Eco-friendly technology to remove heavy metals from waste water using phytoremediation (water hyacinth): A review

Ekhlas A. Abdulkareem [*1], Nisreen Jassam Alaallah [2],and

Maryam Abdulghafor Ahmed[3]

1 Department of Chemistry, Collage of science, University of Diyala, Iraq.

2 Anbar Education Directorate, Ministry of Education, Iraq.

3 Renewable Energy Sciences Department, College of Energy & Environmental Science ،Al-Karkh University of Science.

E-mail : khloosa123aa@gmail.com

Abstract

Environmental contamination, especially water contamination, is a concern in both developed and developing countries. Contamination of water sources with heavy metals is a critical issue that negatively affects living organisms. Because it is not biodegradable, it is stable in the environment, it has a large dispersion with water, and it can accumulate biologically, so there was a need to remove these minerals from wastewater to the permissible limits, and appropriate solutions had to be found. Phytoremediation is a better alternative than traditional physiochemical and biological methods for treating polluted water containing high levels of heavy metals because of its cost-effectiveness and environmental friendliness. Water hyacinth is a floating plant with long roots and green leaves that floats above the surface of the water and is notorious for threatening the survival of aquatic organisms. But it is considered a promising technique for removing pollutants from water, and the plant has been used for various other applications such as the production and generation of ethanol, paper production, and green manure. It was a good support for the technocrats in controlling the growth of this plant, which is a very promising method that removes pollutants with high efficiency and low cost, avoiding many of the drawbacks of traditional methods. This paper presents a comprehensive review of the water hyacinth plant for the treatment of heavy metal contamination in wastewater. This paper also discusses other potential uses of the water hyacinth plant.

Keywords: Water, heavy metals, Phytoremediation, water hyacinth, advantage, disadvantage.

1- Introduction

Water, air and soil are the basic components of the environmental, and water is the main component of any kind of life on the earth and has many uses, including domestic uses (drinking, bathing, and cleaning) in addition to industrial and agricultural uses[1]. With the increasing world population, industrialization and urbanization processes, there will be a great challenge in providing water security for communities in the future[2]. As these developments contribute to an increase in the release of liquid waste to nearby water bodies, and thus a large amount of waste water is generated that contains toxic pollutants including organic, inorganic, and heavy metals[1, 3].In particular, heavy metal pollution. Although some of these metals, like iron (Fe), copper (Cu), zinc (Zn), and manganese (Mg), are needed by living organisms in small amounts because they are necessary for growth and physiological and vital functions, they can be toxic if accumulated at levels above permissible limits. They are called essential metals[4, 5], and others are heavy metals (HMs) like cadmium (Cd), arsenic (As), lead (Pb), and mercury (Hg), highly toxic, living organisms do not require it for any physiological functions, and its presence has a negative impact on human health, living organisms, and the environment[6]. Being non-biodegradable, stable, and having a high water dispersion capacity, they are called non-essential metals[7]. Therefore, great attention has been paid to the development of treatment methodologies to remove HMs from the environment include oxidation and reduction[8]. Electro-chemical methods [9]. Chemical precipitation[10]. Ion exchange [11]. Coagulation [12]. Membrane filtration[13]. And biological methods[14]. But the majority of these procedures have known drawbacks, such as insufficient treatment, large consumption of energy and chemicals, high operating and exorbitant maintenance expenses, in addition to the release of toxic waste into the environment, which requires additional techniques to get rid of these wastes[15]. Therefore, there was a need for a reliable technique for treating wastewater before it is released into bodies of water. So the research is directed towards a low-cost, environmentally friendly technology known as phytoremediation.[12, 13].

By using different plant species [14-18].Such as Brassicai sp. Thlasepicaerulscens, Aeolanithusbiformfolius, and Hamaniastrumkatengense and large aquatic plants such as duckweed (Lemnai sp. and Spiriodella sp.), water hyacinth (Eichhornia sp.), water lettuice (Pistia sp.), and small water fern (Pistia).[16]. Which showed a good capacity to take up a variety of harmful contaminants from aquatic environments. Therefore, it is the best solution in terms of being environmentally friendly, low cost, and processing simplicity; all that is needed is for the plants to develop naturally[17]. This review paper highlights the function and properties of water hyacinth, with final attention given to its use for the removal of heavy metals from wastewater. As a result, it is the ideal option in terms of sustainability, affordability, and processing simplicity; all that is needed is for the plants to develop naturally.

2- Phytoremediation as a green technology

Phytoremediation is one of the waste water treatment techniques that uses plant based systems for removing pollutants[18]. This technique depends on the extent of the parts of the plant's ability to absorb pollutants. There are several types of phytoremediation mechanisms used in the removal of contaminants. translocation, bioaccumulation phytoextraction, phytodegradation, or phytotransformation techniques, plant stabilization, bio-accumulation, rhizodegradation, rhizofiltration, and degradation within the entire plant body[15, 19]. The biological removal of pollutants from solution via interactions between biomaterials and functional groups found in carbohydrates, lipids and proteins found in cell walls [20]. Pollutant eradication is influenced by the length of exposure, the amount of pollutants present, ambient conditions (such as pH and temperature), and plant features (species, root system, etc.).It is worth noting that various aquatic plant species have been successfully used in the phytoremediation of wastewater [6]. Aquatic macrophytes outperformed all other plant species groups in terms of strong potential for phytoremediation. [21].In this regard, numerous studies have been carried out using WH and other aquatic plants; a study reported by Kumar et al.[22] on the accumulation of heavy metals (Pb, Cd, Zn, Ni, Co,and Cu) indifferent aquatic plants like *typhaangustata, Ipomoea aquatica, EchinochloaColonum, Vallisneriaspiralis, Nelumbonucifera, Hydrillaverticillata and Eichhorniacrassipes*,. The results of this study indicated that the most accumulation of zinc (Zn) was found in *Eichhorniacrassipes* compared with other aquatic plants. In addition, leaves and stems of *Eichhorniacrassipes* showed maximum accumulation of minerals such as zinc and chromium compared to leaves and stems of other aquatic plants. The author of this study concluded that the aquatic plants *E. crassipes,T. angrustata, and I. aquaitca* had a high ability to absorb pollutants from toxic metals with a very high efficiency. other study conducted by Mishra et al. studied the phytoremediation of HMs like iron, zinc, copper, chromium, and cadmium by using *P. stratiotes*, *E. crassipes*andS. *polyrrhiza*aquatic plants . The result of study showed that of*E. crassipes*had ahigher ability to removal heavy metals than *P. stratiotes* and *S. polyrrhiza*[23]. Also, study conducted by Hazra et al in India, to accumulation HMs using *Typhalatifolia, Eichhronia. crassipes, and Monochoria hastate*, the result show that *E. crassipes* more efficient towards heavy metals than other plants[24]. Sung et al. studied the removal nutrient from waterenviroments and wet soil by using Ceratophyllumdemersum as submerged plant and E. crassipes as floating plant, the result of this study showed that the presence of phosphorus and nitrogen decreased by a high percentage when the presence of E. crassipesthan Ceratophyllumdemersum[25]. According to a literature review, it was found that water hyacinth is the most efficient from other aquatic plants for removing contaminants from wastewater on a large scale, This is because of its unique life cycle and survival strategy, which give it an advantage over other species, and its ability to adapt to many ecological situations makes eradicating this plant nearly impossible.[26].

3- *Eichhrionia Crassipes*

It is also called water hyacinth (WH), it is a herbaceous perennial vascular plant belonging to the family of the pickerel weed Pontederiaceae, Genus: Eichhorniaof pickler algae[2]. Native to the tropics of South America and Brazil, and it is considered one of the most widespread plants in the world. There are seven different varieties of water hyacinth, including the anchored water hyacinth *E. azurea*, the common water hyacinth *E. crassipes*, the variable leaf water hyacinth *E. diversifolia*, and the Brazilian water hyacinth *E. paniculata*. This plant floats on the surface of the water with round leaves and roots of a It has long, dark blue roots hanging in the water. This root structure can provide suitable media for aerobic microorganisms operating in the septic system[27]. It also grows very quickly in water bodies polluted with heavy metals and other inorganic pollutants and organic pollutants, especially those in the countries of Africa, Nigeria, and the Pacific Ocean, in addition to countries Southeast Asia (including China, Pakistan, India, and Bangladesh) [28]. Biomass of WH is composed of an amount (35%) cellulose and (30%) hemicellulose, which makes the water hyacinth plant suitable in the phytoremediation of wastewater[29]. According to some authors, two weeks is enough to effectively treat waste water with WH [30]. In a review reportedby Rezania et al[31]. On the capacity of WH plant to treat HMs polluted wastewater. The results of this review indicated the ability of WH plant to absorb huge amounts of polluted HMs and nutrients, making it effective in wastewater treatment, the main reason for this is its optimal growth rate[32, 33]. Study was reported by Zheng et al[34]. To determine the effectiveness of WH plant in removing Zn and Cd, the results of this study indicated the high effectiveness of WH in removing these toxic metals from aqueous solutions during 2 weeks, depending on the concentration of the metal and the duration of exposure. Hassan et al. [35]. Found that this plant has the ability to survive in the presence of high concentrations of toxic heavy metals as well as it can withstand harsh conditions. As mentioned by Kay et al.[36], heavy metals accumulations within WH plant tissues were in the order of roots > stems > leaves. As showed by Miretzky et al.[37]. Eichhornia crassipes dehydrated powders can efficiently adsorb heavy metals from aqueous solutions in economic way. Mokhtar et al.[38],noted that at low metal concentrations in water, WH's capacity for heavy metal removal increased. Also, WH has been shown to be successful in removing another numerous contaminants found in wastewater, including turbidity, heavy metals, and nutrients, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), and total solids (TS)[13, 30-34].A study related to Fazal et al. [35],found WH was effective at lowering industrial wastewater's nitrates (67.5%), phosphates (90.2%), Cd (97.5%), Ni (95.1%), Hg (99.9%), and Pb (83.4%). Turbidity was 92.5%, COD was 83.7%, TSS was 91.8%, TDS was 62.3%, and TS was 80%. Another study by Valipour et al.[36]. employing WH on the treatment of domestic wastewater revealed considerable reductions in COD (79%), BOD (86%), TSS (73%), TN (77%), AN (72%), total phosphate (45%), PO4 (39%), total coliforms (94%), and total viable counts (96%).So far, there are not many comprehensive reviews on the removal of heavy metals using hyacinth water. Therefore, the purpose of this paper is to review the benefits and drawbacks of WH and to provide insight into the development of plant processing technology that uses WH for the treatment of various wastewaters with a high HM content.

Figure1: Flower of WH.[27].

3.1 Characteristics of water hyacinth

Recently, a research study was published by Gaurav et al., describing WH as a biomass[39]. Water hyacinth's ability to adsorb water pollutants is due to its unique properties not found in other aquatic plants. WH is composed of structural carbohydrates made up of crystalline cellulose, lignin, and hemicellulose polymers [40].As a result, the surface of WH has important functional groups, including carboxyl, carbonyl, and hydroxyl which serve as a catalyst for the adsorption of water pollutants onto plant-based adsorbents[41]. The functional groups present in the root of WH is phosphate (PO_4^{-3}), carbonyl (C=O), hydroxyl (O-H), and C-H[42]. While, the composition of WH fibers contains significant quantity of cellulose in the form of hemicellulose (33%), cellulose (25%) and lignin (10%)[43]. These WH features are prompting scientists are looking into whether these invasive species are suitable for water treatment. Studies with a strong scientific foundation have suggested using cellulose from WH to remove water pollutants[44]. This is mostly due to the fact that the cellulose backbone of this aquatic plant has contain several hydroxyl groups[45]. These hydroxyl groups, which are chemically modified to help adsorption process. The WH plant is characterized by its porous nature, and scientists exploited this feature, it as they carbonized the plant into mesoporous carbon, Thus obtaining more efficient and active species[40]. WH based adsorbents have smaller surface areas than those synthetic-based adsorbents for adsorption applications. Studies have shown that the root surface area of Water hyacinth is 4.5–5.8 m^2g^{-1} and the petiole surface area is 2.5 - 3.3 m^2g^{-1}[46]. In some cases, WH is chemically modified to increase its surface area and improve its adsorption capacity. Since the adsorption has been shown to be directly related to the particular surface area, researchers view this as a crucial need[47].

3.2 Advantage of water hyacinth

Although there is a list of many aquatic plants used in phytoremediation, water hyacinth (WH) is considered to be one of the most efficient plant species in removing agricultural and industrial pollutants and heavy metals from wastewater on a large scale[48]. The water hyacinth was chosen for its high ability to withstand environmental conditions such as high humidity, temperatures. The WH plant can withstand both acidic (the optimum pH for growth is 6-8) and alkaline conditions, and it can grow in temperatures ranging from 10 to 40 °C (optimum growth at 25-27.5 °C). However, it is also believed that the plant is cold-sensitive and salinity-sensitive[49, 50]. In addition to the possibility of growing and multiplying significantly in the environment polluted with heavy metals, it was found that the accumulation of heavy metals and nutrients is a large in the root than content in the stem and leaves. According to a recent analysis, contaminant uptake generally occurs via roots, which then transfer to aerial tissues such as stems and leaves[51]. Therefore, it contributes to a significant improvement in water quality. It is also becoming more common knowledge to employ water hyacinth in wastewater treatment systems, and successful project reports on phytoremediation techniques have led to the development of treatment systems.[52, 53]. Table 1 lists several previous studies that used WH to remove a variety of heavy metals.

Table 1:Studies used WH to remove heavy metals (HMs).

Heavy metals	Removal efficiency	Material used	Ref.
Cr, Pb, Ni, and Cu	Rate of removal 72.4, 83.3, 82.35, and 63.63%, respectively	WH	[54]
Mn, Pb , and Zn	The result finding the capacity of the roots of WH plants to adsorb lead, manganese, and zinc metals at concentrations of 3.1297, 3.668, and 1.1057 ppm, respectively.	Root of WH	[55]
Cr	Removal efficiency ranged from 25–72% to 35–96%	WH	[56]
Cr	Rate of removal was 80% from standard solution and 99% from water at 0.5 ppm.	WH	[57]
Cr	Maximum rate of removal for stems, roots, and leaves was 31.5%, 40% and 34%, respectively	Different parts (stems, roots, and leaves) of WH	[58]
Cr	Chromium adsorption on biochar was 99%	Root of WH	[59]
Cd and Cu	Rate of removal was 15.9% for Cu and 91.4% for Cd	WH	[60]
Cd	Maximum removal efficiency of 92.45% for Cd(II). The bioaccumulation capacity was 13.81 mg g, and the immobilization effectiveness was 89.3%.	WH with algal cell	[61]
Cu, Cd, Pb, and Zn	Rate of removal for: Cu = 99%, Cd = 98% Pb = 98%, and Zn = 84%	Root of WH	[62]
Cu, Cd, Pb,As, Al,Zn, Cr and Fe	Rate of removal: Cu = 78.6%, Cd = 82.8% , Pb = 73%,As = 74% , Al = 73%, Zn = 65.2% , Cr = 62.8%, and Fe = 61%	WH and P.stratiotes	[63]
Ni	The highest Ni concentrations were 0.29±0.02 in aerial parts and 3.34±0.26 in roots.	Root of WH	[64]
Cd, Pb, Ag, Ba, and Mo	TF (Translocation factors)was equal to: Cd = 0.65 ± 0.09, Pb = 0.06 ± 0.01,Ag = 0.18 ± 0.04, Ba = 0.12 ± 0.03, and Mo = 0.85 ± 0.14.	WH	[65]
Zn, and Cr	The rate of zinc removal was 67% on 9 day, and 100% on day 15. The rate of removal of Cr was 63% on 3 day and 80% on 9 day.	WH	[66]
Pb, Zn, Cu, and Cd	Rate of removal: Pb = 98.33% , Cd = 95.16% , Zn = 93.5% , and Cu = 58.23%	Powdered root of WH	[67]
As	Rate of removal was 37%	Biomass of WH	[68]
As, Hg , and Cd	The heavy metal amounts removed were 0.012 ppm for As, 145.25 ppm for Hg, and 177.25 ppm for Cd respectively.	WH	[69]
As, Sn, Cd, Zn, Sb, Pb, and Cu	Rate of removal 20%	WH	[70]
Pb and Cr	Rate of removal was excellent	WH	[71]
Ni	Rate of removal was 85%	Root and aerial parts of WH	[72]

Cd	Rate of removal approximately 100%	Biochar of WH	[73]
Hg	The accumulation in root, leaf, and tissue was 1.99, 1.74,and 1.39 ppm respectively.	Dry root, leaf, and tissue of WH	[74]
Zn, Cu, Pb, and Cd	Rate of removal after 8 days was 57% for Zn, 24% for Cu, 26% for Pb, and 50% for Cd.	WH	[75]

3.3 Disadvantage of water hyacinth

Water hyacinth is considered an ornamental plant because it has a beautiful and attractive appearance[76]. But, according to published data, WH is a fast spreading plant all over the world[59]. Therefore, it is one of the most disturbing aquatic plants[77]. Water hyacinth plants grow to very dense sizes that may exceed 60 kgm^{-2}[39]. The most common height of the plant is 40 centimeter, and in other cases the maximum height a 1 meter[78]. Water hyacinth has lily-like flowers. Each branch bears about 6 to 10 flowers with a diameter of 4 to 7 cm, reproduction in plants is asexual and occurs quickly[79]. The (WH) plant can reproduce sexually through seeds, these seeds can stay viable for six years[80]. The plant can double its size in five days[81]. Which leads to a complete blockage in water bodies and thus has a negative impact on the lives of other living organisms and may have adverse consequences on the environment, human health, and economic growth[82]. Thus, the vegetative propagation of the plant affects the rate of water flow, and the dark color of the plant leaves blocks sunlight from reaching marine organisms and starves the water of oxygen, which causes the reduction of fish wealth in those water bodies and makes it a suitable habitat for mosquitoes and unwanted insect pests, as a result , this plant affects the ecological balance and causes problems in the areas of irrigation, navigation and power generation[83]. As attempts to control plant growth were not entirely successful. In order to avoid the problems arising from it, the best management strategy is to find appropriate uses for these plants[31]. Optimal use of water hyacinth includes production of animal fodder/fish feed[84], as well as a phytotherapeutic agent[85]. Also, Indian scientists have suggested that the water hyacinth plant is proposed in several medicinal formulations used to treat diseases[86]. In addition, after removing pollutants from wastewater, WH can be used to recover some toxic and non-degradable substances such as HMs [87]. There are many previous studies conducted by researchers showing the optimal use of WH plant, in a study reported by Mahamadi (2011), it was found that the water hyacinth plant can be used in the production of biofuels, and thus it is considered one of the energy sources in the world[88]. Another study conducted by Resania et al. (2015) show that dried WH can be used to production briquette, which is used in a coal power plants[27].This leads us to the conclusion that even though the water hyacinth plant has some damage, there are still other uses for it.

3.4 Mechanism of bio adsorption of heavy metals (HMs) by water hyacinth

Between the different HM removal techniques, adsorption is the most promising technique due to its high efficiency, simplicity, low cost, and ease of usage. [89-91]. Adsorption is regard to as a reliable modern technology preferred by several industries. To eliminated HMs like mercury, cadmium, lead, and arsenic from polluted wastewater, the bio sorption was affected by , type of adsorbent, pH, pollutant concentration, contact time and temperature[92]. Adsorption can be done on many biological materials such as activated carbon, fly ash, zeolite, and others, but the adsorption remains with Phytoremediation especially water hyacinth[93]. This is the best option because it is eco- friendly, inexpensive and its high ability to absorb HMs from polluted water[94]. The mechanism of the adsorption of HMs from wastewater is show in Figure 3. The biomass of WH plant has (35%) cellulose and (30%) hemicellulose which makes it an option for treating contaminated water. This mechanism includes interaction between dissolved heavy elements in waste water with functional groups like OH, NH_2, and C=O groups in the cellulose enable the adsorption of different HMs by cation exchange. According to Rezania et al.[15]. WH is a floating aquatic plant that has the ability to absorb metals from polluted water, these metals are transported (through adsorption) by the roots to the various parts of the plant (specially the aerial part). The removal of pollutants by this aquatic plant depends on its ability to assimilate nutrients, which depends on the biochemical/ physical, and chemical processes that occur within the system[15]. Hemalatha et al.[95], study removal of chromium and zinc ions from wastewater as a result of electroplating processes using dried biomass of the WH plant (root, leaves, and stem) was achieved by conducting several experiments that included changing the optimal conditions, including the bio sorption factor, initial HMs concentration, dose, initial contact time, and pH. The results of the study indicated that WH root was more effective.In the study by Xiaomei et al. [96],WHwas used to measure the amount of zinc and cadmium absorbed in various water hyacinth parts (stem, leaves, roots, and flowers) after a water hyacinth plant was used to remove zinc and cadmium from wastewater. The results found zinc and cadmium accumulations in the roots at about 9650 mg/kg, and 2040 mg/kg, respectively. In a study by Yapoga et al. [97], which used the leaves and roots of the WH plant to remove zinc, copper, cadmium, and chromium from industrial wastewater after 10 days, found the rate of removal of HMs from the roots was much higher than from the leaves. From previous studies, we conclude that the effectiveness of the roots of the WH plant is greater in removing heavy metals compared to the other parts of the plant.

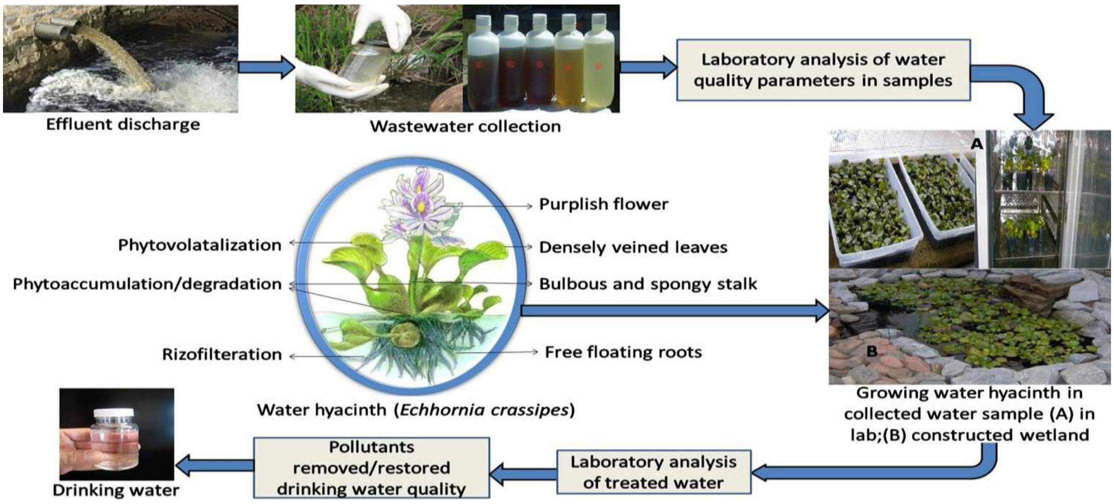

Figure2:- Step-by-step process for treating wastewater using WH [92].

In the laboratory several scientific experiments were conducted using dried and crushed roots of WH, and it was found that the removal percentage of HMs from polluted water by roots was approximately 70%[98]. Figure3, show step procedure of sorption using dried root of water hyacinth, in dried roots of WH, adsorption occurs between HMs and oxygen functional groups in the roots of WH, since oxygen possesses a pair of electrons can be bind with HM positive ions, the HMs are taken up by the roots of the plant and transported to the shoots and other plant tissues, leaving the water in a pure state[98]. In this regard, many laboratory experiments were conducted. In a study conducted by Mokhtar et al.,[99], using the shoot tissues and roots of *E. crassipes* to remove different amount of copper(1.5, 2.5, and 5.5 mg /L) from aqueous solutions, the results of this study indicated a 97.3% copper removal rate after 21 days, with a decrease in aqueous solutions. Another study by Schneider et al.[100],using dried WH roots to removal some HMs lead, copper, cadmium, and zinc ions from contaminated aqueous solution. The researchers found that the dried roots of the WH plant were a more effective biosorbent for removing lead and copper from aqueous solutions compared to the biomass of some bacteria (Mycobacterium umphlei), the yeast Candida parapsilosis, and the fungus Rhizopusoryzae strains. Huynh et al.,[101], reported a study using the roots of WH plants to remove copper, zinc, lead, cadmium, and arsenic from industrial wastewater, and after 30 days, founds the efficiency of heavy metal removal ranged from 57 to 92%. This result indicates the possibility of using the roots of the WH plant to remove heavy metals with high efficiency. Nazir, M., et al.[69], studied the removal of cadmium, arsenic, and mercury metals from waste water by dried roots of the WH plant was studied, and the results show that removing cadmium from waste water is more efficient than removing mercury and arsenic. The results of previous studies indicated that the roots of the water hyacinth plant has a high efficiency in removing many heavy metals from polluted water. Therefore, WH recombinants are an environmentally friendly and promising technology for HMs remediation from aqueous solutions.

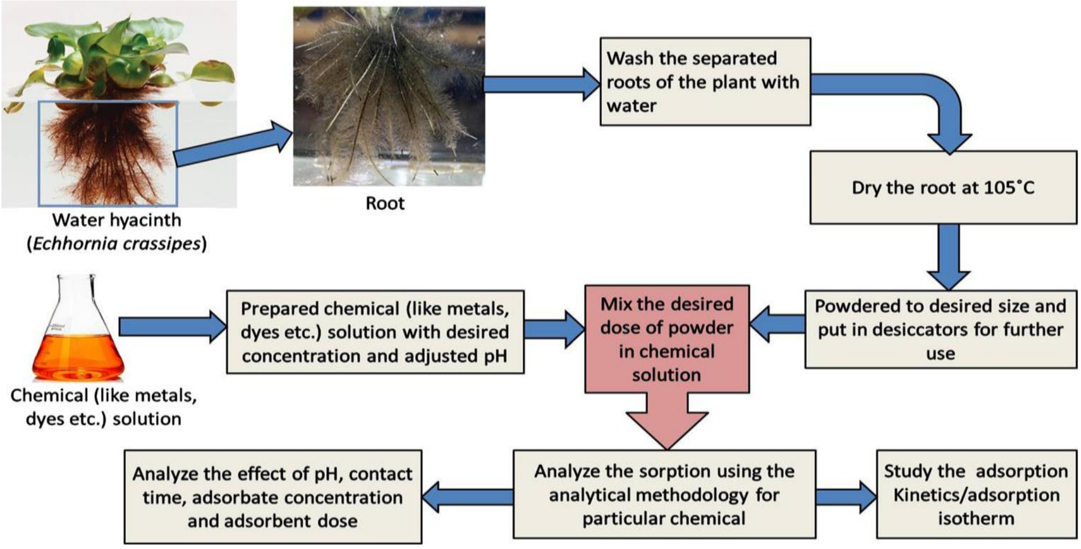

Figure3: Steps for sorption pollutants using the dry root of a WH plant[92].

3.5 Other applications of water hyacinth

Water hyacinth has many applications and is not limited to removing HMs from polluted water. Figure 4, shows different applications of WH. It has been used to combat water contamination [102]. Biomass of WH can removal organics pollution and heavy metals in water[103, 104]. Also, it is used to remove organics dyes[105]. It can be used as a modified adsorbent[106, 107]. Recently, researchers have conducted many modern scientific studies in an effort to benefit from the WH plant instead of eradicating it from water bodies[108]. The results of these studies indicated the possibility of using the WH plant for various purposes, including ethanol and biogas production [109], composting [110], paper manufacturing[111], fertilizer production, green manure, biogas production, animal feed, and the extraction of volatile fatty acids[112]. In a study conducted by Ganguly et al.[113], the mechanism used to produce ethanol from lingo cellulosic rich plant water hyacinth was explained. This application can help to control the number of plants while also providing a simple, low-cost operation that is ideal for developing countries. In other studies, reported by[114-116], they describe the possibility of using the WH plant as animal feed for non-ruminant animals. The high content of minerals and water indicates the possibility of using plants as fodder to feed some animals. The WH can be used for compost and mulch due to its high concentrations of nutrients such as nitrogen, phosphorus, magnesium, calcium, and potassium[117]. The dried plant is also a rich source of minerals, vitamins, and protein. That can be used as feed for growing, ducks and poultry[118]. According to Kivaisi et al.[119]. Egg weight increased when water hyacinth was addition in the ducks' diet, and, as a result, an increase in eggshell weight. Also, WH plant can be used to production hydrogen, Cheng et al.[120], describe the mechanism of the fermentation technique used to produce hydrogen using the WH plant, and the study discovered that 20 g/L of WH can produce up to 76.7 mL H_2/g of total volatile solids of hydrogen. Moreover, the WH can be used in the furniture industry, fiber board, rope, and making baskets [121].

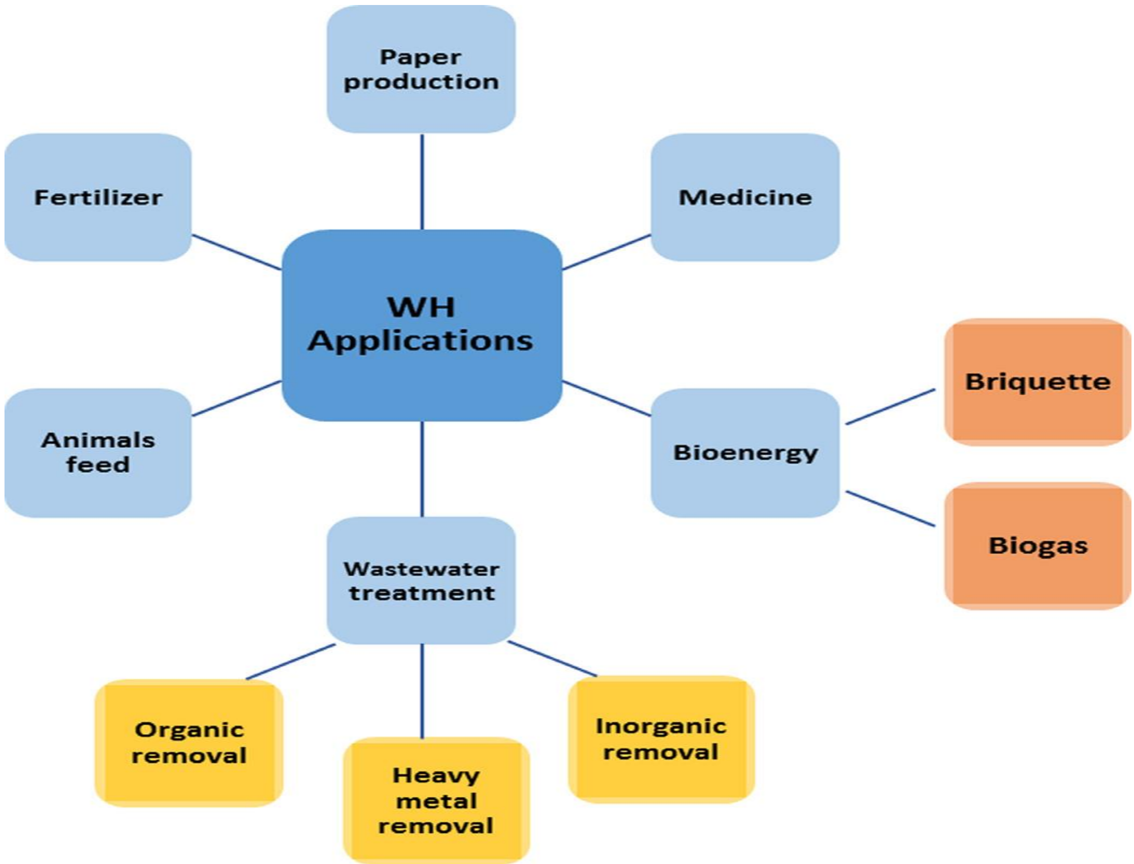

Figure 4 :. Different applications of WH [122].

4. Conclusion

This paper discussed the possibility of using WH to remove HMs from polluted wastewater. Although WH is challenging to control and it extremely difficult to remove from waterways, and can result in economic and environmental disaster. But with creative application, phtotechnology can be a useful tool for many things, including electricity generation, food security, and environmental cleanup. Using WH as part of waste water treatment systems has more significant and exceptional effects on the environment by up-taking CO_2 from the atmosphere, also its nutrient-seeking behavior has provided a potential application for its use in phytoremediation according to a comparison of the current phytotechnology frameworks and phytoremediation using water hyacinth. In terms of cost as well, it is less expensive than other modern technologies that require more money to operate in order to remove pollutants from wastewater. The thorough bio sorption effectiveness of the WH in the elimination of several HMs contaminants contained in waste water was listed in this article. This positive approach will help in the development of many new plant technologies using WH to remove HMs from wastewater in the future.

CONFLICT OF INTEREST

Regarding the current manuscript, the researchers affirm that there are no conflicts of interest.

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