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# Assessment of Phytoremediation Systems for the Removal of Trace Metals from Sewage Water for Irrigation Purposes

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**Abstract** The purpose of this study was to evaluate the potential of Canna indica for reducing trace metals found in sewage water collected from the sewer of Auchi Polytechnic Hostel, Edo State, Nigeria. The sewage water was introduced into geofilters and phytoremediation media at a hydraulic loading rate of 1.5 m/day. The percentage reduction efficiency of trace metals in the sewage water was measured at different hydraulic retention times of 10, 20, and 30 days for both the experimental control and phytoremediation media. The results showed that phytoremediation systems performed better in treating sewage water compared to geofiltration media. The percentage reduction efficiency of trace metals for Zn, Cd, Pb, Fe, and Cu ranged from 7.4% to 53.9% for the experimental control and from 15.4% to 76.9% for the phytoremediation media. The amount of zinc in the phytoremediated sewage water met the guidelines for irrigation use at a hydraulic retention time of 20 and 30 days. This study demonstrates the potential of Canna indica and phytoremediation systems for the reduction of trace metals in sewage water. It suggests that longer hydraulic retention times may be necessary for the phytoremediation of other trace metals such as Cd, Pb, Fe, and Cu to meet wastewater guidelines for irrigation purposes. The findings contribute to the understanding of the effectiveness and applicability of the phytoremediation system as an economical and ecologically useful technology for remediating contaminated water.

**Keywords** Geofiltration, phytoremediation, turbidity, toxicity. hydraulic retention time

## 1. Introduction

An increasing number of people prefer the cleanest and healthiest environment possible, and environmental pollution has emerged as a significant ecological issue on a global scale. Numerous organic and inorganic pollutants have been found to pollute the environment and seriously endanger the health of living things. Because of their high abundance, inability to biodegrade, and environmental persistence, heavy metals are among the most prevailing pollutants [23]. Significant anthropogenic factors that hasten water and soil contamination by metals include mining and processing, fertilizer use, pesticide use, and sewage sludge disposal. [27]. According to [28], excessive pollution in the soil degrades its quality and productivity and exposes the entire food chain. Due to heavy metals' high toxicity, extended persistence, and bioaccumulation traits, soil contamination especially in agricultural soils through irrigation systems with sewage water has drawn attention in recent years [13].

One of the approaches of the phytoremediation system is rhizofiltration and it uses plant roots to absorb, concentrate, and precipitate metals from wastewater [29]. Due to their larger surface area for metal sorption, and stronger, longer, and typically fibrous roots, terrestrial plants are referenced to be suited for rhizofiltration process [7]. Terrestrial plants possess several crucial characteristics of that are appropriate for phytoremediation, and one of these plants is Canna indica L. (Cannaceae) which is a good option for removing heavy metals from contaminated water. Though heavy metals like zinc (Zn) and copper (Cu) are necessary elements, their toxicity to humans and animals makes their increased concentrations in crops and vegetables a source of serious concern [15]. However, some countries practices irrigation with treated sewage that contains heavy metals, which has led to a rise in heavy metal concentrations in plants, soil, and groundwater. A case study was conducted in Delhi, India, to evaluate the long-term effects of sewage irrigation on plants, soils, and groundwater. Zn, Cu, Fe, and Pb concentrations increased significantly by 208%, 170%, 63%, and 29%, respectively, according to the study [21].

Up to 2.5 million possible polluted sites need to be studied in Europe according to researchers. It is anticipated that 14% of these sites will be polluted and will probably need to be cleaned up [20]. One new, affordable, and environmentally friendly method for reducing and controlling heavy metal pollution in the environment is phytoremediation. According to [19], it is the best substitute for the conventionally used physicochemical remediation approaches, which are very costly, produce secondary pollution by polluting neighbouring water, degrade soil fertility, and have a detrimental effect on the agroecosystem. Globally, the use of a phytoremediation system is a green approach for several applications, and the approach is growing for the treatment of municipal sewage sludge. The continuously expanding areas of contaminated or degraded water and soil that are unfit for agricultural use continue to be a source of concern. For these types of water and soil, it is crucial to search for new and sustainable phytoremediation approaches, and this includes growing energy crops with sewage sludge [8].

The designed structures known as phytoremediation set-ups are utilized globally to enhance the quality of water [9]. To remove nutrients, organic matter, heavy metals, and other contaminants from wastewater, these systems combine intricate design, water flow, filter media arrangement, overlaying plants, and microbial consortia. Numerous research has previously adopted vertical flow-built wetlands for the treatment of sewage [2]. On the other hand, not much research has been done on the removal of heavy metals from wastewater. It was shown that inoculating macrophyte species in combination with the right treatment media and hydraulics retention period can successfully remove heavy metals from wastewater. However, additional research is needed to fully validate the benefits of this approach [26]. Therefore, it was suggested that by using VFCW cells, organic molecules, heavy metals, and nutrients may all be recovered from wastewater simultaneously while the ability to remove other contaminants is unaffected by the presence of heavy metals. Studies on a variety of plant species such as A. calamus, T. latifolia, C. indica, and A. calamus revealed that they could absorb significant levels of Mn, Cr, Zn, Mn, Cu, and Fe. [5]. The purpose of this study was to examine the phytoremediation potential of Canna indica plant for the removal of selected trace metals from Auchi Polytechnic sewage water using a constructed wetland approach for irrigation purposes.

## 2. Materials and method

### 2.1 Investigation of raw effluent treatability

Investigating the treatability of sewage water is crucial, and this can be done by following the methodology adopted by [4], who suggest that treatable wastewater should have a BOD5/COD ratio of 0.3–0.8. For the adoption of a biological treatment approach in wastewater treatment, a BOD5/COD ratio of 0.5 is appropriate. The sewage water collected from Auchi Polytechnic hostel sewer was evaluated to be 0.68 under BOD5/COD criteria for wastewater treatability. It might be necessary to use some microbes to break down wastewater pollutants if the ratio of BOD5/COD is less than 0.3.

### 2.2 Collection of macrophytes (Canna indica)

Indian shot (Canna indica) was collected from close to one of the flowing streams at Auchi town, Edo State, Nigeria. The perennial Canna indica plant grows huge leaves up to 50 cm long, 20 cm broad on clumps of stems, and 150–300 cm tall. A big, thick rhizome that resembles a tuber gives rise to the stems. This plant replaces several wetland species and grows in huge, dense clusters, especially in riparian zones. The plants were moved to the experimental setup after being placed in a polythene bag filled with damp soil. For appropriate stability and acclimatization in the phytoremediation media, India shot (Canna indica) was introduced into the experimental setup and watered with clean water for a month. The experiments were carried out by inoculating Indian shot (Canna indica) into a vertical and horizontal basin filled with composite filters [16]. The composite filters (granite, treated sand, and activated carbon) are of different particle sizes and are arranged from the bottom up in the composite drum. The particle sizes of the composite filters (granite, treated sand, activated carbon) are 3 - 3.5mm, <200µm, and 1mm. The vertical and horizontal components of the composite filter housing have a dimension of 28cm height, 32cm diameter (cylindrical housing) and 31cm length, 28 cm width, and 15 cm depth (rectangular housing), and it was carefully placed on a flat slope. The adopted geofilters were separated with a fine net of 0.5mm to assist the filtration process, create turbulence during wastewater flow and provide space for wastewater aeration. The inner part of the horizontal composite filter housing was spaced every 10 cm to create horizontal serpentine flow along its length for adequate treatment.

## 2.3 Collection of domestic sewage and experimental procedure

Sewage water was collected from hostel sewers of Auchi Polytechnic, Edo State. The sewage water was collected from two different sources in the hostel (the sewer of block 1 and the sewer of block 2) with a container of 25Litres each, the sewage water from the two sources was mixed, transported and poured into a 50-litre influent container of the experimental set-up. The sewage water was released to composite filters at a hydraulic discharge rate of 1.5m/day to each of the three composite filter containers. Average length pipe was used to convey sewage water through the vertical and horizontal composite filter containers which were set up separately, the sewage water flow rate was controlled with the aid of a control valve. The study was carried out at an influent detention depth of 25cm for the cylindrical composite filter housing, 12cm for the rectangular composite filter housing and at a detention period of 10 days, 20 days, and 30 days, respectively [12]. The raw sewage and treated effluents were analyzed in a water laboratory for trace metal contents such as zinc (Zn), cadmium (Cd), lead (Pb), Iron (Fe), and Copper (Cu).

## 2.4 Wastewater retention time

The assumed retention period for the wastewater treatment was designed using the formular below

$$T = \frac{\rho \text{ X } Vf}{Qb} \qquad \text{[equ1]}$$

T = Adopted or theoretical hydraulic retention time (hrs)

ρ = porosity of composite filters

Vf = Volume of the filter bed (m3)

Qb= Wastewater flow rate through the filter bed (m3/hr) [12].

2.5 Estimation of trace metals reduction efficiency

The treatment efficiency of the two filters was assessed using the equation below.

$$A = \frac{zi - z0}{zi} \text{ X } 100 \qquad \text{[equ2]}$$

A = Trace metals reduction efficiencies (%)

Zi = Value of trace metals in raw sewage (mg/L)

Z0 = Value of trace metals in treated sewage (mg/L) [12]

## 2.5 Statistical analysis

The data collected from the study were analyzed and interpreted with the aid of a graphical display from Excel page. This revealed the significant differences in the number of trace metals removed by geofilter (control) and phytoremediation systems, respectively.

*Plate 1*

*Plate 2*

*Plate 3*

*Plate 4*

Plate 1&2: Raw sewage water and sample collection
Plate3: Image of harvested and inoculated Canna indica
Plate4: Experimental set-up with geofiltration and phytoremediation systems

## 3. Results and discussion

### 3.1 Interpretation of raw, geofiltered and phytoremediated sewage water

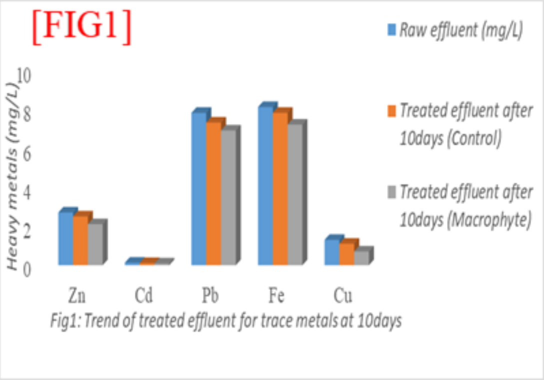


Fig1: Trend of treated effluent for trace metals at 10days

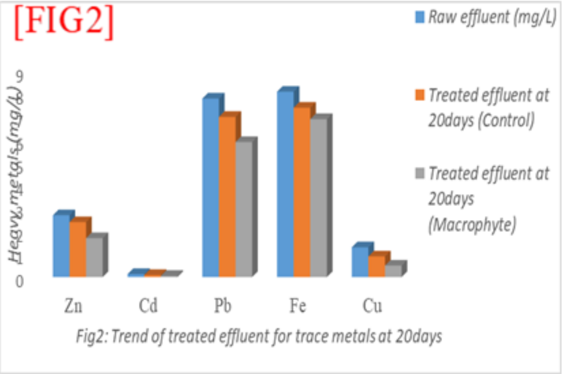


Fig2: Trend of treated effluent for trace metals at 20days

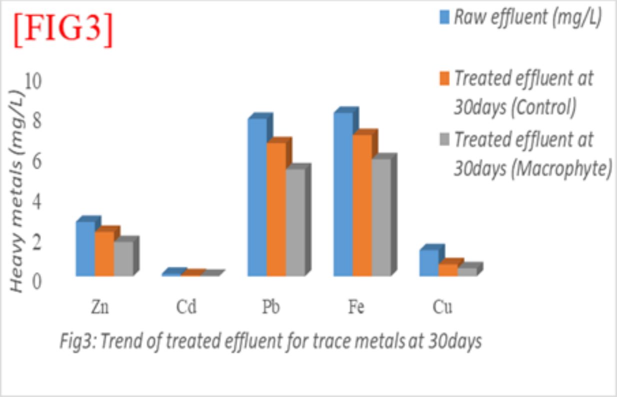


Fig3: Trend of treated effluent for trace metals at 30days

*Fig1, 2, & 3: Trend of raw and phytoremediated trace metals from sewage water at 10, 20, & 30days.*

The collection, analysis, and interpretation of data for raw, geofiltered and phytoremediated sewage water on day 1 (before treatment) and day 10 (after treatment) are shown in FigA above. It was deduced from the graph that the quantity of iron (Fe) present in the sewage water was high compared to other trace metals, while the value of cadmium (Cd) was at lowest compared to others. The order of trace metal abundance in untreated domestic wastewater was reported by [6] and [14] to be Fe > Mn >> Ni ≥ Zn > Cu ≥ As ≥ V ≥ Co ≥ Cr ≥ Pb > U > Cd. This is consistent with the report and largely supports the relative presence of trace metals in the treated wastewater from this study. Additionally, it was stated that in a sludge sample from WWTP-C, the predominance of trace metals was in the order of Fe > Cu > Cd (mg/kg). However, water that has more than 0.3 mg/L of iron can discolour plumbing fixtures and clothes. Mining operations are one of the main human sources of iron in environmental waters. Nonetheless, in addition to natural deposits, this study suggests that the usage of steel and iron cookware, as well as other associated home products, may be connected to the amount of iron (Fe) in the raw sewage water samples [18]. The quality of the treated effluent improved for the adopted media and a retention period of 10 days.

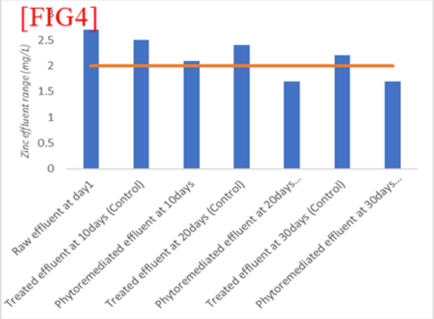
The Fig2 above represents the treatment of sewage water at 20 days of treatment. The value of the treated sewage was compared for geofilter (experimental control) and phytoremediation media. The result from the graph shows that there was a reduction in the value of all trace metals considered in the treated sewage. The value of iron (Fe) was high when compared to other trace metals considered in the study, and the amount of cadmium was low when compared to other trace metals. The result from the graph shows that the constructed wetland approach through the use of India shot (Canna indica) for the removal of trace metals from sewage water is of great importance. The result from the graph also revealed that the higher the retention time, the lower the amount of trace metals in the treated sewage water. The heavy metals that are present in raw and treated sewage are in the order of Fe > Pb > Zn > Cu > Cd.

From Fig3, the number of trace metals in the treated effluent reduced considerably for phytoremediation media at 30 days of treatment and when compared to the number of heavy metals for a detention period of 10 and 20 days, for geofilter and phytoremediation media, respectively. The iron content of the raw and treated effluent was high while that of cadmium was low when compared to other trace metals at 30 days of treatment. The result also reveals the potential of the phytoremediation process for the treatment of sewage water for agricultural land reclamation and reuse.

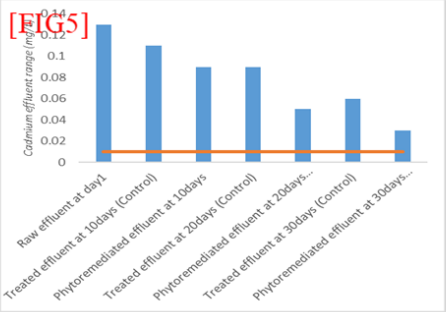
## 3.2 Standards of wastewater use in irrigation

The treated effluent for each of the treatment media and time intervals was subjected to evaluation for its suitability for irrigation use and this was graphically interpreted in Fig 4 to Fig 8 below

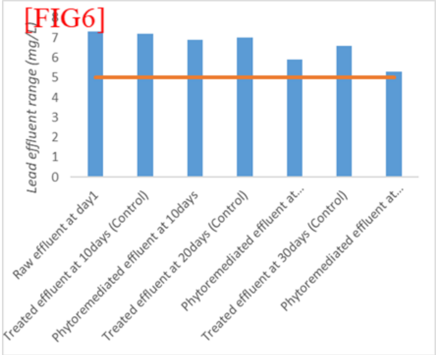
[FIG4]



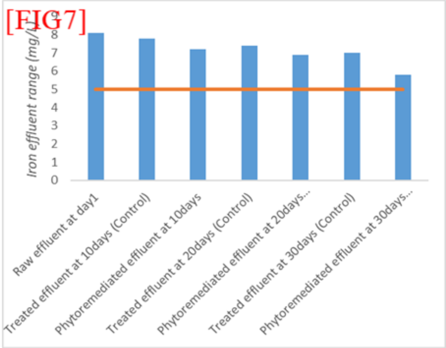
[FIG5]



[FIG6]



[FIG7]



[FIG8]

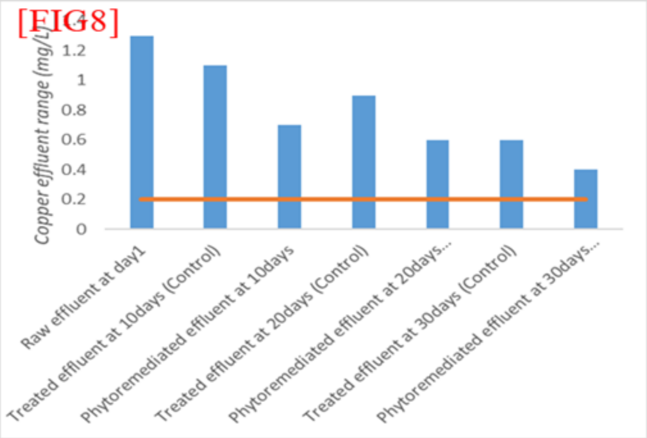


*Fig 4, 5, 6, 7, & 8: Graph of treated effluent and wastewater irrigation standards for Zn, Cd, Pb, Fe & Cu*

Trace metals can be delivered through irrigation water because of their importance for crop productivity. One of these trace metals is zinc. Excess zinc in wastewater used for irrigation systems can cause the chlorosis of plant stems and inhibit root growth [1]. The graph from Fig4 above reveals that the raw effluent on day 1, the effluent from all the experimental control, and phytoremediated effluent on day 10 are above the recommended standard [11] of wastewater use in irrigation systems. The phytoremediated effluent for zinc (Zn) at day 20 and day 30 are within the recommended limit for wastewater use in irrigation systems. The trace elements of 1.7mg/L for zinc were recorded for the two phytoremediation treatments' intervals. The United States Environmental Protection Agency (USEPA) and Food and Agriculture Organization (FAO) recommended a limit of 2.0mg/L of zinc constituents in wastewater reuse for irrigation purposes [11].

Normally, and subject to stringent regulations, cadmium (Cd) can accumulate in crops and pose a health risk to humans when dissolved in water or soil [10]. The USEPA, FAO, Korea, Cyprus, Greece, Israel, and Italy standards recommended a standard of 0.01mg/L for the composition of cadmium in irrigation water [11]. The Fig5 above reveals that the number of cadmium present for all the treatment media and treatment intervals adopted for the treated effluent does not meet the recommended standard for wastewater use in irrigation. Also, cadmium is the lowest trace metals detected in the sewage water.

Due to its breakdown from sustainable materials, lead (Pb) is a continuous toxin and poison that is detected in water; yet, battery smelters and residential plumbing are capable of supplying enough lead Pb [3]. Lead is naturally occurring in the Earth's crust, and most concentrations of lead in the environment are caused by human activity [17]. The graph in Fig6 above reveals that all the treatment media and the treatment interval adopted for the treatment of sewage water do not meet the recommended standard of lead constituent in sewage water use in irrigation. There was a significant reduction in the amount of lead (Pb) in the treated sewage water between the experimental control and phytoremediated sewage water at different treatment time intervals. The value of the treated sewage for lead (5.3mg/L) by phytoremediation systems and at a hydraulic retention time of 30 days was close to the recommended standard of 5.0mg/L by USEPA and FAO [11].

The level of iron (Fe) in the raw and treated sewage water was high when compared to other trace metals (Fig7). There was a steady reduction in the amount of iron constituents in the treated effluents with consideration to the adopted retention period. All the treatment media and treatment intervals adopted do not treat the sewage water to the recommended limit as stipulated by USEPA and FAO [11]. The result of the study corroborated the adoption of phytoremediation systems to geofiltration approach for the treatment of sewage water.

For the catalytic and structural components of enzymes and proteins to function as cofactors, heavy metal ions such as copper (Cu) in the proper quantities are necessary. Additionally, normal plant growth and development depend on these ions. Nonetheless, plants that have higher than ideal levels of this micronutrient and other trace metals experience stress [24;25]. One frequent trace metal that can be found in water and soil is copper, which corrodes copper pipes and finds its way into sewage and groundwater through residential and commercial discharge. Large amounts of copper can lead to serious health issues when applied through irrigation systems, even though it is a trace metal that is required for human health [22]. According to Fig8 above, the amount of copper in the treated sewage did not meet the wastewater guideline for irrigation use despite the adopted treatment media and treatment retention times of (10, 20, and 30 days). The phytoremediation systems yielded the best performance for the reduction of copper in sewage water compared to the experimental control.

[FIG9]

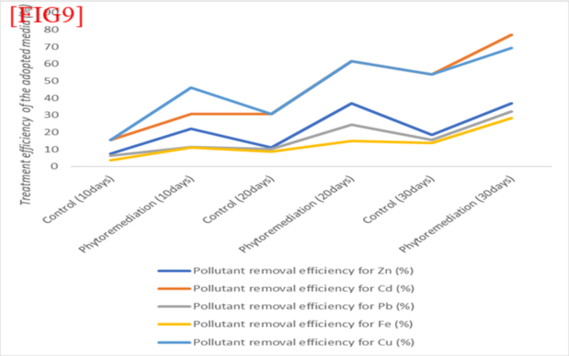


*Fig 9: Treatment efficiency of geofiltration and phytoremediation systems*

The Fig9 above represents the efficacy of geofiltration and phytoremediation system in the reduction of trace metals (Zn, Cd, Pb, Fe and Cu) from the sewage water. This was observed at hydraulic retention time of 10 days, 20 days, and 30 days for each of the treatment media adopted. The graph reveals a trace metals' reduction efficiency in the order of 53.9, 53.9, 18.5, 15.4, 13.6% and 76.9, 69.2, 37.03, 32.1, 28.4% for Cd, Cu, Zn, Pb, and Fe for experimental control and phytoremediation system at 30days of treatment, respectively.

## 4. Conclusion

Numerous evaluations of the literature concur that the treatment of sewage water in artificial wetlands can be greatly enhanced by phytoremediation systems that employ plants like Canna indica. The results of this study indicate that, in comparison to geofiltration systems, phytoremediation systems lower the amount of trace metals in sewage water, highlighting the potential of Canna indica in this regard. Based on the data presented in this study, additional research is required to determine the precise treatment medium and hydraulic retention time for sewage water treatment through a phytoremediation system to reduce trace metals like cadmium, lead, iron, and copper to a safe limit for irrigation use.

## Declaration of conflict of interests

All the authors contributed impactfully to the study and thereby declared no conflicting report with individuals or any group during and after the research.

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## References

[1]. Asano, T., Burton, F. L. and Leverenz, H. L., Tsuchihashi, R. and Tchobanoglous, G. (2007). Water Reuse: Issues, Technologies and Applications; McGraw-Hill: New York, NY, USA.

[2]. Abou-Elela, S. I. and Hellal, M. S. (2012). Municipal wastewater treatment using vertical flow constructed wetlands planted with Canna, Phragmites and Cyprus, Journal of Ecological Engineering, 47: 209-13.

[3]. Ayuso, R. A. and Foley, N. K. (2020). Surface topography, mineralogy, and lead isotope survey of wheel weights and solder: Source of metal contaminants of roadways and water systems. Journal of Geochemical Exploration, Volume 212, 106493.

[4]. Basim-Hussein, K., Ahmed-Makki, A. S. and Rehab, K. J. (2018). Effluent Quality Assessment of Al-Diwaniyah Sewage Treatment Plant Based on Wastewater Quality Index. International Journal of Civil Engineering and Technology, 9(10), pp. 22-31.

[5]. Bhagwat, R.V., Boralkar, D. B. and Chavhan, R. D. (2018). Remediation capabilities of pilot-scale wetlands planted with Typha aungstifolia and Acorus calamus to treat landfill leachate. Journal of Ecology and Environment, 42(1): 1-8.

[6]. Chipasa, K. B. (2003). Accumulation and fate of selected heavy metals in a biological wastewater treatment system. Waste Manag, 23, 135–143.

[7]. Dushenkov, S., Kumar, P. B.A. N., Motto, H. and Raskin, I. (1995). Rhizofiltration: The use of plants to remove heavy metals from Aqueous streams. Environmental Science Technology29 (5), 1239-1245.

[8]. Fijalkowski, K., Rosikon, K., Grobelak, A., Hutchison, D. and Kacprzak, M. J. (2018). Modification of properties of energy crops under Polish condition as an effect of sewage sludge application onto degraded soil. J. Environ. Manag. 217, 509–519.

[9]. García-Ávila, F., Patiño-Chávez, J., Zhinín-Chimbo, F., Donoso-Moscoso, S., Del Pino, L. F. and Avilés-Añazco, A. (2019). Performance of Phragmites Australis and Cyperus Papyrus in the treatment of municipal wastewater by vertical flow subsurface constructed wetlands. International Soil and Water Conservation Research, 7(3): 286-296.

[10]. Gupta, U.C. and Gupta, S.C. (1998). Trace element toxicity relationships to crop production and livestock and human health: Implications for management. Commun. Soil Sci. Plant Anal, 29, 1491–1522.

[11]. Hanseok, J., Hakkwan, K. and Taeil, J. (2016). Irrigation water quality standards for indirect wastewater reuse in agriculture: A contribution toward sustainable wastewater reuse in South Korea. Journal of Water/MDPI.pg 6, https://www.mdpi.com/2073-4441/8/4/169.

[12]. Ibrahim, R., Oyati, E. N., Onuoha S. N. and Ajayi A. S. (2023). Study on the potential of macrophytes in a two-stage filtration of domestic wastewater for irrigation purposes. Journal of Scientific and Engineering Research, 10(4):54-60.

[13]. Jiang, X., Zou, B., Feng, H., Tang, J., Tu, Y. and Zhao, X. (2018). Spatial distribution mapping of mercury (Hg) contamination in subclass agricultural soils using GIS enhanced multiple linear regression. J. Geochem. Explor. 196, 1–7.

[14]. Karvelas, M., Katsoyiannis, A. and Samara, C. (2003). Occurrence and fate of heavy metals in the wastewater treatment process. Chemosphere, 53, 1201–1210.

[15]. Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z. and Zhu, Y. G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environmental Pollution; 152: 686-692.

[16]. Kundan, S., Rajesh, R. D. and Puspendu, B. (2018). A comparative study of macrophytes influence on performance of hybrid vermifilter for dairy wastewater treatment. Journal of Environmental Chemical Engineering, 6, 4714 – 4726.

[17]. Luo, X. L., Yan, X., Yan-Ling, W., Lung, C., Bo, X. and Jing, D. (2015). Source identification and apportionment of heavy metals in urban soil profiles. Chemosphere Volume 127, Pages 152-157.

[18]. Mojeed A. A., Abiodun O. A., Martins A. A. and Omobola O. O. (2020). Heavy Metals inWastewater and Sewage Sludge from Selected Municipal Treatment Plants in Eastern Cape Province, South Africa. Water, 12, 2746, doi:10.3390/w12102746. www.mdpi.com/journal/water.

[19]. Muthusaravanan, S., Sivarajasekar, N., Vivek, J. S., Paramasivan, T., Naushad, M., Prakashmaran, J., Gayathri, V. and Al-Duaij, O. K. (2018). Phytoremediation of heavy metals: Mechanisms, methods and enhancements. Environ. Chem. Lett. 16, 1339–1359.

[20]. Payá Pérez, A. and Rodríguez Eugenio, N. (2018). Status of Local Soil Contamination in Europe: Revision of the Indicator “Progress in the Management Contaminated Sites in Europe"; EUR 29124 EN.; Publications Office of the European Union: Luxembourg; ISBN 9789279800726.

[21]. Rattan, R. K., Datta, S. P., Chonkar, P. K., Suribabu, K. and Singh, A. K. (2005). Long-term impact of irrigation with sewage effluentson heavy metal content in soils, crops and groundwater—a case study. Agriculture, Ecosystems and Environment, 109:310–322.

[22]. Ravisankar, T. and Prasada, R. P. (2016). Trace Analysis of Heavy Metals in Ground Waters of Vijayawada Industrial Area.

[23]. Saxena, G. and Bharagava, R. N. (2017). Organic and inorganic pollutants in industrial wastes, their ecotoxicological effects, health hazards and bioremediation approaches. In Environmental Pollutants and Their Bioremediation Approaches, 1st ed.; Bharagava, R.N., Ed.; CRC Press: Boca Raton, FL, USA, pp. 23–56.

[24]. Singh, A. K. and Kumar, S. R. (2015). Quality assessment of groundwater for drinking and irrigation use in the semi-urban area of Tripura, India. Ecology, Environment and Conservation, 21, 97–198.

[25]. Singh, C. K., Kumar, A. and Bindal, S. (2018). Arsenic contamination in Rapti River Basin, Terai region of India. Journal of Geochemical Exploration, 192, 120–131.

[26]. Sochacki, A., Surmacz-Górska, J., Guy, B. and Faure, O. (2014). Microcosm fill-and-drain constructed wetlands for the polishing of synthetic electroplating wastewater. Chem. Eng. J,2014; 251: 10–16.

[27]. Wang, Y., Zhang, L., Wang, J. and Lu, J. (2020). Identifying quantitative sources and spatial distributions of potentially toxic elements in soil by using three receptor models and sequential indicator simulation. Chemosphere, 242, 125266.

[28]. Yi, K., Fan, W., Chen, J., Jiang, S., Huang, S., Peng, L., Zeng, Q. and Luo, S. (2018). Annual input and output fluxes of heavy metals to paddy fields in four types of contaminated areas in Hunan Province, China. Sci. Total Environ. 634, 67–76.

[29]. Zhu, Y. L., Zayed, A. M., Quian, J. H., DeSouza, M. and Terry, N. (1999). Phytoaccumulation of trace elements by wetland plants: II. Water hyacinth. Journal of Environmental Quality, 28 (1), 339-344.