TREATMENT OF WASTEWATER WITH CONSTRUCTED WETLANDS SYSTEMS AND PLANTS USED IN THIS TECHNOLOGY – A REVIEW

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Abstract. Water issues are still here, urbanization and industries generate different types of wastes which then affect water. Many technologies have been introduced for water treatment and efforts are being made to improve and maintain water quality, while also providing easily available and low-cost technologies. Several methods which are easily available but due to high cost, they cannot be introduced everywhere, especially rural areas. Recently, constructed wetlands have been proven to be an efficient technology to treat water. With its biological, physical and chemical treatment, constructed wetland technology becomes the best choice by many countries around the world. Existing research shows that COD (Chemical Oxygen Demand), BOD5 (Biological Oxygen Demand), TKN (Total Kjeldahl Nitrogen), TSS (Total suspended solids) etc. have been removed to a significant degree by using constructed wetlands. This technology is a system of different materials, such as gravel, vegetation and recently introduced tool knows as biochar. The combination of these makes the system efficient for water treatment but some factors such as area, weather conditions, type of wastes do matter. Selection of constructed wetland type and suitable plants is very important. In this paper, efficiency of constructed wetland system, its mechanism, the types of plants used in the system and role of plants to enhance the efficiency of the wetland system from all over the world are widely reviewed and discussed.
Keywords: *constructed wetlands, water treatment, removal mechanisms, removal of pollutants, plants in wetlands*

Introduction

Recent environmental issues and the discovery of their solutions have been increasing rapidly throughout the world. The discharge of wastewater from industries is a threat to nature creating water borne diseases. Recently, the lack of proper wastewater treatment, rapid urbanization is making the situation worse (Varga et al., 2017; Sanjrani et al., 2017; Brix et al., 2013). There are many options available for water treatment, but wetland technology is more efficient and less-cost. One of the valuable services given by natural, restored, or constructed wetlands is that they generally protect downstream waterways from the impact of nutrient pollution. This happens naturally because constructed wetlands are complex systems with a large number of active physical, chemical, and biological processes that mutually influence each other. Nutrient removal use some of the main physical processes such as particle settling known as sedimentation or volatilization, it releases as a gas into the atmosphere, and sorption which includes a nutrient adhering to a solid or diffusing into another liquid or solid. The chemical processes are involved with transformations and precipitation. The biological processes by plants, algae, and bacteria and further process of transformation are conducted by microbes. Wetland compartments have all of these processes with water; biota i.e. plants, algae, and bacteria; litter; and soil.

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Around the world, wastewater treatment by constructed wetlands has become one of the efficient solutions (Varga et al., 2017; Sanjrani et al., 2019; Jácome, 2016).

CWs are applied to the treatment of varieties of wastewaters created either from industries or human settlements. Some of them are: food industry effluents (including dairy, abattoir, fruit, vegetables and meat industries), effluents of petrochemical and refinery industry, distillery and winery effluents, textile, aquaculture, tannery, steel and mixed industrial effluents, pulp and paper industry etc (Varga et al., 2017). CWs are planned engineered systems that are generally constructed and designed by natural processes such as wetland vegetation, soils, and their associated microbial assemblages (Vymazal, 2014). In this process, it also needs to create a specific environment for the growth of microorganisms and hydrophytes (aquatic and semi aquatic plants) which can live in aerobic, anaerobic and facultative anaerobic environmental systems. Their interactions bring many changes, such as the intensification of oxidation and reduction responsible for the removal and retention of pollutants. These processes are generally supported by sorption, sedimentation and assimilation (Skrzypiec and Gajewska, 2017).

Wastewater is being treated by different types of wetland, i.e. H.F and V.F and a combination of VF and HF systems, known as hybrid wetlands. They are also known as: horizontal subsurface flow constructed wetlands (HSSFCWs), vertical subsurface flow constructed wetlands (VSSFCWs) and free water surface constructed wetlands (FWSCW). Wetlands for the treatment of wastewater, sludge, storm-water, and leachate have been evaluated in laboratory, pilot, and full-scale studies. Due to the benefits acquired from wetlands, wetlands are now at the centres of human evolution and the development of this planet's diverse cultures. Without water we would not exist. In Europe countries, these constructed wetlands are treating water at several places, i.e. tourist resorts, farms and landfills. Various CWs systems show different results in treatment efficiency (Mander et al., 2000). Moreover, recent studies have shown that every country relies on some type of wetlands (Jiang et al., 2016; RAMSAR, 2016; Sirianuntapiboon and Jitvimolnimit, 2007).

Recently, the use of biochar to enhance constructed wetland performance in wastewater has highly appreciated. Different types of biochar have been used to promote wetlands activities. Combining both of these technologies can greatly augment the efficiency of the system. Pollutant removal performance was compared between the controlled and experimental wetland beds. Study reveals that the wetlands with biochar are more efficient as compared to the wetland with gravels alone, which had the average removal rate (Prabuddha et al., 2015). The present paper documents an overall review on the efficiency of wetland systems and common pollutant removal around the world. It also attempts about overall review on the role of the wetland plants in constructed wetlands, efficiency of constructed wetland system, its mechanism, and the types of plants used in the system. Recommendations for future studies have been recommended to improve the efficiency for better treatment.

The efficiency of wetland systems for wastewater treatment

The efficiency of wetland systems for Wastewater Treatment has been proved that it is the best technology around the world. The first experiment on the use of wetland plants for treatment of wastewater was carried in the early 1950s by Dr. Kathe Seidel in Germany. The first full scale systems were put in operation during the late 1960s and since then constructed wetland systems have been speeding throughout the world (Vymazal and Kröpfelová, 2009). Different types of wastes are being treated by wetland technology and

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have shown promising results for the removal of pollutants (Newman et al., 2015). This is the reason; this technology is developing everywhere around the world. There are now more than 1,000 constructed wetland systems (CWs) in the UK (WRC UK, 2012). In Northeastern USA and Eastern Canada, 25 full-scale CWs treated agricultural wastewater and showed an average of good removal efficiencies: BOD5, TKN, TSS, NH_4^+-N, NO_3^--N and TP (Rozema and Andrew, 2016a; Rozema and Zheng, 2016b). In Russia, geographical conditions and the weather, depending on the possibilities for accommodation of certain types of CWs really need careful consideration. Recently, the use of constructed wetlands for xenobiotics removal in climatic conditions in Russia has been conducted. This project was both efficient and low-cost (Schegolkova et al., 2015).

In Korea, because of its lower construction cost and simplicity in operation and maintenance, many different types of wetland treatment systems have been built during the last 10 years, the efficiency of removal of pollutants is great. However, Kim et al. (2006) identified some issues; systems suffer from the reduced effectiveness in performance during the winter. And need to evaluate the partial treatment accomplished during six to seven months per year (Kim et al., 2006). In Pakistan, this technology was introduced relatively late, between 2009 and 2010, a small NGO Sindhica Reforms Society (Sindhica) initiated “Pakistan’s first community managed Constructed Wetland” with the support of Indus for All Programme-WWF Pakistan and the technical support of UN HABITAT water for Asian cities Programme, South Asia region. Constructed wetland Majeed Keerio was designed, with the realization that substrate of the wetland can rapidly fill up with debris, grit, and solids from raw waste water if these materials are not removed prior to the wetland. Therefore, Majeed Keerio was designed as: (1) Preliminary treatment: Removal of large contaminants, such as solid waste and grit to avoid operation and maintenance problems; (2) Primary treatment: Removal of suspended solids and organic matter; (3) Secondary treatment: Removal of biodegradable organic matter; (4) Tertiary treatment: Removal of specific pollutants such as nutrients. This wetland has brought good results in removing pollutants from water (Keryo, 2012).

In Egypt, there are two major challenges that affect the ecosystem and the urban environment: the first being water scarcity and the second being wastewater management. Egypt is an arid country; it is important that reusing wastewater be encouraged as it is documented that reused wastewater is safe and economically feasible. There are several available methods for wastewater treatment; however treatment by wetlands is the most effective method (ElZein et al., 2016). In Malaysia, Faculty of Engineering, Universiti Putra Malaysia has been trying to resolve water treatment issues in Malaysia. In their study (Katayon et al., 2008), results showed that the constructed wetlands have removed 27-96% of NH_4^+, 50-88% of TSS, 56-77% of COD, 20-88% of TP, and 99% of total coliform numbers. In Kerala, India, a CW system made using a laboratory scale model; including plant ‘Reed’ has given good results for removal efficiencies for domestic wastewater treatment at a considerable level (Midhun et al., 2016).

In Ireland, 52 constructed wetland sites from 17 local authorities were aimed to identify the best performing types of constructed wetlands; some constructed wetland sites achieved long or frequent periods of zero effluent discharge and thus did not transfer any waterborne pollution to their receptors during these periods (Hickey et al., 2017).

Besides, there are very few disadvantages of this technology. Depending on design, constructed wetlands may possess a larger land-area than other technology. Mosquito populations increased because of wetlands and can be the reason for the diseases like malaria or other diseases caused by mosquitoes. Wetlands produce about one quarter of the

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Earth's atmospheric methane through the anaerobic decomposition of organic matter. Sometimes nutrients are changed to harmless forms year-round by wetland bacteria. Constructed wetlands may not to treat highly toxic modern wastewater till it is pre-treated in special installations. In climates with cold winters, bacteria and plants living in the constructed wetland's soil die back and release their own nutrients back into the system. A constructed wetland's biological processes are not well understood. Residual pollutants may have a negative effect on the reserve's wildlife (Gutiérrez, 2011; Kielmas, 2018; Permaculture, 2015; Akers, 2012; Patil, 2016).

Removal of pollutants by wetlands

Various studies have documented that wetlands are the best and low-cost available option for removing several pollutants from water. It can be concluded that the use of constructed wetland is very effective in removing major nutrients and pollutants. Some recent studies from all over the world have been mentioned in *Table 1,* which prove that this technology is best option for pollutants removal up to 99%.

Table 1. *Removal percentage of pollutants by wetlands*

S.No.	COD	BOD_5	TN	TKN	TSS	TDS	TP	References
1	99%			94%	98%		83%	Rozema and Andrew (2016a); Rozema and Zheng (2016b)
2	86.6	83.7%		36.66%		87.36%		Midhun et al. (2016)
3			69.96%				82.4%	Patil and Munavalli (2016)
4					83%	58%		Haukos et al. (2016)
5	97.2%		90.6%					Wu et al. (2016)
6	75%		75%				55%	Sartori et al. (2016)
7			67%					Khajah, and Babatunde (2016)
8	74.6-76.6%		60.1-84.7%				49.3-70.7%	Chyan et al. (2016c)
9		87.81%			86.10%	67.27%		Upadhyay et al. (2016)
10	89.2%		90.0%				50.3%	Maucieri et al. (2016)
11	91%							Sultana et al. (2016)
12			60% ± 12%				77% ± 4%	Mateus et al. (2016)
13	95.6%		85.8%					Fan et al. (2016)
14	91.3%		58.3%				79.5%	Prabuddha et al. (2015)
15					85%		68%	Niu et al. (2016)
16	83-88%	90-95%			89-93%			Carballeira et al. (2016)
17	66%		79%					Uggetti et al. (2016)
18	91 ± 7%	95 ± 5%	70 ± 10%				90 ± 6%	Yin et al. (2016)
19		81%		75%	83%		64%	Rozema and Andrew (2016a); Rozema and Zheng (2016b)
20	69%		69%					Wu et al. (2016)
21			43%	38%				Vymazal and Kröpfelová (2009)
22	65%		43%					Wang et al. (2016a)
23	68.1%			78.25%	86.5%		64.85%	Zhao et al. (2016)
24			71%					He et al. (2016)

The data shows that high levels of removal were detected for Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP), Total Nitrogen, ammonium/ammonia, nitrate and nitrite, Biological Oxygen Demand (BOD), Chemical Oxygen Demand

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(COD), and Suspended Sediments (SS). Large amounts were reduced for all these parameters. It can be concluded that constructed wetland systems are effective for the reduction of several pollutants

Removal mechanisms and wastewater constituents

There are many mechanisms involved in the wetlands system which can remove BOD, COD, and Nitrogen, as shown in *Table 2*.

Table 2. *Removal mechanisms and wastewater constituents. (Source: modified from: Newman et al., 2015; Keryo, 2012; FCN, 2014)*

Removal mechanisms and wastewater constituents	
Wastewater constituents	**Removal mechanisms**
Heavy metals	Sedimentation, adsorption, plant uptake, chemical precipitation, infiltration
Bacteria/pathogens	Sedimentation, natural die off
Synthetic organics	Sedimentation, adsorption, oxidation, volatilization, infiltration
Hydrocarbons	Bio-filtration, microbial decomposition, oxidation, plant uptake metabolism
Total phosphorus	Matrix sorption, plant uptake, sedimentation bio-filtration
Nitrate	Denitrification
Nitrite	Denitrification
Ammonia	Nitrification
Biological oxygen demand	Sedimentation, bio-filtration,
Chemical oxygen demand	Sedimentation, bio-filtration, oxidation
Suspended solids	Sedimentation, filtration
Soluble organics	Aerobic microbial degradation, anaerobic microbial degradation
Total nitrogen	Ammonification followed by microbial nitrification, denitrification, plant uptake, matrix adsorption, ammonia volatilization

Efficiency of vegetation in wetlands for water treatment

Efficiency of wetland systems increases with different vegetation for common pollutant removal; it has been demonstrated in several studies around the world. Roy et al. (2016) described that the basin morphometry of constructed wetlands is not same as natural wetlands, which explains the difference in vegetation composition. Plants provide a substrate for microorganisms, and microorganisms, with a source of carbon, are the most important processors of wastewater contaminants. There are various processes through with plants can incorporate pollutants are: (i) Phyto-extraction: the process in which a plant’s leaves and roots play a role in concentrating heavy metals. (ii) Rhizo-filtration: the process in which plants roots play role in absorption and precipitations of metals from contaminated liquid. They are also used to degrade organic compounds. (iii) Phyto-stabililzation: the process in which metal-tolerant plants reduce the power of mobility of metals -- especially chlorinated compounds -- to air or groundwater. (iv) Phyto-stimulation: the process in which roots help bacterial and fungal development for biodegrading the compounds, i.e. petrochemical hydrocarbons, benzene, polyaromatic etc. (v) Phytovolatilization: the process in which plants take up heavy metals and some organic compounds via transpiration and place them into the atmosphere. (vi) Phyto-decomposition: the process in which both terrestrial and aquatic

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plants get organic compounds to decompose and decrease toxicity at a considerable level (FCN, 2014; Leiva, 2018).

Sieben et al., (2016a) studied about the classification of the vegetation in specific type of wetland habitats in semi-arid regions of South Africa and presented the overview. There are two types of resilience (physical human disturbance and altered hydrology). From this, conclusion has been drawn that hydric species are not resilient to hydrological impacts than terrestrial species. Pretorius and Brown (2016) studied different types of wetlands while planting the main drivers of vegetation species in South Africa. This study suggested that vegetation composition vary with the wetland type so they should be evaluated individually for better results. In addition, the immoderate use of these wetlands may accelerate their deterioration because tall indigenous vegetation in wetlands can be used as fibers for traditional crafts and construction (Sieben et al., 2016b; Sieben and Nyambeni, 2016c). Vegetation in CWs also plays a vital role in the removal of nutrients from wastewater because the removal efficiency depends on the type of plants. As Leung et al. (2016) studied about efficiency of CWs on treating mangrove plants (*Bruguiera gymnorrhiza and Aegiceras corniculatum*) and non-mangrove plants (*Canna indica, Phragmites australis, and Acorus calamus*). Comparisons results showed that Mangrove CWs planted with A. corniculatum gave higher application values than the non-mangrove CWs to treat toxic wastewater. Additionally, water hyacinth plant has also efficiency to remove nutrients from wastewater (Patil and Munavalli, 2016). In Eastern Africa, Moges et al. (2016) developed a plant-based index of biological integrity with 122 plant species belonging to 37 families, aiming to evaluate the long term natural wetland conditions, also provide an effective tool, and therefore, facilitate the management of wetlands. In the United States, CWs got big problem due to erosion, which is degrading playa-wetlands in this semi-arid country, so Haukos et al. (2016) evaluated the role of vegetation surrounding playa-wetlands for removal of nutrients, metal, and dissolved/suspended solids from runoff. According to the results, vegetative Buffers removed about 78% of N, 70% P, 58% TDS and 83% TSS. It was suggested that vegetation buffers could be an economical conservation tool for playa-wetlands (Haukos et al., 2016). Ge et al., (2016) highlighted the influence on contaminants removal in the sense of seasonal change. In the study, efficiency of three plants was recorded. *Thalia dealbata outperformed C. indica and Lythrum salicaria* in the removal of total nitrogen (69.96%) and total phosphorus (82.4%) from urban storm-water runoff sewage. It is concluded that it is important to select most suitable plant communities for CWs. Wetland vegetations are important components of wetlands which play several roles in relation to the wastewater treatment processes.

Plants used in constructed wetlands around the world:

There are many plants planted in constructed wetlands (Wu, 2010; Polomski, 2007; Vymazal, 2007). Study (Oluseyi et al., 2011; Wang et al., 2016c) shows the result that three aquatic tropical plants (*Canna indica, Phragmites australis and Sacciolepis africana*) can be planted effectively. Some aquatic plants used in constructed wetlands are: *Lemna valdiviana, Spirodela sp., Typha angustifolia, Typha domingensis, Typha latifolia, Cyperus involucratus, Cyperus giganteus, Thalia dealbata, Cyperus giganteus, Juncus effuses, Phragmites communis, Sagitaria lancifolia* (Appenroth et al., 2010; Sohsalam and Sirianuntapiboon, 2008; Vymazal, 2011).

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Many studies have concluded that most commonly used species, which are given in *Table 3*, are robust species of emergent plants, such as the cattail (*Typha latifolia*), common reed (*Phragmites australis*), and bulrush (Appenroth et al., 2010; Sohsalam et al., 2008; Vymazal and Kröpfelová, 2011).

Table 3. *Plants used in wetlands in different countries*

Location	Types of plants	References
Australia, Logan, Queensland	A combination of banksia *intergrifolia, callistemon pachyphyllus, carpobrotusglaucescens, pennisetumalopecuroides*	Sievers et al. (2018)
Australia, Logan, Queensland	*Melaleuca quinquenervia, Melaleuca alternifolia*	Langergraber and Weissenbacher (2017)
Australia, Melbourne	*Phragmites australis*	Dotro et al. (2017)
Brazil	*Heliconia psittacorum*	Hu et al. (2016)
Brazil	*Alpinia purpurata, Arundina bambusifolia, Canna sp. Heliconia psittacorum L.F.*	Wang et al. (2016a)
Brazil	*Hedychium coronarium, Heliconia rostrata*	Gao et al. (2014)
Brazil	*Hemerocallis flava*	Prata et al. (2013)
Brazil	*Heliconia psittacorum L.F.*	Teodoro et al. (2014)
China	*Canna indica*	Shi et al. (2004)
China	*Canna indica mixed with other species*	Li et al. (2007)
China	*Canna indica Linn*	Yang et al. (2007)
China	*Canna indica*	Zhang et al. (2007a)
China	*R. carnea, I. pseudacorus, L. salicaria*	Zhang et al. (2007b)
China	*Canna sp*	Sun et al. (2009)
China	*Canna indica*	Cui et al. (2010)
China	*Canna indica mixed with other natural wetland plants*	Zhang et al. (2010)
China	*Canna indica mixed with other natural wetland plants*	Qiu et al. (2011)
China	*Canna indica and Hedychium coronarium*	Wen et al. (2011)
China	*Iris pseudacorus mixed with other natural wetland plants*	Wu et al. (2011)
China	*Iris pseudacorus, mixed with other plants of natural wetlands*	Xie et al. (2012)
China	*Canna indica*	Chang et al. (2012)
China	*Iris sibirica*	Gao et al. (2014)
China	*Canna sp*	Qiu et al. (2011)
China	*Iris sibirica*	Gao et al. (2015)
China	*Canna indica L.*	Hu et al. (2016)
China, Changping, Beijing	*Salix babylonica*	Gautam and Greenway (2014)
China, Guangzhou	*Pennisetumsineseroxb Pennisetum purpureum*	Bolton, and Greenway (1999)
China, Guangzhou	*Canna indica*	Saeed and Sun (2011)
China, Guangzhou	*Canna indica and windmill grass*	Wu et al. (2011)
China, Jinan	*Phragmites australis*	Cui et al. (2015)

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China, Shanghai	*Phragmites australis Thypalatifolia*	Huang et al. (2016)
China, Shanghai	*Iris sibirica Thaliadealbata*	Peng et al. (2014)
China, Wuhan	*Thypaorientalis Canna indica*	Wu et al. (2015)
China, Wuhan	*Juncuseffusus*	Xu et al. (2015)
China, Xi'an	*Phragmites australis*	Li et al. (2008)
China, Xi'an	*Phragmitesaustralis, T orientalis*	Zhong et al. (2015)
China, Cuihua, Xi'an	*Thypalatifolia*	Chang et al. (2012)
Chile	*Zantedeschia aethiopica, Canna spp. and Iris spp*	Morales et al. (2013)
Chile	*Tulbaghia violácea, and Iris pseudacorus.*	Burgos et al. (2016)
Colombia	*Heliconia psittacorum*	Madera-Parra et al. (2015)
Colombia	*Alpinia purpurata*	Marrugo-Negrete et al. (2016)
Colombia	*Heliconia psitacorum*	Toro-Vélez et al. (2016)
Costa Rica	*Ludwigia inucta, Zantedechia aetiopica, Hedychium coronarium and Canna generalis*	León and Cháves (2010)
Cuba	*Cyperus alternifolius*	Zheng et al. (2016)
Czech republic, Trebon	*Phragmites australis Phalarisarundinacea*	Zheng et al. (2015)
Egypt, Giza	*Phragmites australis*	Wang et al., (2016b)
Egypt	*Canna sp*	Abou-Elela and Hellal (2012)
Egypt	*Canna sp*	Abou-Elela et al. (2013)
Egypt, Manzala lake	*Phragmites australis Thypalatifolia*	Perez et al. (2014)
Estonia, Paistu	*Phragmites australis*	Vymazal (2011)
Greece	*Phragmites australis Thypalatifolia*	Abou-Elela et al. (2013)
Greece, Pompia	*Phragmites australis Arundadonax*	El-Sheikh et al. (2010)
India, Nagpur	*Thypalatifolia*	Öovel et al. (2007)
India	*Canna indica*	Choudhary et al. (2010)
India	*Canna indica*	Yadav et al. (2012)
India	*Heliconia angusta*	Saumya et al. (2015)
India	*Canna generalis*	Ojoawo et al. (2015)
India	*Canna Lily*	Haritash et al. (2015)
India	*Canna indica*	Patil and Munavalli (2016)
India	*Polianthus tuberosa L.*	Singh and Srivastava (2016)
India, Patancheru	*Thypa Eichhorniacrassipes*	Akratos and Tsihrintzis (2007)
Indonesia, Bandung	*Phragmiteskarka*	Tsihrintzis et al. (2007)
Iran, Isfahan	*P. australis (PA) T. latifolia (TL) A. donax (AD)*	Kadaverugu et al. (2016)
Ireland	*Iris pseudacorus*	Gill and O'Luanaigh (2010)

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Israel, Kiryat	*Lemnagibba L.*	Datta et al. (2016)
Italy, Florence	*Phragmites australis*	Kurniadie (2011)
Italy	*Zantedeschia aethiopica, Canna indica*	Macci et al. (2015)
Japan, Mito	*Zizanialatifolia*	Haghshenas Adarmanabadi (2016)
Kenya, Nairobi	*Cyperus papyrus*	RAN et al. (2004)
Kenya	*Canna sp*	Kimani et al. (2012)
Mexico	*Zantedeschia aethiopoca*	Belmont and Metcalfe (2003)
Mexico	*Zantedeschia Aethiopica and Canna flaccida*	Belmont et al. (2004)
Mexico	*Heliconia psittacorum*	Orozco et al. (2006)
Mexico	*Strelitzia reginae, Zantedeschia esthiopica, Canna hybrids, Anthurium andreanum, Hemerocallis Dumortieri*	Zurita et al. (2006)
Mexico	*Zantedeschia aethiopica*	Zurita et al. (2008)
Mexico	*Zantedeschia aethiopica*	Ramírez-Carrillo (2009)
Mexico	*Strelitzia reginae, Anthurium, andreanum.*	Zurita et al. (2009)
Mexico, Ocotlan, Jalisco	*Stretlitziareginae A combination of Stretlitziareginae, Anthuriumandreanum and Aganpanthusafricanus*	Masi and Martinuzzi (2007)
Nepal	*Canna latifolia*	Singh et al. (2009)
Nigeria, Akure	*Azollapinnata*	Abe et al. (2014)
Portugal	*Canna indica mixed with other plants*	Calheiros et al. (2007)
Portugal	*Canna flaccida, Zantedeschia aethiopica, Canna indica, Agapanthus africanus and Watsonia borbonica*	Calheiros et al. (2015)
Singapore, Nanyang	*Thypaaugustifolia*	Mburu et al. (2012)
Spain	*Iris sp*	García et al. (2007)
Spain	*Iris pseudacorus*	Ansola et al. (2003)
Spain, Santiago of Compostela	*Phragmites australis*	Akinbile et al. (2016)
Spain, Galicia, Boimorto	*Phragmites australis*	Zhang et al. (2012)
Spain, Valencia	*Cattail Phragmites australis*	Ávila et al. (2016)
Srilanka	*Canna iridiflora*	Weragoda et al. (2012)
Srilanka, Peradeniya	*Thypaaugustifolia*	Vazquez et al. (2013)
Taiwan	*Canna indica*	Chyan et al. (2016a)
Taiwan	*Canna indica*	Chyan et al. (2016b)
Thailand	*Canna sp*	Sirianuntapiboo n and Jitvimolnimit (2007)
Thailand	*Canna siamensis, Heliconia spp and Hymenocallis littoralis*	Sohsalam et al. (2008)
Thailand	*Heliconia psittacorum L. f. and Canna generalis L. Bailey*	Konnerup et al. (2009)
Thailand	*Canna hybrida*	Kantawanichkul et al. (2009a)
Thailand	*Cannae lilies, Heliconia*	Brix et al. (2011)

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Thailand, Bangkok	*Typhaangustifolia Cyperusinvolucratus*	Martin et al. (2013a)
Thailand, Bangkok	*Canna*	Eerakoon et al. (2016)
Thailand, Chiang Mai	*Oryzasativa L*	Mayo and Bigambo (2005)
Thailand, Petchaburi	A combination *of Thypaangustifolia, Cyperuscorymbosus, Brachiariamutica, Digitariabicornis, Vetiveriazizaniodes, spartina patents, Leptochloafusca, Echinodoruscordifulia*	Kantawanichkul et al. (2009b)
Tunisia, Joogar	*Phragmitesaustralis and thypalatifolia*	Klomjek and Nitisoravut (2005)
Turkey	*Iris australis*	Tunçsiper (2009)
Turkey, Garip	*Thypalatifolia*	Konnerup et al. (2009)
Uganda, Kampala	*Cyperus papyrus*	Kantawanichkul and Duangjaisak (2011)
USA	*Canna flaccida, Gladiolus sp., Iris sp.*	Neralla et al. (2000)
USA	*Canna sp.*	Zachritz et al. (2008)
United Kingdom	*Iris pseudacorus*	McKinlay and Kasperek (1999)
Vietnam, Can Tho	*Phragmitesvallatoria*	Kouki et al. (2009)

Most commonly plants used in CW

Around the world, four most commonly genera plants used in CW are: *Canna, Iris, Heliconia, Zantedeschia, Phragmites and Typhas* have been recommended as the main species planted in constructed wetland due to their effectiveness, even though they are considered invasive and outside their native range. Common plants planted in constructed wetlands in North America are *cattails* (*Typha latifolia*). *Cattails (Typha latifolia)* have the ability to grow at different water depths, are easy to transport and transplant, and they have broad tolerance of water composition (including pH, dissolved oxygen, salinity, and contaminant concentrations), making them ideal plants for constructed wetlands. Another species known as Common Reed (*Phragmites australis*) is also commonly found in both black-water treatment and in grey-water treatment systems to clean wastewater. *Bulrush* is also known as effective species (Appenroth et al., 2010; Sohsalam and Sirianuntapiboon, 2008; Vymazal, 2011).

Conclusion

The overall finding of this review is that all wetland types are very effective at reducing major nutrients and suspended sediments. Constructed wetland is recommended for wastewater treatment because it treats water biologically, physically and chemically, making it the best option. It is no surprise that many countries around the world opt to use constructed wetlands. The data previously published have concluded that consistently high levels of removal were found for Total Nitrogen, nitrate and nitrite, ammonium/ammonia, Total Phosphorus (TP), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Suspended Sediments (SS). Therefore, it can be concluded that wetland systems are effective for the reduction of all of these parameters as they were reduced by large amounts. While reviewing, it was found that “Biochar” is being used in wetlands. The use of biochar to enhance

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constructed wetland performance in wastewater has highly appreciated. Different types of biochar have been used to promote wetlands activities. Combining both of these technologies can greatly augment the efficiency of the system, so it is recommended that Biochar from different materials be considered for further improvement. With this change, societies around the world may get easy and sustainable way of water treatment, especially in the affected areas, while also keeping in mind of the social, cultural and economic status of the population. It is concluded that most of plants play a vital role to enhance the efficiency of wetlands to treat all the types of wastewater, either it is natural wetlands or constructed wetlands. Several studies around the world have proved that plants have ability to remove the contaminant at considerable level.

It is recommended that before selection of plants for wetlands; consider the condition such as weather of the area, type of wetlands, and type of water need to be treated so that removal percentage should be higher. Addition of biochar/ACF boosts efficiency of the system. It is recommended that select an efficient material for media. Wood biochar is less expensive than other synthetic materials like granular activated carbon. Therefore, use of wood biochar for removal efficiency is recommended as a simple, cost effective, and environmentally friendly solution for constructed wetland system especially in developing countries. Furthermore, future research is needed on combination of different advanced techniques to undertake stability and mechanism of things which are involved in the constructed wetland system for better solution during water treatment. Additionally, it is important to elucidate the possibility and efficiency of suitable approaches to treat and safely dispose of the resultant material after the treatment process. There is still gap and need to investigate as industrialization and urbanization is changing the world every day and creating different water issues.

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