hydrology MDPI

Review

Constructed Wetlands as Nature-Based Solutions for Wastewater Treatment in the Hospitality Industry: A Review

Sara Justino [1,2], Cristina S. C. Calheiros [1,2,*], Paula M. L. Castro [3] and David Gonçalves [1]

[1] Institute of Science and Environment (ISE), University of Saint Joseph, Macau SAR, China; sarasousajustino@gmail.com (S.J.); david.goncalves@usj.edu.mo (D.G.)
[2] Interdisciplinary Centre of Marine and Environmental Research (CIIMAR/CIMAR), University of Porto, Novo Edifício do Terminal de Cruzeiros do Porto de Leixões, Avenida General Norton de Matos, S/N, 4450-208 Matosinhos, Portugal
[3] CBQF—Centro de Biotecnologia e Química Fina—Laboratório Associado, Universidade Católica Portuguesa, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal; plcastro@ucp.pt
* Correspondence: ccalheiros@ciimar.up.pt; Tel.: +351-22-340-1800

Abstract: The hospitality industry is increasing its awareness of how the integration of nature-based solutions can decrease its environmental impact while maintaining or increasing the service level of the sector. Constructed wetlands (CWs) constitute a promising sustainable solution for proper in situ domestic wastewater treatment. This literature review elucidates the status of CWs implementation in the hospitality industry to help foster the exchange of experiences in the field and deliver examples of approaches in different contexts to support future applications of this technology. Most of the studies reported in the literature were conducted in Europe, but studies emanating from Asia and South America are also available. The design of CWs, the horizontal and vertical subsurface flow CWs (HSFCW, VSFCW), and hybrid systems have been reported. The average removal efficiencies of the systems ranged from 83 to 95% for biochemical oxygen demand, 74 to 94% for chemical oxygen demand, 78 to 96% for total suspended solids, 75 to 85% for ammonium, 44 to 85% for ammonia, 50 to 73% for nitrate, 57 to 88% for total Kjeldahl nitrogen, 51 to 58% total nitrogen, and 66 to 99% for total phosphorus. The majority of the systems were implemented as decentralized treatment solutions using HSFCWs, with the second most common design being the hybrid CW systems in order to reduce area requirements, increase treatment efficiency, and prevent clogging. Overall, CWs are a promising sustainable solution which may support access to adequate sanitation worldwide as well as safe wastewater recycling and reuse, leading to more sustainable tourist destinations.

Keywords: hospitality industry; constructed wetlands; decentralized system; nature-based solution; wastewater treatment

Citation: Justino, S.; Calheiros, C.S.C.; Castro, P.M.L.; Gonçalves, D. Constructed Wetlands as Nature-Based Solutions for Wastewater Treatment in the Hospitality Industry: A Review. *Hydrology* **2023**, *10*, 153. https://doi.org/10.3390/hydrology10070153

Academic Editors: Maximo Florin and Monzur Imteaz

Received: 15 April 2023
Revised: 15 July 2023
Accepted: 17 July 2023
Published: 20 July 2023

1. Introduction

The tourism or hospitality industry is able to make major contributions to achieving social, economic, and environmental sustainable development goals, being recognized by the United Nations as one of the 10 sectors with the capacity to turn communities towards a green economy [1,2]. The sector's growth has benefited from the process of globalization and the falling costs associated with traveling; while the increase in international tourism arrivals differed across regions of the world, international tourist arrivals in emerging economies have grown from 441 million in 2010 to 684 million in 2019, with expenditures by international inbound visitors reaching USD 536 billion [3].

Tourist resorts need to be attractive in order to appeal to tourists; however, they are responsible for producing large amounts of waste (solid and sewage). Regarding water resources, studies have shown that the per capita use of water by tourists exceeds that of locals and that the demand is likely to increase with higher tourist numbers, higher-quality hotels, and tourist expectations for water-dependent facilities such as pools, spas, and golf courses [4–6]. In addition, the preferred touristic regions are often placed in naturally vulnerable areas, in which hotels or other forms of accommodation are located far from wastewater treatment infrastructures [7].

Wastewater derived from tourism presents high variations in terms of flow and quality, often related to the occupancy rate, though its origin is similar to domestic wastewater [8]. In general, all the wastewater produced in hospitality units goes to the sewage system; although, according to its origin and composition, hospitality wastewater has great potential to be segregated into graywater—originating from sinks, showers, baths, kitchens, and laundry activities—and blackwater—originating from toilets (containing water, urine, feces, and toilet paper) [9]. Blackwater contains the main part of the organic load and pathogens, and though it is less abundantly produced compared to graywater, blackwater poses the biggest contamination risk; thus, it needs to be subjected to adequate treatment [10].

The implementation and maintenance of centralized sanitation systems is usually challenging and costly worldwide [11]. For this reason, decentralized systems have been considered as an alternative solution; these systems include nature-based solutions which benefit from the activities of microbes, soil, and/or plants in waste stabilization and resource recovery without the need for mechanical or energy-intensive equipment [12]. Examples of these natural systems include waste stabilization ponds, aquatic weed ponds, constructed wetlands (CWs), and land treatment processes [13]. More specifically, CWs are nature-based solutions that use a combination of processes to optimize biological, physical, and chemical reactions that occur in the natural wetland systems but in a controlled environment [12,14,15]. Based on hydrology type, CWs can be categorized into two main groups. The first group is the free water surface flow CW (FWSCW), where the majority of flow occurs through a water column above the substrate. The second group is subsurface wetlands, where the flow goes below the surface of a porous medium. The latter can be further divided into horizontal subsurface flow CW (HSFCW), where the influent is fed in a horizontal flow path until the effluent is collected on the opposite influent side, and vertical subsurface flow CW (VSFCW), where the influent flows onto the bed surface, percolating and draining vertically by gravity through the media in a batch mode [16,17].

CWs are characterized by low operational and maintenance requirements and are stable in terms of performance, with less vulnerability to inflow variation. Nevertheless, the required surface area is generally larger than for conventional systems, and clogging may appear if suspended solids are not pre-treated. Public perception addresses concerns such as odors and insects, but in subsurface flows, these issues are minimized due to the flow type [17,18].

The simulation of decontamination mechanisms in CWs remains a challenging task due to the involvement of various simultaneous processes, including physical, chemical, biological, and plant assimilation processes, in the removal of pollutants [19]. Numerical models have emerged as a promising tool for the design of CWs and for enhancing our understanding of these simultaneous processes. These models can generally be classified into hydraulic models that focus on water flow, hydrodynamic and/or clogging models, and those that concentrate on the removal of specific pollutants or a set of pollutants. The latter typically incorporates hydraulic and hydrodynamic models of varying complexity as well [20–22].

In this type of nature-based solutions, biological processes transform pollutants into essential nutrients or harmless by-products at high rates. Moving toward more ecological solutions for the treatment of wastewater will improve the sustainability of the hospitality industry. Therefore, CWs can contribute to this, providing effective sanitation and pollution load reduction while creating additional green spaces [18].

Information on the use of CWs in the hospitality industry is scattered among both the technical and scientific literature. The goal of this article was to collect an updated profile of CWs implemented as wastewater treatment technologies in hospitality units worldwide, with the ultimate aim of creating a database containing information on the location, treatment design, and performance of these systems for use as a reference tool for future stakeholders.

2. Materials and Methods

The use of CWs in the hospitality industry has been investigated worldwide by integrating the methodologies proposed by Tranfield et al. [23] and Boland et al. [24] for supporting the compilation and analysis of scientific and academic information.

Based on this, we revised publications in the literature from 2000 to 2021 during October 2021. The following terms were used: ("hotel" OR "resort" OR "lodge" OR "hospitality" OR "tourism") AND ("constructed wetlands" OR "artificial wetlands"). The platforms used were Science Direct (https://www.sciencedirect.com/, accessed on 4 October 2021) and Web of Science (https://www.webofknowledge.com, accessed on 4 October 2021). Only peer-reviewed research and review articles are included in this review.

A total of 44 peer-reviewed articles were found via the Web of Science platform, and 608 were found via the Science Direct platform. Publications about CWs implemented at sites other than hotels, resorts, lodges, or other hospitality areas were excluded, as were publications that did not contain information about the design process of CWs. Consequently, 23 papers from Web of Science and 585 from Science Direct were excluded since their abstracts did not include CWs implemented in the hospitality industry. After fully reading the remaining retrieved papers, 26 articles were excluded as they did not provide enough information regarding the design process of the CW implemented, leading to a final total of 18 peer-reviewed research studies being used to illustrate case studies for the development of this literature review. Figure 1 presents a summary of the screening process.

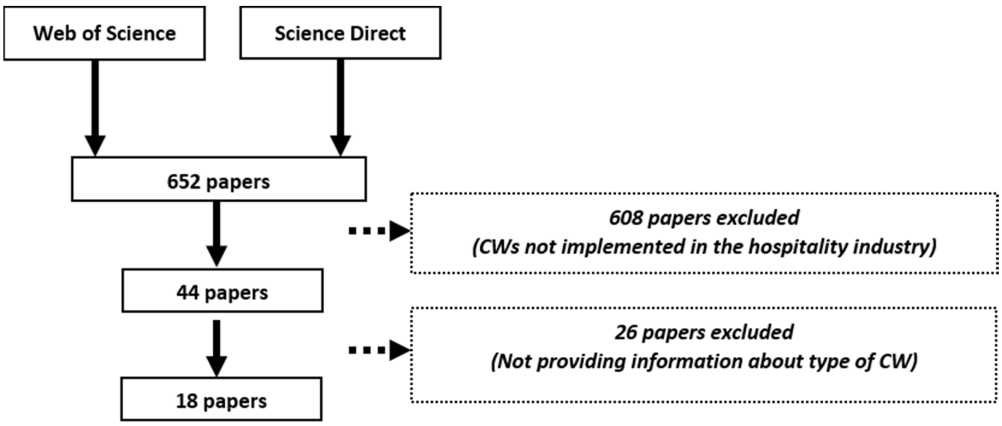

Figure 1. Summary of the screening process used for the methodology process.

3. Constructed Wetlands as Nature-Based Solutions in the Hospitality Industry

The combination of CWs with pre-treatment systems in the hospitality industry was the most commonly reported. Table 1 shows the locations, treatment processes, areas, flows, and plant species reported in the selected articles in relation to CWs.

Most of the studies reported were conducted in Europe (10), but studies in Asia (4) and South America (2) were also available. It is worth noting that the retrieved CWs were located in temperate to subequatorial zones, ideal areas for successful wetland treatment due to the warmer temperatures. The use of CWs in colder climates poses challenges that need to be accounted for when considering this type of application [25]. The biogeochemical processes, plants species, and level of contaminant removal must be addressed when considering the implementation of CWs in the hospitality industry [26,27].

Table 1. Constructed wetlands applied in the hospitality industry reported in the literature as per the reviewed papers.

Location	Treatment Processes	Area	Flow	Plants	References
Portugal (Ponte de Lima)	Septic tank → HSFCW → pond	Total of 40.5 m^2	4.1 m^3/d	*Canna flaccida*, *Canna indica*, *Zantedeschia aethiopica*, *Watsonia borbonica*, and *Agapanthus africanus*	[8,27–31]
Spain (Almería)	Series 1, 2, and 3: anaerobic stabilization pond → Hybrid flow CW; Series 4: WWTP effluent → Hybrid flow CW	24 tanks; each with a surface area of 1 m^2	Series 1 and 2: 0.19 m^3/d; Series 3: 0.37 m^3/d; Series 4: 0.29 m^3/d	*Phragmites australis* and *Typha dominguensis*	[32]
Spain (Lleida)	Septic tank → HSFCW	Two parallel beds; each with a surface area of 187.5 m^2	11 m^3/d	The development of the macrophytes was very poor; thus, both CWs are considered unplanted	[33]
Spain (Lloret de Mar)	Pre-treatment tank → Hybrid flow CW	Installation area of 4.5 m long × 1.5 m wide	Three flow rates tested: 0.75 m^3/d, 1.01 m^3/d, and 1.4 m^3/d	*Cyperus alternifolius* L., *Monstera deliciosa*, *Carex acutiformis*, *Ficus pumila* L., *Juncus inflexus* L., *Philodendron scandens* K., *Juncus effuses* L., *Philodendron erubescens*, *Equisetum hyemale* L., *Syngonium podophyllum*, *Spathiphyllum wallisii*, *Iris laevigata*, *Spathiphyllum wallisii 'sensation'*, *Mentha aquatica* L., and *Calathea* sp.	[34]
Spain (Lloret de Mar)	Pre-treatment tank → Hybrid flow CW	Total of 7.2 m^2	2 m^3/d	Combination of 14 species, such as *Iris* sp., *Juncus* sp., *Carex* sp., *Cyperus* sp., and *Monstera* sp.	[35]
Italy (Florence)	Imhoff tank + septic tanks → HSFCW	Total of 108 m^2	0.4–7 m^3/d	*Phragmites australis*	[36]
Italy (Appennines)	Imhoff tank → VSFCW	Surface area 126 (63 + 63) m^2	2–7.5 m^3/d	*Phragmites australis*	[36]
Italy (Arezzo)	Imhoff tank → Hybrid flow CW	Surface area of 160 m^2 for HF and 180 m^2 for VF	13–33 m^3/d	*Phragmites australis*	[36]
Italy (Florence)	Blackwater: septic tank → HSFCW; Graywater: degreaser → HSFCW	Surface area of 116 m^2 for graywater and 126 m^2 for blackwater	0.9–2.4 (black); 3–10 (gray) m^3/d	*Phragmites australis*	[36]
Italy (Florence)	Imhoff tank → Hybrid flow CW	Surface area of 160 m^2 for HF and 180 m^2 for VF	17–33 m^3/d	*Phragmites australis*	[37]
Italy (Florence)	Imhoff tank → Hybrid flow CW	Surface area of 160 m^2 for HF and 180 m^2 for VF	17–33 m^3/d	*Phragmites australis*	[38]
Italy (Mount Sibillini National Park)	Grid → Hybrid flow CW	Total area of 1014 m^2 for VRBF and 1000 m^2 for VF	N/A	N/A	[34]
Mexico (Cancun)	Septic tank → HSFCW	N/A	2–3 m^3/d	Seventy vascular plant species were identified	[38]
India (N/A)	Screening → sieves → HSFCW	Installation area of 2.3 m long × 0.12 m wide	23 mL/min	*Colocasia esculenta*	[39]

Table 1. *Cont.*

Location	Treatment Processes	Area	Flow	Plants	References
Thailand (Koh Phi Phi)	Septic tank → Hybrid flow CW	Three VSFCW = 2300 m^2; Three HSFCW = 750 m^2; Three FWSCW = 750 m^2; 200 m^2 polishing ponds	400 m^3/d	*Canna*, *Heliconia*, and *Papyrus*	[40]
Poland (Paszków)	Septic tank → HSFCW	Surface area of 214.1 m^2	4.0 m^3/d	*Phragmites* L.	[41]
China (Wuhan)	Iron carbon micro-electrolysis reactors → sedimentation tank → HSFCW	Total of 1000 m^2	150 m^3/d in winter; 400 m^3/d in summer	*Calamus*, *Typha orientalis*, *Phragmites*, little iris, and *Thalia dealbata.*	[42]
Costa Rica (BahíaBallena)	Septic tank for sewage + grease trap graywater → HSFCW	Seven HSFCW, each with a surface area of 12 m^2	N/A	*Agapanthus africanus* (L.) *Hoffmanns*, *Canna generalis* L. H. Bailey, *Chlorophytum comosum (Thunb.) Jacques*, *Cyperus alternifolius* L., *Cyperus papyrus* L., *Heliconia caribaea* Lam., *Heliconia rostrata*, and *Renealmia alpinia (Rottb.) Maas*	[14]
Malaysia (Selangor)	Secondary wastewater from WWTP → FWSCW	Installation area of 670 mm long × 420 mm wide	N/A	*Salvinia molesta*	[43]

Note: CWs = constructed wetlands; HSFCWs = horizontal subsurface flow constructed wetlands; FWSCWs = free water surface constructed wetlands; VSFCWs = vertical subsurface flow constructed wetlands; VF = vertical flow bed; HF = horizontal flow bed; SF = surface flow bed; VRBF = vertical flow reed bed filters; WWTP = wastewater treatment plant; N/A = not available.

Septic tanks were the most frequently installed pre-treatment type, followed by Imhoff tanks, which are two-story septic tanks composed of an upper sedimentation compartment and a bottom sludge digestion compartment. Other pre-treatment systems used were iron-carbon micro electrolysis reactors, degreasers, or grids/screens/sieves. In terms of the design of treatment wetlands, in the 16 studied, 9 were HSFCWs types, 5 were hybrid systems composed of HSFCWs with VSFCWs, 1 was a SF type, and 1 was a VSFCW type. In subsequent sections, a more detailed analysis of the CWs found in the literature is provided.

3.1. Free Water Surface Flow Constructed Wetlands

FWSCWs aim to replicate the naturally occurring processes of a natural wetland, marsh, or swamp, in which wastewater flows above a sealed substrate to prevent seeping into the surroundings. Planted macrophytes are either emergent, submerged, or floating, and treatment occurs through the wetland bed and plant components [17]. Low construction, maintenance, and energy costs are advantages of this type of CW design, although the fact that wastewater is exposed to the atmosphere increases the possibility of mosquito breeding [44].

A lab-scale experiment evaluating the weight variation of *Salvinia molesta* plants on wastewater phytoremediation was set in Malaysia using wastewater samples from a university campus that included a laundry area, toilets, hostels, restaurants, staff quarters, offices, and a hotel. The experimental design consisted of three tanks built with acrylic plastic sheets, with the dimensions of 670 mm × 420 mm × 220 mm (L × W × H), where different weights of *S. molesta* (70 g, 140 g, and 280 g) were planted. A t-shaped structure installed in the middle of the tanks served as a flowing guide, and the inlet was installed above the outlet to maintain the water level. The performance of different weights of *S. molesta* plants in wastewater treatment was observed for 14 days at a 24-h retention time. For inlet concentrations varying from 2.53 to 3.52 mg/L for phosphate (PO_4^{3-}), 10.79 to 11.00 mg/L for ammonia nitrogen (NH_3), and 4.2 to 4.4 mg/L for NO_3^-, removal efficiencies reached 97.7% for turbidity, 99.7% for PO_4^{3-}, 99% for NH_3, and 90.6% for NO_3^-

for the *S. molesta* system planted with the highest weight (280 g) [43]. It should be noted that, despite the design simplicity, FWSCWs present some disadvantages, such as higher land requirements, the risk of human exposure, and long-term operational issues, if plant litter is not removed and substrate maintenance is not performed [17,44].

3.2. Horizontal Subsurface Flow Constructed Wetlands

The configuration most widely reported in the reviewed literature was HSFCWs, representing 56% of the CW typology. As it was implemented worldwide, studies were retrieved from China, Costa Rica, India, Italy, Mexico, Poland, Portugal, and Spain. HSFCW advantages stem from their low energy requirements for operation, low construction and maintenance costs, and little need for specialized labor [8,17,35]. In Portugal, Figure 2 shows a CW for wastewater treatment. The system consists of a septic tank followed by a HSFCW and a pond installed in a rural tourism hotel [8]. The flow design was 4.1 m^3/d of domestic wastewater for occupation rates ranging from 6 to 40 persons. The CW surface area was 40.5 m^2, and the system was planted with a polyculture of *Canna flaccida*, *Canna indica*, *Zantedeschia aethiopica*, *Watsonia borbonica*, and *Agapanthus africanus* in an expanded clay substrate. The treatment system achieved removal rates of 95.1% for TSS, 93.8% for COD, 94.0% for BOD_5, 72.8% for TP, and 43.5% for NH_3 from an average COD loading rate of 156 kg/ha·d and BOD_5 loading of 66 kg/ha·d. The CW was also shown to be efficient at removing fecal indicator bacteria, with removal rates for total coliforms and *Escherichia coli* of up to 3.0 log10 [8]. In 2017, Calheiros et al. [28] reported a decrease in fecal bacteria indicator counts, with a special focus on *E. coli* since, in general, they were not detected in relation to an inlet of 3.0 ± 0.9 log CFU/mL. Total coliform counts and fecal coliforms also decrease up to 3 log in relation to an inlet of 5.3 ± 0.8 log CFU/mL for total coliforms and 5.3 ± 0.7 log CFU/mL for fecal coliforms.

With the goal of better understanding the route of pathogenic bacteria and indicator organisms in CWs, the system was again analyzed by Calheiros et al. [29]. Pathogenic indicators of *E. coli* achieved reduction rates of up to 2 log at the outlet, Enterobacteriaceae achieved reduction rates of up to 3 log, *Salmonella* spp. was never detected at the outlet, and *Listeria monocytogenes* was detected in only one sampling [29]. Later, in order to address the dynamics of the arbuscular mycorrhizal fungi communities colonizing the roots of *C. indica*, *C. flaccida*, and *W. borbonica*, Calheiros et al. [26] again analyzed the same CW, reporting removal efficiencies of 88% for TSS, 91% for COD, 66% for PO_4^{3-}, and 48% for NH_4^+ for a BOD/COD ratio between 0.3 and 0.8. In general, higher values of COD and BOD_5 were registered in hot seasons, corresponding to the increase in overnight accommodations.

After being in operation for more than 5 years, Calheiros et al.'s [31] system continued to report constant removal rates of up to 87% for COD and BOD_5, up to 99% for TSS, up to 91% for PO_4^{3-}, and up to 97% for NH_4^+ and NO_3^-. These studies documented the long-term operation of a nature-based solution applied in the hospitality industry, showing that CWs have the ability to decrease the toxicity of wastewater from small tourism units and reinforcing the notion that CW can be a sustainable nature-based solution for treating domestic wastewater [31].

Fattoria Baggiolino is a farm holiday site located 25 km from Florence, Italy, which is inhabited by the owners from November through to March and marketed for weekly rentals from early March through to October; this is a type of countryside tourism promoted in remote areas of Italy, which are usually far away from centralized wastewater solutions [44]. The onsite wastewater treatment consisted of one Imhoff tank and two septic tanks, where effluent lines were combined into a single-bed HSFCW. The wastewater production was approximately 30 PE, with a mean organic loading rate of 4.2 g COD/m^2·d, for an accommodation capacity of 24 beds, and after the onsite treatment, the effluent was discharged for sub-irrigation [45]. The surface area of the CW was 108 m^2, and it was designed to produce treated wastewater that complies with the discharged water quality limits outlined by The Regional Environmental Protection Agency of Tuscany and the Scandicci (TSS 90–95%, BOD_5 90–99%, NH_4^+ 40–50%, TP 30–50%, fecal coliforms 98–99.99%). The net construction price of the completed plant in 2002 was EUR 10,864, with operational costs estimated at approximately EUR 230 per year, or EUR 0.19 per m^3 of treated wastewater [36].

Figure 2. Horizontal flow constructed wetland installed in a rural tourism unit for wastewater treatment; (**a**,**b**): landscape integration; (**c**,**d**): constructed wetland in two different times of the year.

Similarly, a HSFCW was chosen as a decentralized wastewater treatment solution for a camping site called “La Cava”, also in Italy. The accommodation capacity was 24 beds and 48 tents; eight people permanently live at the site. Wastewater was segregated into two parallel lines: one for graywater and the other for blackwater. Graywater was treated at a flow rate of 9.5 m^3/d, passing first through a degreaser, followed by a one-cell HSFCW with a surface area of 115 m^2 and planted with reeds. Blackwater was treated at a lower average flow rate of 6.5 m^3/d, passing first through a septic tank and then flowing into a one-cell HSFCW planted with reeds, whose surface area was 126 m^2. The segregation of fluxes allowed for safe reuse of the treated graywater, which was pumped back to the buildings for toilet flushing, while treated blackwater was reused for drop irrigation in green areas [36]. For blackwater, COD achieved high average reductions of 89% and an average organic loading rate of 11 g COD m^2/d; TKN achieved an 84% reduction, TP average removal rate was 99%, and NH_4^+ averaged a 55% reduction. As for graywater, for an average organic loading of 36 g COD m^2/d, the average COD removal rates were 40%, while TKN averaged 96%, NH_4^+ averaged 99%, and TP averaged 95% [36].

In China, a full-scale wastewater treatment system was developed at a touristic household farm in Wuhan. The system consisted of four treatment units: a regulation-size pond, iron-carbon micro-electrolysis (ICME) reactors, sedimentation tanks, and a two cell HSFCW with a surface area of 1000 m^2. The ICME reactors were composed of three consecutives units: the first two for micro-electrolysis and the third as a deposit unit in which sludge and activated carbon particles are trapped before being recirculated back to the ICME. Forced aeration to the first two ICME units allowed for the maintenance of the aerobic environment to enhance ammonia oxidation efficiency. As for the HSFCW, the bed media was composed of geotextiles, loess, and gravel; planted with Calamus, cattail (*Typha orientalis*), and reed (*Phragmites*); and embellished by little iris and *Thalia dealbata* [42]. During the sampling period, the average wastewater flow was 150 m^3/d in winter and 400 m^3/d in summer (below the design flow of 600 m^3/d). After choosing the optimal conditions (a Fe-C/water ratio of 1:1, an initial pH of 4, and a Fe-C/water ratio of 1:4) the CW reduced COD, BOD_5, and NH_4^+ in the final effluent to the range of 8.8–28.3 mg/L, 2.7–5.7 mg/L, and 0.4–1.5 mg/L, respectively, which satisfied the environmental quality standards for surface water in China [42].

In Costa Rica, a biogarden system was built to treat wastewater generated at a hotel. The system comprised septic tanks and grease traps for sewage and graywater pretreatment, followed by seven HSFCWs. The hotel's maximum capacity was 141 people, with the high tourism seasons occurring from December to February and July to September. Raw water was extracted from a well at an average of 16 m^3/d and used by the hotel guests, employees, restaurant, laundry room, greenhouse, artificial pond, and swimming pool [14]. As observed by Pérez-Salazar et al. [14], the average pollutant loads in all influents were close to or higher than the permitted discharge limits in Costa Rica of 50 mg/L and 150 mg/L for BOD_5 and COD, respectively [46]. Thus, wastewater pre-treatment was not sufficient to meet the national criteria and, given that there were no municipal wastewater treatment solutions in the area, the biogarden system was created. Each CW cell had an average area of 12 m^2 and contained river cobble as a support material, gravel as a bed, and *Cyperus papyrus* and *Heliconia* sp. plants. The average removal rates for BOD_5, COD, and TSS was 80%, 66%, and 72%, respectively, thus producing an effluent in compliance with current national legislation. The study also demonstrated that this system was able to cope with significant load variations between the high and low tourist seasons and/or between the rainy and dry seasons [14].

In Spain, a HSFCW system was set up to treat 11 m^3/d of domestic wastewater generated from a hotel. The system consists of two septic tanks in series, from which the effluent is distributed to two parallel beds (each 187.5 m^2). Bed 1 remained unplanted, while common reed (*P. australis*, [Cav.] Trin. ex Steudel) was planted in bed 2; however, the development of the macrophytes was very poor. Thus, for data interpretation, the author considered both beds as unplanted. The CW influent TSS and BOD_5 averages were 120 mg/L and 410 mg/L, respectively, and average removal rates of 54% for BOD_5 and 36.84% for TSS were achieved. In comparison to the removal rates reported in the literature [17,47], this system presented lower efficiencies. García et al. [33] pointed to four possible explanations: (1) because data were obtained during the first year of operation, it is possible that the biofilm did not develop, leading to the low degradation of OM; (2) in HSFCW reed beds, studies indicate that to achieve BOD_5 reductions lower than 25–30 mg/L, the areal organic loading rate (AOLR) should be under 6 g BOD/m^2 per day, but in the Vilagrassa hotel, the loading was an average of 13.6 g BOD_5/m^2 per day; therefore, the author points to the possibility that this CW was not well dimensioned; (3) the use of large quantities of disinfectants such as NaOCl in the hotel may have interfered with the beds' microbiological development; (4) flow design constrictions such as flow short-circuiting [33,44,48,49].

In India, an aquatic macrophyte-based system was established for treating wastewater collected from a nearby hostel, hotel, and houses. Wastewater flowed in subsurface mode at 23 mL/min through three parallel shallow raceways filled with gravel, in which two were planted with C. esculenta and one was operated as an unplanted control. Four experiments—I, II, III, and IV—were conducted in which diluted wastewater concentrations varied from 450 to 1650 mg/L for COD, 3.2 to 5.0 mg/L for NO_3^-, and 2.8 to 4.5 mg/L for PO_4^{3-} [39]. The systems were operated with a retention time of 3.6 days during 10 days, after which the systems were emptied and the second run of the experiment was initiated with untreated wastewater, repeating initial conditions for another 10 days while plants remained in the raceways. Systems I and II were conducted with only one wastewater change on day 10, while the wastewater for systems III and IV was changed every fifth day of the experiment. Therefore, within the entire duration of the experiment (20 days), the wastewater was changed four times for systems II and IV, while the wastewater treatment was changed two times for systems I and II [39]. Between the two nutrients tested, the removal of NO_3^- was better than PO_4^{3-} in all raceways, including the controls, with better (albeit not statistically significant) nutrient removals observed for the planted railways than the controls. A significant reduction in COD was achieved in all raceways, with planted ones performing better than the controls: 85.6% vs. 97.8% for experiment I, 82.3% vs. 90.2% for experiment II, 91.7% vs. 93.5% for experiment II, and 91.2% vs. 94.5% for experiment IV.

In Poland, Pawęska and Kuczewski, [41] presented the efficiency of five small wastewater treatment plants (max. 350 inhabitants) designed to treat domestic sewage after preliminary mechanical treatment in a septic tank. Within these five units, two CW beds were built in Paszków and Mroczeń to treat wastewater coming from an adjoining holiday resort and a primary school for later effluent discharge in adjoining streams. Three main parameters—BOD_5, COD, and TSS—were considered as the main indicators for pollutant reduction, as required by the Ordinance of the Minister of Environment for PE < 2000 [40]. The treatment plants were designed as a hydroponic technology system (for the present purpose, it was considered subsurface flow) in concentric circular trenches, with a depth and diameter of 2 m and the addition of light-expanded clay aggregates (LECA) as filling. In the case of the CW installed in Paszków, it was planted with reeds (*Phragmites* L.) and comprises a total capacity of 4 m^3/d, a surface area of 214.1 m^2, and a total of four beds. The average wastewater inflow characteristics were 114.2 mgO_2 d/m^3 for BOD_5, 499.8 mgO d/m^3 for CODCr, 302.5 mg/dm^3 for TSS, 50.1 mgN d/m^3 for TN, and 7.4 mgP d/m^3 for TP. The respective removal rates were 97.7% for BOD_5, 86.09% for CODCr, 66.35% for TSS, 58.88% for TN, and 56.76% for TP. From the five wastewater treatment plants, the best effluent quality was achieved by CWs, although the TSS limits did not always comply with national legislation. Finally, the results obtained in this study showed lower efficiency than those reported in the literature, with the author suggesting that a design or clogging problem hindered the treatment efficiency [41].

Several subsurface CWs were built in Mexico by using the high biodiversity of plants to treat wastewater flowing from houses, condominiums, restaurants, and small hotels. The treated wastewater was discharged to subsurface drains, and the resulting trials showed a 65–70% decrease in COD, a TSS removal of 44.4%, and a BOD_5 removal of 87.9% [38].

Table 2 shows a BOD_5 average removal rate of 88%. COD presented a slightly higher variation, but the average removal rate was 87%, making OM removal consistent with previously reported values for domestic wastewater [17,40,50,51]. When available, the data reported for nutrients varied considerably, with NH_4^+ varying from 48 to 99%, NH_3^+ from 25 to 99%, PO_4^{3-} from 66 to 91%, and TP from 57 to 99%.

Table 2. Average removal rates efficiencies (%) per HSFCW analyzed from the retrieved papers.

CW Scale	BOD_5	COD	TSS	NH_4^+	NH_3	NO_3	TKN	TN	PO_4^{3-}	TP	References
Real	94%	94%	95%	N/A	44%	88%	N/A	N/A	73%	73%	[8]
Real	>80%	>80%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[28]
Real	75%	75%	83%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[29]
Real	91%	91%	88%	48%	N/A	N/A	N/A	N/A	66%	N/A	[30]
Real	87%	87%	99%	97%	N/A	97%	N/A	N/A	91%	87%	[31]
Real	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[36] *Baggiolino tourism farm*

Table 2. *Cont.*

CW Scale	BOD_5	COD	TSS	NH_4^+	NH_3	NO_3	TKN	TN	PO_4^{3-}	TP	References
Real	N/A	Black—88%; Gray—40%	N/A	Black—55%; Gray—99%	N/A	Black—25%; Gray—98%	Black—84%; Gray—96%	N/A	N/A	Black—99%; Gray—95%	[36] *La Cava*
Real *	2.7–5.7 mg/L	8.8–28.3 mg/L	N/A	0.4–1.5 mg/L	N/A	N/A	N/A	N/A	N/A	N/A	[41]
Real	80%	66%	72%	N/A	N/A	N/A	85%	N/A	76%	N/A	[14]
Experiment	N/A	Experiment I—85.6 vs. 97.8%, Experiment II—82.3 vs. 90.2%, Experiment III—91.7 vs. 93.5%, Experiment IV—91.2 vs. 94.5% (Unplanted vs. Planted)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[39]
Real	97%	86%	66%	N/A	N/A	N/A	N/A	59%	N/A	57%	[41]
Real	88%	65–70%	44%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[37]
Real	54%	37%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[33]

Note: * Removal results for ideal conditions of pH = 4; Fe-C/water ratio of 1:4; N/A: not available.

3.3. Vertical Subsurface Flow Constructed Wetlands

VSFCWs were initially developed as a middle stage, after the anaerobic septic tank and before HSFCWs. Their main advantage is related to higher oxygen transfer capacities when compared with horizontal flow CWs, which leads to lower treatment areas and associated constructions costs [17].

The Abetina Reale Shelter is a mountain shelter with a restaurant that is open to the public mainly on weekends and in the summer, meaning that the site is characterized by wastewater load fluctuations. Prior to CW implementation, wastewater was directly discharged into a first-class category river, having only an Imhoff tank for pre-treatment. To improve its wastewater treatment, a buffer tank was installed after a new septic tank, which fed two parallel VSFCW cells (63 + 63 m^2). Designed for a 100 PE and an average organic loading rate of g COD/m^2.d, for discharge on a first-class category river, the following theoretical removal percentages must be complied with (according to The Water Authority): TSS 98–99%, COD 90–97%, BOD_5 90–97%, NH_4^+ 75–85%, TN 60–75%, TP 50–60%, fecal coliforms 99.90–99.99% [36].

In general, the overall mean removal efficiencies of the VSFCW beds were between 52 and 99% for TSS, 48 and 99% for BOD_5, 44 and 95% for COD, 34 and 95% for NH_4^+, 20 and 94% for TN, 21 and 97% for TP, and 26 and 92% for PO_4^{3-}, depending on the VSFCW design [17]. Therefore, it is expected that the Abetina Reale Shelter's CW will comply with The Water Authority's requirements for discharge on a first-class category river.

3.4. Hybrid Flow Constructed Wetlands

HSFCWs have limited oxygen content, which hinders nitrification processes occurring on their beds, while VSFCWs provide sufficient oxygen transfer, increasing nitrification efficiency but leading to poorer denitrification rates. Hence, mixed wastewater treatments using both typologies can explore the advantages of one type to balance the disadvantages of the other, theoretically leading to a balanced treatment [17,51–53].

A hybrid system was installed at "Relais Certosa", a hotel in Florence. It comprised a hybrid design for the secondary treatment of hotel wastewater, starting with primary treatment tanks that fed the HSFCW cell. The effluent continued to flow toward a repartition well that fed two separated chambers of a VSFCW [36,37,44]. The HSFCW cell had a surface area of 160 m^2, while the two VSFCW cells, laid out in parallel, had a total surface area of 180 m^2 (90 m^2 each). The systems used a high-density polyethylene (HDPE) geomembrane for waterproofing, and while the HSFCW used gravel as substrate, the VSFCW used both sand and gravel. Both CWs were planted with reeds and, after filtration through the VSFCW, a portion of the effluent was discharged to the river while the remainder was stored for reuse [36,37,44]. Designed for a 140 PE and an average organic loading rate of 17.5 g COD/m^2.d at the HSFCW and 2 g COD/m^2.d at the VSFCW, the following theoretical removal percentages must be complied with (as required by The Water Authority) for a first-class category river: COD 94%, BOD_5 95%, TSS 90%, TKN 60%, NH_3 85%, and TP 94%.

In Lloret de Mar, Spain, a HSFCW was integrated into a cascading vertical set-up (vertECO) for decentralized graywater treatment in order to decrease potable water consumption by reusing graywater for toilet flushing, leading to a potable water consumption reduction of 80% per guest per night [54]. Specifically, the design used a vertical set-up with four cascading stages combined with a horizontal subsurface water flow. A time-controlled pump intermittently fed 7 L/min of wastewater from an oxygenated water tank to the top floor of the vertical ecosystem. The horizontal subsurface water flowed through the rhizosphere and was forced by gravity into the next floor, maintaining a saturated wastewater level. A light-expanded clay aggregate was used, as well as oxygenation enhanced by pumping air through perforated hoses in the bottom of the containers in order to promote aerobic microorganisms for efficient rhizosphere degradation processes. The installation stage's top layer was planted with a polyculture of *Cyperus alternifolius* L., *Monstera deliciosa*, *Carex acutiformis*, *Ficus pumila* L., *Juncus inflexus* L., *Philodendron scandens*, *Juncus effuses* L., *Philodendron erubescens*, *Equisetum hyemale* L., *Syngonium podophyllum* S., *Spathiphyllum wallisii*, *Iris laevigata*, *Spathiphyllum wallisii* 'sensation', *Mentha aquatica* L., and *Calathea* sp. [34]. The organic load averages were 158 mgO_2/L for COD and 116 mgO_2/L for BOD_5, with reported average removal efficiencies of more than 90% for COD, BOD_5, TSS, and turbidity, while total organic carbon reached more than 80%. The effluents consistently met the standards for various reuse applications, even at different hydraulic retention times [34]. In terms of organic micropollutants, influent graywater was characterized by high concentrations, but more than 95% were reported to be removed by the vertECO system, such as acetaminophen, ibuprofen, salicylic acid, caffeine, estradiol, progesterone, testosterone, triclosan, and methyl-, ethyl-, and propylparaben. In addition, a more than 80% removal rate was achieved for diclofenac, atenolol, and trimethoprim. Hydrochlorothiazide, sulfamethoxazole, and salbutamol were not reduced by more than 30%. Statistically significant differences were found at different hydraulic retention times for acetaminophen, atenolol, ibuprofen, ethylparaben, ris(2-chloroisopropyl) phosphate, and tris(2-butoxyethyl)phosphate [34].

The vertECO system was again analyzed in 2021, achieving removal rates higher than 84.0% for COD and TSS and higher than 95.4% for turbidity and BOD_5. Therefore, the effluent continued to comply with reuse legislation [35]. Microbiological indicators were also analyzed, with fecal enterococci achieving a log removal of 4, *E. coli* achieving a log removal > 4, and total coliforms achieving a log removal of 2.7.

An installation consisting of an experimental multi-stage CW system was set up at a wastewater treatment plant in Mojacar, Spain. This plant used a lagoon system to treat wastewater from the village and tourist resort area, experiencing pronounced fluctuations in hydraulic and organic load throughout the year. The design consisted of 24 tanks laid out in four series by three stages, with each series replicated. Series 1, 2, and 3 were fed with pre-treated water from an anaerobic stabilization pond, and series 4 was fed with the effluent from the lagoon system. Different hydraulic loads were supplied automatically at regular 60-min intervals [32]. All tanks were planted with emergent macrophytes from nearby wetlands, *P. australis* and *T. dominguensis*. In the first tank (stage 1) in series 1, *Phragmites* was grown on a surface flow CW. The first tank (stage 1) in series 2 and 3 was designed with an upflow VSFCW and planted with *P. australis*. The first tank (stage 1) in series 4 was also planted with *P. australis*, but a HSFCW was used due to the higher oxygen concentration of the influent since it was pre-treated wastewater. The second tank in each series, or stage 2, was designed with a horizontal subsurface flow and planted with *T. dominguensis*. Sand was used in series 1 and 4, while fine gravel was used in series 2 and 3. The removal of TSS was 90% for series 1, 96% for series 2 and 3, and 95% for series 4; the

COD removal rates were 87% for series 1 and 2, 78% for series 3, and 70% for series 4; the BOD_5 removal rates were 90% for series 1, 2, and 4 and 88% for series 3. Regarding the TP removal rates, it were 66% for series 1, 55% for series 2, 48% for series 3, and 60% for series 4. TN removal rates were 38% for series 1, 41% for series 2, 23% for series 3, and 78% for series 4 [25]. The third tank (stage 3) in each series was designed with a vertical subsurface flow and planted with *P. australis*. To ensure homogeneous water distribution over the substrate surface, two parallel channels (2 cm wide and 140 cm long) were used approximately 20 cm over the substrate. This design improves water oxygenation. The substrate consisted of coarse gravel and stones combined with a layer of iron filings in series 1. The net treatment area (stages 1, 2, and 3) per PE in terms of hydraulic loading rate was 2.3 m^2 for series 1 and 2, 1.2 m^2 for series 3, and 1.6 m^2 for series 4. The use of sand improved TSS retention; however, because of the risk of clogging, the advantages of the use of sand must be pondered. The addition of iron to the substrate improved phosphorus retention from 55% to 66%. Although the performance of this treatment for organics removal is high, the subsurface flow system does not offer conditions for nitrification. Therefore, if nitrogen has to be removed in the next treatment stage, water oxygenation has to be ensured [32].

Koh Phi island located in Thailand experiences land and energy scarcity, with more than 1 million tourists visiting every year. After the 2004 tsunami, the Danish Government gave a relief grant to Thailand to help re-establish the nation's wastewater management services [40]. The island stakeholders designed a wastewater treatment installation that uses a recovery-based, closed-loop system wherein wastewater is collected, treated, and reused in an integrated system. The system was dimensioned to treat up to 400 m^3/d of mixed blackwater and graywater, where odor control, aesthetics, and social involvement was equally important to the treatment performance; in fact, the creative process garnered a design concept based on a butterfly and a flower, which comprised the application of CW with different operational flows. The wastewater was pumped to siphons which distribute the wastewater in intervals to three VSFCWs, or the first petal of the flower, which has an area of 2300 m^2, being filled with gravel, and planted with *Canna* and *Heliconia*. The flow later goes to three HSFCW cells, the second petal of the flower, which has an area of 750 m^2 and was also filled with gravel and planted with *Canna*. From there, it flows to three surface flow CWs, the wings of the butterfly (which have an area of 750 m^2 and are planted with Papyrus). It then finally arrives to the polishing ponds, or the butterfly's body, which has an area of 200 m^2 [40]. Treated effluent is stored in an underground reservoir for irrigation. The average removal rates were 90.00% for TSS, 91.58% for BOD_5, 38.89% for TKN, 50.00% for NO_3^-, 46.43% for TP, 90.09% for oil and grease, and 92.31% for fecal coliforms. The effluent from the system mostly met the Thai effluent standards for pH, TSS, and TKN, but the effluent BOD_5 concentrations were slightly higher (average 25 mg/L) than the 20 mg/L effluent standard. Also, the outlet concentrations of oil and grease were higher than the 5 mg/L requirement [40]. The installation experienced problems with high concentrations of oil and grease in the effluent, probably due to high influent concentrations as a consequence of illegal connections to the wastewater collection systems and the lack of oil and grease traps at individual residential houses, restaurants, hotels, and other businesses. The lack of grease traps resulted in high levels of oil and grease in the collection system and in the treatment plant, which increased the clogging of the gravel beds [40].

In the Italian region of Castelluccio, the installed wastewater treatment plant was inadequate to support the tourism load, which shifts from less than 50 people during winter up to 1000 or more people during summer. Therefore, a multi-stage CW system consisting of a French scheme, or VSFCW reed bed filters, was installed with an area of 1800 m^2, followed by two parallel free water-pond systems as a polishing stage and a recreational pond holding several rare aquatic plants typical of the Castelluccio plateau. This hybrid configuration permits a considerable reduction in the total surface needed for the treatment and, consequently, a reduction in water loss by evapotranspiration. The removal efficiencies were >90% for TSS, COD, and BOD_5 [38].

Different design typologies were analyzed in the hybrid section. The first used a horizontal flow stage to remove organic matter (OM) and TSS and provide denitrification, followed by a vertical flow stage to enhance OM and suspended solids (SS) removal and increase nitrification [36,38,44]. The Verteco design was developed for the treatment of graywater by using a vertical structure with four cascading stages combined with horizontal water flow and aeration in the root zone in order to enhance nitrification. As for [32] study, different designs were tested, but in general, Stage 1 focused on sedimentation and secondary wastewater treatment with an oxygenated effluent for nitrification. Stage 2 used saturated conditions to enhance denitrification, and stage 3 enhanced the oxygenation of the medium. In this last stage, series 1 contained a thin iron layer to increase phosphorus fixation. The last two hybrid systems used a VSFCW stage first in order to remove OM and TSS and enhance nitrification. The second stage was a HSFCW for denitrification [40] or another VSFCW stage to enhance nitrification [38].

Table 3 presents the reported removal efficiencies (%) for BOD_5, COD, TSS, NH_4^+, NH_3, NO_3^-, TKN, TN, and TP observed in the hybrid CWs studied in this review. For COD, BOD_5, and TSS, the median removal efficiencies were equal to or above 90%, while the NH_4^+ and NH_3 medians were 78% and 85%, the TN median was 45%, and the TP median was 57%.

Table 3. Average removal rate efficiencies (%) per hybrid subsurface flow constructed wetlands (CWs) analyzed.

CW Scale	BOD_5 (%)	COD (%)	TSS (%)	NH_4^+ (%)	NH_3 (%)	NO_3-N (%)	TKN (%)	TN (%)	TP (%)	References
Real	95%	94%	90%	N/A	85%	N/A	60%	N/A	94%	[36–38]
Real	96%	94%	91%	56%	N/A	N/A	73%	43%	N/A	[34]
Pilot	98%	84%	86%	99%	N/A	N/A	N/A	65%	N/A	[35]
Real	90%	81%	94%	N/A	N/A	N/A	N/A	45%	57%	[32]
Real	92%	N/A	90%	N/A	N/A	50%	39%	N/A	46%	[40]
Real	N/A	98%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[38]

It is worth noting that the application of CWs for the removal of micropollutants from hotel graywater was also addressed by Zraunig et al. [34]. As expected, there was a high level of influent concentration variability, but the vertECO system was able to remove many Pharmaceutically Active Compounds (PhACs) and endocrine disruptors (EDCs), although others showed more persistence. Therefore, CWs may be a solution for minimizing micropollutant discharge through wastewater, although further research is needed to provide a better understanding of the removal mechanisms of these compounds.

4. Conclusions

This review article lists the features of CWs applied to the hospitality industry. The CW systems analyzed exemplify sustainable, low-cost, and aesthetic wastewater treatment solutions for areas where centralized sewer systems may not be available. This review article also describes the ability of these systems to cope with fluctuations in wastewater production, which are common in the hospitality industry. Hybrid systems, such as the “vertECO” or the Hotel Relais Certosa, demonstrate the possibility of re-using the treated effluent from CWs for irrigation, toilet flushing, and landscaping, reducing potable water consumption and wastewater generation. When ornamental plants are integrated, biodiversity conservation and aesthetic enhancement are further functions of CW systems. Moreover, CW systems can reduce energy consumption, reduce the greenhouse gas emissions associated with wastewater treatment, and sequester carbon dioxide. These benefits show that these systems are promising nature-based solutions for the hospitality sector, especially when the industry is looking for more sustainable solutions to decrease its environmental impact, as encouraged by The United Nations’ Sustainable Development Goal 6, Targets 3 and 4.

In addition, tourism's interrelationship with other sectors implies that, when pursuing sustainable development, coordinating various stakeholders, such as authorities, tourists, businesses, and local people, is essential. Promoting synergetic relations between various stakeholders during the decision-making process is essential to effectively facilitate sustainable development. In this sense, nature-based solutions such as CWs provide a range of benefits that go beyond water treatment, such as decreased associated costs and toleration to flow fluctuations, by also being capable of adapting to different climatic conditions, aesthetic enhancement, and habitat creation. The possible commercialization of crops and flowers, biomass production for energy generation, and climate and flood regulation should also be considered during decision making processes; thus, all services should be clarified to stakeholders during the decision making process.

However, CW systems also face some challenges and limitations that need to be overcome. For example, CW systems usually require more land area than conventional wastewater treatment systems, which may be a constraint in urban or densely populated areas. CW systems may also demonstrate variance in their performance depending on influent quality and quantity, which may fluctuate due to seasonal variations or occupancy rates. Furthermore, CW systems may need periodical operation and maintenance to ensure their functionality and efficiency, such as plant harvesting, sediment removal, and inlet and outlet control.

From the studies analyzed, only one laboratory scale study was conducted in India, while other CWs were implemented as onsite treatment solutions. HSFCWs were the most used design, probably due to their reliability when there are no land area restrictions and because, in general, they perform well, with average removal rates of 88% for BOD_5, 87% for COD, 72% for NH_4^+, 44% for NH_3, 76% for PO_4^{3-}, and 65% for TP (for different inlet pollutant concentrations). In addition, hybrid systems were also analyzed within the articles reviewed, wherein there was no preference for the CW typology sequence. These different hybrid systems were usually able to achieve higher removal rates when compared with horizontal ones, with median removals of 95% for BOD_5, 94% for COD, 78% for NH_4^+, 85% for NH_3, and 57% for TP.

Finally, as with the majority of studies, the design of the current study is subject to limitations. The methodology used restricted the information obtained to peer-reviewed research and review articles. Also, some retrieved publications did not specify the design of the CWs, limiting the number of analyzed studies. Further research is needed to address this gap in the literature, and one way this can be achieved is by expanding the methodology to other platforms and types of studies. As previously stated, the information regarding CWs in the hospitality industry is dispersed; therefore, with the objective of creating a reference tool for stakeholders, continuously improving this database via supplementation with different types of information must be considered.

Author Contributions: Conceptualization, C.S.C.C., P.M.L.C., D.G. and S.J.; methodology, C.S.C.C., P.M.L.C. and D.G.; analysis, C.S.C.C., P.M.L.C., D.G. and S.J.; writing—original draft preparation, C.S.C.C., P.M.L.C., D.G. and S.J.; writing—review and editing, C.S.C.C., P.M.L.C., D.G. and S.J.; supervision, C.S.C.C., P.M.L.C. and D.G.; funding acquisition, D.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: Authors are grateful to FCT—Fundação para Ciência e Tecnologia within the scope of projects UIDB/04423/2020 and UIDP/04423/2020 (CIIMAR) and UIDB/50016/2020 (CBQF).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Pisano, U.; Endl, A.; Berger, G.; The Rio+20 Conference 2012: Objectives, Processes and Outcomes. ESDN Quarterly Report No 25. *European Sustainable Development Network (ESDN).* 2012. Available online: https://www.esdn.eu/fileadmin/ESDN_Reports/2012-June-The_Rio_20_Conference_2012.pdf (accessed on 9 April 2023).
2. Abdou, A.H.; Hassan, T.H.; Dief, M.M.A. Description of green hotel practices and their role in achieving sustainable development. *Sustainability* **2020**, *12*, 9624. [CrossRef]
3. International Monetary Fund. World Economy Outlook. 2021. Available online: https://www.imf.org/en/Publications/WEO/Issues/2021/03/23/world-economic-outlook-april-2021 (accessed on 9 April 2023).
4. Crase, L.; O'Keefe, S.; Horwitz, P.; Carter, M.; Duncan, R.; MacDonald, D.H.; McKenzie, F.H.; Gawne, B. *Australian Tourism in a Water Constrained Economy: Research Agenda*; CRC for Sustainable Tourism Pty Ltd.: Gold Coast, Australia, 2010; ISBN 9781921658303.
5. Becken, S. Water equity—Contrasting tourism water use with that of the local community. *Water Resour. Ind.* **2014**, *7–8*, 9–22. [CrossRef]
6. Cole, S.K.G.; Mullor, E.C.; Ma, Y.; Sandang, Y. Tourism, water, and gender—An international review of an unexplored nexus. *WIREs Water* **2020**, *7*, e1442. [CrossRef]
7. Antakyah, D.; Krampe, J.; Steinmetz, H. Practical application of wastewater reuse in tourist resorts. *Water Sci. Technol.* **2008**, *57*, 2051–2057. [CrossRef] [PubMed]
8. Calheiros, C.S.C.; Bessa, V.S.; Mesquita, R.B.R.; Brix, H.; Rangel, A.O.S.S.; Castro, P.M.L. Constructed wetland with a polyculture of ornamental plants for wastewater treatment at a rural tourism facility. *Ecol. Eng.* **2015**, *79*, 1–7. [CrossRef]
9. Morel, A.; Diener, S. *Greywater Management in Low and Middle-Income Countries, Review of Different Treatment Systems for Households or Neighbourhoods*; Sandec Report No. 14/06; Sandec (Water and Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science and Technology): Dübendorf, Switzerland, 2006.
10. Paulo, P.L.; Azevedo, C.; Begosso, L.; Galbiati, A.F.; Boncz, M.A. Natural systems treating greywater and blackwater on-site: Integrating treatment, reuse and landscaping. *Ecol. Eng.* **2013**, *50*, 95–100. [CrossRef]
11. United Nations Children's Fund (UNICEF); World Health Organization. *State of the World's Sanitation: An Urgent Call to Transform Sanitation for Better Health, Environments, Economies and Societies*; United Nations Children's Fund (UNICEF): New York, NY, USA, 2020; ISBN 978-92-4-001447-3.
12. Moreira, F.D.; Dias, E.H.O. Constructed wetlands applied in rural sanitation: A review. *Environ. Res.* **2020**, *190*, 110016. [CrossRef]
13. Liamlaem, W.; Benjawan, L.; Polprasert, C. Sustainable wastewater management technology for tourism in Thailand: Case and experimental studies'. *Water Sci. Technol.* **2019**, *79*, 1977–1984. [CrossRef]
14. Pérez-Salazar, R.; Mora-Aparicio, C.; Alfaro-Chinchilla, C.; Sasa-Marín, J.; Scholz, C.; Rodríguez-Cor, J.Á. Biogardens as constructed wetlands in tropical climate: A case study in the Central Pacific Coast of Costa Rica. *Sci. Total Environ.* **2019**, *658*, 1023–1028. [CrossRef]
15. Calheiros, C.; Pereira, S.; Castro, P.M.L. Chapter 3. Constructed wetlands as nature-based solutions. In *An Introduction to Constructed Wetlands*; Jespersen, A.N., Ed.; Nova Science Publishers: New York, NY, USA, 2020. Available online: https://novapublishers.com/shop/an-introduction-to-constructed-wetlands/ (accessed on 9 April 2023).
16. Fonder, N.; Headley, T. The taxonomy of treatment wetlands: A proposed classification and nomenclature system. *Ecol. Eng.* **2013**, *51*, 203–211. [CrossRef]
17. Stefanakis, A.; Akratos, C.S.; Tsihrintzis, V.A. *Vertical Flow Constructed Wetlands: Eco-Engineering Systems for Wastewater and Sludge Treatment*; Elsevier: Amsterdam, The Netherlands, 2014; ISBN 9780124046122. [CrossRef]
18. Stefanakis, A.I.; Calheiros, C.S.C.; Nikolaou, I. Nature-Based Solutions as a Tool in the New Circular Economic Model for Climate Change Adaptation. *Circ. Econ. Sustain.* **2021**, *1*, 303–318. [CrossRef]
19. Kadlec, R.H.; Wallace, S. *Treatment Wetlands*, 2nd ed.; Taylor & Francis,: Boca Raton, FL, USA, 2009. [CrossRef]
20. Meyer, D.; Chazarenc, F.; Claveau-Mallet, D.; Dittmer, U.; Forquet, N.; Molle, P.; Morvannou, A.; Pálfy, T.; Petitjean, A.; Rizzo, A.; et al. Modelling constructed wetlands: Scopes and aims—A comparative review. *Ecol. Eng.* **2015**, *80*, 205–213. [CrossRef]
21. Barros, M.L.C.; da Silva, T.D.; da Cruz, A.G.B.; Rosman, P.C.C. Numerical simulation of wetland hydrodynamics and water quality. *J. Braz. Soc. Mech. Sci. Eng.* **2020**, *42*, 444. [CrossRef]
22. Imteaz, M.A.; Uddameri, V.; Ahsan, A. Numerical model for the transport and degradation of pollutants through wetlands. *Int. J. Water* **2016**, *10*, 1–12. [CrossRef]
23. Tranfield, D.; Denyer, D.; Smart, P. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *Br. J. Manag.* **2003**, *14*, 207–222. [CrossRef]
24. Boland, A.; Cherry, M.G.; Dickson, R. *Doing a Systematic Review: A Student's Guide*; SAGE: Newcastle upon Tyne, UK, 2017.
25. Wang, M.; Zhang, D.Q.; Dong, J.W.; Tan, S.K. Constructed wetlands for wastewater treatment in cold climate—A review. *J. Environ. Sci.* **2017**, *57*, 293–311. [CrossRef]
26. Stein, O.R.; Hook, P.B. Temperature, plants, and oxygen: How does season affect constructed wetland performance? *J. Environ. Sci. Health—Part A Toxic/Hazard. Subst. Environ. Eng.* **2005**, *40*, 1331–1342. [CrossRef]
27. Zhu, H.; Zhou, Q.; Yan, B.; Liang, Y.; Yu, X.; Gerchman, Y.; Cheng, X. Influence of vegetation type and temperature on the performance of constructed wetlands for nutrient removal. *Water Sci. Technol.* **2018**, *77*, 829–837. [CrossRef]

28. Calheiros, C.S.C.; Pereira, S.I.A.; Brix, H.; Rangel, A.O.S.S.; Castro, P.M.L. Assessment of culturable bacterial endophytic communities colonizing Canna flaccida inhabiting a wastewater treatment constructed wetland. *Ecol. Eng.* **2017**, *98*, 418–426. [CrossRef]
29. Calheiros, C.S.C.; Ferreira, V.; Magalhães, R.; Teixeira, P.; Castro, P.M.L. Presence of microbial pathogens and genetic diversity of Listeria monocytogenes in a constructed wetland system. *Ecol. Eng.* **2017**, *102*, 344–351. [CrossRef]
30. Calheiros, C.S.C.; Pereira, S.I.A.; Franco, A.R.; Castro, P.M.L. Diverse Arbuscular Mycorrhizal Fungi (AMF) Communities Colonize Plants Inhabiting a Constructed Wetland for Wastewater Treatment. *Water* **2019**, *11*, 1535. [CrossRef]
31. Calheiros, C.S.C.; Castro, P.M.L.; Gavina, A.; Pereira, R. Toxicity Abatement of Wastewaters from Tourism Units by Constructed Wetlands. *Water* **2019**, *11*, 2623. [CrossRef]
32. Cerezo, R.G.; Suarez, M.L.; Vidal-Abarca, M.R. The performance of a multi-stage system of constructed wetlands for urban wastewater treatment in a semiarid region of SE Spain. *Ecol. Eng.* **2001**, *16*, 501–517. [CrossRef]
33. García, J.; Ojeda, E.; Sales, E.; Chico, F.; Píriz, T.; Aguirre, P.; Mujeriego, R. Spatial variations of temperature, redox potential, and contaminants in horizontal flow reed beds. *Ecol. Eng.* **2003**, *21*, 129–142. [CrossRef]
34. Zraunig, A.; Estelrich, M.; Gattringer, H.; Kisser, J.; Langergraber, G.; Radtke, M.; Rodriguez-Roda, I.; Buttiglieri, G. Long term decentralized greywater treatment for water reuse purposes in a tourist facility by vertical ecosystem. *Ecol. Eng.* **2019**, *138*, 138–147. [CrossRef]
35. Estelrich, M.; Vosse, J.; Comas, J.; Atanasova, N.; Costa, J.C.; Gattringer, H.; Buttiglieri, G. Feasibility of vertical ecosystem for sustainable water treatment and reuse in touristic resorts. *J. Environ. Manag.* **2021**, *294*, 112968. [CrossRef]
36. Masi, F.; Martinuzzi, N.; Bresciani, R.; Giovannelli, L.; Conte, G. Tolerance to hydraulic and organic load fluctuations in constructed wetlands. *Water Sci. Technol.* **2007**, *56*, 39–48. [CrossRef]
37. Masi, F.; Martinuzzi, N. Constructed wetlands for the Mediterranean countries: Hybrid systems for water reuse and sustainable sanitation. *Desalination* **2007**, *215*, 44–55. [CrossRef]
38. Makopondo, R.O.B.B.; Rotich, L.K.; Kamau, C.G. Potential Use and Challenges of Constructed Wetlands for Wastewater Treatment and Conservation in Game Lodges and Resorts in Kenya. *Sci. World J.* **2020**, *14*, 9184192. [CrossRef]
39. Bindu, T.; Sylas, V.P.; Mahesh, M.; Rakesh, P.S.; Ramasam, E.V. Pollutant removal from domestic wastewater with Taro (Colocasia esculenta) planted in a subsurface flow system. *Ecol. Eng.* **2008**, *33*, 68–82. [CrossRef]
40. Brix, H.; Koottatep, T.; Fryd, O.; Laugesen, C.H. The flower and the butterfly constructed wetland system at Koh Phi Phi-System design and lessons learned during implementation and operation. *Ecol. Eng.* **2011**, *37*, 729–735. [CrossRef]
41. Pawęska, K.; Kuczewski, K. The small wastewater treatment plants—Hydrobotanical systems in environmental protection. *Arch. Environ. Prot.* **2013**, *39*, 3–16. [CrossRef]
42. Ma, T.; Zhang, L.; Xi, B.; Xiong, Y.; Yu, P.; Li, G.; Li, J.; Zhao, C. Treatment of farmer household tourism wastewater using iron-carbon micro-electrolysis and horizontal subsurface flow constructed wetlands: A full-scale study. *Ecol. Eng.* **2018**, *110*, 192–203. [CrossRef]
43. Mustafa, H.M.; Hayder, G. Cultivation of *S. molesta* plants for phytoremediation of secondary treated domestic wastewater. *Ain Shams Eng. J.* **2021**, *12*, 2585–2592. [CrossRef]
44. United States Environmental Protection Agency. *Wastewater Technology Fact Sheet: Free Water Surface Wetlands*'; Environmental Protection Agency: Washington, DC, USA, 2000; pp. 1–8. Available online: https://www3.epa.gov/npdes/pubs/free_water_surface_wetlands.pdf (accessed on 9 April 2023).
45. Iridra. Constructed Wetlands System for Wastewater Treatment for Fattoria Baggiolino. 2002. Available online: http://iridra.eu/attachments/article/112/Baggiolino.pdf (accessed on 9 April 2023).
46. Ministerio de Ambiente y Energia. Reglamento de Vertido y Aguas Residuales No 33601'. *La Gac.* **2007**, *55*, 56.
47. Brix, H.; Arias, C.A. Danish guidelines for small-scale constructed wetland systems for onsite treatment of domestic sewage. *Water Sci. Technol.* **2005**, *51*, 1–9. [CrossRef] [PubMed]
48. García, J.; Aguirre, P.; Mujeriego, R.; Huang, Y.; Ortiz, L.; Bayona, J.M. Initial contaminant removal performance factors in horizontal flow reed beds used for treating urban wastewater. *Water Res.* **2004**, *38*, 1669–1678. [CrossRef]
49. United States Environmental Protection Agency. Constructed Wetlands Treatment of Municipal Wastewaters. 2000; p. 165. Available online: http://www.epa.gov/ORD/NRMRL (accessed on 9 April 2023).
50. Brix, H. Functions of macrophytes in constructed wetlands'. *Water Sci. Technol.* **1994**, *29*, 71–78. [CrossRef]
51. Calheiros, C.S.C.; Rangel, A.O.S.S.; Castro, P.M.L. The effects of tannery wastewater on the development of different plant species and chromium accumulation in Phragmites australis. *Arch. Environ. Contam. Toxicol.* **2008**, *55*, 404–414. [CrossRef]
52. Vymazal, J. Removal of nutrients in various types of constructed wetlands. *Sci. Total Environ.* **2007**, *380*, 48–65. [CrossRef]
53. Vymazal, J.; Kröpfelová, L. A three-stage experimental constructed wetland for treatment of domestic sewage: First 2 years of operation. *Ecol. Eng.* **2011**, *37*, 90–98. [CrossRef]
54. Gabarda-Mallorquí, A.; Garcia, X.; Ribas, A. Mass tourism and water efficiency in the hotel industry: A case study. *Int. J. Hosp. Manag.* **2017**, *61*, 82–93. [CrossRef]