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Review

Treatment Wetlands in Mexico for Control of Wastewater Contaminants: A Review of Experiences during the Last Twenty-Two Years

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Abstract: Constructed or treatment wetlands (CWs) are a sustainable option to clean wastewater in the face of water pollution problems. Consequently, this study was aimed at reviewing and analyzing the use of CWs in Mexico. This involved types, sizes, and functionality in the removal of pollutants, as well as the main plant species that are used. Furthermore, 67 studies regarding CWs were found, which were classified according to the treatment area as microcosms, mesocosms, pilot scale, and full-scale at 18, 30, 25, and 27%, respectively. The most used types of CWs are those of subsurface flow (87%) versus free-water surface (13%), of which horizontal flow direction (58%) are the most common. Considering Full-Scale CWs, the pollutant removal reported for COD, BOD_5, TN, and TP oscillated between 50–90%, 60–90%, 30–90%, and 30–70%, respectively. Among the vegetation that is more used for Mexican CWs, 78 different species were detected; *Typha* and *Cyperus* hydrophytes species and ornamental flowering plants as *Zantedeschia aethiopica*., *Canna* genus., *Heliconia* genus, *Hedychium coronarium*, and *Anturium andreanum* species (plants with commercial value) were the most used plants. It was concluded that although there is an important advance in the use of ecotechnology as it is an attractive answer for decentralized wastewater treatment in Mexico, results revealed the need to migrate towards the use of CWs in full-scale size, in order to address real pollution problems. Thus, the further implementation of CWs in rural and urban regions with similar tropical and subtropical characteristics as in Mexico is suggested by the authors.

Keywords: constructed wetlands; ornamental plants; phytoremediation; wastewater treatment

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1. Introduction

Water is an essential element that allowed the emergence of life in ecosystems and human development. Two-thirds of the Earth's surface is covered with water [1]; however, the use of this vital liquid in the development of human activities has caused the degradation of environment and human health due to the discharge of untreated domestic wastewater into water bodies [2,3].

Municipal wastewater treatment is a process that has not received enough attention, mostly in developing countries due to the costs in the construction and implementation of the most conventional methods, as they rely on electricity 24 h per day, which increases the costs [4], turning these processes into a great challenge for their implementation. A recent study [5] reported that in Xaltianguis, Guerrero, Mexico, a sludge treatment plant with an expenditure of 1080 m^3/day required USD 298,250 plus a monthly operating cost of USD 1944 per cubic meter. Thus, many of these systems are abandoned due to insufficient financial resources.

On average, high-income countries treat 70% of the municipal and industrial wastewater generated. In upper/middle income countries, this average falls to 38% and to 28%. In lower-middle income countries, only 8% of total municipal and industrial wastewater generated is treated. According to UNESCO in its World Report on the Development of Water Resources (2017) [6], these data support the statement that in the world, more than 80% of wastewater is discharged without any treatment. This situation has a worse impact on developing countries such as Mexico [7].

According to the latest National Inventory made by the National Water Commission (CONAGUA), there are 2786 plants in Mexico operating with an installed capacity of 196.7 $m^3\ s^{-1}$ and a treated flow of 144.7 $m^3\ s^{-1}$ [8]. Regarding the municipal wastewater collected, 63.73% is treated and of the non-municipal, including industrial wastewater, only 40.1% is treated [9]. Even worse is the case for rural areas whose number of inhabitants (<25,000) make it impossible to implement a treatment system.

Faced with such a situation in the country, alternatives based on nature have been sought to mitigate water pollution. To this respect, constructed wetlands have been an option that has begun to be used as a treatment system in recent decades in a parsimonious manner [10–12]. Thus, the objective of this work was to analyze and discuss the current scenario regarding the use of wetlands as a treatment alternative in Mexico in the last 22 years (2000–2022), as well as types of wetlands, dimensions, and vegetation type used in order to replicate them in sites with similar pollution problems.

1.1. Composition of the Population in Mexico

The United Mexican States, also known as Mexico or the Mexican Republic, is located in North America with a continental surface of 1.964 million km^2 and a political division of 32 states populated by 126, 014, 024 inhabitants (2020), occupying the 11th place among the most populous nations in the world [13]. Despite the fact that the population in Mexico is predominantly urban (>2500 inhabitants; 79%) and the trend since the 1950s is towards a decrease in the percentage of the rural population (<2500 inhabitants; 21%), the proportion of the Mexican population distributed in rural localities is still high (185, 243 localities).

1.2. Context of Constructed Wetlands Eco-Technology in Mexican Regions

Constructed wetlands (CWs) eco-technology or eco-engineering systems are a nature-based solution (NBS), where natural processes are optimized to improve water quality. NBS is defined by the International Union for the Conservation of Nature as "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" [14,15].

CWs are characterized by relatively low establishment costs, robustness, easily operation and maintenance, and a high potential for application in developing countries, particularly in small rural communities. These systems replicate the various wetland processes in a more beneficial way for humans and under controlled environmental conditions [16,17].

Thus, CWs technology seems to be a sustainable solution for the municipal, rural, agricultural and industrial wastewater treatment for decentralized wastewater management, as they are known for their capacity to remove a wide range of pollutants from water through biological, physical, and chemical processes, and produce effluents that can meet the most stringent discharge standards and satisfactory treatment [12,18,19].

According to the water flow, constructed wetlands can be classified as follows: [20–22] (Figure 1):

1. Surface flow or Free Water Surface Constructed Wetlands (FWS)are shallow open waters, where plants are rooted in a soil layer on the bottom; these systems are strongly related to natural wetlands. The technology arose in the 1970s in the United States of America with the ecological engineering of natural wetlands for wastewater treatment.
2. Horizontal Subsurface Flow Constructed Wetlands (HSSFW) are shallow watertight beds, filled with porous media. The media has high hydraulic conductivity that should guarantee the possibility of the development of the attached biofilm. Plants are rooted in the water-saturated beds, and water is loaded in the inlet of the bed; it flows below the surface in a horizontal pattern, in contact with the media and the plant roots, and is collected at the other end of the bed.

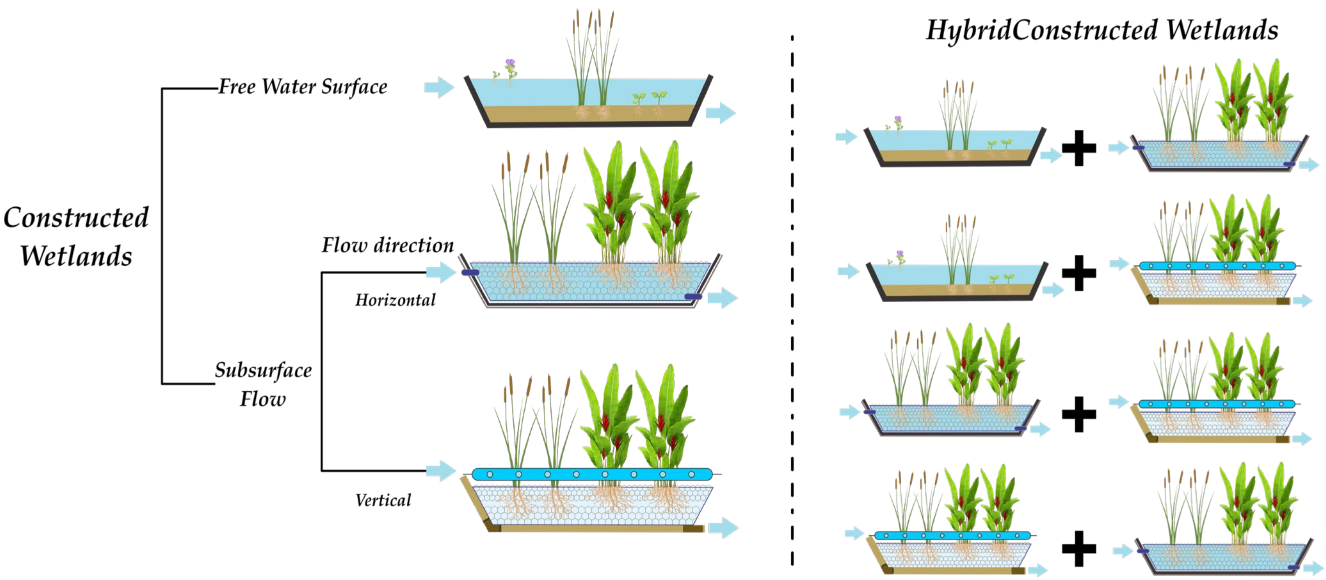

Figure 1. Scheme of constructed wetland types.

This type of wetland was first researched in Germany in 1954 by Dr. Seidel and Dr. Kickuth with the "root method" in 1960 [23], but it was only about 25 years ago that constructed wetland systems were applied to the decentralized wastewater treatment of single houses, institutions, and small to medium-sized settlements.

3. Vertical Subsurface Flow Constructed Wetlands (VSSFW): Typically unsaturated, with a one-meter deep bed filled with a porous medium (sand, gravel, etc.). Water is treated as it trickles down through the media and is in contact with the plant roots. Plants support the vertical drainage process. The water is distributed homogeneously through a pressurized pipe network on the surface of the bed, trickles down, and is collected at the bottom of the bed through perforated drainage pipes.

An important feature of this type is the intermittent hydraulic loading with rest-ing intervals between the single discharges to the vertical bed. This intermittent load-ing provides an effective aeration mechanism because pores of the filter bed refill with oxygen during the intervals. As a result, high nitrification rates can be achieved in the filters. Denitrification can be carried out by recirculating the effluent into the primary treatment unit (septic tank) to eliminate nitrogen

4. Hybrid constructed wetlands: various types of constructed wetlands may be combined in order to achieve higher treatment effects, especially for nitrogen. VSSFW systems have a much greater oxygen transport capacity and, therefore, provide much better conditions for nitrification. However, very limited or no denitrification occurs in VSSFW systems. Generally, studies that use hybrid systems combine VSSFW and HSSFW systems, however, all types of constructed wetlands could be combined.

In hybrid systems, the advantages of various types of wetlands can be combined to complement each other. It is possible to produce an effluent low in biochemical oxygen demand (BOD), which is fully nitrified and partly denitrified, and hence it has much lower total-N concentrations.

A recent study [24] showed that "the research content and methods in the field of constructed-wetland and water-management research are constantly being enriched and deepened, including the research methods frequently used in constructed wetlands in water management and in the research content under concern, the functions and roles of constructed wetlands, the relevant measurement indicators of the purification impact of constructed wetlands on water bodies, and the types of water bodies treated by constructed wetlands in water management".

The lack of use of CW technology lies in the fact that most of the published documents dealing with CW experiences available are experimental and there is a shortage of local design guidelines, along with other issues of scarcity including professional and economy capacity [10,25]. Furthermore, nature-based solutions are not the focus of engineering schools in the region [19].

This review will also be an inventory of constructed wetlands in Mexico for decision makers in the region.

2. Materials and Methods

This review is based on the results provided by the Scopus® (www.scopus.com; accessed on 15 October 2022) database, and the Google Scholar web pages using the keywords "constructed", "wetlands", "artificial-wetlands", "humedales construidos", "humedales artificiales", "treatment wetland", and "phytoremediation", along with "Mexico", and limited to publications between 2000 and 2022.

Considering that the aims of this review were to describe and evaluate the "state-of-the-art" of CWs in the country, all the experiences published in papers were considered, including local reports, abstracts of congress regarding wetlands and non-published information obtained directly from the scientific community PanAmerican CW Network (HUPANAM) 2014–2021 (www.hupanam.com, accessed on 15 October 2022).

A total of 55 scientific papers, 19 papers of reviews, 10 books, 13 studies not published in papers but presented at wetland conferences, 3 local reports published online, and 12 institutional reports regarding the use of CWs in Mexico were found and analyzed.

To present the performance of systems, the gathered and processed information according to Rodríguez-Domínguez et al. [12] includes: location; type of technology; surface area; organic loading rate (based on biological oxygen demand (BOD_5); chemical oxygen demand (COD))., concentration in the influent and the effluent; total nitrogen (TN) or total phosphorous concentration in the influent and the effluent; plant species used.

Description of the CW Size in the Reviewed Experiences

The size of the systems varied according to the scale of the experiment. In this study, the CW size was classified as follows: 1. Laboratory-scale (microcosms): regardless of the nature of the influent wastewaters, experiments developed in the laboratory with less than 0.99 m^2 of surface area. 2. Mesocosm-scale: regardless of influent water origin, experiments carried out in the laboratory or greenhouse, with an effective surface area of 1 to 1.99 m^2. 3. Pilot-scale: experiments settled on the site where wastewater is produced, receiving real wastewater to determine the system's performance 2.0 to 19.99 m^2. 4. Full-scale: experiments that were developed on-site, where the wastewater is generated, and treated, at least, part of the influent water on the site. The surface area ranges from 20 m^2 to unlimited surface

3. Results and Discussions

3.1. Most Used Treatment Systems in Mexico for Wastewater Treatment

The processes designed for the treatment of wastewater are varied; in general, they can be grouped into conventional technologies based on electrical energy and those of ecological treatment, which are environmentally friendly, simple, and low cost systems.

CONAGUA [12] reports the situation of the drinking water, sewerage, and sanitation subsector, and describes the most used treatments of municipal wastewater treatment plants, a total of 2786 wastewater treatment plants in operation (Figure 2). The type of treatment used in more plants is that of stabilization ponds, (827 plants; 29.7%). It is followed by activated sludge (795 plants; 28.5%). In third place is the up flow anaerobic reactor process (RAFA) (364 plants; 13.1%). In fourth place, wetlands stand out as a treatment alternative, of which 230 systems (8.25%) are registered treating from 2 to 190 ls^{-1}, although there are not details regarding their design, construction, and operation.

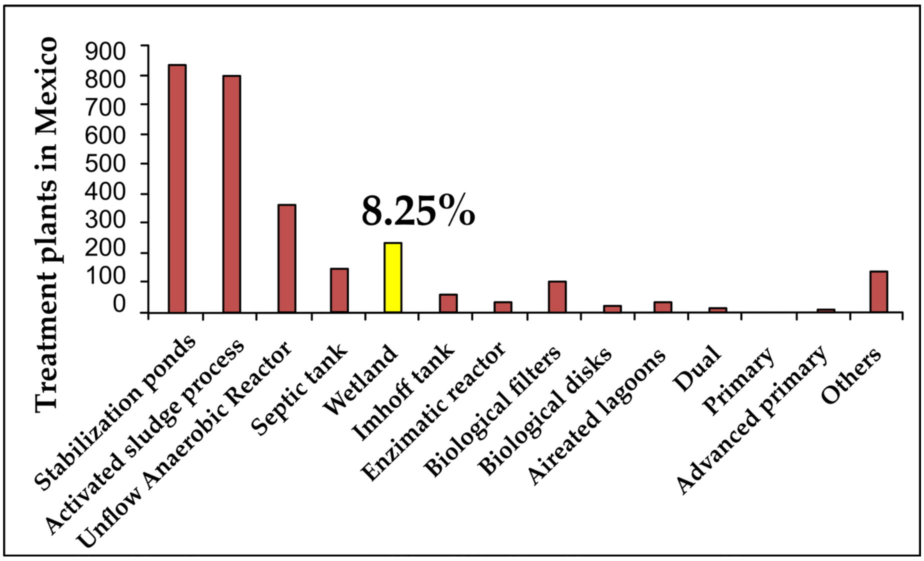

Figure 2. Municipal wastewater treatment plants in Mexico. Elaborated with data from CONAGUA [12].

These systems can work by themselves or combined with other technologies such as electromechanical, stabilization lagoons and anaerobic systems. Some general recommendations on wetland design and wetland pretreatment have already been reported recently [26,27]. In the National Inventory of Treatment Plants (2015) [28], only 68 wetlands were reported as pilot treatment systems, which suggests the importance of their application in the country.

It is highlighted that the 230 CWs reported are located in Sinaloa (116), Oaxaca (40), Tabasco (12), Chihuahua (24), Tlaxcala (7), Hidalgo (6), Jalisco (5), Michoacán de Ocampo (5), Aguascalientes (4), Campeche (3), Morelos (2), Querétaro de Arteaga (2), Guerrero (1), Nayarit (1), Sonora (1), and Zacatecas (1). In Veracruz, 6 CWs are reported combined with RAFA. These are the CWs reported by the different municipalities to CONAGUA, however, not all studies on wetlands in the country are included, especially when they are created by academic and scientific projects, and they are not reported to CONAGUA.

In the case of industrial wastewater treatment plants, CONAGUA [12] reports that there are 3375 plants in operation in the country and they generate a treated flow of 71,638 L per second. However, it is indicated that such inventory does not include treatment plants for hotels, shopping malls, hospitals, housing units, schools, and other establishments that provide services. For this type of wastewater treatment, there are not any reports using CWs.

3.2. Constructed Wetland Systems Used as an Alternative for Wastewater Treatment in Mexico

Conventional wastewater treatment removes pollutants through processes that require large amounts of electricity, with short hydraulic retention times, occupying smaller areas, and being especially advantageous in urban areas where the land has a high commercial value. However, its use brings with it the depletion of non-renewable resources and the corresponding environmental degradation in their processing, as well as the pollution caused by the sludge generated and its higher construction costs, operation, and maintenance [29].

In contrast, ecological treatment systems such as CWs, although they require larger spaces to be installed (3.4–4 m^2/people equivalent) [26,30], they have the advantage of low operation and maintenance costs, relatively simple design, and high ease of operation, which makes them a treatment option mainly for rural communities where priority attention is focused on water distribution and/or sewerage implementation [31,32].

According to the data reviewed, 67 published studies on CWs performance were found and grouped according to their size (Figure 3a), 18% were studies in microcosms or laboratory level [33–44], 30% were CWs in mesocosms size [5,45–63] and, 25% were CWs in Pilot models [64–80], while 27% were CWs operating in full-scale conditions (Table 1). These results revealed the need to migrate towards the use of CWs in full-scale, addressing real pollution problems in both rural and urban areas.

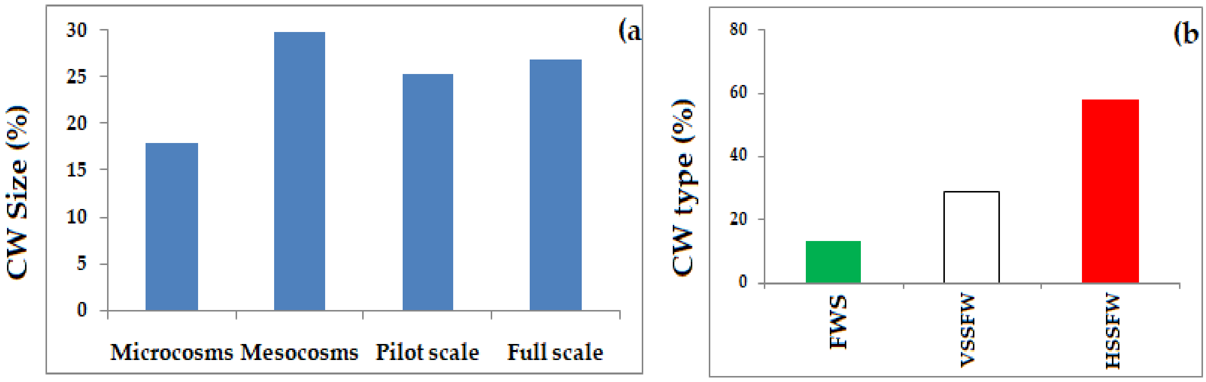

Figure 3. Mexican constructed wetlands according to the size (**a**), and percentage of CWs type (**b**).

Six years ago, 76 published documents on CWs in Mexico were reported, but 33 texts were classified as graduate and postgraduate theses (not counted in this review), only 7 studies were classified as consolidated, operating to treat water in order to solve a water quality problem [10]. This comparative allows to reflect on the increase of initiatives using CW ecotechnology. Some authors punctuate [33–35] the importance of phytotechnologies or bioplants for the reduction of discharge of untreated wastewater like agricultural, industrial tannery, dairy, textile, pulp, paper, etc., in order to minimize the impact on the environment.

On the other hand, when the CWs analyzed were grouped according to the wetland type (Figure 3b), 13% studies used FWS, followed by VSSFW with 29%, and HSSFW with 58%. Generally, the higher use of subsurface CW versus FWS is related with most optimum performance in pollutant removals in organic compounds, with benefit given by the filter material media. Between vertical and horizontal flow of CWs, the first has been the least used as the water needs to be pumped intermittently to program the discharge (electric cost) [37–40].

Advances show that Mexico has begun to gain experience in the design and operation of wetlands and that in the medium term the number of CW treatment plants will increase. Thus, more specific and detailed manuals in Spanish are necessary to promote the use of CWs, as well as greater dissemination at educational levels of these alternatives.

Considering the size of CWs, 18 systems in full scale treating mainly domestic, community, or municipal wastewater were detected (31–11,600 m^2) and described in Table 1. All of the full-scale CWs were operated in horizontal subsurface flow, indicating that such a condition is an important factor to consider in other CW designs.

In all cases, the pollutant removal of COD, BOD_5, TN, and TP was observed, with variations of 50–90%, 60–90%, 30–90%, and 30–70%, respectively (Table 1). Such removals of BOD and COD comply with the established limits by Mexican Norms (NOM-001-SEMARNAT-2021), but compounds of N of P perhaps need coupling of new strategies to improve their elimination. Some studies have reported better nitrogen eliminations adding internal solid source of organic carbon in order to distinguish the role of nitrification-denitrification and Anammox in the nitrogen removal process [38,44,81].

It is important to highlight that some studies with more than 1000 m^2 of CW area reported has been the result of funded projects with civil associations, governments, and community participation. These studies may serve as an example, that is, they could be replicated in other areas. In addition, it is essential to provide the communities with adequate training for the management of CWs in those sites that lack treatment systems. Data regarding dimensions, study sites, pollutant removals, and plant species used can be an option to analyze and to replicate these studies in other sites with wastewater issues.

It is also important to highlight the use of CWs not only in rural areas, but also in urban and peri-urban areas. Some studies have reported the cultural and economic potential when using CWs with ornamental flowering plants, generating cleaning, aesthetics areas, and new ecosystems for birds, butterflies, and other insects [82–86].

A social study regarding the relationship between people and CWs reported that the relationship between the foundation or the projects and the community is successful as the creation and operation of the artificial wetland is the result of trust, reciprocity, and interest between both actors to achieve local development [87]. These data were compared with reviews regarding the use of CWs in other countries [8,18,19,25,85], which shows the similitude in removal of pollutants but with differences in the vegetation used.

Table 1. Full-scale constructed wetlands in Mexico.

Study Site	Wastewater Treated (CW Type)	Plants Used	CW Area (m^2)	Pollutant Removal (%)	Reference
Erongarícuaro, Michoacán	Municipal (HSSFW)	*Phragmites communis*, *Typha latifolia*	11,600	BOD_5: 70–90 COD: 70–90	[88]
Santa Fe de la Laguna, Quiroga, Michoacán	Municipal (HSSFW)	*Phragmites australis*, *Typha latifolia*	8800	BOD_5: 94–98 COD: 91–93 TS: 97–97 TN: 56–88	[30,89]
Nautla, Veracruz	community (HSSFW)	*Canna hybrids*, *Alpinia purpurata*, *Cyperus papyrus*	2500	COD: 80–90	[90]
Cucuchucho, Tzintzuntzan, Michoacán	Community (HSSFW)	*Phragmites australis*, *Typha latifolia* y *Zantedeschia aethiopica*	2000	COD: 89 TN: 80 TP: 74	[89,91]
Acamixtla, Taxco de Alarcón, Guerrero.	Municipal	*Phragmites australis.*, *Typha latifolia.*, *Cyperus papyrus*	~2500	DBO_5: 70–95 DQO: 70–90	[92]
San Juán de Aragón, Gustavo A. Madero. México	Eutrophic lake (HSSFW)	*Phragmites australis.*, *Equisetum hyemale* y *Cyperus papyrus*	1613	BOD_5: 88 TN: 72 TP: 50	[93]
Argovia, Tapachula, Chiapas.	Coffe wash industry (HSSFW)	*Saccharum* spp., *Panicum máximum.*, *Heliconia psittacorum.*, *Vetiveria zizanoides* y *Clorophytum conmutatum*	300	COD: 91 Coliforms: 93	[94]
UAM-Azcapotzalco. Mexico City	Municipal (HSSFW)	*Phragmites australis.*, *Typha latifolia*	200	BOD: 80	[95]
Area "Instituto Tecnológico de Boca del Río, Veracruz"	University	*Alpinia purpurata.*, *Ruellia brottoniana.*, *Canna hybrids.*, *Cyperus papyrus.*, *Heliconia pisittacorum.*, *Pennisetum setaceumy* and others ND.	157	NT: >70% PT: >70% DQO: 15%	[96]
Felipe Carrillo Puerto, Tapachula, Chiapas.	domestic (HSSFW)	*Heliconia psittacorum.*, Alpinia purpurata, *Typha domingensis.*	110	COD: 64 BOD: 50 TN: 30–39 TP: 40	[97]

Table 1. *Cont.*

Study Site	Wastewater Treated (CW Type)	Plants Used	CW Area (m^2)	Pollutant Removal (%)	Reference
Chapala, Jalisco, México	Municipal (HSSFW)	*Canna hybrids* y *Strelitzia reginae*	70	COD: 86 TN: 30–33 TP: 44	[98]
Pinoltepec, Emiliano Zapata, Veracruz	Municipal (HSSFW)	*Typha sp., Zantedeschia aethiopica., Hedychium coronarium. Cyperus papyrus*	60	TN: 47 TP: 33 COD: 67 TS: 67 N-NH_3: 27	[5,49]
Pastorías, Actopan, Veracruz	community sewage (HSSFW)	*Typha sp., Canna hybrids*	60	COD: 92.5 N-NH_4: 80.5 TSS: 80 TP: 85	[99]
Area UAM Xochimilco, México.	Municipal (HSSFW)	*Arundo donax, Medicago sativa* y *Zandechia aethiopica*	55	COD: 92 N-NH_4: 85 P-PO_4: 80	[100]
Akumal, Quintana Roo	Tourist area (HSSFW)	*Alocasia* spp., Typha sp., Matteuccia struthiopteris., *Cordia sebestena., Carex* sp., *Cocos nucifera., Cassia* spp. *Ixora, Hymenocallis littoralis, Nerium, Dracaena* spp., *Acalypha* spp., *Cyperus ligularis., banana, coconut and Carica papaya., Acrostichum danaefolium., Tradescantia* sp., *Crinum* sp., *Musa* sp., *Epipremnum aureum., Chrysalidocarpus lutescens.canna* spp., *Thrinax radiata. Philodendron* spp. *Acalypha wilkesiana Sansivieria, Hibiscus* spp. *Dieffenbachia Caladium* spp. *Dracaena* spp. *Vinca rosea, Hedera helix Cestrum nocturnum, Ficus* spp, *Aloe vera Heliconia, Ravenala madagascariensis Unidentified Tree/Shrub Chamae- dorea (palm)*	50.41(average size of 30 CW)	N-NH_4: 15–97 P-PO_4: 7–92 COD: 68–85	[101–103]
Xalapa, Veracruz	Wastewater from apartments (HSSFW)	*Hedychium coronarium, Strelitzia reginae, Zantedeschia aethiopica, Lilium* sp., *Cyperus papyrus, Heliconia* sp.	48	P-PO_4: 44–62 N-NH_4: 68–98 DBO_5: 70–80	[104]
Santa María Nativitas, Texcoco, Mexico	Municipal (HSSFW)	*Calla lily., Zantedeschia aethiopica*	31.6	COD: 80 TSS: 25 TN: 63 N-NH_4: 26	[105]
Area university "Instituto Tecnológico de Xalapa"	University	*Cyperrus papyrus, Heliconia* sp.	196	Not described	[106]

3.3. Plants Used in Mexican CW Experiences

The Mexican region lies in the tropical and semitropical zone, and therefore the variety of plants that can be used is broader than in temperate or boreal zones. Warm temperatures, extensive radiation hours, wide diversity of plants and available land in Mexico, make it an important area for the use of CWs. This section presents the result of the reviewed information regarding the vegetation reported in Mexican CWs (Table 2). From the reviewed documents, it was possible to obtain a list of 78 different plant species, used in diverse conditions of density, cultures, and experiments in CWs, which represents 68.4% of the species reported in CWs in Latin America and the Caribbean [8].

The plants that grow in CWs have several properties related to the water treatment process, which makes them an essential component of the design [85,107–109]: (a) macrophytes are the main source of oxygen in CWs through a process that occurs in the root zone "radial oxygen loss", (b) the roots of plants are the site where the microorganisms have a source of microbial attachment and release exudates, an excretion of carbon that contributes to the denitrification process, (c) other physical effects in plant tissue in water include: reduction in the velocity of water flow, promotion of sedimentation, decreased resuspension, and uptake of nutrients, (d) hence, roots and rhizomes in the sediment stimulate the stabilizing of the sediment surface, less erosion, nutrient absorption, prevention of medium clogging (in subsurface conditions), and improved hydraulic conductivity.

Some studies evaluate the differences in the performance between the use of monocultures or polycultures, the capacity of certain species to remove specific pollutants according to the position, water or filter media type, differences between environmental conditions associated with plant response and biomass production, or comparing vegetation of natural wetlands to ornamental terrestrial plants adapted to CWs conditions. The most commonly used plants in CWs in the world have been the *Typha* (*latifolia, angustifolia, domingensis, orientalis, and glauca*), *Scirpus* (e.g., *lacustris, validus, californicus, and acutus*) and *Phragmites* (*communis, australis*) spp. [85,109].

In Mexico, studies have focused on the use of upland ornamental plants in CWs in the last decade (Table 2), with a focus on the commercialization of flowers, and the aesthetic of constructed wetlands with pollutant removal efficiency similar to CWs with hydrophytes. In this review, 23 experiences used *Typha spp.*, similar to the ornamental plant *Zantedeschia aethiopica* with 19 experiences. Furthermore, typical plant species as *Cyperus papyrus* (13 experiences) or *Phragmites* sp. (11 experiences) are being replaced by flowering ornamental plants as *Zantedeschia aethiopica* (19 experiences), *Canna* family (16 experiencies), *Hedychium coronarium* (8 experiences), *Alpinia purpurata* (8 experiences), *Strelitzia reginae* (8 experiences), Heliconia Family (8 experiences), *Anthurium andreanum* (6 experiences) or *Iris* sp. (5 experiences).

On the other hand, some species were reported only in one, two, or three cases (Table 2), for example, *Lillium* sp., *Iris sibirica*, *Zingiber spectabile*, *Agapanthus africanus* or the multiple-species survey conducted by Sinha et al. [101] for 30 subsurface CWs. Some of the plant species that were used are novel as they have never been reported before as plants used for CWs. Table 2 shows all the reported species and the frequency of each one in the experiences reviewed.

Table 2. Plant species reported in Mexican CWs.

Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference	Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference
Typha sp. *(domingensis, latifolia)*	Tules, tifas, aneas	23		[5,30,33–37, 39,41,45,48–51,62,63,68, 76,80,94,95, 101,110]	*Lilium* sp.	Azucena	2		[5,104]
Phragmites (communis, australis)	Carrizos	11		[30,34,36,47, 62,68,88,91, 93,95,105]	*Heliconia latispatha*	Heliconia pinza de langosta	4		[58,101, 104,106]
Cyperus papyrus	Papiros	13		[5,39,49,68, 70,72,75,90, 93,101–103,106]	*Heliconia stricta*	Jamaica enana	1		[97]
Cyperus alternifolius	Sombrillas	2		[5,49]	*Heliconia psittacorum*	avecilla, pico de loro	3		[75,94,97]
Zantedeschia aethiopica	Alcatracez	19		[5,37,40,46, 49,51,53,54, 57,64,66,75, 91,100,104, 105,111–113]	*Alpinia purpurata*	Jengibre rojo	8		[51,60,65, 73,90,97, 99,104]

Table 2. *Cont.*

Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference	Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference
Anthurium andreanum	Anturios	6		[5,46,53,64,66,104]	*Strelitzia reginae*	Ave de paraíso	8		[40,44,46,66,75,98,104,112]
Hedychium coronarium	Jengibre blanco, huele de noche	8		[5,64,65,71–73,75,104]	*Agapanthus africanus*	Agapanto, lirio africano	1		[66]
Lilium sp.	Azucenas	2		[5,104]	*Pontederia sagittata*	Espiga de agua	3		[52,69,70]
Heliconia latispatha	Heliconia pinza de langosta	4		[58,101,104,108]	*Iris germánica*	Lirio común	1		[59]
Heliconia stricta	Jamaica enana	1		[97]	*Iris sibirica*	Lirio de Siberia	4		[37–39,110]
Iris japonica	Lirio persa	1		[75]	*Arundo donax*	Caña de castilla	1		[100]
Canna hybrids	Banderas	9		[46,57,59,64,65,74,90,98,110]	*Medicago sativa*	Alfalfa	1		[102]
Canna lily	platanillo	1		[105]	*Zingiber spectabile*	Maracas	1		[99]
Canna indica	Banderillas	5		[40,52,60,72,101]	*Eleocharis macrostachya*	Junquillo	1		[67]
Hemerocallis dumortieri	Lirio de día	1		[46]	*Schoenoplectus americanu*	Junco	1		[67]

Table 2. *Cont.*

Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference	Scientific Name	Typical Name (Spanish)	*n*	Plant (Photo)	Reference
Spathiphyllum blandum	Cala de francia, lirio de la paz	2		[55,56]	*Sagittaria lancifolia*	Cola de golondrina	1		[63]
Spathiphyllum wallisii	Cuna de moisés	6		[52–54,60,71,75]	*Alocasia* sp.	Hoja elegante	2		[75,101]
Lavandula sp.	Lavanda	1		[54]	*Scirpus* sp.	Juncos	1		[76]
Chlorophytum (comosum, conmutatum)	Cinta, lazo	2		[61,94]	*Eichhornia crassipes*	Jacinto de agua	2		[77,79]
Vetiveria zizanoides	Pasto vetiver	1		[94]	*Thalia geniculata*	Platanillo, hoja de lengua	2		[34,78]
Saccharum spp.	Caña	1		[94]	*Paspalum paniculatum*	Zacatón	1		[78]
Panicum máximum.,	Pasto guineo / privilegio	1		[94]	*Eleocharis macrostachya*	Cabeza larga	1		[43]
Equisetum hyemale	Cola caballo	1		[93]	*Eleocharis interstincta*	Zacate laguna	1		[80]
Matteuccia struthiopteris., *Cordia sebestena.*, Carex sp., *Cocos nucifera.*, *Hymenocallis littoralis.*, *Dracaena* spp., *Acalypha* spp., *Cyperus ligularis.*, banana., *Carica papaya.*, *Acrostichum danaefolium.*, *Tradescantia* sp., *Crinum* sp., *Ixora* sp., *Musa* sp., *Epipremnum aureum.*, *Chrysalidocarpus lutescens.*, *Thrinax radiata.*, *Philodendron* spp. *Acalypha wilkesiana.*, *Sansivieria hibiscus.*, *Dieffenbachia Caladium* spp., *Dracaena* spp. *Vinca rosea.*, *Hedera helix.*, *Cestrum nocturnum.*, *Nerium* spp (oleander). *Ficus* spp. *Cassia* spp. (notebook). *Aloe vera.*, *Ravenala madagascariensis.*									[101]

n = number of experiences or studies where the specie was used.

This review shows the feasibility to produce flowers in treatment wetlands. Future studies conducted to evaluate the health of the plants to assess if the plants are suffering stress from the flooding with wastewater conditions of the wetlands are necessary. A report from 2008 with fluorescence spectra and the calculated ratio (F690 nm/F740 nm) indicated that *Zantedeschia aethiopica* in HSSFW were healthier than those in a VSSFW. The physical measurements led to the same conclusion. The results suggest that the plants in the VSSFW were stressed because less water was available for them under the cyclic flooding and draining characteristic in this type of wetland. It is also possible that the use of non-stratified media was influenced by reducing the water–root contact time [113].

On the other hand, other studies in Mexico have reported the coupling of wetlands with other systems to clean wastewater from coffee or pork processing [114,115], where the authors describe in an accessible way the stages of construction, operation, and maintenance of artificial wetlands. Such options are also an example of collaborative work between academia and government institutions.

4. Conclusions

In terms of wastewater treatment in Mexico, there are eco-friendly alternatives such as constructed wetlands, which in recent decades have become an important option to avoid contamination in Mexico. In this review, 67 studies were found which support the previous claim. When these studies were grouped according to the operation size, 27% subsurface CWs were detected in full-scale level. Such biological systems are already among the most used systems in the country, and they favor the elimination of pollutants through a filter medium, microorganisms, and vegetation. Likewise, 76 plant species have been evaluated within the Mexican CWs, highlighting some ornamental plants such as: *Zantedeschia a.*, *Canna* spp., *Hedychium* c., or species of the genus Anthurium/Heliconias, which in addition to functioning as phytoremediators, they are an alternative for economic use as they are commercial plants, mainly for rural communities, where they hardly ever have the option of implementing conventional water treatment systems and where economic remuneration or jobs are scarce.

The study revealed that Mexican CWs use commonly ornamental flowering plants, such plant species can influence people's interest when using CWs, as well as the impact of the technology either by floral appearance or integration in the place of establishment (floral planters).

Horizontal flow subsurface artificial wetlands have turned out to be an option in Mexico to solve real problems of water contamination, therefore their replication can be a pertinent need in all those places with a lack of wastewater treatment systems. Important eliminations of COD and BOD were detected, which makes them a sustainable alternative for wastewater treatment, mainly in rural communities where the dispersion of housing, high installation, and operation costs make it difficult to set up conventional treatment plants.

With this review regarding CWs in Mexico, it is demonstrated how this country is migrating to the use of nature-based solutions, still analyzing the vicissitudes of the use of such eco-technology.

In this task, it will be necessary to coordinate efforts to promote the transfer of technology and dissemination of these types of projects not only on the part of the government and society, but also the support of research centers, academia, private sector, and society as a whole, creating awareness about the environment for the benefit of present and future generations. Thus, new public policies to normalize the use of CWs as treatment systems and nature-based solutions are necessary.

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