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Systematic Review of the Efficiency of Aquatic Plants in the Wastewater Treatment

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Abstract. Wastewater treatment uses a phytoremediation strategy that sets significant trends according to recent research from the 2019-2021 period, being one of the most efficient strategies regarding the removal of pollutants using artificial wetlands with aquatic plants. Therefore, the objective of the review article is to determine the efficiency of the aquatic plant in the phytoremediation process for the treatment of industrial, domestic, and municipal wastewater through a systematic mapping method that allows us to summarize the theoretical framework avoiding. The exclusions also have a comparative descriptive design for the study variables where it has been found that *Eichhornia Crassipes* is an aquatic weed that removed NO2- and NO3- up to 93% of industrial wastewater, in *Pistia stratiotes* it removed Turbidity (98.5%), N total (100%), P total (100%) and COD (79.18%) in household wastewater in 60 days. Finally, *Azolla Filiculoides* removed SO_4^{2-} (83%), Cl (76%), PO_4^{3-} (84%), NO3- (76%), COD (79%), BOD (63%) and EC (49%) from municipal wastewater in 21 days.

1. Introduction
Population growth and industrial development in the world contribute at a high level to water pollution, generating negative impacts on ecosystems and thus becoming the greatest threat to the environment [1]. Wastewater treatment is an encouraging proposal to restore the initial conditions after industrial, domestic, or municipal use, with phytoremediation being the treatment with the highest demand for use in the last two decades [2], therefore this review aims to find the most efficient aquatic plant in wastewater treatment through an exhaustive analysis of current trends considering phytoremediation as a biological treatment that can be achieved through phytoextraction, rhizofiltration, phytostabilization and phytotransformation (phytodegradation) enhancing the photosynthetic activity and growth rate of the species used to adapt them to the contaminated environment and thus have control of the organic or inorganic agents to be removed [3]. These applications have the advantage of their low cost [4], the main element is the aquatic plant, and it is shown in the literature that about 30 are used for the treatment of industrial wastewater and 24 for agricultural and domestic waters [1]. The main operational properties and characteristics are based on degradation, extraction, and transformation or detoxification [5], through the use of well or pond systems with depths ranging from 0.4 to 1.5 meters where strategies are implemented in the form of wetlands by the load of the growth activity of the aquatic plant [3].

2. Study methodology
The search for information was carried out through official sites for scientific research such as Scopus, Web of Science, EBSCO host, the Journal of Environmental Pollution, Springer, and Science direct looking as keywords: Phytoremediation of municipal, industrial and domestic wastewater, aquatic plants for wastewater treatment and wastewater treatment. In this way, a considerable list of recent articles for

the period 2019 - 2021 was obtained. Through a systematic mapping, the collected information was synthesized in order not to exclude any of the critical positions of the researchers and the description and comparison were made through the tables that highlight the dimensions and indicators of each variable under study.

3. Wastewater phytoremediation

Wastewater phytoremediation is a cleaning technology that uses aquatic plants for the elimination of water contaminants, this method is applied through 4 systems: Constructed wetlands, treatment system with floating aquatic plants, integral treatment system, and rhizofiltration system, driven by solar energy in the process of photosynthesis and the genetic adaptation of the plant in the aquatic environment where it removes and/or accumulates heavy metals, nitrites, nitrates, organic matter, sulphates, phosphates, and other contaminants [6][7]. From the research collected in table 1, the advantages and disadvantages of the implementation of a phytoremediation process in an aquatic environment, contaminating from an economic, social, and environmental approach were classified [8][6][9].

Table 1. Review of the advantages and disadvantages of wastewater phytoremediation

Advantages	Disadvantages
Sustainable technology	Relatively slow process
It has low cost and does not require specialized personnel for its management	Vegetation growth can be limited by excess environmental toxicity.
It is efficient for treating various types of contaminants in situ or ex-situ.	Not all plants are tolerant or accumulating.
It is little harmful to the environment and generates less disturbance of the place	It can promote the development of insects such as mosquitoes
It does not generate secondary contaminants.	Possibility of contaminants entering the food chain

Source: [10][11][4][6][12].

4. Wastewater

Wastewater is liquid effluent that comes from everyday use and these are introduced into the drain of each infrastructure to be transported through the sewer to a wastewater treatment plant as shown in figure 1, [13][7].

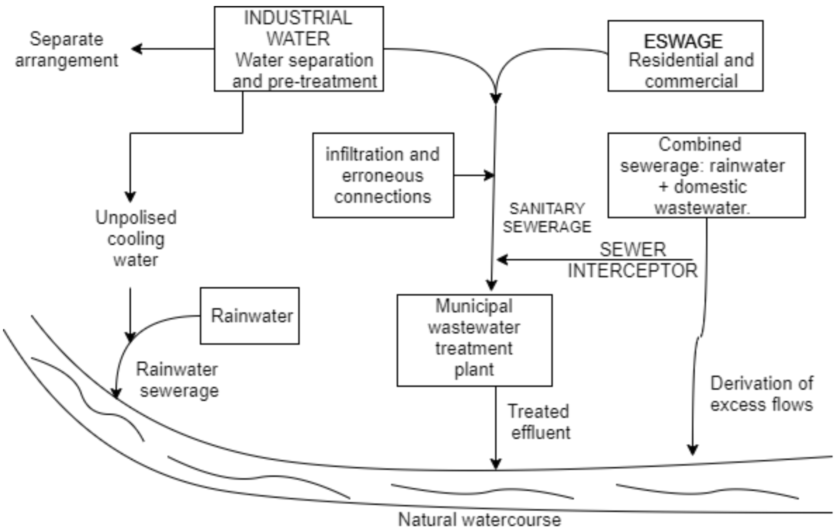

Figure 1. Municipal wastewater sources [13].

4.1. Domestic wastewater
It's the residential and commercial wastewater, which contain physiological wastes generated as a result of human activity, and must be properly disposed of [13][14][15].

4.2. Industrial wastewater
It's the industrial wastewater, a product of a productive process, including mining, agriculture, energy, agro-industrial, textile, etc. [13][14][15].

4.3. Municipal wastewater
These are domestic and industrial wastewaters that may be mixed with storm drainage water or with previously treated industrial wastewater, to be admitted to combined sewerage systems [13][14][15].
Therefore, according to the origin of wastewater supply, water pollutants are classified, whether physical, chemical, or organic, which contribute to the decrease in oxygen, which delays biological degradation and these are responsible for disease transmissions, so each nation guarantees the fine-tuned treatment of wastewater [16][17].

5. Artificial wetlands
Artificial wetlands have the purpose of the design and construction of the reservoir of biosolids and water in various conditions, involving a natural process to contribute to the removal of polluting load such as heavy metals, organic matter, nitrogen load among others [18][19]. Likewise, according to table 2, the efficiency of the wetland depends on the configuration of the system or the area, so that according to the speed of the flow and the hydraulic retention time it defines the flooded areas [11][19]. Artificial wetlands, compared to natural wetlands, can reduce several pollutants. In addition, wastewater can be treated by various designs according to the proposed water quality objective and can be in situ or ex-situ [11][20].

Table 2. Review of the characteristics of the types of artificial wetlands (In parentheses the values are recommended by the ART manual)

Wetland Type	Physical characteristics		Hydraulic characteristics	
	Depth (m)	**Unit Areas (m2 / P.E.)**	**Hydraulic retention time (HRT) (d)**	**Hydraulic applied load (mm / d)**
SFW	0.2->1.2 (0.6)	5.0-20.0	0.1-15.0	12-160
SFW	0.3 - 1.0(0.5)	2.5-10.0 (5.0)	2.0-10.0	23 - 138 (40)
VSFW	0.8-1.0 (0.9)	0.85-5.5 (2.0-3.0)	1-2	27-1500 (35 - 38)

Source: [19].
In this way, according to the hydraulic behaviour, they are classified as follows, as shown in figure 2,

5.1. Surface flow Wetlands (SFW)
For this type, there is a combination of aquatic plants: emergent and submerged. In addition, it has a depth of water subject to changes to 0.75 m, while in the areas of water mirrors it is 1.20 m [19][20].

5.2. Subsurface Flow Wetlands (SFW)
It is designed specifically for the treatment of some type of wastewater or in its final phase of treatment, typically constructed in the form of a riverbed or canal [19][20].

5.3. Vertical Subsurface Flow Wetlands (VSFW)
These are systems where wastewater flows through the substrate, usually gravel, coming into contact with microorganisms that colonize the surface of both the roots of plants and the substrate itself [11][19][20].

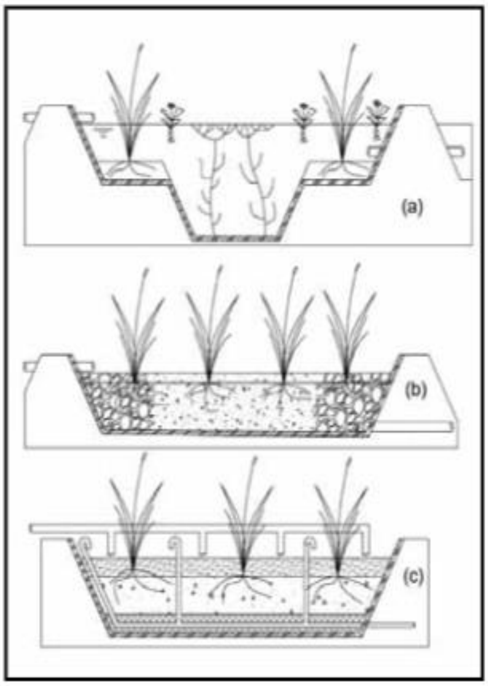

Figure 2. (a) Surface flow wetlands, (b) Subsurface flow wetlands and (c) Vertical subsurface flow wetlands [19][17].

6. Wastewater characterization
For the characterization of wastewater, an appropriate sampling program should be taken into account to ensure the representativeness of the sample, in addition to laboratory analyses to ensure accuracy and accuracy in the results [13][7]. In the reviewed articles the authors detail that the characterization appropriated should consider the following parameters: pH, Salinity, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrate (NO3), Ammonia (NH3), Sulphate (SO4), Volatile Organic Compounds (VOCs), Total Nitrogen (NT), Electrical Conductivity (CE), Total Phosphorus (PT), Turbidity, Dissolved Oxygen (OD), Temperature (T°) and Heavy Metals [21]. In this way, a test before, during, and after the treatment demands an efficiency of removal of the polluting load produced by the aquatic plant.

In the case of industrial wastewater treatment, the most used for the proper characterization shown in figure 3, the trend of use is highlighting the need to focus on data of pH, heavy metals, COD, and BOD. Likewise, for the case of municipal and domestic wastewater, as shown in figure 4, the turbidity, COD, BOD, pH, NO3, and TSS are relevant. However, the complete characterization is essential, according to the need of the researcher or the engineering proposal giving greater emphasis to the indicated parameters aimed at identifying the removal of contaminants and determining the effectiveness of the treatment [7][13][22].

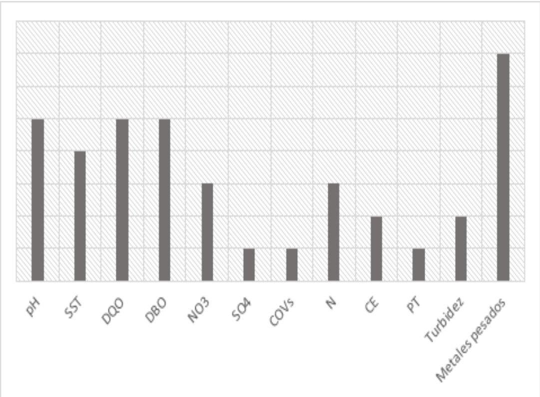

Figure 3. Characterization of industrial wastewater
Source: Own elaboration

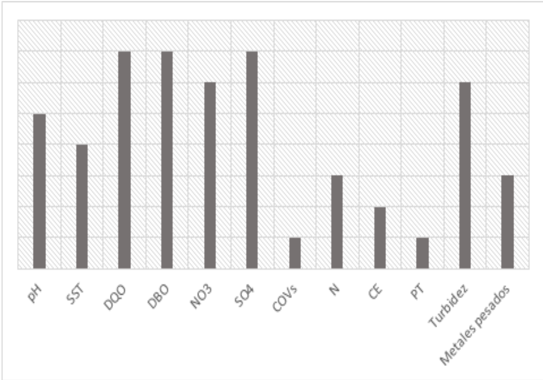

Figure 4. Characterization of domestic and municipal wastewater
Source: Own elaboration

7. Aquatic phytoremediation plants
These are plants that are part of an aquatic treatment system, which are applied to wastewater on natural or artificial humid soils with the sole purpose of removing their contaminants [10][23][24]. Aquatic plants have a main function in freshwater ecosystems, since they provide food, structure, coverage, at the same time shelter for different terrestrial and aquatic animal species. Currently, treatment is applied by artificial wetlands to reduce contaminants by rhizofiltration thus forming part of a phytotransformation system [13][25]. The main desirable characteristics of aquatic plants are Morphological and physiological adaptations for development in different aquatic environments, leaves with morphological modifications, and special structures that allow them the ability to float on the surface of the water [4][26]. However, these aquatic plants have characteristics that contribute to the advantages and disadvantages for treatment as shown in table 3, generally, the floating leaves are oval and succulent while the submerged leaves are branched and filamentous, these plants are large, showy, and brightly coloured or they can also be tiny and modified to survive in an aquatic environment with pollination [27][28]. We can classify them as:

7.1. Emerging aquatic plants
These are plants that are found on the surface of the water where their structure is either its stem, root, leaves, and flowers are floating freely. Its main function in wastewater treatment is to retain contaminants and clarify or filter the water [11][29]. Within this type of plant, we find: *Scirpus Validus, Typha latifolia, Ceratophyllum demersum, Potamogeton pectinatus, Maranta arundinacea, Lemna spp, Eichhornia crassipes and Pistia Stratiotes.*

7.2. Submerging aquatic plants
These are plants that are submerged between 40 to 80 cm under the surface of the water, thus guaranteeing regular oxygen for the flora and fauna, limiting the development of algae [11][29]. They can be *Algae, Chara Vulgaris, Myriophyllum aquaticum, Myriophyllum spicatum and Hydrilla verticillata.*

Table 3. Review of the advantages and disadvantages of treatment with aquatic plants.

Advantages	Disadvantages
They can be used for water purification a secondary or tertiary treatment or a stabilization pond.	They can generate stagnation in irrigation and navigation canals.
They have efficient cellulose production.	When they are in decomposition and accumulate, thus generating organic matter in the sediments, it becomes anaerobic, which is not favourable for the aquatic habitat.
They have a biogas reproduction capacity.	If they are not in an active state, they can act as a source of vectors that spread diseases.

Source: [5][11][30][31][29].

8. Results and discussions

The selection criteria were independent of the type of wastewater, and we proceeded to make a systematic breakdown of municipal wastewater, industrial wastewater, and domestic wastewater by descriptively comparing the collected research [7][13][32].

8.1. Industrial wastewater

For the type of industrial water, the type of industry was taken into consideration because each source has different components depending on the business line, and the parameters subjected to experimentation were also taken into account, which served to focus the use of the aquatic plant and evaluate the removal. Therefore, it was important to identify the initial condition of the artificial wetland before the procedure, the period that the treatment lasted and the efficiency achieved by each plant, and finally the distinction of the place so that the variables could be tested independently of the weather and climate conditions, the distinction of the author and year. According to table 4, the most efficient aquatic plant is *Eichhornia crassipes*, not only because of the demand for its use in recent research but also because the degree of removal in different sectors such as the textile industry, food manufacturing, ammonia waste has been 70-98% in 15 days; likewise, *Salvinia molesta* showed its capacity to remove contaminants at 96%.

The researchers Mohammed and Mustafa tell us that *Eichhornia Crassipes* is an aquatic weed that performs an effective removal of nitrates and nitrites up to 93% in this way the free nutrients of the wastewater eliminate the pollutants once the interaction with the plant from the root has taken place, especially metallic pollutants such as ammonia, lead, zinc and cadmium, with results after 2 days, which makes it doubly effective [33][31][34].

Eichhornia Crassipes known as water hyacinth or water lily, from the *Pontederiaceae family*, is considered as an invasive plant in the world by the International Union for Conservation of Nature (IUCN), however, it does not live at temperatures lower than 0°C and the type of reproduction is vegetative through stolons, although it can also be obtained through seeds, but with a low germination rate [4][35][26]. The rapid growth, ease of collection, and high productivity of E. c. make it one of the most favourable plants for phytoremediation of wastewater, and its accumulation and high tolerance to metals make its use common in industrial wastewater [36][2][37].

8.2. Domestic wastewater

In table 5, We found that the most efficient aquatic plant was *Eichhornia crassipes* where the removal is quantified in N (97.79%), Ammonium (92.03%), BOD5 (77.23%), COD (157.63%), TOC (39.24%), TSS (95.94%), TDS (75.17%), oil and grease (99.33%) in 21 days, It is worth mentioning that this aquatic plant is in high demand for use both for residential discharges and minor housing; however, it was *Pistia stratiotes* that in a 60-day treatment achieved the removal of Turbidity (98.5%), total N (100%), total BOD (100%) and COD (79.18%) [38][29].

Hauwa M and Gasim Hayder classify *Pistia stratiotes* as an aquatic plant with a removal value of up to 65% in contaminants for food manufacturing and 83.3% in household waste, capable of removing up to Nitrate and 84.8% of nitrogen after 10 days of experimental subjection, the researchers show that regardless of the type of wetland, whether vertical or horizontal, the systems work. In addition, the environmental conditions favourable for its growth are described as; temperature (27.07 ± 0.07), pH (6.37 ± 0.27), OD (2.07 ± 0.0), and nitrate (0.90 ± 0.15) [1][24].
Pistia Stratiotes, a floating aquatic plant described as a "weed" from the *Araceae family*, called "water lettuce", is native to Asia, Africa, and equatorial America.
"It is native to Asia, Africa, and equatorial America. This floating plant can grow up to 40 cm long and its leaves have small hairs [39]. *Pistia stratiotes* develops in a temperature range of 15°C to 30°C, does not persist in cold winters, prefers very luminous environments, presents a type of reproduction by seeds and stolons which makes it an invasive plant [40], this aquatic plant can tolerate and remove concentrations of metals such as Pb and Cr with percentages higher than 70% of removal, since it has a high level of enzymatic and non-enzymatic antioxidants, although there are studies that mention that it is affected by being exposed to Hg concentrations [40][41]. This plant is widely used due to its efficiency in the removal of pollutants in industrial and domestic wastewater, reducing concentrations of BOD, COD, nitrate, phosphate, and metals [3][42].

8.3. Municipal wastewater
As shown in table 6. The municipal waters were taken from cities with average population indices, under usual environmental conditions, thus more in line with the reality of the conditions that a municipal wastewater treatment plant must meet, whether in primary, secondary or tertiary treatment. In addition, a systematic comparison was made to validate the efficiency of the aquatic plants and in this sense, it was *Azolla filiculoides* who removed SO4 (83%), Cl (76%), PO4 (84%), NO3- (76%), COD (79%), BOD (63%), EC (49%) in a period of 21 days after having a pH (7. 9), Cl (320 mg/L), NO3- (8.6 mg/L), SO_4^{2-} (550 mg/L), BOD (160 mg/L), COD (290 mg/L), in the city of Egypt, a city with high solar radiation demand environments but presenting extreme temperature variation at night hours [43][44][45]. *Azolla filiculoides* is an aquatic plant used for cleaning contaminated water of organic and inorganic compounds, it is also tolerant to various metals such as Cu and as, and has a high growth rate [46][42]. It belongs to the *Azollaceae family*, it is native to North and Central America, the optimum pH range is 6 and 7, it does not tolerate temperatures below 0°C or above 35°C, it reproduces by spores, and by nature, it is a nitrogen bio-accumulator through biological nitrogen fixation processes. Unlike *Eichhornia Crassipes*, it has a higher percentage of biomass yield since it can double its biomass in 3 days due to its accelerated reproduction [30][25][45].

Table 4. Review of the phytoremediation efficiency of aquatic plants for industrial wastewater.

Plant	Type of industrial wastewater	Type of wetland	Evaluated Parameters	Initial condition	Period (day)	Achieved efficiency	Place	Author
Salvinia biloba	Artificially contaminated with Cadmium (Cd), Copper (Cu), Lead (Pb) or Zinc (Zn)	SFW	Physiologic al - Heavy metals (Cu, Pb, Cd, Zn)	Cd (5,6 ± 0,2 y 11,2 ± 0,1 mg / L), Cu (3,2 ± 0,1 y 6,4 ± 0,1 mg / L), Pb (10,4 ± 0,4 y 20,7 ± 0,2 mg / L) o Zn (3,3 ± 0,1 y 6,5 ± 0,1 mg / L)	2	Cu, Pb y Cd (79 ± 4% y 56 ± 2% for 50 ± 2 y 100 ± 1 μ M) y Zn (77 ± 5% y 70 ± 4% for 50 ± 2 y 100 ± 1 μ M)	Paraná medio, Argentina	[35]
Eichhornia crassipes	Textile industry	SFW	Volatile Organic Compounds	2.5 l of 10 mg / l RB in the first, 2.5 l of 10 mg / l XO in the second, 2.5 l of 10 mg/l CV in the third and 2.5 l of 10 mg/l RhB in the fourth. / l RhB in the fourth	20	Cationic dyes (79 - 90.8%) and Anionic dyes (33.3 - 62.8%)	Basai village, Gurugram district, Haryana state, India	[23]
Vetiveria zizanioides y Zeliac	Tofu Industry	SFW	COD, BOD, pH, TSS	COD(5759mg/L)/BOD(580mg/L)/pH (3.9)/STS(552mg/L)	15	COD (76%), BOD (71.78%), TSS (75.28%) and an increase in pH (7.8).	Bogor, Indonesia	[47]

Lemna Minor	Industrial Wastewater	SFW	Heavy metals (Cr)	Cr (97%)	14	Cr (58%) in considerations < 9 mg/L Cr	Haryana, India	[2]
Spirodela polyrhiza				94.34 mg/L (NH4)2SO4, 246.4 mg/L MgSO4.7H2O, 27.22 mg/L KH2PO4, 153.49 mg/L Ca(NO3)2.4H2O, 243.96 mg/L		NH3 (64%), NO3 (30%), PO4 (72%) y Biomass (34%)		
Salvinia molesta	Synthetic	SFW	NO3, N, PO4, NH3, COD, pH, (BIOMASS)	K2SO4, 232.36 mg/L CaSO4.2H2O, 0.74 mg/L MnCl2.2H2O, 1.43 mg/L H3BO3, 0.11 mg/L ZnSO4.7H2O, 0.04 mg/L	12	NH_3 (31%), NO3- (19%), PO_4^{3-} (36%) y Biomass (39%).	Kerian District, Perak, Malaysia.	[37]
Lemna Minor sp.				CuSO4.5H2O, 0.013 mg/L Na2MoO4.2H2O, 2.51 mg/L FeSO4.7H2O and 3.37 mg/L Na2.EDTA.2H2O		NH_3 (44%), NO3- (6%) , PO_4^{3-} (86%) y Biomass (61%)		
Vetiveria zizanioides L.	Agriculture	VSFW	CE, BOD, DO, NO3	EC(1846 ± 16)/ DBO5 (14,4 ± 0,2)/ DQO (1,6 ± 0,1)/ NO3 (43,4 ± 1,6)	160	DBO (78.47%), NO3 (90.53%)	Shahid Chamran University (SCU), Ahvaz, Iran.	[48]
Centella asiática, Ipomoea aquatica, Salvinia molesta, Eichhornia crassipes, Pistia stratiotes	Industrial Wastewater	VSFW	T°/pH/ COD/Conductivity/Turbidity/TSS/ BOD 5/ F / N	T ° (27.77 ± 0.06) / pH (8.29 ± 0.02) / COD (4.63 ± 0.04) / Conductivity (95.73 ± 0.15) / turbidity (205.00 ± 1.00) / TSS (45.67 ± 0.60) / BOD5 (1.06 ± 0.03) / Phosphate (0.35 ± 0.10) / N (4.20 ± 0.10)	14	NH3-N (98%), TSS (90%) and PO_4^{3-} (64%). I. Aquatic TSS and NH 3- N (73%) and phosphate (50%). E. crassipes, phosphate (98%), TSS (96%) and NH 3- N (74%). S. molesta was efficient TSS (89.3%), phosphate (88.6%) and NH 3- N (63.9%).	Malaysia	[15]
Eichhornia crassipes and Pistia Stratiotes	Batik Industry	SFW	NH3 - Cr	Prior to treatment of the 4% Batik wastewater, ammonia of 5.73 mg L -1 and Cr of 596 mg L -1 were observed.	15	NO3- Ammonia was reduced by 78.36% in E. crassipes and 73.13% in P. stratiotes. Cr was reduced by 63.76% in E. crassipes and 83.39% in P. stratiotes.	Malang, Indonesia	[34]
Typha latifolia	Industrial Wastewater	SFW	Heavy metals like Fe	30 mg L -1 in the Fe microcosm configurations.	14	Fe 1.67 ± 0.076 mg L -1 (94.43%) and 0.087 ± 0.013 mg L -1 (97.10%)	Loktak, northeastern India.	[24]
Eichhornia crassipes	Ammoniacal wastewater	SFW	pH, temperature, turbidity, BOD5, COD, TSS, heavy metals (Cd, Cu, P, Fe, Pb, Zn) and AN.	7 pH (6.54), temperature (26.5), turbidity (1.9275), BOD5 (30 mg/L), TSS (6 mg/L), heavy metals: Cd (0.0074 mg/L), Cu (0.0131 mg/L), P (0.4090 mg/L), Pb (0.2244 mg/L) and AN (40 mg/L).	15	5.79% for ammonia nitrogen removal efficiency response for Ammonia Nitrogen	Sarawak, Malaysia	[26]

Source: [2][15][35][23][47][37][48][34][24][26].

Table 5. Review of phytoremediation efficiency of aquatic plants for domestic wastewater.

Plant	Type of domestic wastewater	Type of wetland	Parameter	Initial condition	Period (day)	Achieved efficiency	Place	Author
Eichhornia crassipe	Residential wastewater	SFW	pH, BOD, COD, TSS, TKN and TP.	pH (7,19 ± 0,13), DBO (268 ± 12), COD (522± 28), TSS (326 ± 13), TKN (18,8 ± 0,62), TP (11,9 ± 0,37)	15	DBO (90.1 ± 3.7%), DQO (85.1 ± 4.2%), TSS (85.5 ± 2.9%), total N (61.4 ± 1.9%), total P (85.3 ± 2.9%)	Bangkok, Thailand	[38]
Pistia stratiotes	Post-treatment of wastewater from domestic sewage systems	SFW	Temperature, pH, turbidity, TS, COD, total N, total P	Turbidity (1000 NTU)	60	Turbidity (98.5%), total N (100%), total P (100%) and COD (79.18%)	Toledo-PR, Brazil	[24]
Eichhornia crassipes	Raw sewage from cooking	SFW	Nitrate Nitrogen - BOD5 – NH4+ N - Total Organic Carbon - TSS	Ammonia nitrogen (54.93)	21	pH (55.01%), N (97.79%),NH4+ (92.03%), BOD5 (77.23%), DO (157.63%), TOC (39.24%), TSS (95.94%), TDS (75.17%), Fat and Oil (99.33%)	Bogor, Indonesia	[42]
Bacopa monnieri (L.)	Gray water	VSFW	Indicators: SS, COD, BOD, N, P, Zn, Cu, Ni and Mn of approximately 90%, 76 - 77%, 80%, 65%, 55%, 56%, 42% and 41%,	COD (2886 ± 240), BOD (1550 ± 235), SS (243 ± 43), pH (7.7 ± 0.6), NKT (87.6 ± 10.9), P (56.2 ± 15.3), Zn(7.4 ± 0.6), Cu (4.0 ± 0, 4), Ni (3.8 ± 0.5), Mn (3.3 ± 0.4), TC (6.3 ± 0.4), FC (6.4 ± 0.5), FS (5.4 ± 0.3), FS (5.4 ± 0.3).	30	SS (90%), COD (76%), BOD (77%), N (80%), P (65%), Zn (55%), copper (56%), Ni(42%) and Mn (41%).	India	[28]
Salvinia molesta	Secondary treated domestic wastewater	VSFW	Turbidity, phosphate, ammoniacal nitrogen and nitrate	turbidity (18.23 ± 1.47), phosphate (2.53 ± 0), ammoniacal nitrogen (10.79 ± 0), and nitrate (4.4).	14	Turbidity (97.7%), PO_4^{3}-(99.7%), Ammonia Nitrogen (99%) and NO3- (90.6%).	Kajang of Selangor	[45]
Eichhornia crassipes	Gray water	SFW	Water temperature, pH, total dissolved solids, turbidity, COD, ammonium - nitrogen and phosphate - phosphorus	T° (23.1 to 24.9 ° C), pH (6.94 to 7.94, TSS (192 to 648 mg / L), turbidity (9.8 to 49.9 NTU), COD (51.2 -179.2 mg / L), ammonium-nitrogen (2.8-6.16 mg / L) and phosphate-phosphorus (0.45-1.168 mg / L).	20	Ammonium-Nitrogen (63.26 ± 10.47%), Phosphate-Phosphorus (61.96 ± 12.11%) and COD (51.91 ± 5.32%).	Surat, Gujarat, India	[29]

Source: [38] [24][42][28][45][29].

Table 6. Review of the phytoremediation efficiency of aquatic plants for municipal wastewater.

Plant	Type of wetland	Parameter	Initial condition	Period (day)	Achieved efficiency	Place	Author
Azolla filiculoides	SFW	Heavy metals (SO4, NO3, Cl), COD, BOD and EC	pH 7.9/ Cl 320 mg/L - NO3 8.6 mg/L - SO4 550 mg/L- BOD 160 mg/L- COD 290 mg/L	28	SO_4^{2}- (83%), Cl (76%),PO_4^{3-} (84%), NO_3- (76%),DQO (79%), DBO (63%),CE (49%).	Al-Tuwaitha (Iraqi Atomic Energy Agency, IAEA)	[43]
Typha angustifolia	SFW	Turbidity, BOD, COD, TN, TP	Turbidity (111.5 ± 29.16 NTU), BOD (90.7 ± 7.9 mg L-1), COD (263.9 ± 144.2 mg L-1), TN (6.64 ± 2.24 mg L-1), PT (1.15 ± 0.175 mg L-1), TQ (1.15 ± 0.175 mg L-1).	90	Turbidity (98.4%) , BOD (83.3%), COD (95.8%), total N (99.9%), total P (99.7%)	Lago Marriott from Egypt	[49]

Chlorella vulgaris	VSFW	COD and TSS	COD (361 mg L−1) , TSS (116 mg L−1)	16	COD (81,80%) y TSS (89,91%)	El Salitre-Torca Basin, Bogotá	[50]
Wolffia arrhiza	SFW	BOD5, COD, total nitrogen and phosphorous phosphorus	DMP (1.03), DEP (0.91), DPP (0.42), DIBP (0.43), DnBP (0.72), DIHP (0.65), DEHP (0.90), DINP (0.69)	7	BOD5 (86 and 91%), COD (69%), PMD (95.5), PED (95.6%), PPD (97.5%), DIBP (96.4%), DnBP (87.2%), DEHP (97.7%), DINP (95.6%)	Poland	[51]

Source: [43][49][50][51].

9. Conclusions

Wastewater treatment with aquatic plants is a phytoremediation strategy that sets significant trends for the year 2021 and requires low treatment costs. In addition, the efficiency of pollutant removal is independent of the origin of the discharge, whether it is industrial, domestic, or municipal. From the research collected, it was obtained that plants have a better location if the environment is adapted to their living conditions in horizontal or vertical flow, which will motivate the plant to an imminent development for the most marked removal as is the case of *Echornia crassipes*, an aquatic weed that has an effective removal of nitrites and nitrates up to 93% for industrial wastewater, *Pistia stratiotes* which removed Turbidity (98.5%), total N (100%), total P (100%) and COD (79.18%) in 60 days for domestic wastewater and *Azolla filiculoides* which removed SO_4^{2-} (83%), Cl (76%), PO_4^{3-} (84%), NO3- (76%), COD (79%), BOD (63%), EC (49%) for 21 days for municipal wastewater. Likewise, in the 35 articles reviewed, it was specified that for the efficiency of aquatic plants, it is relevant to characterize the water at the source and to emphasize physicochemical parameters such as turbidity, COD, BOD, pH, NO3, and TSS for industrial and municipal wastewater, and finally pH, heavy metals, COD and BOD for industrial wastewater.

10. References

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