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Bioaccumulation of heavy metals using aquatic plants in wastewater

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ABSTRACT

Heavy metals are very harmful to the environment if present in excessive concentrations and will have an effect on humans if they interact directly. Knowing the findings of heavy metal bioaccumulation in aquatic plants when reducing pollutants in liquid waste is the main goal of this study. Various types of data were developed and analyzed to answer the specific goals set through the EBSCO, ProQuest, and Science Direct Search Engine, by looking at several parameters. Bioaccumulation data for aquatic plants in liquid waste were obtained from five articles that met the criteria. The findings showed that there are six types of plants that can be used as heavy metal bioaccumulators in wastewater, including Limnobium laevigatum, Salvinia auriculata, *Lemna minor, Colocasia esculenta, T. latifolia, and T. palustris*. Data was also obtained that most research was carried out using liquid waste originating from within the city with a research time ranging from 1-45 days. The heavy metals that were most commonly accumulated in these plants were Zn, Pb, Cr, Ni, Cu, Fe, Mn, and Cd. It can be concluded that bioaccumulation using aquatic plants is very reliable for various types of heavy metals that can be removed.

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1. INTRODUCTION

Heavy metals are pure metal components found in the Earth's crust and are useful to the Earth itself. However, in many ecosystems, certain heavy metals are toxic to humans and the environment. In recent years, environmental pollution caused by heavy metals has become a problem for all countries, not only for individuals but also for communities in modern society, with very harmful cumulative effects [1], [2]. All human activities produce waste, both internal and liquid waste, especially in the use of water, because almost 80% of water ends up as waste water. There is a lot of waste water management proposed by previous researchers, and if this management is not done properly, it will become a serious problem for the environment in general, and the impact will also be felt by humans. Effective wastewater management is one way to manage liquid waste, so it does not pollute the environment. Waste water treatment has always been an important matter in community practice, this is for reasons of environmental health and the community itself. The importance of knowing the heavy metals in wastewater is not only beneficial for the environment but is also useful for human survival, where we will be able to determine its consistency, potential changes, make action adjustments if needed, and assess the functionality of the drainage system due to heavy metal contamination.

Heavy metals refer to elements that are metalloids and metals [3]. Various sources of heavy metals in the earth including weathering of rocks, volcanic eruptions, and atmospheric deposits [4]. Heavy metal accumulation can be defined as the melting of heavy metal elements in ecosystems, especially in aquatic ecosystems [5]. The exposure of aquatic plants to toxic levels of heavy metals initiates a wide spectrum of physiological and metabolic changes [6]–[8] which includes decreased plant growth, changes in cell metabolism, damage to cell membranes, protein changes, and inhibition of photosynthesis, leading to senescence and, ultimately, plant death [9], [10]. Many aquatic plants have the ability to tolerate heavy metals in the surrounding water and can even accumulate these metals into their roots and other body parts [11]–[13]. There are also many plants that grow in conditions where the surrounding waters are polluted with heavy metals die due to oxidative stress.

Mitigation technology for heavy metals exposure to the organisms in aquatic environment currently tends to be expensive [14]. In various countries, aquatic plants are often used as bioindicators of water quality [15], [16]. Study from Ali *et al.* [17] demonstrated that aquatic plants accumulate certain metals to varying degrees from one species to another [18]. Many aquatic plants can be used as indicators of water quality [19]. Several studies of aquatic plants have been conducted under laboratory conditions. In a laboratory study of heavy metal phytoremediation by three wetland macrophytes [20], highlighted that all tested species accumulated higher concentrations of the four heavy metals such as Pb, As, Mg, and Hg examined compared to their media. Abdallah [21] investigated two aquatic macrophytes, *Ceratophyllum demersum* and *Lemna gibba*, for the removal of two toxic metals (Pb and Cr) from aqueous solutions.

Many studies have studied heavy metals, both their effects on humans, animals and plants and some of these studies also explain how plants are capable of being bioaccumulators, however, there is no research that thoroughly studies which plants can be used as bioaccumulators of heavy metals in wastewater. Therefore, this meta-analysis will try to find out what types of plants can be used as bioaccumulators in wastewater by looking at some of the supporting parameters such as what heavy metals can accumulate in aquatic plants, how big are the accumulations, how long does it take to accumulate and where are they accumulated.

2. RESEARCH METHOD

The Literature Study used in this writing was 51 articles and a selection was made of the title and parameters to be studied, it was concluded that 5 articles met the requirements to be discussed in depth. The selection process was carried out using the PRISMA technique is a review technique by paying attention to the checklist to be examined such as title, abstract, introduction, method, results, discussion and conclusion. The stages of this research include i) defining the feasibility of features, ii) defining information sources, iii) selecting literature, iv) collecting data, and v) selecting data items. Obtained data can be seen in Figure 1 (see in Appendix). The several databases have been developed to achieve a specific purpose, including peer-reviewed reports, original articles, and case studies, and are sourced from journals that have been published in their entirety in academic databases or search engines, such as EBSCO, ProQuest, and Science Direct. In the EBSCO database, four articles matched the search category out of the 15 articles that appeared related to the topic that is wanted to search for with the selected keywords, whereas in the ProQuest database, no related articles were found. The Science Direct database found one out of 36 articles, taking into account the keywords “wastewater, bioaccumulation, and aquatic plants”. The data obtained were then combined, reviewed, and analyzed by examining the causation between the influential variables by considering the frequency distribution of the data obtained. Data were also collected and studied in depth to determine the effectiveness of aquatic plants as bio-accumulators and in accumulating heavy metal waste in wastewater by examining several supporting parameters such as plant height and root length. Preliminary data obtained from the search showed that as many as 5 articles were included in the search category, and the data were then sorted based on predetermined parameters such as the ability to accumulate heavy metals, the types of heavy metals that accumulated, the types of aquatic plants that could be used as bio accumulators, the types of waste water used. Contain heavy metals and the long time of accumulation.

3. RESULTS AND DISCUSSION

According to several studies Table 1 (see in Appendix) [22]–[26], six types of plants were found that could be used as bioaccumulators of heavy metals in liquid waste, including *Limnobium laevigatum, Salvinia auriculata, Lemna minor, Colocasia esculenta, T. latifolia, and T. Palustris*. Data was also obtained that most research was carried out using liquid waste originating from within the city with a research time ranging from 1-45 days. The heavy metals that were most commonly accumulated in these plants were Zn, Pb, Cr, Ni, Cu, Fe, Mn, and Cd. More details can be found in table.

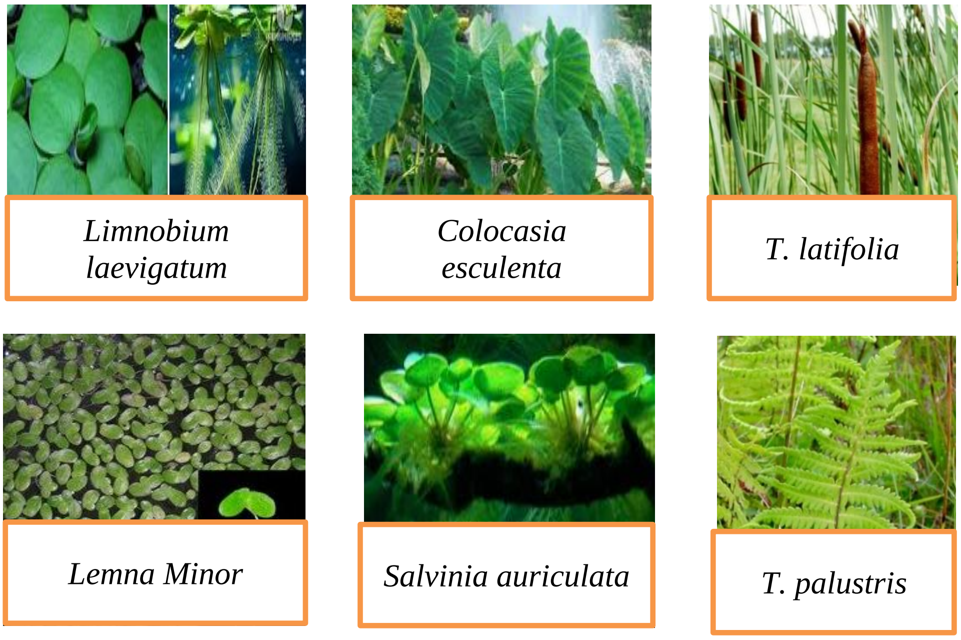

Figure 2. Types of plants capable of accumulating heavy metals in wastewater
Soucre: [22], [23], [24], [25], and [26]

Plants that can be used as bioaccumulators in liquid waste include *Limnobium laevigatum, Colocasia esculenta, T. latifolia, Lemna Minor, Salvinia auriculata, T. Palustris* can be seen in Figure 2 above. The findings showed that Limnobium laevigatum plants were able to accumulate heavy metals in their roots for the longest time, up to 28 days, with the heavy metals that accumulated being Pb and Cr 1,000 µg, Ni 500 µg, and Zn 100 µg [22]. The longer the exposure time to liquid waste containing heavy metals, the greater the content or accumulation of heavy metals in plants. The heavy metal Cd can also be accumulated by aquatic *Lemna minor* plants with the ability to accumulate 0.332 µg in their roots in just four days. The same thing applies to Pb which can accumulate up to 0.132 µg at the same time [24].

Generally, heavy metals are able to accumulate well by aquatic plants such as *Limnobium laevigatum* [22], *Salvinia auriculata* [23], *Lemna minor* [24], *Colocasia esculenta* [25], *T. latifolia* and *T. palustris* [26]. This is supported by the fact that the use of plants to remove pollutants has been used successfully, by a technique known as phytoremediation [27]–[29]. Some aquatic plants have definitely been used as heavy metal decomposition in the environment as is done in Australia by using Eleocharis dulcis (Chinese water chestnut) to treat uranium mine runoff in Australia [30], and to remove arsenic, previous studies found Neptunia oleracea (water mimosa) to be reliable [31]. Despite the advantages of using aquatic plants to remove heavy metals, they are likely to be harmful to humans by entering the food chain or by direct consumption. Hidden risks that can be caused by heavy metals which are toxic to plants at very low or very high concentrations will cause systemic symptoms [32], [33].

There are various aquatic plants that should be further studied to ascertain their vital role of aquatic plants in accumulating heavy metals. Heavy metal contamination in water bodies that receives less attention is generally located in rural areas and its bioaccumulation into plants which are a source of food for humans is not yet known, one example of an aquatic plant that is often used as food is Nelumbo nucifera (wild lotus). This plant is popular in Chinese food and medicine with all its roots, leaves, fruits, and flowers that can be eaten as medicine [34]. Some aquatic plants tend to accumulate metals biologically depending on their initial concentrations in water. In such cases, the type of metal accumulated may vary depending on the plant species [35]. In some cases, the accumulation of heavy metals in plants can also affect aquaponic systems, a biointegration system in which fish and plants live in a symbiotic environment through a combination of aquaculture and hydroponics [36], [37].

Some heavy metals, such as Fe, Zn, Cu, and Mn, are toxic to humans at higher concentrations, and metals such as mercury, Hg, Cd, As, and Pb are toxic even at the lowest levels [38]. Adverse effects, either directly or indirectly, on human health are numerous. The accumulation of heavy metals in plants is influenced by several factors, such as the plant growth stage, variety of plant species, absorption of elements, degree of tolerance to different contaminants, growth rate, and biomass [35]. Although the accumulation ability of aquatic plants is lower than that of terrestrial plants, they can still accumulate large amounts of metals when they have dense root systems, which increases the surface area for metal uptake [39]. Plant species used as bioaccumulators must have native characteristics, such as fast growth rates, high biomass yields, extensive root systems, tolerance to high salinity and pH, various habitat adaptations, and the ability to accumulate absorbed pollutants [40].

The entry of heavy metals into the environment can come from the natural or artificial environment such as water pollution and soil solution [41]. Aquatic plants are also known as accumulators of heavy metals in the aquatic environment based on several previous studies at several locations [39]. Factors that influence the entry of heavy metals into aquatic plants include the type of plant species, the stage of plant growth, and the types of heavy metals present in the waters themselves [42]. Based on research results, several plants are known to be able to absorb heavy metals, such as *Typhalatifolia plants* [43], water hyacinth (*Eichhornia crassipes*) [44], and *Ceratophyllum demersum* [45] and *Potamogeton malaianus* [46], *Urtica dioica L.* [47]–[49] has the ability to accumulate heavy metals.

The bioaccumulation coefficient is the ratio between the concentration of metals in plant tissues and the surrounding media, in both water and soil. This coefficient varies among plants [50]. Metals that have been absorbed by plant tissues through roots, stems, or leaves can return to the surrounding media. This can occur because of external and internal factors. The absorption of heavy metals by plants is influenced more by biotic and abiotic factors, including temperature, pH, and the ionic population of the water system [51]. The increase in heavy metals in plant parts is due to the binding of heavy metals to plant cells, which creates a gradient across the membrane [52]. With time, as the concentration of metals in the tissue increased, leading to saturation, a subsequent decrease in uptake was effectively observed. This can also occur because of toxic effects caused by metals, such as oxidative stress, which can be caused by Cu, Cd, and Zn [53]. After entering plant roots, metal ions may be stored in roots or transported to shoots, most likely via the xylem, with some suggestion that the phloem may also contribute to this [53].

4. CONCLUSION

Interesting findings show that There are six types of plants that can be used as heavy metal bioaccumulators in wastewater: *Limnobium laevigatum, Salvinia auriculata, Lemna minor, Colocasia esculenta, T. latifolia, and T. palustris.* It was also found that most research is currently being carried out using man-made liquid waste and natural wastewater from waste water treatment plants and also urban sewerage. accumulation in these plants was Zn, Pb, Cr, Ni, Cu, Fe, Mn, and Cd. Analysis of between variables was not carried out because the data obtained varied and it was not possible to get rid of one variable with a variable that was not owned in other studies. For further research, it is expected to take several determining parameters so that homogeneous data is obtained so that it can be tested for differences in each variable.

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APPENDIX

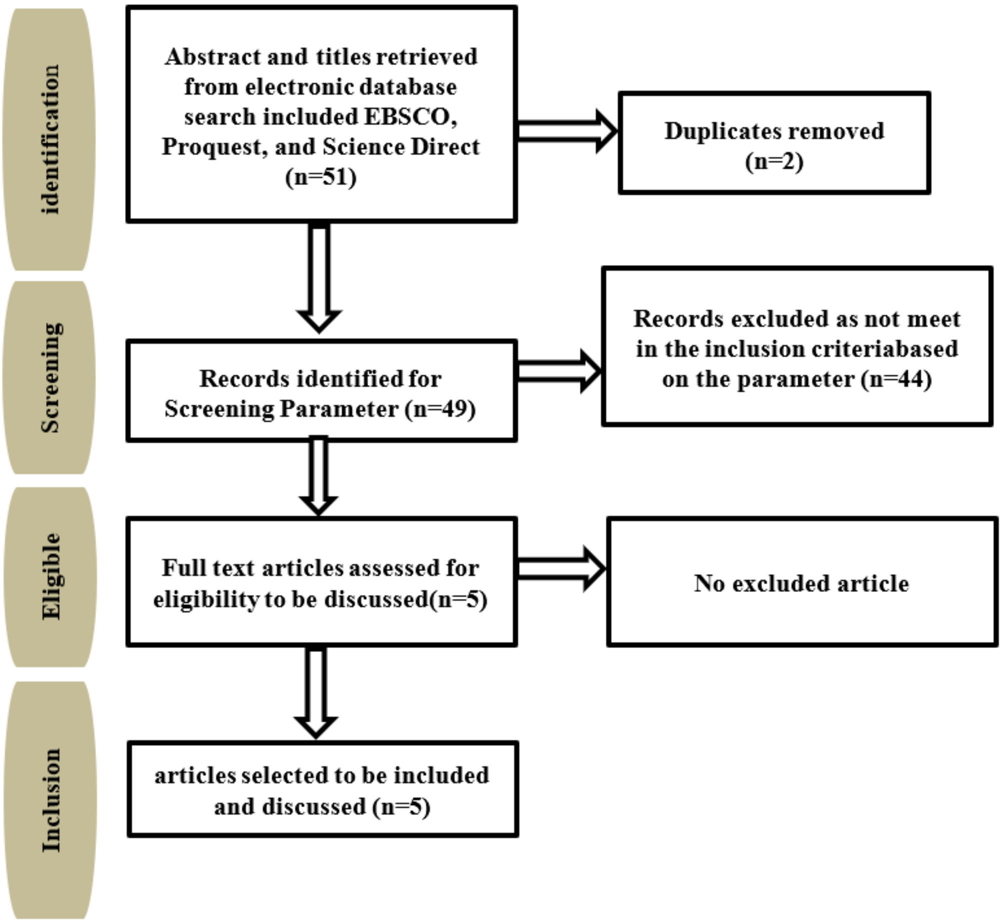

Figure 1. Research flow chart using PRISMA

Table 1. Summary of systematically evaluated studies related to bioaccumulation of heavy metals by using aquatic plants in liquid waste *(Continue)*

Plant type	Waste source	Accumulation of heavy metals in roots	Accumulation of heavy metals in leaves	Duration	References
Limnobium laevigatum	treatment of wastewater	(T1) were Pb 1 µg Cr 4 µg Ni 25 µg and Zn 30 µg (T2) were Pb 70 µg Cr 70 µg Ni 70 µg and Zn 70 µg (T3) were Pb 1,000 µg Cr 1,000 µg Ni 500 µg and Zn 100 µg	NM	T1=14 days T2=21 days T3=28 days	[22]
Salvinia auriculata	Artificial wetlands wastewater	(T1) were Cr 6.8 µg Mn 43µg Zn 74 µg Fe 1,541 µg Cu 49 µg (T2) were Cr 5.4 µg Mn 86 µg Zn 114 µg Fe 1,591 µg Cu 64 µg (T3) were Cr 16.7 µg Mn 22 µg Zn 49 µg Fe 2,412 µg Cu 52 µg (T4) were Cr 4,2 µg Mn 14 µg Zn 33 µg Fe 2,159 µg Cu 48 µg (T5) were Cr 4.4 µg Mn 127 µg Zn 74 µg Fe 1746 µg Cu 44 µg (T6) were Cr 6.0 µg Mn 156 µg Zn 70 µg Fe 1834 µg Cu 43 µg (T7) were Cr 4.7 µg Mn 13 µg Zn 25 µg Fe 1553 µg Cu 31 µg	(T1) were Cr 2.1 µg Mn 8.6 µg Zn 17.1 µg Fe 176 µg Cu 3.7 µg (T2) were Cr 1.4 µg Mn 9.2 µg Zn 11.7 µg Fe 64 µg Cu 2.0 µg (T3) were Cr 1.7 µg Mn 4.5 µg Zn 17.8 µg Fe 122 µg Cu 5.5 µg (T4) were Cr 3.2 µg Mn 5.8 µg Zn 16.2 µg Fe 134 µg Cu 6.3 µg (T5) were Cr 4.0 µg Mn 9.0 µg Zn 16.1 µg Fe 146 µg Cu 6.2 µg (T6) were Cr 3.0 µg Mn 19.4 µg Zn 17.6 µg Fe 162 µg Cu 5.7 µg (T7) were Cr 3.1 µg Mn 5.6 µg Zn 17.6 µg Fe 181 µg Cu 6.5 µg	T1=1 day T2=2 days T3=5 days T4=8 days T5=15 days T6=22 days T7=29 days	[23]
Lemna minor	Wastewater	Cd 0.332 µg Ni 0.359 µg Pb 0.132 µg	NM	4 days	[24]

Table 1. Summary of systematically evaluated studies related to bioaccumulation of heavy metals by using aquatic plants in liquid waste *(Continue)*

Plant type	Waste source	Accumulation of heavy metals in roots	Accumulation of heavy metals in leaves	Duration	References
Colocasia esculenta	Spiked synthetic wastewater	NM	Pb 0.079 µg, Cd 0.050 µg	20 days	[25]
T. latifolia	Wastewater	T1 Zn 105.80 mg/L Cu 25.92 mg/L T2 Zn 271.64 mg/L Cu 47.54 mg/L	NM	T1=15 days T2=45 days	[26]
T. palustris	Wastewater	T1 Zn 414.67 mg/L Cu 136.12 mg/L T2 Zn 409.26 mg/L Cu 105.58 mg/L	NM		[26]