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Natural wastewater treatment-large-scale treatment plants

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ABSTRACT

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Large scale natural wastewater treatment plants are used more and more worldwide. The most common types of natural treatment systems are the constructed wetlands serving as secondary treatment steps in the wastewater treatment facilities. The aim of this work was to make a literature review on the application of natural treatment units in large scale wastewater treatment. In this work several large-scale wetlands and other different types of natural wastewater treatment plants in use are presented. Additionally, the possibilities of using natural treatment units in China are considered.

This study showed that the main natural techniques applied in large scale are artificial shallow basin wetlands, floating treatment wetlands, large scale offshore photobioreactors and settling basins. Different wetlands have their own benefits for the surroundings, but the varying efficiency is a general problem. For the natural wastewater treatment plant, the removal for main pollutants like BOD, COD or phosphorus are well enough, but there is still long way to be efficient for other pollutants. Natural treatment systems are also sensitive to variation in the pollutants. Mixing of different types of wastewater causes mixing of the pollutants that might compromise the purification. For example, a wetland originally designed for school, hospital, and agriculture wastewater, cannot deal with industrial wastewaters. Antibiotic resistant genes appearing in hospital wastewaters treated in wetlands pose a threat to human health. Natural treatment plants are not the best solution for wastewater treatment in China, mostly because urbanization and high transportation costs.

Key words: natural wastewater treatment, large scale wetlands, constructed wetlands,

CONTENTS

GLOSSARY

HFCW	Horizontal Flow Constructed Wetlands
VFCW	Vertical Flow Constructed Wetlands
BF	Biofilters
UV degradation	Ultraviolet degradation
ARGs	Antibiotic-resistant genes
BOD	Biochemical oxygen demand
COD	Chemical Oxygen Demand
Cr	Chromium
Ni	Nickel
Zn	Zinc
Cu	Copper
Cd	Cadmium
Co	Carbon Monoxide
SOP	Sydney Olympic Park
SS	Suspended Solids
FTWs	Floating Treatment Wetlands
NEQS	National Environmental Quality Standard
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
PBRs	Photobioreactors
SB	Settlement Basin
OF	Overland Flow
WARMS	Water Reclamation and Management Scheme
FVI	Floating Vetiver Island System
VG	Vetiver Grass

1 INTRODUCTION

Water is an important resource in the world even our planet is covered by water. Our planet has covered with 71% water but most of them are sea water which cannot be used directly for human. According to Zumdahl, 97.25% of water is in oceans and only 2.05% is found in polar ice caps and glaciers which the rest is in lakes, rivers, and groundwater. Only small part of the water is clear water that can be used directly for drinking. Therefore, reducing the wastewater is a big and popular issue in current situation. The natural wastewater treatment had been used more as a new tool for saving water. Around 70% of freshwater is contaminated with organic and inorganic pollutants especially in developing countries. Large amount of untreated wastewater is discharged directly into the environments and pollutes the sources for drinking water. Therefore, professionals are searching for efficient and affordable water treatment solutions. Many farmers irrigate with diluted, untreated, or partly treated wastewater for agriculture which generate adverse health effects. Untreated wastewater will cause health risks from parasitic worms, viruses, and bacteria (Pedrero et al.,2010).

Natural wastewater treatment

Natural wastewater treatment systems are relevant, high efficiency alternatives to traditional system for small communities and dwellings. They also have the advantages of low establishing costs, low operation and management requirements for constructed wetlands, biological sand filters and other decentralized solutions. Usually, the most important step in wastewater treatment is to remove the nitrogen and it is also key factor to increase the efficiency on the removal rate. As the common technologies in Western countries the following types of natural treatment systems are used: Horizontal Flow Constructed Wetlands (HFCW), Vertical Flow Constructed Wetlands (VFCW) and biofilters (BF).
In order to work properly, there are several different factors for wetlands that need to be taken into consideration: system's capacity, plant species used, colonization characteristics of certain microbial groups, and the interactions of biogenic compounds together with particular contaminants (Stottmeister et al., 2003). One

of the main mechanisms of pollutant removal in a wetland is filtration. However, filtration is not the only important process in the wetlands, most removal processes are microbial-mediated decompositions. Additionally, chemical transformations, volatilization, sedimentation, sorption, photodegradation, plant uptake, transpiration are also important during the treatment processes (Kadlec and Wallace, 2009).

Aquatic treatment plants based on microalgae production are other type of natural wastewater treatment. Because the microalgae are considered as producers of sustainable biofuels in recent research, many of reviews strongly recommended using municipal or agricultural wastewater as their food source. Microalgae can consume both nutrients and carbon from wastewater efficiently and nitrogen and phosphorus can be almost completely removed. In that case, it reduces biofuel production cost and provides cumulative benefits while providing efficient wastewater treatment services. (Novoveská et al., 2016)

PICTURE 1. Lahan basah Taman Nasional Danau Sentarum, Kalimantan Barat CC by RaiyaniM

2 SCOPE

The idea of the work was to make a literature review on natural wastewater treatment systems applied in large scale. Additional scope was to figure out the possibilities to apply natural wastewater treatment as large-scale wastewater treatment in China. The thesis analyzed several previous research of natural wastewater treatments and grouped and compared based on the location, advantages, disadvantages, treated pollutant type and pollutant removal rate. The thesis does not include real-field test. All the resources and data were searched from Internet.

3 MATERIALS AND METHODS

3.1 Research tool

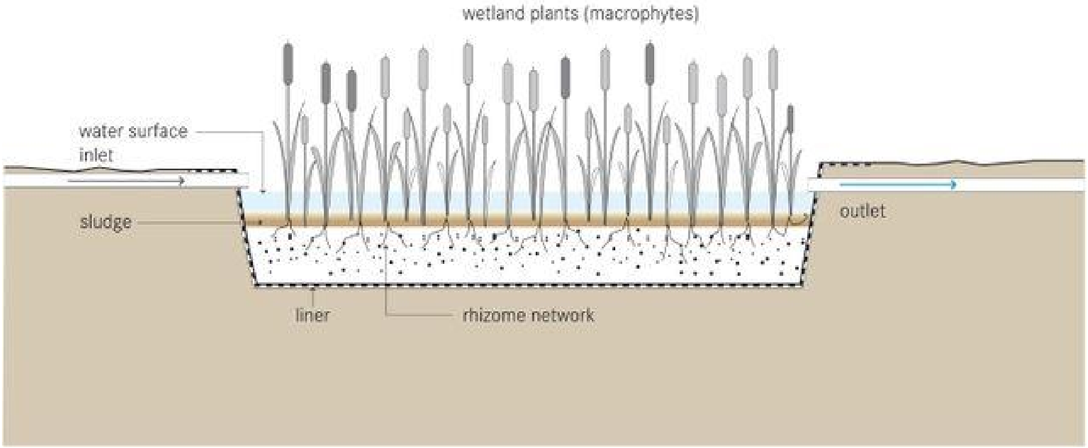
The whole research is a literature review type of thesis. As this type, the research is mainly on the articles from Google Scholar and China CNKI professional Academic Journals Website. This research focused on the collection of previous research and publications on large-scale wetlands. Snowball method, considered a good tool in literature review, was used in this work. This method consists of finding the main article, and the following article is based on the bibliography in the key document. The advantage of this method is that a lot of articles and literature in certain field can be found quickly and relatively easy. But the disadvantage is this method is a retrospective type of method and the resource found from this method will be older than the previous one. This method could make the research in a focused way and there is less time spending for reading irrelevant materials. This research started by searching with keyword “Wetland”, and then from the wetland field, more research was done by using the sources from the first article. The amount of the reference was around 30-50 in order to make the analysis. The basic research is from Google Scholar and the key word using for searching is “Wetland” and “Natural wastewater treatment”. (Information Literacy History)

3.2 Group separation

The natural wastewater treatment plants used in large scale wastewater treatment, found in literature were grouped into two parts: wetlands, and other wastewater treatment plants. Some old wetlands used in China were also presented. Some small wetlands using on other techniques were also included just to make comparison.

4 RESULTS AND DISCUSSION

4.1 Wetlands and constructed wetlands



PICTURE 2. Schematic of the Free Water Surface Constructed Wetland CC by Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph., Zurbrügg, C

Natural or human-made wetlands can be continuously flooded wetlands, intermittently flooded wetlands, and non-flooded system wetlands. The wetlands need time for the chemical, physical, and biological changes when the soil is sufficiently wet for long time. Because the soil saturated with water would not be able to provide aerobic condition, plant species are growing in seasonally or continuously flooded soils in anaerobic or low oxygen conditions. Climate can also affect the wetlands functioning, as the tropical wetlands differ from the ones found in temperate environment, and this needs to be considered when using wetlands for wastewater treatment. The growth of the plants as well as hydrological and temperature variations are greatly influenced by climate conditions, and these will affect the purification efficiency of wetlands treating wastewater. cause the efficiency change for treating the wastewater as well as hydrologic and temperature variation effects. Because of the need for the less energy intensive treatment of the wastewater as well as its reclamation and reuse, wetlands fulfilling this need to become more widespread. Wetlands have benefits that they require simpler

operational activities and lower capital and operation costs. The price for building a wetland might be key factors for developing countries. Vertical-flow and horizontal-flow wetland systems have basis made by soil, sand, or gravel. These wetlands are used to treat domestic and industrial wastewaters, mine drainage as well as urban and motorway surface runoffs. Wetlands can also be seen as a wildlife conservation resource and landscape of the local community (Norio et al., 2011). Wetlands are also benefiting for the local economic growth. As one example, the Tres Rios project is a project that use wetlands support the economy, health and wildlife in Phoenix, Arizona. More than 2 million gallons of wastewater enter Tres Rios and thousands of bird flock to Tres Rios. Even the beavers are moved into this wetland. In the end, the cost of construction of Tres Rios is less expensive than a new water treatment plant (Aryal, et al, 2019).

Natural wetlands are commonly found in saturated soil condition such as swamps, bogs, fens marshes and estuaries. According to Norio et al. (2011), the ecological importance coming from the natural purification processes that are undergoing in the wetland had been noticed and studied in the last decades and the purification processes in a wetland are becoming more and more applied in environmental management. By using the interactions between the sun, soil, air, water, plants, animals, microorganisms, and environment, constructed wetland is build and function as the natural wetlands. According to Omondi & Navalia, (2020), the plants are special that could adapt on the unique hydric soil. Most wetlands are filled with mosses or grasses as their main plant type, but some wetlands are filled by trees, and others are watery grasslands that are covered by thick and spongy mosses. The natural wetland could support soil formed from the decayed plant material and accumulated around trees and roots. This soil can become the shelter for crabs, conchs, and other shellfish. Some certain types of plants might only grow in wetland areas.

4.1.1 **Structure of the constructed wetlands**

Most constructed wetlands are made by human in similar way as natural wetlands. Most constructed wetlands in USA and Europe are horizontal-flow system using soil or gravel which are used for urban runoff, domestic and industrial

wastewater. According to Omondi & Navalia, (2020), the structure of constructed wetlands has mainly 3 parts. The constructed wetland has an impermeable layer which generally is made by clay, above it there is a gravel layer providing nutrients and creating space for root growth of the plants. Vegetation layer is above the water surface. The soil/sludge accumulates in time in the same way like in the natural wetlands, becoming the energy source for mostly bacteria mediated biological reactions that will contribute to the purification of the wastewater.

4.1.2 **Function of constructed wetlands**

In wetland ecosystems, the growth of the plants slows the water flow and create microenvironments providing attachment sites for microbial communities. Microbes get carbon, nitrogen, and phosphorous from the dead plants that serve as fuel for microbial processes. The physical and chemical characteristics of soil and other substrates might change when they are wholly or mostly below water surface level. For example, in water saturated substrate situation, the substrates change into anoxic condition which are important for nitrogen and metal removal. Most of the treatment functions relate to each other. Nutrient and organic matter and pollutant removal is undertaken biologically by microbiological degradation, protozoic predation and digestion, plant uptake and storage; or chemically by adsorption, oxidation, reduction, and UV degradation and by physical means: like filtration and settling. (Omondi & Navalia, 2020)

4.2 Constructed wetlands used in large scale wastewater treatment plants.

In this study seven large scale application of constructed wetlands was found, the main features are presented in Table 1. The table also shows the advantage and disadvantage of using the wetlands for domestic and industrial wastewater treatment. The main advantages are the high efficiency to treat domestic wastewater with a high removal rate of COD and BOD. The nutrient removal is also efficient for domestic wastewater treatment.

TABLE 1. Wetlands and information

Wetland type	Place, scale	Purification performance	Positives	Negatives	Source
Constructed wetlands	Large scale artificial shallow basin	Not mentioned	Low cost and more affordable. Able to tolerate fluctuation and sustainably facilitate water recycling. Create place for mammal. Different types of technology can be used in different wetlands.	Decrease contaminant removal rate over the time. Large area needs and landscape is limited. Efficiency not stable and depending on the weather and seasons. Antibiotic-resistant genes (ARGs) come from the polluted sources.	Omondi & Navalia (2020)
Sydney Olympic Park (SOP)	Large scale natural wetland	Not mentioned	Reduce the nutrient. Become a natural filter for wastewater. Reuse the water as drinking water.	The algal blooms based on eutrophication. Huge growth for mosquito species Loss of migratory shorebird living area.	Aryal, et al (2019)
Ingham wetland	Large scale, build on Free Water Surface	BOD reduction: 48% Total nitrogen reduction: 52% Total phosphorous reduction: 8%	Scrub flue gases in sugar mill. Irrigate farms in the area. Supplement water resources in local creek.	Unknown about the phosphorus accumulation and heavy metal.	Greenway and Simpson (1996)
Townsville Wetland	Large scale, artificial shallow basin	BOD reduction: 67% Suspended solids reduction: 44% Total nitrogen reduction: 74% Ammonia-nitrogen reduction: 65% Nitrate-nitrogen reduction: 91% Total phosphorous reduction 6%	Treatment for wastewater treatment plant. Filled the local reservoir. Become popular tourist spot for bird watching.	Not mentioned	Greenway and Simpson (1996)
Blackall Wetland	Large scale, artificial shallow basin	BOD reduction: 46% Suspended solid reduction: 68% Total phosphorous reduction only 3%	Becoming a riverbank ecotourism wetland complex.	Phosphorus reduction rate is not good enough.	Greenway and Simpson (1996)

Wetland type	Place, scale	Purification performance	Positives	Negatives	Source
Karachi, NED University of Engineering and Technology	Small scale, artificial shallow basin	BOD reduction: 50% COD reduction: 44% Suspended solids reduction: 73%-86% Ammonia-nitrogen reduction: 49% Ortho-phosphate-phosphate reduction: 52% Cr: 55% Ni: between 25-35% Zn: between 25-87% Cu: 9% Cd: 33% Co: 75%	Good reduction rate for the pollutant and elements.	Not mentioned	Pedrero, Kalavrouziotis, Alarcón, Koukoulakis, & Asano. (2010).
Huang Jia river wetland	Large scale, artificial shallow basin	BOD reduction: around 96-97% COD reduction: 88-93% NH3-N reduction: 98% NI-13-N effluent content: 0.lmg/L Conditions of influent COD: 209-408 mg/L BOD: 52-80 mg/L NH3-N: 15.3-24.6 mg/L Stable effluent COD: around 30 mg/L BOD less than 4 mg/L NH3-N: less than 0.5 mg/L	Low cost and benefits as the yard for university. Effluent water will be used for campus green irrigation, toilet flushing. Some part is disinfected to becoming the feed water in swimming pool.	Problems with thickness of biofilm and sludge yield. Clogging problem of carbon layer. The SS was not detected.	HU, CHENG, & LI. (2008)

As the Table 1 shows, the main disadvantage of wetlands used in large scale can be seen in decreased performance when additional wastewater was loaded into the treatment system, e.g., the system designed to treat domestic and some industrial water could not purify properly the additional textile wastewater (Aryal et al., 2019).

Another problem that can appear in using artificial wetlands for wastewater treatment is the possibility of emerging antibiotic-resistant genes (ARGs). ARGs are originally in wastewater from hospital. Effluent wastewater, sewage sludge, and animal slurry in farmland, soil, surface water, and sediments are mostly contaminated by ARGs. Resistant genes are the main courses of antibiotic resistance. This ARGs become one of the fey issues for global health problem. This is usually caused by misuse and overuse of antimicrobials. Antibiotic resistance has significant effect on human health care, veterinary, and agriculture. The constructed

wetlands aim to treat wastewater, but the wetland system creates the horizontal or vertical gene transfer between different microorganisms. The antibiotic resistance is caused by the changes or mutations in DNA of microorganisms that makes them to become insensitive to antibiotics. The wastewater is the main route that antimicrobials, therefore the chance to genetic mutations is the highest in the wastewater, from which the ARGs enter into natural ecosystems. Even though the wetlands decrease the load of bacteria, but the final effluent may still have ARGs and sometimes the concentration of ARGs might be higher than in raw wastewater. (Omondi & Navalia, 2020)

Another study describes the artificial wetland at Sydney Olympic Park (SOP) constructed by transformation of a wasteland (mixture of plants and trash) into wastewater treatment unit. The Sydney Olympic Park has huge area of 175 hectares of wetland, 40 hectares of woodlands and 210-hectares of picnic areas. Before the SOP, the whole area was contaminated with different types of pollutants over 400 hectares. The contaminants included petroleum waste, unexploded ordnance, potential acid sulphate soil, illegally dumped wastes, dredged sediments, industrial waste, and other wastes that are bad for the health and sustainability of the wetland ecosystems. Additionally, the natural wetlands at Homebush Bay, site close to the SOP, were destroyed because of human activities. Therefore, the Olympic game in 2000 had additionally the goal to clean-up the contaminants and pollutants on the sites. The major wetland was separated as 13 different ecosystem/habitat type in SOP, and it was able to significantly reduce the nutrient and become a natural filter for the wastewater. Water Reclamation and Management Scheme (WRAMS) is a complete system in Australia and can save more than 850 million liters of drinking water for a year. (Aryal, et al 2019)

The management of wetlands requires special attention. Hydrology is the most important factor affecting the health, function, and wellbeing of the wetlands. The problems that might cause malfunction of wetlands include: the algal blooms causing eutrophication, huge growth for mosquito species because of the depressions in saltmarsh and mangrove, the loss of migratory shorebird living area and

many more. During the management of wetlands other factors needs to be considered, such as local people and business demand, Biodiversity, mosquito control and importantly public use. (Aryal, et al, 2019)

Greenway and Simpson (1996) did a research on three different types of wetlands. Those cases are described where free water surface and subsurface flow artificial wetlands were used for different wastewater types in Queensland, Australia. The treated water was used for golf course irrigation, river discharge and agricultural using. The first wetland, Ingham Wetland, uses 5 different types of plants arranged in a U-shaped channel with dimensions of 110 m × 12 m × 500 mm. Incoming wastewater is detained for 12 days. The second wetland, Townsville Wetland, which had a U-shape channel with dimensions of 60 m × 4 m × 400 mm and detention time is 5 days. This wetland had 6 different types of macrophytes which 2 of them are floating plants, 2 submerged plants and 3 emergent plants. The last one is called Blackall Wetland, which is a four-linear channel with dimensions of 120 m × 7 m × 600 mm and detention time is 4 days. This wetland has 3 different types of macrophytes.

Mustafa (2013) described a horizontal surface-flow constructed wetland made in Karachi (NED University of Engineering and Technology). This is a small, low flow system mainly treating domestic sewage wastewater. The aim of this small laboratory wetland is to access the reuse of the application of constructed wetlands. The structure is with the dimension of 6 × 1.5 m × 0.6 m and surface are 9 m^3. The detention time is 4 days with the flow rate 1 m^3/day. As the effluent water, 48% of BOD concentration is lower than threshold value which is 30 mg/L. The wetland also ensured the reduction of total and fecal coliforms in range from 93-99%.

4.2.1 **Natural treatment in China**

Hu, Chen & Li (2008), describes a wetland using the process of contact oxidation combined with Japanese technique natural circulation method for treating wastewater. The flowrate of wastewater from College of Traditional Chinese Med-

icine is 2000 m^3/d, consisting of pre-treated wastewater from hospital, Experimental Center of Traditional Chinese Medicine Science, the domestic wastewater from student apartment and the wastewater from the canteen. The main pollutants are SS, COD, BOD, ammonia nitrogen, animal, and vegetable oil. The effluent water will be used for campus green irrigation, toilet flushing, and some part is disinfected to becoming the feed water in swimming pool. This project does not require reduction for the total nitrogen and total phosphorous, so the nitrogen removal is omitted. The pool is made by contact aeration pool, special carbon pool, decolorization and deodorization pool. The contact aeration tank is filled by suspended spherical fillers that could convert NH_3-N to $N0_3$-N and further degrade organic matter under aeration. The special charcoal and limestone used as filter material can provide the quality of the effluent water reaching the surface water standard (Table 2).

TABLE 2. Basic parameter for wetland design

Pollutants	COD(mg/L)	BOD(mg/L)	SS(mg/L)	NH_3N(mg/L)
Influent Concentration	250	150	200	30
Effluent Concentration	30	6	10	1.5

This project was commissioned from 1st September 2005 to 31st September 2005. There was black water contain small amount of charcoal powder in special charcoal pool, decolorization and deodorization pool. The powder disappeared after 10 days operation. After 2 months, COD, BOD, SS, NH, -N reached the design standard value. Total area of the project is 1200 m^2 with total installed capacity 109.8kW, common power 37kW. The unit electricity consumption is 0.26¥/m^3, labor cost 600¥/month/person. The sewage treatment cost is 0.32¥/m^3 without the equipment depreciation cost. (Hu, Chen & Li, 2008)

4.2.2 **Natural treatment and other wastewater treatment plants in China**

Natural wastewater treatment plants are a sustainable way for treating the wastewater. In China however, the number of natural treatment units used for treating the wastewater is still low. The overall costs of the natural treatment system might be higher than the costs of conventional systems, mostly because of transportation and land use costs. Calculations done in a study (Tran et al., 2015) revealed that the average cost for 227 different wastewater treatments has average operating cost 1.38 ¥/ton, average construction cost 1.01 ¥/ton, and average functioning cost 1.01 ¥/ton. From 2013, the unit operating cost of completed wastewater treatment facilities in China is 1.25 ¥/ton, and the unit operating cost is 0.86 ¥/ton. In this study 227 wastewater treatment facilities were included and noticed that the cost of the facilities depends on the place. The unit operating costs in descending order are western region, eastern region, and central region. The operating costs of sewage treatment plants are generally higher than the sewage treatment fee collection standards because the current sewage treatment fee can generally cover the operating costs of sewage treatment plants but cannot cover the full operating costs. (Tan et al, 2015)

4.3 Floating treatment wetlands

Floating treatment wetlands (FTWs) are also called hydroponic root mats, are ecotechnology to treat wastewater with natural wetlands. In these systems, by cooperation between the plants and microorganisms, the water will be treated. The efficiency depends on the amount and dimension of the root biomass and on the water flow. With the low-oxygen environments on the root area, the root can grow better and create environments for microorganisms that transform the pollutants. The buoyancy FTW system is made up by buoyant mats and could be also supported by synthetic mats. This system has the advantage of slowing down the water flow that in turn enhances the sedimentation of suspended matter. The success of treatment by FTWs is ensured by plant species that can create dense root network that generate buoyant mat and create growing condition for plant. Additionally, FTWs could be the purification barriers for littoral zone and provide places for fish and birds to live that can be seem like landscape views. (Afzal et al, 2019)

The results of review on floating treatment wetlands are presented in Table 3.

TABLE 3. Floating Treatment Wetlands in different place

Wetland name	Place	Pollution water	Chemical type	Removal performance	Sources
Hydroponic root mats	Not mentioned	Not mentioned	BOD	43%	Chen et al, 2016
			COD	68%	
Floating Treatment Wetlands	Faisalabad, Pakistan	Wastewater	COD	79%	Afzal et al, 2019
			BOD	88%	
			TDS	65%	
			total FC	From 5.8*109 to 2.8*106 per 100ml.	
Floating Treatment Wetlands	Southern Brazil	Sewage water	COD	55%	Benvenuti et al, 2018
			BOD	56%	
			TSS	78%	
			TN	41%	
			TP	37%	
Floating Treatment Wetlands	Southern Brazil	River water	TP	10.5%	Fang et al, 2016
			TN	11.8%	
			COD	8.2%	
Floating Treatment Wetlands	Veracruz, Mexico	wastewater from oil exploration and production	hydrocarbons	99.1%	Afzal et al, 2019
			TDS	82.4%	
			BOD	98.9%	
Floating Vetiver Island	Malaysia	Wastewater from stormwater, domestic and industrial	COD	77%	Kusin et al, 2019
			nitrate	73%	

According to Afzal et al. (2019) large-scale wetlands are a good solution for developing countries when there are limited or insufficient wastewater treatment plants. A Floating Treatment Wetland is cost-saving and can be used to treat different types of wastewater. The sample FTWs presented in the article was receiving sewage (60%) and industrial (40%) wastewater. Total area is 1858m^2 built on the wastewater stabilization pond. This wastewater treatment plant was evaluated for 3 years. The whole system reaches to the maximum efficiency from the second and third year. The treatment plant also receives many industrial wastewaters including textile-, food-, and chemical wastewaters. The high organic and inorganic pollution give pressure to the efficiency of the system, that the purified water cannot satisfy the quality standard. During the evaluation period, about 60 million m^3 wastewater was treated for each year on average, with the cost for each m^3 of 0.00026 US dollar. From the research and evaluation, the

authors concluded that FTW is an applicable ecotechnology for large-scale treatment on sewage and industrial wastewater. The whole project was separated into 3 periods, the first one is the beginning from June 2014 to February 2015, second period is middle phase from April 2015 to August 2016 and the last one is mature phase from December 2015 to April 2017. From the data resulted that FTWs create positive effect on reduction of TSS, TDS, BOD, COD, oil, and other pollutant from wastewater. Most of load was removed in the beginning phase and the performance keep stable in the middle and mature phase. During the whole project, the pH value stayed between 6 and 9 without huge changes. The heavy metal concentrations decreased over time. The microbiological indicators improved significantly in the mature phase. Regarding plant growth, the specie Phragmites Australis reached maximum productivity earlier than the other plant types. The authors assessed that an established floating system can efficiently treat wastewater for over 15 years. The researchers recommended to use FTWs more than traditional wastewater lagoons, as FTW had shown to be a simple, low cost and passive solution for wastewater treatment. (Afzal et al, 2019)

Another FTW system was studied by Afzal et al, (2019) for nutrient removal and other quality indicators that characterize the removal efficiency. The authors measured an increase in DO up to 92% in heavy polluted river after using FTWs system. The COD removal rate was up to 77% and nitrate removal rate up to 73%. The installation of FTWs improved the DO amount in the river already the middle phase. The wastewater coming to the wetland has TSS 358 ± 82 mg/L and TDS of 3890 ± 635mg/L which is considered high. Pakistan's Water and Sanitation Agency (WASA) created a wastewater treatment plant consisting by primary and secondary treatment ponds in 1998. The area for primary pond is 26460 m^2, depth 2.5 m, hydraulic retention time 2.5 days, water flow 0.05 m/s and capacity 66150 m^3; and secondary pond is 149466 m^2, depth 1.5 m, hydraulic retention time 4.86 days, water flow 0.035 m/s, capacity 244199 m^3. Because of the development of the city create huge growth number of industries. The ponds in Pakistan had been overloaded and decreased 27% treatment efficiency. Also due to the limit of water resources, other 70% of Chokera's agriculture is supplied with the wastewater from the treatment ponds. From the institute result by International Water Management Institute, 200 farmers have used about 60000 m3 of

wastewater for one day even though the effluent water from the ponds are not suitable for crop irrigation with its quality.

According to Kusin et al, (2019), Floating Vetiver Island (FVI) System is used to check a certain plant in wetland called vetiver grass (VG). VG has been used for treating stormwater, domestic and industrial wastewater. The industrial wastewater also includes palm oil mill, sewage, and mine tailings for FVI system. The FVI system are mainly used to test for the polluted running water such as river, stream, or canal. VG is used from the result as a great tool because of its fine massive root system to trap both fine and coarse sediment in running water. VG has great protentional in removing organic matters as an effective biofilter. They concerned the FVI system is only suitable for small river and there must be clear from invasive plants. After six-week testing time, the Water Quality Index (WQI) is increased by 14%, and there is high removal on COD and nitrogen.

4.4 Large scale natural treatment plant

Besides the constructed wetlands there are also other types of natural treatment plants. One common type is based on microalgae technology. The different type of system applied with treatment technology is shown in the Table 4.

4.4.1 Wastewater treatment in large-scale offshore photobioreactors

Significant amount of current research is focusing on microalgae, as they are promising in producing sustainable biofuel. The main advantage of microalgae is that it can grow rapidly, and it can utilize saltwater and wastewater, therefore does not compete with food crops in arable land. Additionally, this technology combines wastewater treatment with biofuel production. The challenge for micro-algae production is the high present-day production cost and reliable long-term and large-scale data sets are needed for further development in the industry.

TABLE 4. Treatment by different type of system

Treatment technology	Treatment system	Chemical type	Remove
large-scale offshore photobioreactors	PBRs	BOD	92%
		Total nitrogen	75%
		Total phosphorus	93%
	SAF system	BOD	92%
		N	75%
		P	93%

Novevská et al. (2016) studied an Algae System LLC designed for municipal wastewater treatment used to cultivate microalgae in offshore photobioreactors (PBRs). With this technology, influent water of 50000 gal/day was treated. According to the authors, the long-term observation of the reactor showed huge changes in the algal community. The initial Scenedesmus dimorphous was replaced by the community of naturally algal species. Some algae were able to grow in the disinfected wastewater. The wastewater treatment efficiency was high because of three important factors. The first one was the oxygen produced by photosynthesis contributing to aeration of the water. Second factor was the mixing produced by wave energy and pumping during feed and harvest of PBRs. The third factor was the increasing biomass amount meaning energy production while the algae is growing. Dissolved oxygen could reduce the BOD. As the requirement in Europe, this system fits the limitation of the water quality guideline. Total nitrogen (15mg/L) or total phosphorus (2mg/L) measured in the effluent water satisfied the quality requirements. The system overall was highly stable, resilient, worked with high resource efficiency, produced almost complete nutrient removal, and resulted in stable chemical composition of biomass. (Novoveská et al, 2016)

4.4.2 Natural wastewater treatment as Settling basin

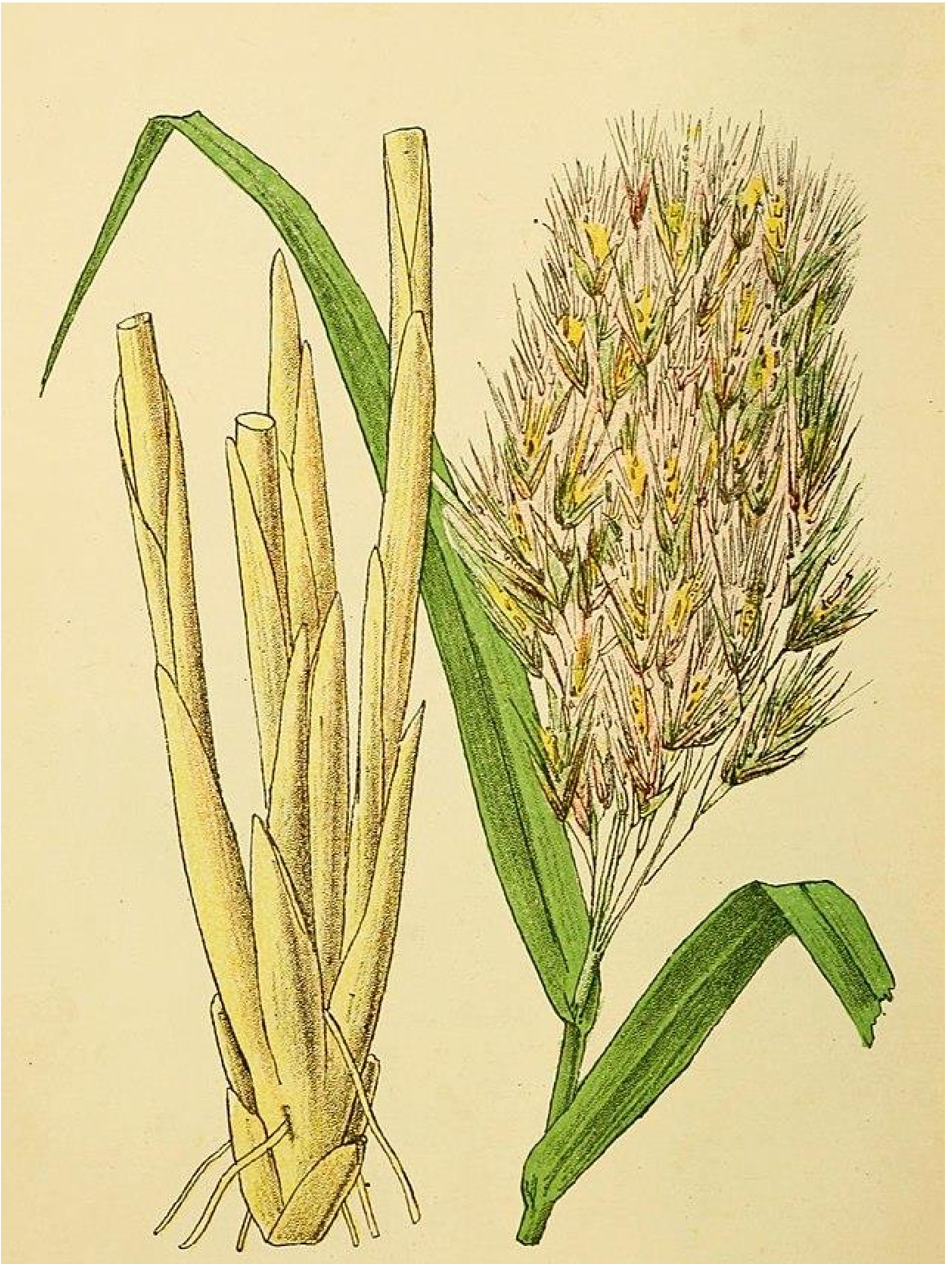
PICTURE 3. 20210417 Phragmites australis 02 CC By David Rasp

TABLE. 5 Removal rates for different system (Tunçsiper, 2019)

Chemical type	Condition		System type			
			SB	FWS-CW	OF	Overall removal
TSS	Cold	Average removal (%)	45	54	31	85%
	Warm		47	70	32	
BOD	Cold	Average removal (%)	37	54	29	85%
	Warm		40	76	30	
COD	Cold	Average removal (%)	40	50	28	
	Warm		40	62	29	
TP	Cold	Average removal (%)	13	28	13	49%
	Warm		16	34	18	

Tunçsiper (2019) described a natural wastewater treatment system using three different treatment units to reduce existing pollution in the over polluted area Kızılca creek, Nigde, Turkey. The three units were settlement basin (SB), free water surface constructed wetland (FWS-CW), and overland flow (OF). The FWS-CW was planted with the Phragmites communis in the wetland. The water came from a feeding basin to the SB unit, used as the first treatment step to prevent the clogging of the following in FWS-CW unit. These two units removed

together TSS, particulate and especially dissolved organic matter (Table 5). Using SB system as the first step of the treatment contributed to remove organic matters and it could also increase the efficiency of FWS-CW system and overall of NWT system. SB system could not remove some dissolved organic matter, but those were efficiently removed in the following units, mostly by aerobic oxidation by bacteria as well as plant uptake. According to the author, these types of systems can be efficiently used to treat urban, industrial, agricultural and storm water runoffs. (Tunçsiper, 2019)



PICTURE 4. Plantenschat1898 324 158 Riet.—Phragmites communis CC By Frederike J. Uildriks, Vitues Bruinsma

5 CONCLUSIONS

As the conclusion, there are several natural treatment plants as large scale around the world, but still tiny percent of the total amount of wastewater treatment plants. There are many different technologies based on natural processes tested at small scale but less used in large scale wastewater treatment. The main natural techniques applied in large scale are artificial shallow basin wetlands, floating treatment wetlands, large scale offshore photobioreactors and settling basins. Different wetlands have their own benefits for the surroundings, but the varying efficiency is a general problem. If the efficiency could stay constantly high, the big wetlands could benefit both for environment and economy. For the natural wastewater treatment plant, the removal for main pollutants like BOD, COD or phosphorus are well enough. But there is still long way to be efficient for other pollutants. Natural treatment systems are also sensitive to variation in the pollutants. Mixing of different types of wastewaters causes mixing of the pollutants that might compromise the purification. For example, a wetland originally designed for school, hospital, and agriculture wastewater, cannot deal with industrial wastewaters. ARGs is also a big problem for the wetland because of the wastewater from hospital. The ARGs could transfer through different micro-organisms, plants and even the sludge. The bacteria with drug-resistant genes will spread in multiple ways and effect on human health.

As the conclusion for the possibility of large-scale natural wastewater treatment plant in China, the idea is good, but the real situation is different. There are too many people in China which cause strict limitations on the land use. A natural treatment plant is good for the environment but is not the good solution for the situation in China. The wetland can be used in the countryside where there are not many people, but now China is trying to develop more into urban area. This could create problems for building the wetland inside the city. Another problem is the distance for transporting the water. The cities are huge in China and there might be few hundreds of kilometers from the natural wastewater treatment plant to the city area. This causes extra costs for making the pipeline or other tunnel for wastewater. Maybe some new technology/development of natural wastewater treatment systems could make them more applicable in China in the future.

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