	0.02	1.55

According to [11-13], soil pollution with heavy metals is a global environmental issue that is becoming more significant. People are exposed to heavy metals in a variety of ways because they are pervasive in the environment as a result of both natural and anthropogenic activities [14], [15]. The predominant form of cationic metals absorbed by living things is their free ion species [16]. The highest bioavailability of Fe for plants was found in sewage-fed lake water by Lokeshwari et al. [17].

4.CONCLUSION

Azadirachta indica (Neem), *Melingtonia hortensis* (Neem), *Pongamia pinnata* (Indian Beech), and *Tamarindus indica* (Tamarind) are trees known for their extended lifespans and remarkable resilience. While they may not be hyperaccumulators of heavy metals, their longevity and adaptability make them suitable candidates for afforestation in areas with low to moderate heavy metal contamination. These trees can play a valuable role in gradually stabilizing and improving soil quality over time, reducing the risk of heavy metal leaching into the environment. Their multi-faceted benefits, including shade provision, carbon sequestration, and ecosystem enhancement, make them valuable choices for sustainable land remediation and ecological restoration initiatives.

Ricinus communis (Castor bean), Jatropha curcas (Physic nut), and Nerium oleander (Oleander) have shown low physiological damage when exposed to heavy metals, making them promising candidates for phytoremediation in contaminated areas. Their ability to thrive in such conditions indicates resilience and efficiency in metal absorption and accumulation, contributing to environmental cleanup efforts. On the other hand, Datura metal (Thorn apple) might absorb heavy metals but is not recommended due to its medicinal value. Utilizing Datura for phytoremediation could potentially compromise its safety for medicinal purposes, as heavy metal accumulation may contaminate its tissues and render it unsafe for traditional medicinal use, emphasizing the need for careful species selection in remediation projects.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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