Table 1

Plant species	Part used	Feasibility and Industrial uses	References
Eichhornia crassipes	Leaves	This plant might be utilized as an efficient, economical and ecological alternative to accelerate the removal and degradation of agro-industrial wastewater polluted with ethion.	**[1]**
Eichhornia crassipes	roots	Determine the concentration of toxic elements present in surface water such as cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), uranium (U), and zinc (Zn).	**[5-2]**
water hyacinth	Both live plants and dried straw	Applied to a sequential treatment of swine wastewater for nitrogen and phosphorus reduction. So it is an economically feasible means to apply water hyacinth phosphorus straw for the swine wastewater treatment.	**[7 ،6]**
water hyacinth	Roots	the possibility of using the thiol group content to assess the bioconcentration of heavy metal ions in water hyacinth and as a general parameter for monitoring the heavy metal pollution of water	**[9 ،8]**
Eichhornia crassipes	Roots and leaves	This species is suitable for phytoremediation of waters subject to	**[12-10]**

		discharge of mixed industrial effluents containing elevated Cu concentrations (>/=15 mg Cu/L), as well as nutrient-rich domestic wastewaters	
Eichhornia crassipes (Mart).	leaves and roots	potentially useful for phytoremediation programmes in environments contaminated by arsenic (As), and to produce of biogas.	**[13, 14]**
water hyacinth	Whole plant	was effective for purifying wastewater from an intensive duck farm during the water hyacinth growing season, as harvested water hyacinth had an excellent performance as duck feed and The eggshell thickness and strength were among the egg qualities significantly increased in ducks fed with water hyacinth	**[15]**
E. crassipes	Roots and leaves	Remove Copper (Cu) pollution in aquaculture ponds poses substantial ecological threats . remediate Cu by phytoextraction with an aquatic macrophyte, Eichhornia crassipes, and establish the efficacy of such endeavors by Clarias batrachus bioassay	**[16]**
water hyacinth	Whole plant	biogas production, recover bioenergy from anaerobic digestion of water hyacinth (WH)	**[17]**

		and from its co-digestion with fruit and vegetable waste (FVW) nitrogen can be recovered in the liquid effluent with a potential for use as a liquid fertilizer.	
Eichhornia crassipes	long-root	reclaimed as a multi-functional activated carbon (MFAC) to remove fluoroquinolones (FQs) from contaminated water	**[18]**
Eichhornia crassipes	Roots and leaves	water hyacinth in serving as an efficient and reliable accumulator for heavy metals.	**[19, 20]**
Eichhornia crassipes	Roots	Metal(arsenic (As), gold (Au), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), uranium (U), and zinc (Zn)) removal by absorption and adsorption within or on the external root surfaces	**[21-25]**
Eichhornia crassipes	macrophytes	promising technology with higher efficiency and no energy consumption to treat textile effluents rich in COD, BOD, dyes, and heavy metals (Pb, Fe, Cd, Cu)by Phytoremediation	**[26]**
Eichhornia crassipes		promising candidate for fuel ethanol production in tropical countries because of their high availability and high biomass yield	**[27-29]**

Eichhornia crassipes		enhance the removal of pollutants through their consumption as nutrients by devoid rhizospheric bacteria, to reduce naphthalene (a polyaromatic hydrocarbon) present in wastewater and wetlands.	**[30]**
Eichhornia crassipes		attractive technology in dealing with this dangerous pollutant. Cyanide BF blow down water could possibly be removed by the water hyacinth because of its high biomass production, and tolerance to cyanide (CN)	**[31]**
Eichhornia crassipes	stem biochar	remove of Cd(2+) from aqueous solution	**[32]**
Eichhornia crassipes	Leaves	can be used as an immunostimulant for prawn through dietary administration to enhance immune responses and resistance of M. rosenbergii against L. garvieae.	**[33]**
Eichhornia crassipes	root powder of long-root	Used as a biosorbent to remove aqueous sulfachloropyridazine (SCP) and other sulfonamides.	**[34]**
Eichhornia crassipes		exhibited antibacterial activities against both the gram positive bacteria; Bacillus subtilis and Streptococcus faecalis; and the gram negative bacteria; Escherichia coli and Staphylococcus aureus.	**[35, 36]**

		Growth of Aspergillus flavus and Aspergillus niger were not inhibited by either E. crassipes crude extract nor its five fractions. In contrast, Candida albicans (yeast) was inhibited by all.	
Eichhornia crassipes		be feasible for the removal of different pollutants of paper mill effluent, responsible for the eutrophication of the aquatic resources.	**[37]**
Eichhornia crassipes		Alternative fuel source by converting water hyacinth (Eichhornia crassipes) charcoal into briquettes with molasses as binder.	**[38]**
E. crassipes	leaves	Application in ethnomedicine, particularly as drugs preparation against staphylococcal infections due to the biopotency of these plants against pathogenic MRSA present in cattle, and SOSA as well as CoNS bacteria present in rabbits, which could be a serious issue for livestock	**[39]**
Eichhornia crassipes		as cellulose source and polyvinyl alcohol directly as cross-linker via a facile and environment-friendly process, exhibited excellent oil/solvent sorption capacities, super-hydrophobicity as well as remarkable	**[40]**

	reusability	
Eichhornia crassipes	an excellent bioindicator of water polluted by worrying organic pollutants such as endocrine disruptors and neonicotinoids so it is new perspectives for the remediation of water polluted by alarming organic pollutants.	**[41]**
Eichhornia crassipes	is a promising biosorbent for the removal of uranium pollutants.	**[42]**
E. crassipes	could be useful in treating cyanide effluents from small-scale gold mines.	**[43]**
duckweed	suitable for the uptake of most heavy metals.	**[44-46]**
water hyacinth, Canna x generalis, Lemna minor, Cyperus alternifolius	showed promising results for the application in the treatment of Cd-polluted waters given its ability to tolerate high Cd concentrations in the media (up to 10 mg Cd/L) and its capacity for uptake and accumulation.	**[44, 47, 48]**
Eichhornia crassipes straw	as adsorbents for heavy metals by CS(2) sulfonation and magnesium substitution after degumming with alkali, self-isolated A(1) strain and pectase, respectively. the two bio-degumming treatments, especially the pectase degumming treatment, are more	**[49]**

		beneficial to prepare heavy metal adsorbents than the alkali degumming treatment.	
Eichhornia crassipes	dried roots	the biomass could remove 54% of the initial uranium present within 4 min of contact time	**[50]**
Eichhornia crassipes, Hydrilla verticillata		provide an alternative solution for the removal of co-contamination between antibiotics and heavy metals from livestock and poultry wastewater	**[51, 52]**
Eichhornia crassipes	macrophyte	as an organic fertilizer of Colossoma macropomum (tambaqui) larvae in ponds is provided. It is quite cheap and easily available, it may be conveniently used to enhance fish yield in ponds.	**[53]**
Eichhornia crassipes	dried roots, stems, and leaves	an effective and inexpensive biomaterial for dye removal from aqueous dye solutions and industrial effluents	**[54]**
Typha angustifolia and Eichhornia crassipes		as a potential alternative energy source since species is available extensively in freshwater, marine, and aquatic ecosystems throughout the world	**[55, 56]**
Portulaca oleraceae		used for salinity reduction in the natural conditions.	**[57]**
E. crassipes	rough surface of E. crassipes leaf	utilize the plants as cost-effective and environmentally friendly oil sorbents	**[58]**

Eichhornia crassipes	removing two herbicides (mesotrione and fomesafen) with long degradation cycles in water so it is applied as an efficient, economical, and ecological alternative to accelerate the removal and degradation of agro-industrial waste water polluted with mesotrione and fomesafen.	**[59]**
Eichhornia crassipes	has the ability to phytoremediation the antibiotic sulfadiazine (SDZ) is a challenging threat to the health of aquatic organisms, as it frequently occurs in aquatic ecosystems contaminated water.	**[60]**
(Eichhornia crassipes) (WH) and sawdust (SD)	low-cost biosorbents may be used as alternatives to activated carbon in applications including selective separation of Zn(2+) from multi-metal ion solutions containing Ni(2+), and water and wastewater treatment	**[61]**
Eichhornia crassipes (Mart.) Solms (Waterhyacinth)	demonstrated to possess pharmacological activities, the phytochemistry, and several applications	**[62]**
Eichhornia crassipes	low-cost biomass may be used to produce liquids, gases, and biochar in a costefficient and	**[63]**

	environmentally friendly way via pyrolysis or co-pyrolysis in the future

Industrial uses

1. **Treatment of waste water**

   A sensible phytoremediation development for the incredible removal of risky poisons and dangerous pollutants from mines wastewater utilizing a few water plants [Portulaca oleraceae, Eichhornia crassipes, Hydrilla verticillata] might be utilized as a compelling, proficient and natural decision to animate the ejection and degradation of agro-current debased wastewater has been inspected effectively (Table 1) [1, 6, 10, 12, 15, 29-31, 51, 56, 61, 63-80].

   Applied to a back to back treatment of swine wastewater for nitrogen and phosphorus decline. So it is a fiscally feasible plans to apply water hyacinth phosphorus straw for the swine wastewater treatment. Reclaimed as a multi-practical initiated carbon (MFAC) to expel fluoroquinolones (FQs) from debased water[1, 6, 7, 15, 65, 69, 70, 73, 76, 77, 81-90]

   Alluring innovation in managing this hazardous toxin. Cyanide blow down water might be expelled by the water hyacinth in light of its high biomass creation, and resilience to cyanide (CN) be practical for the evacuation of various poisons of paper factory emanating, answerable for the eutrophication of the oceanic assets[31, 43].

   An excellent bioindicator of water polluted by worrying organic pollutants such as endocrine disruptors and neonicotinoids so it is new perspectives for the remediation of water polluted by alarming natural organic pollutants [24, 41].

   Eichhornia crassipes is consider a promising biosorbent for the expulsion of uranium contaminations and could be helpful in treating cyanide effluents from little scope gold mines[2, 21, 42, 50].

give an elective solution for the expulsion of co-pollution among antibiotics and heavy metals from domesticated animals and poultry wastewater[51, 91]. A viable and economical biomaterial for color expulsion from fluid color arrangements and mechanical effluents [12, 26, 54, 92-95].

use the plants as financially savvy and naturally agreeable oil sorbents, minimal effort biosorbents might be utilized as options in contrast to initiated carbon in applications including specific partition of Zn(2+) from multi-metal particle arrangements containing Ni(2+), and water and wastewater treatment [58, 61].

expelling two herbicides (mesotrione and fomesafen) with long debasement cycles in water so it is applied as an effective, prudent, and biological choice to quicken the evacuation and corruption of agro- industrial waste water contaminated with mesotrione and fomesafen[59].

2. **Biogas production**

Biogas is a clean and condition agreeable fuel created through the anaerobic assimilation of natural squanders such as: cow excrement and vegetable squanders. It is progressively getting significant in local and industry as fuel because of its expenses and tidiness. The fundamental part of the gas is methane, carbon dioxide, hydrogen, nitrogen and hydrogen sulfide. Water hyacinth can be utilized as a potential feedstock for biogas creation because of its wealth and high carbon-nitrogen proportion. This investigation focuses on assessing the capability of usage of water hyacinth for biogas creation. Conceivably helpful for phytoremediation programs in situations polluted by arsenic (As), and to create of biogas. Biogas creation, recover bioenergy from anaerobic absorption of water hyacinth (WH) and from its co-assimilation with leafy foods squander (FVW) nitrogen can be recuperated in the fluid profluent with a potential for use as a fluid manure. Minimal effort biomass might be utilized to create fluids, gases, and biochar in a cost efficient and ecologically inviting way through pyrolysis or co-pyrolysis in the future[12, 14, 17].

3. **Adsorbent of heavy metals**

The contamination of aquatic ecosystems with poisonous substantial metals is speaking to a major natural issue, because of discharging

these metals to biological surrounding without treatment, prompting their determination and non-biodegradation in the earth. Different customary strategies are used as an endeavor to evacuate overwhelming metals from squander water yet at the same time without gaining any real ground. This study estimates that Eichhornia crassipes (water hyacinth) dried leaves powder is potential in evacuating a portion of these substantial metals (HM), including lead, copper ،cadmium and chrome from fluid arrangements by means of biosorption affected by a few variable test factors. Determine the concentration of toxic elements present in surface water such as cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), uranium (U), and zinc (Zn). the possibility of using the thiol group content to assess the bioconcentration of heavy metal ions in water hyacinth and as a general parameter for monitoring the heavy metal pollution of water.[2]

The chance of utilizing the thiol bunch substance to survey the bioconcentration of substantial metal particles in water hyacinth and as a general parameter for observing the overwhelming metal contamination of water. This species is appropriate for phytoremediation of waters subject to release of blended modern effluents containing raised Cu fixations (>/=15 mg Cu/L), just as supplement rich local wastewaters [11, 19-21, 46, 49, 52, 96-107].

4. Alternative energy source

Environmental change and its effects are driving the advancement of sustainable power source assets internationally. There is a developing mission to enlarge the stockpile of biomass assets for bioenergy creation.

Promising candidate for fuel ethanol production[27, 29] in tropical countries because of their high availability and high biomass yield.

Elective fuel source by changing over water hyacinth (Eichhornia crassipes) charcoal into briquettes with molasses as fastener[38].

As cellulose source and polyvinyl liquor straightforwardly as cross-linker through a simple and condition amicable procedure, showed incredible oil/dissolvable sorption limits, super-hydrophobicity just as surprising reusability[40]

Typha angustifolia and Eichhornia crassipes as a potential alternative energy source since species is available extensively in freshwater, marine, and aquatic ecosystems throughout the world[55, 56]

5. **Pharmacological & biological activities**

Eichhornia crassipes can be utilized as an immunostimulant for prawn through dietary organization to improve invulnerable reactions and obstruction of M. rosenbergii against L. garvieae[33]. Also utilized as a biosorbent to expel watery sulfachloropyridazine (SCP) and different sulfonamides[34].

Eichhornia crassipes displayed antibacterial activites against both the gram positive microscopic organisms; Bacillus subtilis and Streptococcus faecalis; and the gram negative microorganisms; Escherichia coli and Staphylococcus aureus. Development of Aspergillus flavus and Aspergillus niger were not repressed by either E. crassipes rough concentrate nor its five divisions. Interestingly, Candida albicans (yeast) was repressed by all[35].

Application in ethnomedicine, especially as medications readiness against staphylococcal contaminations because of the biopotency of these plants against pathogenic MRSA present in cows, and SOSA just as CoNS microscopic organisms present in bunnies, which could be a difficult issue for domesticated animals[39]

Eichhornia crassipes (Mart.) Solms (Waterhyacinth) demonstrated to possess pharmacological activities, the phytochemistry, and several applications**[62]**

6. **Animal feed [15,30,53]**

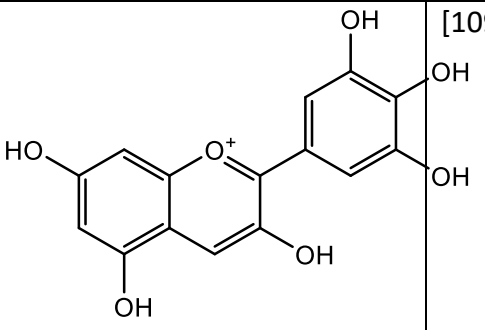
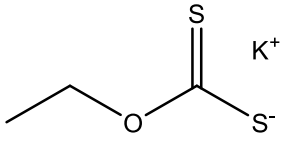
Eichhornia crassipes was viable for cleaning wastewater from an escalated duck ranch during the water hyacinth developing season, as gathered water hyacinth had a great exhibition as duck feed and The eggshell thickness and quality were among the egg characteristics altogether expanded in ducks took care of with water hyacinth[15]

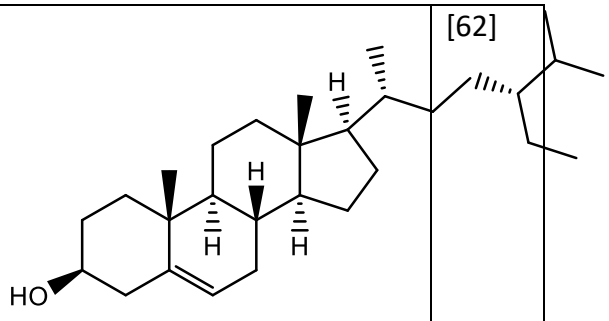
It upgrade the expulsion of contaminations through their utilization as supplements by empty rhizospheric microscopic organisms, to

lessen naphthalene (a polyaromatic hydrocarbon) present in wastewater and wetlands[30].

May be used as a natural compost of Colossoma macropomum (tambaqui) hatchlings in lakes is given. It is very modest and effectively accessible, it might be advantageously used to upgrade fish yield in lakes[53]

Table 2

Plant species	Extract/ substances	Structure	References
water hyacinth	thiol group	…….. not found	[8]
water hyacinth	flavonoids, alkaloids, anthroquinones and anthocyanins	…….. not found	[108]
(E. crassipes) ، Pistacia vera (P. vera)	phenols and saponin content of leaf extracts	…….. not found	[39]
blue-purple flowers of Eichhornia crassipes	acylated delphinidin glycoside		[109]
Syngonium podophyllum (SP) and Eichhornia crassipes (EC) leaf aqueous extracts	flavonoids, terpenoids, reducing sugars, alkaloids, and saponins.	Not found	[36]
shoot and root biomass of Eichhornia crassipes	Alkali-treated straw and cellulose xanthogenate		[110]

Eichhornia crassipes (Mart.) Solms (Waterhyacinth	Phenalenone compounds and sterols		[62]
roots and leaves of Eichhornia crassipes (Pontederiaceae).	8-phenylphenalenone	Not found	[111]

Chemical Composition

A thiol group protectant, used commonly in peptide and protein chemistry. Therefore, it is often added at high concentrations in preparations of proteins relevant to heavy metal biochemistry. Using the thiol group content to assess the bioconcentration of heavy metal ions in water hyacinth and as a general parameter for monitoring the heavy metal pollution of water[8].

Flavonoids, a gathering of regular substances with variable phenolic structures, are found in natural products, vegetables, grains, bark, roots, stems, blossoms, tea and wine. These regular items are notable for their advantageous consequences for wellbeing and endeavors are being made to separate the fixings purported flavonoids. Flavonoids are presently considered as a basic part in an assortment of nutraceutical, pharmaceutical, therapeutic and restorative applications. Nearness of metabolites like flavonoids, alkaloids, anthroquinones and anthocyanins in the tried concentrates may be the explanation behind the larvicidal and pupicidal action of the plant concentrates and fractionates of waterhyacinth. It acts as Mosquito-repellent movement[108].

Phenol has various medical advantages and can be useful to treat a couple of various conditions. Saponins are one of the numerous auxiliary metabolites found in regular sources ،which is found specifically bounty in different plant species. A few saponins are harmful to merciless

creatures and creepy crawlies at specific fixations. The nonsugar part of saponins have additionally an immediate cell reinforcement action. The outcome of the exploitation of methanolic extract of P. vera, Z. amole, and E. crassipes leaves for their possible application in ethnomedicine, particularly as drugs preparation against staphylococcal infections. The study indicates the biopotency of these plants against pathogenic MRSA present in cattle, and SOSA as well as CoNS bacteria present in rabbits, which could be a serious issue for livestock [39].

In human wellbeing, anthocyanins have been related with different advantages due to their antioxidant, hostile to inflammatory, neuroprotective, and against diabetic properties. The chromatoof 1 are shown in with aliglycoside was isolated from the blue-purple flowers of Eichhornia 3-~-(6”-~-(~-D-glucopyranosyl)-~-D-glucopyranosyl(((by spectral methods. The three dimensional crassipes as a (6”structure ofthis pigment of the negative Cotton effect at A,,, 535 nm that delphinidin (chromophore) as a binary complex[109].

Plant terpenoids(Syngonium podophyllum (SP) and Eichhornia crassipes (EC) leaf aqueous extracts) are utilized for their fragrant characteristics and assume a job in customary natural cures. The in vitro cancer prevention agent, antibacterial, and cytotoxic capability of Syngonium podophyllum (SP) and Eichhornia crassipes (EC) leafaqueousextractsaswellastheir in vivo impact on oxidative pressure and hepatic biomarkers in isoniazid actuated rodents. The two concentrates showed extensive antibacterial action against Proteus vulgaris, Salmonella typhi,and Bordetella bronchiseptica. Coadministration of E. crassipes separate with isoniazid in rodents represented 46% lessening in malondialdehyde content and 21% expansion in FRAP estimation of plasma. It additionally alelviated the isoniazid incited changes in serum compounds (SGOT, SGPT, and ALP), complete bilirubin, creatinine, and hemoglobin substance. S. podophyllum extricate was seen as hepatotoxic[36].

Soluble base treated straw and cellulose xanthogenate were gotten from shoot and root biomass of Eichhornia crassipes by treatment with NaOH and CS2. Soluble base treatment expanded the crystallinity of crude plant material, while the consequent CS2 treatment had the switch impact. The

warm security of the plant material was decreased by soluble base treatment yet was reestablished by consequent CS2 treatment. Antacid treatment evacuated the majority of the lignin and hemicellulose from the crude plant material, though the development of cellulose xanthogenate presented new C@S and O–CS–S utilitarian gatherings[110]

Phenalenones are individuals from a one of a kind class of characteristic polyketides showing different organic potential. Eichhornia crassipes (Mart.) Solms (Waterhyacinth), an amphibian enduring herb present all through the world, has a heap of metabolites. Phenalenone mixes and sterols have been detached from this plant. Concentrates, just as unadulterated mixes detached from this plant, have been exhibited to have pharmacological exercises[62].

Phenylphenalenones with a parallel phenyl ring in irregular 8-position have been separated from Eichhornia crassipes (Pontederiaceae). The structures were clarified by spectrometric strategies including NMR and MS investigation. The joining of two atoms of [1-13C]phenylalanine gives trial proof to the biosynthesis by means of 1,2-aryl relocation from a middle of the road of the 9-phenylphenalenone type[111].

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