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Review

Constructed Wetlands in Latin America and the Caribbean: A Review of Experiences during the Last Decade

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Abstract: The review aims to report the state-of-the-art constructed wetlands (CW) in the Latin America and Caribbean (LAC) region not limited to national and local conditions. The aim is with a broader view, to bring updated and sufficient information, to facilitate the use of the CW technology in the different countries of LAC. Thus, 520 experiences extracted from the 169 reviewed documents in 20 countries were analyzed. According to the data, horizontal subsurface flow wetlands are the most reported CW in the region (62%), the second most common CW technology in the region is free water surface CW (17%), then vertical flow systems (9%), followed by intensified constructed wetlands (8%), and finally French systems (4%). The performance for nutrient removal is analyzed, finding that the mean of Chemical Oxygen Demand (COD), Total Nitrogen (TN), and Total Phosphorous (TP) removal efficiencies varies from 65% to 83%, 55% to 72%, and 30% to 84%, respectively. The results suggest a generally good performance for COD and TN removal, but a low performance for TP removal. Regarding plant species used for CWs, 114 different plant species were reported, being until now the most extensive report about plant species used in CWs in the LAC region.

Keywords: constructed wetlands; Latin America and Caribbean; nature-based solutions; wastewater treatment; state-of-the-art

1. Introduction

1.1. Latin American and Caribbean Wastewater Context

The term Latin America and the Caribbean region (LAC) refers to 48 countries; 14 in continental South America, 8 in Central America, and 26 islands in the Caribbean [1] located in the American Continent. The region has a surface of approx. 21,111,500 km^2 (~14% of the world surface), with an estimated population of 650 million inhabitants and is the most urbanized region in the world, producing in more than 30 km^3 of wastewater each year the urban settlements [2]. UNEP (2016) [3] estimates the pollution in rivers and freshwater in the region has increased, and since 1990, up to one-third of the rivers, and one-seventh of the length of them are receiving untreated wastewater.

In the region, social status and wealth correlate with sanitization level and wastewater treatment coverage. The coverage numbers vary from different authors. The OMS/UNICEF (2016) [4] has estimated that the level of enhanced sanitization in the region reaches 88% in the urban areas and 64%

in the rural areas (enhanced sanitization systems are defined as no human contact with human excreta, i.e., toilet connected to the sewage system or septic tank, or a latrine, are examples of such systems); with some countries such as Nicaragua, El Salvador, Panama, Bolivia, and Haiti, having only 25% of enhanced sanitization coverage [5]. The FAO (2017) [2] estimates that during the last two decades, due to the population in the region growing by 160% while wastewater treatment coverage has not expanded at the same rate, around 60% of the wastewater is discharged to nature without receiving any previous treatment. For other authors like Hernández-Padilla et al. (2017) [6], only 20% of the municipal wastewater of the LAC region receives treatment before being discharged. Nonetheless, all the authors agree about the fact that there is low coverage for wastewater treatment and sanitization in the LAC region.

Some of the LAC region's countries reported high coverage of wastewater treatment, however, in many cases the systems do not work correctly, or they are not working at all, mostly as a consequence of the high operational and maintenance cost. For example, Mexico reported one of the most extensive wastewater coverages and one of the largest wastewater treatment infrastructures in the LAC region with around 3500 systems; nonetheless, around 700 of these wastewater treatment plants of the country (21%) have been reported as "not operational" [7].

1.2. Context of Constructed Wetlands Technology in the LAC Region

Constructed wetlands (CW) technology is a nature-based solution, where natural processes are optimized to improve water quality. CWs are characterized by relatively low establishment costs, robustness, easily operated and maintained, and a high potential for application in developing countries, particularly by small rural communities [8]. Rural communities are defined as those agglomerations having less than 2500 inhabitants, primarily dispersed in the territory, a distance of at least five kilometers from cities, but in some cases isolated and being more than 2.5 km from the nearest road [9]. Furthermore, the existing environmental conditions in some of the LAC region (warm temperatures, extensive light radiation periods, and available land) can enhance CWs performance [10]. Additionally, according to Arias et al. (2009) [11], CWs are considered the best investment in regards to performance for (i.e., treatment indicators), and value return (i.e., energy to lifetime price). Moreover, CWs are also an attractive choice for mitigating climate change and resource consumption associated with wastewater treatment [12]. Thus, CW technology seems to be an adequate, affordable and sustainable solution for the wastewater treatment needs in LAC considering that the CW technology is known for its capacity for removing a wide range of pollutants from waters and produce effluents that can meet the most stringent discharge standards and satisfactory treatment, if correctly designed and operated [13–16].

However, in the LAC region, there seems to be a gap between the current use of the CW technology and other wastewater treatment technologies. CW solutions seem to be trailing behind compared to other technologies [17]. Noyola et al. (2012) [18], estimated that CW in LAC are only used to treat 0.22% of the total wastewater flow in the region, while stabilization ponds, activated sludge, and the up-flow anaerobic sludge blanket (UASB) reactors, provide treatment to around 81% of the total flow. This suggests that the use of CW technology, in the LAC region has been slow and not widespread.

According to García-García et al. (2016) [19], the lack of use of CW technology lies in the fact that most of the published documents dealing with LAC CW experiences available are experimental and there is a shortage of local design guidelines, combined with the lack of training and knowledge of stakeholders and decision-makers. Furthermore, nature-based solutions are not the focus of engineering schools in the region [20].

This review aims to bring an updated inventory and a state-of-the-art report of CW in the region, not only limited to national and local conditions, but with a broader view, and providing information regarding location, characteristics and performance of the system so the information becomes a reference tool in the use of the technology for stakeholders in the region.

2. Materials and Methods

2.1. Selected Countries for the Study

The selected countries for the review are those considered by the United Nations (2018) [1] as part of the Caribbean and Central- and South-American region:

Anguilla, Belize, Argentina, Antigua and Barbuda, Costa Rica, Bolivia, Aruba, El Salvador, Brazil, Bahamas, Guatemala, Chile, Barbados, Honduras, Colombia, British Virgin Islands, Mexico, Ecuador, Caribbean Netherlands, Nicaragua, Falkland Islands (Malvinas), Cayman Islands, Panama, French Guiana, Cuba, Guyana, Curacao, Paraguay, Dominica, Peru, Dominican Republic, Suriname, Grenada, Uruguay, Guadeloupe, Venezuela (Bolivarian Rep. of), Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Saint Maarten (Dutch part), Trinidad and Tobago, Turks and Caicos Islands, and the United States Virgin Islands.

2.2. Bibliometric Report

The bibliometric data analyzed aim to present an overview of the scientific productivity in LAC, establishing a standardized criterion to build a database to produce reliable information regarding scientific activity in the region. However, the bibliometric report cannot be assumed as an absolute report of productivity for each country or region reported because the search was done based on peer-reviewed scientific literature that can be limited by factors such as language, reach, and costs. The report is based on the results provided by the Scopus® database, through the web page www.scopus.com using keywords "constructed", "wetlands", "reed bed", "bio-garden", "humedales construidos", "root method", and "phytoremediation" combined with the "name" of each country, and limited to publications between 2009 and 2019. Using a peer-reviewed database can guarantee the quality of the research.

2.3. Paper Review Report

This section aims to describe and evaluate the "state-of-the-art" constructed wetlands in the region. Nevertheless, the review is not a census and does not pretend to report 100% of the scientific production in the LAC region (not all the experiences are peer-reviewed published). However, the CWs' information available was analyzed including local reports and non-published information obtained directly from the scientific community in the LAC's members of the Pan-American CW Network (HUPANAM).

A total of 169 documents were found and analyzed, including scientific papers, books, and local reports, found in media, such as internet, databases, and direct contact with local researchers. To present the performance of systems, the gathered and processed information includes:

- Location;
- Design capacity of the whole system;
- Operational status;
- Type of technology;
- Location;
- Surface area;
- Organic Loading Rate (based on BOD_5 or COD);
- Chemical Oxygen Demand (COD) concentration in the influent and the effluent;
- Total Nitrogen (TN) concentration in the influent and the effluent;
- Total Phosphorus (TP) concentration in the influent and the effluent;
- Plant species used.

The criteria used to identify and evaluate the experiences from the 169 documents was based on the following statements:

- If the performance was evaluated during different seasons or periods, the review considered one different experience per each season or period;
- If the performance was evaluated under different operational conditions, the review considered one different experience per operational condition;
- If the reviewed document considered replicates to evaluate the performance of a CW, this review was considered only as one experience. The mean between the values reported for the experiment and replicates was adopted as the value for the experience;
- If the reviewed document evaluated the performance of a CW using different plants for the same system, each experiment with different plant species was considered as one;
- If the reviewed document was considered to evaluate the performance of non-planted experiments (without vegetation), they are not wetlands and were not considered in this review.

2.3.1. Description of the CW Classification in the Reviewed Experiences

Kadlec and Wallace (2009) [21] have classified CW in three main categories:

1. Free Water Surface Constructed Wetland (FWS): shallow open waters, where plants are rooted in a soil layer on the bottom;
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, 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.
3. Vertical Flow Constructed Wetlands (VF): Typically unsaturated, with a one-meter deep bed filled with a porous media (sand, gravel, etc.) and planted, water is treated as it trickles down through the media and in contact with the plant roots. 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 by perforated drainage pipes.

However, as technology developed, this classification seems to be insufficient. Fonder and Headley (2008) [22] published a taxonomic classification of CW that includes all the different classifications that could apply to any CW. In the present document, two additional denominations will be used:

4. Intensified Constructed Wetlands (ICW): are systems modified to improve performance by increasing energy input, using reactive media, modifying the operation schemes, combining CW types (VF + HSSFW, VF + FWS, FES + HSSFW), or even using specific bacteria. Among the intensification methods are: draw in air to maintain high oxygen transfer rates, the use of reactive media to improve performance, modifying the operation by loading schemes, or the use of electroactive bacteria (METlands).
5. French system: is a variation of the VF technology designed to treat raw wastewater directly. According to Millot et al., (2016) [23], the classical "French CW systems" typically consist of two vertical-flow constructed wetland (VFs) stages, with at least three initial VF beds, that are fed sequentially and with resting periods of 3.5 to 7 days, in between each bed loadings followed by a second stage where the number of beds and type can change.

2.3.2. Description of the CW Size in the Reviewed Experiences

The size of the systems varied according to the scale of the experiment, established as follows:

1. Laboratory-scale: regardless of the nature of the influent wastewaters, experiments developed in the laboratory with less than 0.2 m^2 of surface area.
2. Mesocosm-scale: regardless of influent water origin, experiments carried out in the laboratory or a greenhouse, with an effective surface area of 0.2 to 2.0 m^2.

3. Pilot-scale: regardless of the size, experiments settled on the site where wastewater is produced, receiving real wastewater to determine the system's performance.
4. Full-scale: experiments that are developed on-site, where the wastewater is generated, and treats, at least, part of the influent water on the site. The surface area ranges from 2.0 m^2 to unlimited surface.

3. Results

Figure 1a shows the number of scientific articles available in the Scopus database related to scientific articles dealing with constructed wetlands (or the other given names). The figure shows the comparison between CW publications among LAC and other countries between 2009 and 2019. The research activity does not show considerable growth in the region during the last decade, reporting a production between 18 to 23 articles per year since 2009.

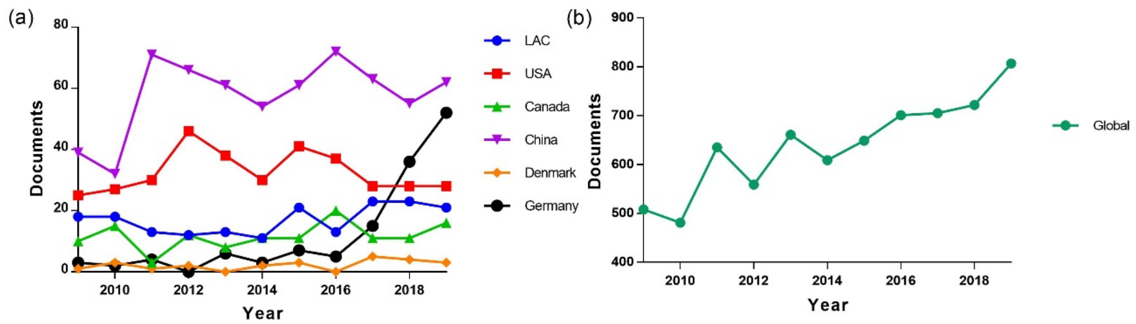

Figure 1. (**a**) CW publications comparison among LAC and selected countries between 2009 and 2019, (**b**) global tendency of scientific production related to CW from 2009 to 2019. (Data modified from Scopus® [24]).

According to the data gathered, scientific production dealing with CW seems to be stable in the analyzed countries (only Germany shows a growing tendency). However, this tendency is different from the global tendency (Figure 1b), due to the research published from countries that are not considered in Figure 1a.

3.1. Bibliometric Report

3.2. Results of the Paper Review

From the 169 reviewed documents it was possible to extract 520 experiences reported in the region. Around 80% of the reviewed documents refer to experiences in four countries: namely Brazil 37%), Argentina (19%), Mexico (13%), and Colombia (12%). Nonetheless, another 20 of the countries in the region (40%) reported at least one experience. Table 1 summarizes the publications by country, Figure 2 shows a map related with the number of publication by country.

Table 1. Shows the different documents found with the corresponding references for each country for the analyzed period.

Country	Reviewed Documents (Titles Can Be Found in the Reference List)
Argentina	[25–59]
Bahamas	[60]
Bolivia	[61,62]
Brazil	[10,63–115]
Chile	[12,116–125]
Colombia	[14,126–143]
Costa Rica	[144–150]
Cuba	[151–153]
El Salvador	[154]
Guatemala	[155]
French Guyana	[156,157]
Honduras	[158]
Jamaica	[159]
Mexico	[19,160–181]
Nicaragua	[182,183]
Peru	[178]
Puerto Rico	[60]
Surinam	[184]
Uruguay	[185]

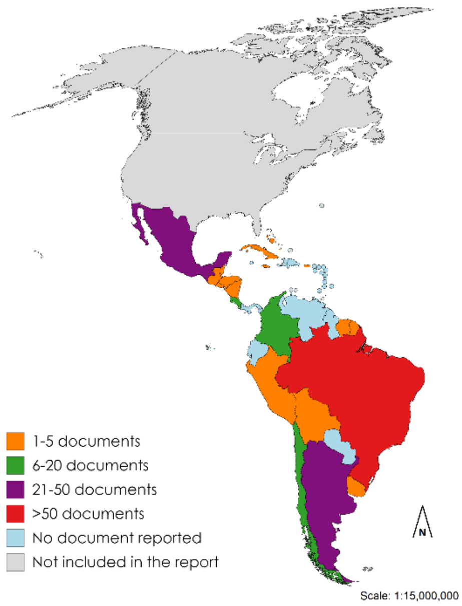

Figure 2. The number of reviewed documents per country.

3.2.1. Most Productive in Terms of Publications Regarding CWs Countries in the LAC Region

Brazil

According to the results of this review Brazilian scientists are the most prolific authors within the region, with around 32% of the total production in the region and a contribution of 53 documents to this review. The information produced by Brazilian scientists dealing with CW covers a wide spectrum of topics, including papers describing the state-of-the-art constructed wetlands in the country [10,110], life-cycle analysis contributions [63], hydraulics [112], removal of recalcitrant pollutants [115], and other topics related to the performance of CWs operating under different conditions. Brazil is the only country that has reported research on the five different technologies analyzed. The largest system reported in the country is a 3144 m^2 VF system, and it is located in the city of Palhoça, in the Santa Catarina state.

Argentina

Argentina is the country with the second-highest scientific publication production. The results of some of the Argentinian research have been important for the LAC region, and have been considered in global reports [186] as representative of the work done in the region, specifically related to the industrial wastewater management. One of the studied systems, located in the city of Santa Fe, has been reported in 12 of the 33 reviewed papers for the country (36% of the experiences in the country), becoming one of the most studied systems in the region. Regarding the studied technologies, Argentina's CWs are mainly FWS. Only one full-size system was reported dealing with HSSFW technology [47], and two documents analyzed Hybrid Systems [39,41]. VF technology was analyzed in one document [40]. Regarding ICW, Argentinian scientists have studied the new electro-active bacteria-based technology, METland technology [58]. No French system technology report was found in Argentina.

Mexico

Out of the scientific experiences reviewed, including the evaluation of the performance of CW in many different conditions, two documents published by the Mexican Government are relevant: (1) The National Inventory of Municipal potabilization and wastewater treatment plants [7]. The first governmental document in the LAC region that reports the number and the operational status of wastewater treatment plants based on the CW technology for the whole country. From the 3517 wastewater treatment systems installed in Mexico (including all the technologies and systems reported for the country), 209 use CW technology. From all the wastewater systems reported, 735 (21%) had the "not active" status. At the same time, only 21 (10%) of the 209 CW-based systems have this status. The hydraulic-load installed capacity reported for the CW-based systems is 1.7 m^3/s that represents 0.4% of the wastewater produced in Mexico—Mexico produces around 443 m^3/s of wastewater [187]. The largest CW-based system treats 700 Lps (60,480 m^3/d); nonetheless, 13 of the reported systems had a capacity bigger than 10 Lps (864 m^3/d). The State (province) with the larger number of wastewater treatment systems based on CW in Mexico is Sinaloa with 112 systems; (2) the national guidelines for designing wastewater treatment plants based on CW [188]. The only governmental official guidelines for the CW design available in the LAC region. The book is based on the HSSFW and FWS technologies and includes specific recommendations in the Mexican context, including local building materials and plant species to be used.

Colombia

Colombia is the fourth most prolific country in CW research in the LAC region. The Colombian scientific work has focused mainly on HSFFW and VF technology, being the country in the region with the highest percentage of research systems using VF technology (around 22% of the reviewed systems). In Colombia, the CW technology has been tested, besides domestic and industrial wastewaters, for the treatment of water polluted with pesticides drained from agricultural land [127], heavy metal coming from mining activities [133], and landfill leachate [136,138]. The largest system reported in Colombia found in the review is a 6000 m^2 HSSFW operating in the city of Rionegro, Antioquia, treating wastewater from a chocolate producing factory [134]. Colombia published national technical regulations in 2017 [189] including the "artificial wetland" technology, however, the document does not go in to technical details, and could be considered wrong or obsolete from the described reference parameters and assumptions.

3.2.2. CW Technologies Reviewed

The total number of reported experiences in the LAC region for the review was 520, however, the 209 systems reported in the National Inventory of Municipal potabilization and wastewater treatment plants of Mexico [7] were not taken into consideration because the documents do not provide sufficient data (performance information, layout of the systems such as influent and effluent, nutrient concentration, hydraulic retention time, surface area, plant species, organic load rate, nutrient and pollutant removal efficiencies) to compare with the other 311 experiences extracted from the rest of the reviewed documents. Table 2 shows the number of experiences reported per each technology in the LAC region.

Table 2. CWs technologies reported in the LAC region.

Type of Technology	Number of Experiences Reported (n)	Percentage
HSSFW	193	62%
FWS	54	17%
VF	27	9%
ICW	24	8%
French System	13	4%

From the 311 analyzed experiences, 193 were HSSFW (62%); the most reported and studied CW technology in the LAC region. The second most common CW technology in the region was FWS with 54 experiences (17%). VF systems reported 27 experiences (9%), ICW reported 24 experiences (8%), and the French system reported 13 experiences (4%).

HSSFW

HSSFW technology is, by far, the most studied technology in the LAC region. The performance of the technology has been evaluated under different conditions and for different pollutants. The HSSFW has been evaluated regarding the performance for sewage and domestic wastewater, but also for other kinds of wastewater like that from swine [78,100,119,181], the coffee [67] and chocolate industry [134], landfill leachate [42,138], rejection of reverse osmosis processes [59], and greywater [104,146]. The influence of the plants in the general performance of the CWs has been evaluated in many of the studies, but also the use of the plants as an ornamental element [122]. The role of the filling media and its capacity for phosphorus removal [116], and the removal of elements [165] has been reported. Some of the studies tackle hydraulics [71,111,128], clogging phenomena [112], kinetics for nutrient removal [47] and flow patterns [143]. Some studies deal with climatic effects, including systems in super-arid areas [125], and in tropical regions [14,130,140,144]. Some studies have focused on the effect and performance of HSSFW combined with other wastewater technologies, which have also been reported [85,107,108]. Finally, life cycle analysis [63] and economic performance was assessed. All in all, the HSSFW has been broadly researched and the results are available.

FWS

FWSs are probably the oldest CW technology that has been tested and used around the world [190]—Brix [191] states that the first system was studied during the nineteen seventies decade. This CW technology is the most spread full-scale CW technology in the LAC region, being studied to evaluate the potential of retention of heavy metals [54], light metals [38], and organic pollutants [175]. Their role is valuable in the restoration of ecosystem processes [155], but problems related to a high nutrient release, hosting breeding grounds to vectors such mosquitos, and the potential for algae growth hinders the use for wastewater treatment [158].

VF

VF technology is widespread in European countries; nonetheless, in the LAC region, it does not seem to be widespread with a lack of implementation when compared with the HSSFW or the FWS technology. From the 168 reviewed documents, only Argentina, Brazil, Colombia, Costa Rica, Cuba, and Mexico produced VF references. The technology has been evaluated for nutrient removal [102,132], and emergent contaminants removal efficiency [115]. The VF technology has been tested to treat wastewater coming from swine [78,105], mariculture (marine shrimp post larvae culture) [69], dairy [101], gray water [104], and different cases of domestic effluents. The effect of the hydraulics [83] and loading patterns [80] have been reported, and some results regarding with the hydraulics have been modeled [135]. In the economic context, the life cycle [147] of the VF has been assessed, and also some approach to the role of the VF in the landscape function.

ICW

Some of these technologies are relatively new and have been used to treat highly loaded waters where a high oxygen demand is necessary, e.g., run-off from anti-icing fluids in airports [192], waters from food production [193], and petroleum industry discharges [194]. ICW also included in this review shows the use of hybrid systems in different configurations and operational schemes in the region; e.g., recirculation of HSSFW and VF systems [39,88], hybrid systems (combining HSSFW and VF systems) [41,140,161] aerated systems [67,103,121], using algae turf filters [89] and microalgae ponds [98], evapotranspirative systems [114], and the use electroactive bacteria-based constructed wetlands (METland) [58] in the region. The ICW has been used to treat wastewater from domestic sewage [89,114,121], coffee production [67,103], swine [161], and landfill leachate [88]. The 24 ICW systems are established in five countries: Argentina, Brazil. Chile, Colombia, and Mexico.

French System

The French system CW is the least spread technology in the LAC region. Only two countries (Brazil and French Guyana) have reported 13 experiences. Nine of the thirteen experiences were developed directly by a French research group, Irstea, in 2010 and planted with *Phragmites australis* in the overseas territories of France in the Caribbean (Martinique Island and Bois d'Opale), without the participation of local researches. The other four reported experiences were established in Belo Horizonte, Brazil, and developed by local researchers. All the experiences with French systems were developed at full-scale for treating domestic swage.

3.2.3. Size of the Experiences

The review provided data from CWs varying in size. The surface of the systems varied from lab-scale experiences to full-scale, to operational systems treating actual polluted waters. Figure 3 presents all the analyzed experiences according to size. The graph is presented in log scale to stress the difference in size.

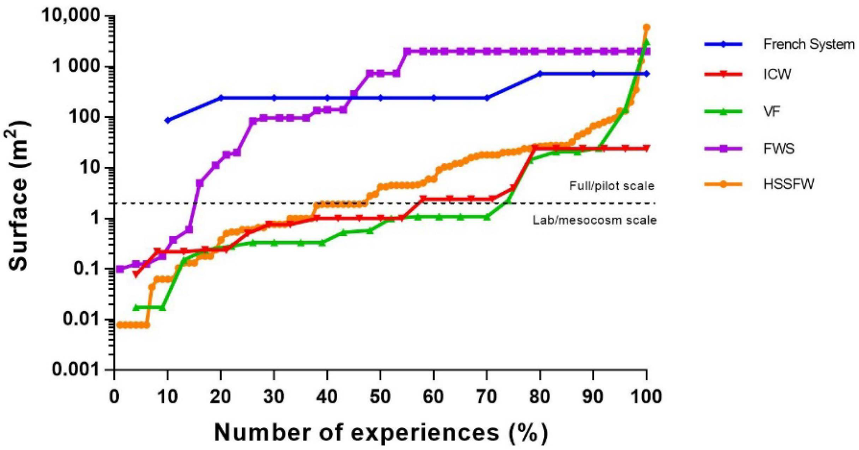

Figure 3. Cumulative distribution size of the studied CW experiences in the LAC region.

Figure 3 shows that, while the FWS lab and mesocosm scale systems (>2 m^2) represent around 15% of the experiments, the other four technologies represent 50% in the case of HSSFW to around 75% in the case of the VF and ICW. On the contrary, 100% of the analyzed French systems, around 85% of the FWS, 50% of the HSSFW, and less than 20% of the VF and ICW are full-scale systems. Table 3 shows the information regarding the size of reviewed experiences in the LAC region.

Table 3. Highlighted information regarding the size of reviewed experiences in the LAC region (only systems with data available are included).

Type	Number of Experiences	Largest System (m^2)	Smallest System (m^2)	Median Size Reported (m^2)	Average Surface (m^2)
HSSFW	180	6000	0.0078	4.2	62
FWS	41	2000	0.1	733	1010
VF	27	3144	0.0176	1	125
ICW	24	24	0.0775	1	6.1
French System	10	700	240	240	386

The most extensive CW system reported in the region is established in the city of Rionegro, Antioquia, Colombia [134]; a 6000 m^2 HSSFW is part of a treatment that receives secondary treated combined wastewater from the production from a chocolate factory and domestic sewage. The systems receive a flow of 173 m^3/d and a daily BOD_5 and COD load of 1354 and 1889 mg/L, respectively. The system has been in operation since 2008 [Maria Solange Sánchez, Pers. Comm.] and has gone through a refurbishing process due to mistakes in the design. After the intervention, the reported loading is of 5.8 g/m^2d with BOD_5 and COD removal of 98% and 94%, respectively. The largest FWS system is reported in Argentina with a surface of 2000 m^2 [26] that treats industrial wastewater, and it receives a flow of around 100 m^3/d, with an average of BOD_5 and COD load of 80 and 206 mg/L, respectively, reporting removal efficiencies around 70% for BOD_5 and COD. The largest VF system was estabæished in the city of Palhoça, Santa Catarina, Brazil with a surface of 3144 m^2 receiving domestic wastewater [195], and a flow of 18 m^3/d with a COD load of 154 mg/L, reporting a removal efficiency for COD of 88%. The biggest full-scale ICW was developed in Mexico; a 24 m^2 hybrid (FWS + HSSFW) CW that treats wastewater from a pig-farm [161], receiving an inflow between 0.5 to 1 m^3/d, and a COD load around 600 mg/L, the reported COD removal efficiency was around 80%. Concerning the French system technology, the most extensive system is located in Martinique Island, in the French Overseas Territories, with an effective area of 720 m^2 treating from 12 to 60 m^3/d of domestic wastewater [156], with a BOD_5 and COD load of 512 and 1000 mg/L, respectively, reporting a BOD_5 and COD removal rate of 94% and 90%.

3.2.4. Organic Matter and Nutrient Removal

Table 4 shows all the information available from all the reviewed experiences, classified according to the scale (lab, mesocosms, pilot, or full) established for this review. It is possible to observe that HSSFW is the technology with the largest amount of information, not only about size and location, but also for TN and TP removal. FWS present information mainly for the full scale experiences, VF and ICW present a lack of information regarding TN and TP. The mean COD, TN, and TP removal efficiencies vary from 65% to 83%, 55% to 72%, and 30% to 84%, respectively. The results suggest a generally good performance for COD and TN removal and a bad performance for TP removal.

Table 4. Nutrient removal and size for CW in the LAC region.

Technology		**HSSFW**				**FWS**				**VF**				**ICW**				**French System**			
Scale +		+**L**	+**M**	+**P**	+**F**	+**L**	+**M**	+**P**	+**F**	+**L**	+**M**	+**P**	+**F**	+**L**	+**M**	+**P**	+**F**	+**L**	+**M**	+**P**	+**F**
Size	n	33	53	25	69	6	ND	1	34	3	13	ND	6	1	12	5	6	ND	ND	ND	13
	$\overline{X}_{Size}$ (m^2)	0.08 ± 0.06	1.1 ± 0.6	4.9 ± 1.6	160 ± 733	0.25 ± 0.20	ND	5	1218 ± 910	0.06 ± 0.08	0.64 ± 0.37	ND	561 ± 1266	0.08	0.66 ± 0.35	2.7 ± 0.7	24 ± 0	ND	ND	ND	304 ± 247
COD	n	32	31	21	31	ND	ND	1	26	ND	8	ND	6	ND	11	5	6	ND	ND	ND	10
	$\overline{X}_{Influent}$ (mg/L)	468 ± 507	1762 ± 1984	470 ± 566	439 ± 354	ND	ND	81	203 ± 186	ND	411 ± 257	ND	1461 ± 2660	ND	1728 ± 1921	211 ± 271	794 ± 335	ND	ND	ND	821 ± 812
	$\overline{X}_{effluent}$ (mg/L)	187 ± 269	599 ± 941	221 ± 326	144 ± 126	ND	ND	42	50 ± 43	ND	95 ± 92	ND	125 ± 155	ND	148 ± 150	ND	225 ± 174	ND	ND	ND	122 ± 131
	$\overline{X}_{removal}$ (%)	65 ± 13	61 ± 24	57 ± 19	65 ± 31	ND	ND	ND	70 ± 14	ND	80 ± 19	ND	80 ± 21	ND	74 ± 24	ND	74 ± 12	ND	ND	ND	82 ± 8
TN	n	16	16	12	25	ND	ND	ND	3	ND	8	ND	6	ND	9	ND	6	ND	ND	ND	4
	$\overline{X}_{Influent}$ (mg/L)	97 ± 30	328 ± 307	48 ± 38	79 ± 89	ND	ND	ND	28 ± 3	ND	162 ± 129	ND	211 ± 401	ND	116 ± 37	ND	81 ± 39	ND	ND	ND	98 ± 7
	$\overline{X}_{effluent}$ (mg/L)	34 ± 16	135 ± 97	28 ± 27	46 ± 63	ND	ND	ND	6 ± 1	ND	79 ± 137	ND	25 ± 33	ND	76 ± 73	ND	41 ± 32	ND	ND	ND	27 ± 8
	$\overline{X}_{removal}$ (%)	68 ± 20	56 ± 30	47 ± 29	47 ± 30	ND	ND	ND	78 ± 7	ND	56 ± 19	ND	72 ± 35	ND	47 ± 36	ND	55 ± 18	ND	ND	ND	72 ± 7
TP	n	13	19	8	21	4	ND	ND	30	ND	ND	ND	3	ND	5	ND	6	ND	ND	ND	9
	$\overline{X}_{Influent}$ (mg/L)	13 ± 5	39 ± 37	19 ± 17	15 ± 37	52 ± 99	ND	ND	2 ± 3	ND	ND	ND	20 ± 42	ND	13 ± 3	ND	20 ± 9	ND	ND	ND	5 ± 4
	$\overline{X}_{effluent}$ (mg/L)	6 ± 4	21 ± 18	15 ± 12	6 ± 9	ND	ND	ND	1 ± 1	ND	ND	ND	1 ± 1	ND	6 ± 2	ND	9 ± 8	ND	ND	ND	7 ± 1
	$\overline{X}_{removal}$ (%)	46 ± 31	38 ± 27	23 ± 21	41 ± 28	ND	ND	ND	49 ± 27	ND	ND	ND	84 ± 13	ND	42 ± 15	ND	64 ± 22	ND	ND	ND	30 ± 9

+ The size of the experiments is described as follow: L, laboratory scale; M, mesocosms scale; P, pilot scale; F, full-scale. ND: Not data reported. $\overline{X}$: Refers to the mean of the available values (size, influent, effluent, and removal) for each parameter (Size, COD, TN, and TP) in the evaluated scale (L, M, P, and F) for each technology (HSSFW, FWS, VF, ICW, and French system).

Organic Load Rate

Organic Load Rate (OLR) is a design and operational parameter inherent to the wastewater technology and provides information regarding the organic pollutant loaded per area unit. Figure 4 compares the cumulative OLR loaded of all the reviewed systems. Reference lines are related to the maximum OLR recommended for the design of full-scale systems for FWS, HSSFW, VF, and French system. Fifty percent of the experiments regarding HSSFW, were performed with an OLR higher than 8 g/m^{2}d, maximum OLR recommended for full scale systems [196]. Thirty-five percent of the FWS experiences were operated with a higher loading than the OLR recommended for full-scale systems: 2–4 g/m^{2}d [21]. VF experiences 65% of the cases operated with OLR higher than the recommended of 20 g/m^{2}d [190]. The OLR for the French system ranges from 8 to 45 g/m^{2}d. The range is lower than the reported by the French designers where the design OLR limit is up to 150 g/m^{2}d [197]. Figure 4 shows that the highest OLRs were reported for the ICW and VF; as a consequence of the better performance capacity for the removal for organic matter. The HSSFW experiences reported OLR in the entire range of magnitude, from 0.01 to around 200 g/m^{2}d.

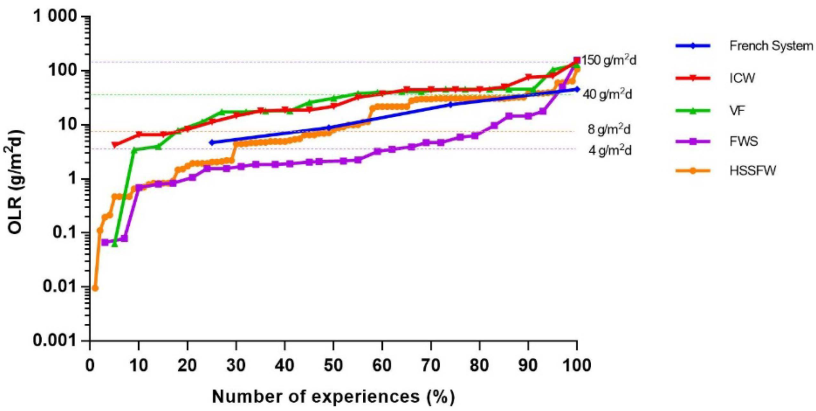

Figure 4. Cumulative distribution of OLR of the studied CW experiences in the LAC region.

Chemical Oxygen Demand (COD)

COD is a parameter used to evaluate the organic matter load and a common parameter to describe the performance of a wastewater treatment, the concentration for COD influent and effluent is reported for almost all the reviewed experiences. Figure 5a,b presents the cumulative distribution of the COD concentration in the influent and the effluent of the studied systems. Figure 5a shows that ICW and the French system are the technologies that receive the highest loading. Figure 5b shows that the VF and French systems are the technologies that reported the lowest effluent COD concentration. From Figure 5a,b, it is possible to observe FWS received, in around 80% of the cases, an influent COD concentration lower than 200 mg/L, considered as a light COD load according to Kadlec and Wallace [21]. Nonetheless, the effluent COD concentration for 80% of the cases was lower than 40 mg/L.

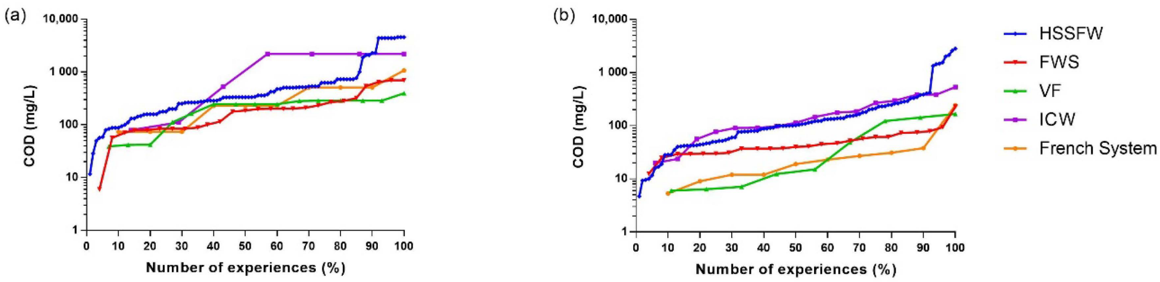

Figure 5. Cumulative distribution of COD influent (**a**) and effluent (**b**) in the studied CW experiences in the LAC region.

Total Nitrogen (TN)

TN is the parameter that combines all the nitrogen species in the wastewater. TN removal in CW is mostly done via a biological path. Following ammonification, nitrification, and denitrification. Therefore, TN removal is affected by the type of CW established. In spite of the importance of the parameter, it is not always evaluated in the studies in the LAC region maybe due to the fact that nutrient removal is not yet a discharge requirement in most of the LAC countries. Figure 6a,b shows that when influent and effluent are compared, there is a clear lack of data reported, being the most evident case is the FWS. In general, TN is effectively removed, for all the technologies, Table 4 shows average removal efficiencies in a range from 47% to 78%. The comparison shows that the influent TN concentrations reported are relatively high and even reaching concentrations above 8000 mg/L.

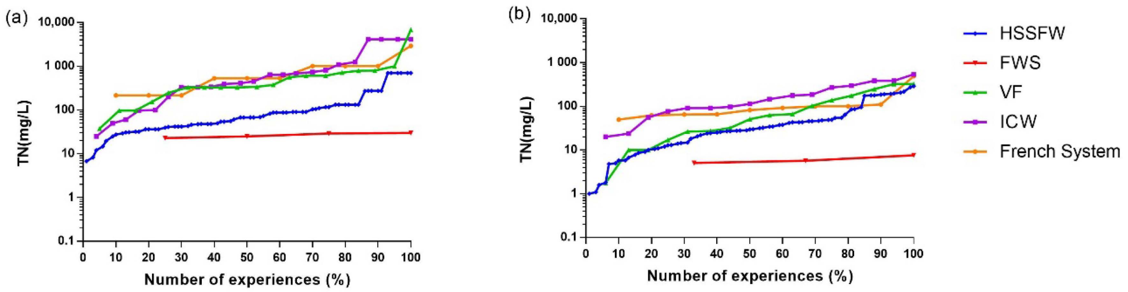

Figure 6. Cumulative distribution of TN influent (**a**) and effluent (**b**) in the studied CW experiences in the LAC region.

Total Phosphorous (TP)

Phosphorous is an essential element for controlling environmental pollution associated with the eutrophication of receiving waters. CW's aim to remove this nutrient from wastewaters to improve environmental quality. The TP parameter also presents a lack of information in the CW experiments, reporting results about influent and effluent TP concentration in only 10% of the reviewed experiences. VF and ICW are the technologies with less information available. From the available information showed in Figure 7a,b, it is possible to observe that the range of values between the TP inflow concentration and the TP effluent concentration is almost the same for all the evaluated technologies, furthermore, Table 4 shows low efficiency for all the scales and technologies for TP removal, with average removal efficiencies for almost all the technologies lower than 50%.

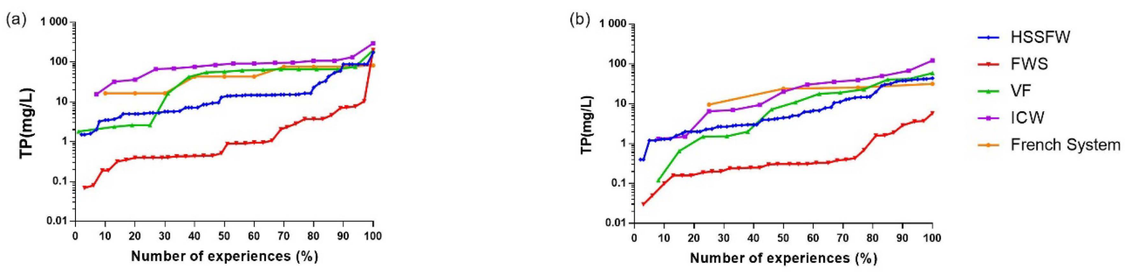

Figure 7. Cumulative distribution of TP influent (**a**) and effluent (**b**) in the studied CW experiences in the LAC region.

3.2.5. Plants Used in CW Experiences

The LAC region lies in the tropical and semitropical area and therefore the variety of plants that can be used is broader than in temperate zones. Plants are not affected by cold winters, and they do not present latency periods, being able to grow during the entire year, and therefore participating actively during the treatment process in the CW throughout the year. This section presents the result of the reviewed information, regarding the plant species reported as being used for the evaluated period and reports in the region.

From the reviewed documents, it was possible to obtain a list of 112 different plant species used in diverse conditions and experiments in CWs in LAC. Some studies evaluate the differences in the performance between the use of two or more species, the capacity of certain species to remove specific pollutants, the differences between environmental conditions associated with plant response and biomass production. The most commonly used plant was the *Typha domingensis*, reported in 54 experiences, but also other species, namely *Eichhornia crassipes* (40 experiences), *Typha latifolia* (36), *Cyperus papyrus* (34), *Phragmites australis* (33), *Heliconia psittacorum* (30) and *Pistia stratiotes* (27), were commonly used. On the other hand, some species were reported only in one case, for example, *Cocos nucifera* (coconut), *Carica papaya* (papaya), and *Aloe vera*.

Some of the reported plant species are interesting because they have never been reported before as plants used for CW. Table 5 shows all the reported species and the frequency of each one in the experiences reviewed.

Table 5. Plant species reported in CW in the LAC region.

No.	Scientific Name	n	Reference
1	*Typha domingensis*	54	[4,25–37,39–46,49–52,54–57,73,74,81,82,84,85,87,101,158,169,180].
2	*Eichhornia crassipes*	40	[25–32,39,44,60,73,74,82,87,115,122,162]
3	*Typha latifolia*	36	[47,48,61,62,66,67,70,78,83,86,91,96,106–109,118,135,139,166,174,181].
4	*Cyperus papyrus*	34	[14,62,64,88,99,105,122,139,140,144,149,156,166,167]
5	*Phragmites australis*	33	[36,60,117,123,126,141,143,154,166,174,180]
6	*Heliconia psittacorum*	30	[14,88,90,127,132,136,138,144,156,160,169].
7	*Pistia stratiotes*	27	[25–33,49,50,53,55,60]
8	*Cyperus alternifolius*	23	[25–32,153,154,156]
9	*Thalia geniculata*	20	[25–32,154,164].
10	*Pontederia cordata*	17	[25–32,73,82,87].
11	*Salvinia herzogii*	15	[25–32,49,53].
12	*Eryngium eburneum*	13	[25–32]
13	*Iris pseudacorus*	13	[37,122].
14	*Panicum elephantipes*	13	[25–32].
15	*Polygonum punctatum*	13	[25–32]
16	*Pontederia rotundifolia*	13	[25–32]
17	*Scirpus californicus*	13	[37,60,106,118,119,123,124]
18	*Typha angustifolia*	13	[119,154,157]
19	*Gynerium sagittatum*	12	[136,138,159]
20	*Tulbaghia violacea*	12	[122]
21	*Colocasia esculenta*	10	[136,138]
22	*Schoenoplectus californicus*	10	[61,116,117,121,198]
23	*Typha* sp.	9	[161,168]
24	*Canna indica*	7	[60,104,112–114].
25	*Cynodon dactylon*	7	[68,76,78,79,92,93,100,102].
26	*Arundo donax*	6	[157].
27	*Brachiaria mutica*	6	[154].
28	*Cyperus giganteus*	6	[73,74,82,87].
29	*Hedychium coronarium*	6	[160,199].

Table 5. *Cont.*

No.	Scientific Name	n	Reference
30	*Scirpus* sp.	6	[161]
31	*Alocasia* sp.	5	[160,168,200].
32	*Zantedechia aetiopica*	5	[160,199,200].
33	*Avena strigosa*	4	[77]
34	*Cortaderia atacamensis*	4	[125]
35	*Festuca Orthopylla*	4	[125]
36	*Hymenachne grumosa*	4	[65,89,94,98].
37	*Iris japonica*	4	[160,200].
38	*Lolium multiflorum*	4	[103]
39	*Schoenoplectus americanus*	4	[125]
40	*Spathiphyllum wallisii*	4	[160,200].
41	*Strelitzia reginae*	4	[160,200]
42	*Canna flacida*	3	[60,160]
43	*Costus spiralis*	3	[156].
44	*Cyperus ligularis*	3	[130,168]
45	*Eleocharis interstincta*	3	[181]
46	*Eleocharis mutata*	3	[142,184].
47	*Eriochloa aristata*	3	[91,142].
48	*Heliconia* sp.	3	[200].
49	*Heliconia stricta*	3	[160,169]
50	*Lemna minor*	3	[33,60]
51	*Musa cavendishii*	3	[104,114]
52	*Xanthosoma sagittifolium*	3	[104,114].
53	*Azolla caroliniana*	2	[60].
54	*Canna edulis*	2	[60].
55	*Chrysalidocarpus lutescens*	2	[168].
56	*Cordia sebestena*	2	[168].
57	*Echinocloa colona*	2	[130].
58	*Epipremnum aureum*	2	[168].
59	*Heliconia rostrata*	2	[95,115]
60	*Hymenocallis littoralis*	2	[168]
61	*Ipomea aquatica*	2	[60]
62	*Ixora* spp.	2	[168]
63	*Sagittaria falcata*	2	[60]
64	*Sagittaria montevidensis*	2	[60]
65	*Spirodela polyrhiza*	2	[60]
66	*Wolffia* sp.	2	[60]
67	*Acalypha wilkesiana*	1	[168]
68	*Acrostichum danaeifolium*	1	[168]
69	*Aloe vera*	1	[168]
70	*Alpinia perpurata*	1	[160]
71	*Anemopsis californica*	1	[160]
72	*Anthurium andreanum*	1	[160]

Table 5. *Cont.*

No.	Scientific Name	n	Reference
73	*Brachiaria humidicola*	1	[108]
74	*Calla Ethiopia*	1	[61]
75	*Canna generalis*	1	[199]
76	*Canna hybrids*	1	[160]
77	*Canna* spp.	2	[110,168]
78	*Carica papaya*	1	[168]
79	*Cassia* spp.	1	[168]
80	*Cestrum nocturnum*	1	[168]
81	*Chamaedorea chuspata*	1	[168]
82	*Cocos nucifera*	1	[168]
83	*Cortadeira selloana*	1	[44]
84	*Crinum* sp.	1	[168]
85	*Cyperus articulatus*	1	[131]
86	*Dieffenbachia Caladium spp*	1	[168]
87	*Dracaena* spp.	1	[168]
88	*Eleocharis macrostachya*	1	[173]
89	*Ficus* spp.	1	[168]
90	*Gladiolus spp*	1	[160]
91	*Hedera helix*	1	[168]
92	*Heliconia Cassia*	1	[168]
93	*Hemerocallis Dumortieri*	1	[160]
94	*Iris sibirica*	1	[160]
95	*Lilium* sp.	1	[160]
96	*Limnocharis flava*	1	[133]
97	*Ludwigia inucta*	1	[199]
98	*Musa* spp.	1	[168]
99	*Nerium* spp.	1	[168]
100	*Nymphaea amazonum*	1	[184]
101	*Paspalum paniculatum*	1	[164]
102	*Oryza sativa*	1	[75]
103	*Philodendron spp*	1	[168]
104	*Ravenala madagascariensis*	1	[168]
105	*S. intermedia*	1	[33]
106	*Sansivieria Hibiscus* spp.	1	[168]
107	*Scirpus americanus*	1	[185]
108	*Spartina alterniflora*	1	[69]
109	*Thrinax radiat*	1	[168]
110	*Tradescantia* sp.	1	[168]
111	*Vetiveria zizanioides*	1	[72]
112	*Vinca rosea*	1	[168]

n: Number of experiences reporting the use of the specie.

4. Discussion

The LAC region is the longest geographical region in the world; it starts in the austral circle in Argentina–Chile, close to Antarctica in the south and extends all the way to the southern border of the USA in Mexico, passing through the equator. Weather and environmental conditions vary, and since CW are affected among others by temperature, light incidence, type of wastewater and type of plants, then a generalized assumption regarding how CW are related to the geographic or climatic conditions cannot be made. To do so, it could only be by selecting systems established in different countries but under similar conditions but on the other hand, wastewater quality would be an issue. Based on the performance reported for more than 300 experiences, it is possible to state that, due to the different efficiencies, most of the systems reach a satisfactory pollutant removal efficiency (see Table 4), which means that the designing parameters and the type of system are appropriate.

However, the social, political, and cultural similarities seem to be a common factor in the LAC region, making it possible to assume some generalities regarding how the government structure and public policies are related to technology development in the region. Then, it is possible to state, that the lack of use in the LAC region of the CW technology lies in a possible lack of communication between the local scientific communities and governments that delays the adoption of the technology.

The positive effect of adopting the CW technology in the official policies and regulations can be observed in the Mexican case, where the government has adopted the CW technology in their local guidelines for wastewater treatment [188]. This fact could confirm that, because of different reported advantages related to CW, they tend to be more robust, more resilient, and require less maintenance than technical systems, an issue that is responsible for most of the failures of wastewater treatments in developing countries.

It is relevant that the same research group produces most of the publications in each country. For instance, in Argentina in the last decade, although it is one of the most productive countries publication wise, the same groups produces the majority of the publications. Similar situations occur in Mexico, Colombia, and Brazil, where no more than three research groups in their countries are responsible for the core of the publications. The number of scientists and their capacity to produce in terms of both time and funding hinders scientific production.

However, if CWs are to be used more frequently, it is important to improve and raise the dissemination activities and communication among the actors, namely scientists, stakeholders, decision-makers, etc. Another factor affecting the "popularity" of CWs is the lack of knowledge from engineers, contractors, and biologists. In a study by Vera et al. [201], the group analyzed engineering education taught in developing countries and the results showed that nature-based solutions are not a priority and very seldom taught. Technical systems are preferred by the universities, which are not tackling the actual needs of the countries. A common characteristic of the LAC region countries is the lack of resources for construction and posterior operating and maintaining technical wastewater systems, and then, those systems are often neglected and stop functioning. Nature-based solutions like CWs, offer a relatively low cost and demand low maintenance. Universities and technical schools should realize that innovation also means to use systems that fit to the national needs, and then, should adopt nature-based solutions as appropriate technology. Universities and technical schools should realize that innovation is using systems that fit to the national needs and adopt the nature-based solutions as appropriate technology.

Another obstacle for spreading information and consequently reducing the implementation of the CW in the LAC context seems to be the language barrier. Even though most of the important CW research groups in the LAC region have been able to produce reports and documents for international journals, it seems that many local experiences have not been published because of the language differences and when published in English the information does not reach the final users. It is possible to observe the language barrier even in the Spanish edited bibliography where two books were edited and published as open access during 2018. These books only include general guidelines and references for the design and construction of HSSFW and VF. The production of two books and the lack of information regarding the "new CW" technologies suggest a 10-year knowledge gap, which has also affected the implementation of CW in the LAC region.

Additionally, communication among scientists are limited due to resource scarcity and bureaucratic requirements, limiting the chance of attending expert meetings and international conferences. Thus, much of the research and data produced by LAC scientists is either never published or is only disseminated at a local level.

As it has been shown in this document, around 80% of the information developed in the LAC region deals with the performance of CW based on the HSSFW and FWS technology. HSSFW technology is well studied and pros and cons for the technology are well known and have been described by many authors around the world. The study also shows that the LAC region is not the exception and, the performance of the HSSFW and FWS have been studied under different conditions, such as a wide range of OLR, nitrogen and phosphorous removal. The results point to the fact that the HSSFW and FWS reduce their efficiencies for nutrient removal when the organic charge is high (higher than the recommended guidelines, as shown in the COD accumulative graph (Figure 5).

The experiences related to FWS systems point to the fact that this technology, considered the simplest, has a reduced capacity to treat highly polluted wastewater, however, it is the technology with the highest percentage (~80%) of full-scale experiences in the region, used successfully to treat low polluted wastewater.

VFs are starting to be more common but are still not well distributed among the countries. VF CWs have a higher capacity than HSSFW and FWS for treating organic matter and nitrifying. Through interviews with local builders, it was clear that the lack of knowledge and the fact that the systems require pressurized distribution systems seem to limit the use of it.

On the other hand, results and performance related to novel intensified CW technologies, like aerated, hybrid, French or METland systems should be adopted by local researchers in order to enhance and reinforce the results of this document that suggest a greater capacity of those systems to remove COD, TN, and TP. The available information related to this kind of technology is limited, reaching less than 20% of all the reviewed experiences.

Regarding TP removal capacity, the analyzed experiences seem to indicate a weak capacity from all the studied technologies to remove phosphorus. Then, the possibility to enhance the performance of CW using pre or post-treatment to remove TP seems to be the best option for water pollution control.

The role of the plants has been described in many reports related to the effect of improving or participating in the pollutant removal process. Plants are an important component of CW, but the role of them has been under debate during the last decades. Vegetation plays an important role in CW among others providing a surface for microorganism development, a source of carbon, oxygen to the root zone [202], and an aerobic habitat for microorganisms within the reduced soil. Also, in FWS they provide conditions to enhance the treatment via physical phenomena, reducing current velocity, and allowing solids to settle out of the water column [203]. In addition, plants also take up nutrients from wastewater [204,205]. Plants can provide a habitat for wildlife [206], could enhance the ecosystem services [207], can make the wastewater treatment systems aesthetically pleasing and increasing social acceptance, and the plants can even be a new source of income for the surrounding communities through the production of commercial flowers [208]. Plants also may serve as bioindicators of toxicity in the wastewater, which otherwise would not be measurable in toxicity/chemical tests for a single contaminant [209].

However, the role of the plants in CW should be reconsidered and evaluated according to the new perspective of the CW technology in the context of nature-based solutions for cities. The current state of the technology and the environmental challenges demands a new approach to identify new roles of the plants in the CWs. As the review has shown, the variety of plants used in the region is large and according to the review, plants are considered either as an accessory of the systems or a performance element. Nonetheless, CWs need to be reconsidered from the circular economy perspective, and as an instrument to realize the Millennium Development Goals [210]. Massi et al. (2017) [211], states that the worldwide research related to "circular economy and resource-oriented" is the least studied field regarding CW. If CW has the potential to produce a synergistic positive impact in the general conditions of the place where they are settled, then the technology should be re-considered as a source of multiple targets besides water treatment. Production of biomass for biofuels [212], plant-based products (plastics, chemicals [213], textiles, and pharmaceutical products), fertilizers, cut flower production, and the whole system as a provider of urban green areas that can enhance the biodiversity and the landscape [214], are just some examples.

This study presents a list of reported plants used for CW, settling a reference start point for the role of the plants in CW in the new perspective of sustainability. Additionally, the database can provide information to urbanists and landscape architects on new possibilities for designing and restoring urban spaces. Then, the LAC region, due to the wide diversity of used plants for CW and the potential from all those plant species to have an improved value for further uses, and due to the great environmental challenges in the region, could lead to a new generation of CW studies in the circular economy and sustainable cities context.

5. Conclusions

The LAC region is a heterogeneous territory, with a wide variety of environmental conditions that interact in many different ways with CWs. However, CWs seem to be an adequate solution for the wastewater challenges of the region, since the technology seems to face and solve the specific requirements of the region. CW technology is a proven and robust method that can better deal with different types of wastewaters and if properly maintained can be operational longer than conventional technologies.

The scientific information in the LAC region has been developed under a wide range of climatic conditions, and with different CW technologies like HSSFW and FWS. From the revised literature, it is possible to state that the efficiency of removing organic matter, TN, and TP does not differ between different conditions, maintaining similar removal yields. Although, HSSFW and FWS systems that seem to perform badly is due to overloading or improper design.

FWS systems seem to be an adequate solution for low-polluted wastewater or tertiary treatment, due to the design and building simplicity.

ICW and French systems showed, from the reviewed information, an improved capacity to deal with highly-polluted wastewater; however, the assumption should be substantiated with more studies in the region, since the actual information comes from less than 20% of the evaluated systems.

TN is effectively removed from wastewater by the five different types of technologies reviewed. On the contrary, TP was hardly removed from the effluents, and the results seem to have the same tendency independent of the evaluated technology, but it is not different from in other regions of the world where P removal is still often lacking a good solution.

The large number of plant species reported in the LAC region is a precedent for further studies, where the plants could take other roles in the CW besides the effects in the treatment performance. The study shows that the tendencies in the performance of the different technologies are not significantly affected by the plant species, but the plant species can influence the interest or the impact of the technology either by beautification or integration in the place of establishment.

The study stresses the need for integration among the water field actors to include and accept the use of CW technology in public policies. It would be beneficial for the countries with less experience to get support from the scientific community of the countries with more experience in the region to share information and enhance dissemination and collaboration with local governments and to neighboring countries by transferring results.

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Administration, M.A.R.-D., C.A.A., and H.B.; Funding Acquisition, M.A.R.-D. All authors have read and agreed to the published version of the manuscript.

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