Zagazig J. Agric. Res., Vol. 49 No. (2) 2022 221-235

Plant Production Science

Available online at http://zjar.journals.ekb.eg
http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

A REVIEW ON THE CHARACTERISTICS OF TREATED WASTEWATER USED IN AGRICULTURE IN CHINA

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Received: 12/04/2022 ; Accepted: 27/04/2022

ABSTRACT: As the most important resource for life, water has been a central issue on the international agenda for several decades. However, water pollution is a major environmental problem worldwide, especially in developing countries, the world's supply of clean fresh water is steadily decreasing due to extensive agricultural demand for land. In this study, various long-term data analysis (such as water quality, sewage treatment plants, pollutant discharge, *etc.*) was undertaken to systematically understand the process of water pollution control in China in the past 20 years. The results highlighted that China's wastewater collection and treatment capacity approached the level of developed countries, with treatment rates exceeding 90% in both urban and country areas. The environmental quality of surface water has been constantly improved, but water pollution problems remain in eastern China's river basins, with remarkable economic progress. Rapid economic growth, not population growth, was the limeting factor in water pollution control in China. Therefore, water resources must be used more efficiently, and the use of non-conventional water resources, such as treated wastewater (TW) must be increased. TW reuse can be an alternative option to increase water resources. Thus, many countries have decided to convert wastewater into a resource for irrigation to help meet urban demand and address water shortages. However, due to the nature of that water, there are potential problems associated with its use for agriculture. The objectives of this comprehensive literature review are to highlight the characteristics of treated wastewater used in agriculture in China. To minimize these unfavorable effects when TW is used for irrigation, appropriate guidelines for wastewater reuse and management should be followed to reduce negative impacts significantly.

Key words: Fresh water, wastewater, China's river, water resources, agriculture.

INTRODUCTION

Water is essential for agriculture, industry, and domestic. With population growth, economic development, and changing water consumption patterns, the global water demand has increased by 600% in the past 100 years (**Wada, 2016**). Besides, urbanization also contributes in increasing water consumption (**Chen, 2017**). It is estimated that 52% of global population now live under water scarcity (**Mekonnen and Hoekstra, 2016**), according to the United Nation's Water Report, at least 3.6 billion people will be under water scarcity in 2050. Water plays an essential role in the growth of countries because a steady supply of fresh water is a crucial prerequisite for establishing a permanent community. Yet, the world's supply of clean freshwater is steadily decreasing. In many countries, the water demand surpasses the supply, and as the world population continues to rise and demands for water increase, freshwater shortages have emerged (**Hussain *et al.*, 2019**). Irrigation is considered the main user of freshwater. Irrigation of cultivated accounts for approximately 80% of the total freshwater usage (**Hussain *et al.*, 2019**), and it will account for an additional 15% by 2030 (**Guterres, 2017**), which

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will cause water crises in the regions that suffer from water shortages, such as Middle East and North Africa region, for example. In addition, (**Rizzo *et al.*, 2020**) mentioned that by 2025, nearly 1.8 billion people will live in a region that suffers from water shortages. Therefore, it is essential to use alternative sources of water. Within the following decades, it is estimated that over 40% of the total population will confront water stress or scarcity, representing a meaningful impact on water security (**Elgallal *et al.*, 2016**). Therefore, the reuse of wastewater is an important asset for agricultural purposes (**Becerra-Castro *et al.*, 2015**). Wastewater reuse is considered one of the most important options to manage water shortages (**Ghernaout *et al.*, 2019**). Treated Wastewater (TW) is defined as "water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility" (**FDEP, 2020**). The characteristics of wastewater vary greatly according to its origin, and it is important to study when treating and reusing it. The safety of TW that is reused for crop irrigation is a relevant issue worldwide (**Ghernaout *et al.*, 2020**). The reuse of TW could be one of the main alternative options to expand water resources (**Chojnacka *et al.*, 2020**), especially in dry areas, because it represents another source of renewable water (**Hussain and Qureshi, 2020**). Furthermore, the 2017 World Water Development Report highlighted the relevance of water reuse (**Connor *et al.*, 2017**). Therefore, the utilization of TW in the countries that suffer from water shortages is encouraged (**Chang and Ma, 2012**), especially because there are huge amounts of wastewater. For instance, China ranked first regarding the amount of wastewater. In 2012.

Approximately 68.5 billion tons of this water was released from industrial and municipal sources, which is equivalent to the yearly stream volume of the Yellow River (**Feng *et al.*, 2018**). About 108.16 billion m^3 of wastewater (34.33 billion m^3 from domestic sources and 73.83 billion m^3 from industrial sources) are being generated annually in China (**NPSCB, 2010**). In Egypt, about 5 billion m^3 of sewage water were collected every year (**Feng *et al.*, 2018**). Therefore, the TW can add up to 5 billion m^3 to Egypt's water resources. Wastewater treatment and use for irrigation represent a valuable resource and an appealing choice, especially in dry regions, because wastewater is considered a further inexhaustible, reliable, and dependable source of water and nutrients (**CAPMAS, 2016**). Therefore, in several water-scarce countries worldwide, wastewater reuse is considered a long-established practice and very important (**Lazarova, 2013**).Potential wastewater reuse applications include agricultural and landscape irrigation, groundwater recharge, industrial reuse, urban applications such as street cleaning, and firefighting and ecological and recreational uses (**Haberkamp *et al.*, 2019**). However, the reuse of wastewater for agricultural irrigation is more acceptable than its reuse in other fields (**Ghernaout, 2018**). Recently, TW irrigation has gained a high degree of importance, particularly in dry regions (**Khan *et al.*, 2019**). Most countries do not have rules to control wastewater reuse, and, in contrast, many countries have very strict regulations. There are no significant constraints on using the secondary TW as a fertigation source. Besides the decrease in using freshwater, wastewater reuse has decreased the release of wastes into ecosystems and enhanced the soil with nutrients and organic matter (OM) (**Ganjegunte, 2018**). **De Carlo *et al.* (2020)** stated that using TW as an irrigation source has economic and environmental benefits since it could reduce or even eliminate the need to supply expensive chemical fertilizers to the soil. Wastewater has OM and nutrients that are useful plants (**Chen *et al.*, 2017**), and thereby has been recognized as an important resource for an agricultural production increase with low cost (**Jeong *et al.*, 2014**). However, there are dangers with reusing the wastewater in agriculture; for example, its use led to a rise in the soil salinity, as well as the existence of microbial microorganisms and pollutants (**Shakir *et al.*, 2017**). Moreover, this water can carry pathogens that effect human health, besides raising the risk for parasitic, viral, and bacterial diseases in consumers of crops irrigated with this water. TW reuse will not only alleviate the water shortage problem for agricultural development but also remedy the pollution and health hazards related to the indiscriminate disposal of untreated sewage water (**Chefetz *et al.*, 2006**).

Untreated or insufficiently treated wastewater can cause public health, environmental, and economic problems (**Libutti *et al.*, 2018**). Therefore, the correct methods must be

Followed in the treatment and use of wastewater, particularly because wastewater reuse may cause public health hazards if the treatment is not appropriate (**Al Arni and Amous, 2019**). Showed that the different degrees of conventional treatment are:

Preliminary

Remove the large solid materials from the crude wastewater that are conveyed by sewers that could hinder the discharge or cause damage to equipment, such as wood, rags, fecal material, and heavier grit particles.

Primary

Remove the suspended solids (SS) and floating substances.

Secondary

The secondary treatment process aims to diminish the biochemical oxygen demand (BOD), chemical oxygen demand (COD), and SS, and the set of other harm parameters by removal or reduction in residual settle able solids and floating materials from primary treatment. BOD is the amount of dissolved oxygen needed by aerobic biological organisms in water to break down organic material existing in a water sample at a certain temperature over a specific period (**Dionisi, 2017**). The COD represents the quality of oxygen required to stabilize the carbonaceous organic matter chemically (**Von Sperling, 2007**).

Tertiary and/or advanced: Removal of nutrients and heavy metals (HM), which are not removed by the previous treatment. Additionally, decreasing the microbiological constituents by using some options such as chlorination, ultraviolet rays, and ozonation in disinfection operation. In general, the negative impact of TW can be reduced significantly by selecting a proper irrigation system, an appropriate cropping pattern with appropriate and effective irrigation management, as well as continuous examination of water, soil, and plant quality, and by taking careful and precautionary actions against pathogens. Water plays an important role in supporting and maintaining human health and sustainable ecosystem development. Population growth, urbanization, industrialization and consumption pattern changes have generated ever-increasing demands for freshwater resources worldwide (**UNESCO, 2015**). By 2030, the world is projected to face a 40% global water deficit under the business-as-usual scenario. Asia and the Pacific area have lower renewable water resources per capita than the global average, as the population grows, more water will be required for socio-economic activities (**UNESCAP, 2013**). China, an Asian country with the largest population and the second-largest economy in the world, has been considered as an emerging market country, where the water use situations are far from optimistic (**Hsu *et al.*, 2014**). Over the past several decades, ever-growing demands and misuse of water resources have caused severe water stress as well as the risks of water contamination in many parts of the country.

Aim of the Study

China's water resources are in a critical situation, surface water resources are already fully exploited and groundwater resources are reaching full production. China is facing an increasing demand for water needs, as a result of rapid population growth, increasing urbanization, rising living standards, and agricultural policy based on increasing production in order to feed a growing population. The use of raw sewage without any treatment has led to agricultural or industrial irrigation. Or drinking alcohol on health, humans and animals in many countries. The study aims to:

1- Shed light on the water resources available in China

2- Investigate about the sewage, agricultural and industrial treatment systems in China.

3- Getting acquainted with the update methods used in the field of wastewater treatment in general, as well as study the possibility of applying these methods in Egypt.

4- Attempting to search for solutions to the problem of shortage of water resources in China by providing water for irrigation, agriculture or drinking purposes, which reduces pressure on water resources.

Methodology

The study desigen

Theoretical study with a focus on literature, therefore the study is based on general historical, objective and description and analytical research principles. Applying these methods in the research enables to consider scientific knowledge as an integral system in which each previous approach indirectly or directly influenced the next one. All this together made it possible to compile a systematic series of scientific and theoretical calculations on the given issue. The views of authors are discussed regardless of ethno cultural preferences and political inclinations, which necessitates a thorough comparison of facts and phenomena in aggregate, that is, a comprehensive study of the problem. In addition, a systematic approach, which takes into account both features of the research objects themselves and factors that determine these features, is used in the paper. Such approaches allow to identify not only gaps in the studied subject, but also some particular aspects of the problem that might not have come to the scholars' attention for one reason or another. In general, this gives the opportunity to objectively compare these aspects and, on their basis, determine the prospects for further research.

Water Resources and Consumption

On one hand, water availability in China is approximately 2000 m^3 per capita in 2014, a value approaching the defined scarcity threshold of 1700 m^3 per capita per year (**Jiménez-Cisneros, 2014**). On the other hand, the national water consumption in China has been increased by 10.5%, from 550 billion m^3 in 2000 to 610 billion m^3 in 2014. Presently, large water consumers include agricultural, industrial, domestic and ecological environment applications (*e.g.*, artificial wetlands, stream, river and lake flows, recreational impoundments, fountains and waterfalls) with the corresponding proportions of 63.5%, 22.2%, 12.6% and 1.7%, respectively (**MWR, 2015**). In the next few years, the rapidly ascending industrial and urban demand growth, along with an increasingly complex water-energy nexus, will put mounting pressure on water supply in. According to a report by presented by Water Resources Group, there will be a gap of about 201 billion m^3 between China's current water supply and projected water demand in 2030. Particularly, severe gaps may exist in central and southeast China. Fig. 1 depicts the geographical locations of 31 provinces in China. From the provincial view point, China's water resources are not equally distributed throughout the year among different regions. About 82.9% of total renewable water resources are concentrated in southern regions of the country, while only 17.1% in northern regions (**MWR, 2015**). Besides, southern regions have affluent rainfall which may last as long as seven months, while northern regions experience a more arid climate. Consequently, 9 out of 31 Chinese provinces, including Beijing, Tianjin, Hebei, Shanxi, Shanghai, Jiangsu, Shandong, Henan, and Ningxia, suffer from extreme water shortage problems where water availability is less than 500 m^3 per capita per year. In terms of economic development, China's coastal provinces, especially Guangdong, Jiangsu, Zhejiang and Shandong, outpace other inland provinces in GDP figures. Notably, 12 coastal provinces had a collective per capita GDP 50% higher than the national average in 2009. Thus, water consumption is relatively high in east China, followed by central and west regions. Considering different types of water users, agriculture is still the largest consumer for most of regions while domestic and industrial consumption have been increased largely in east and central China (**MWR, 2015**).

Water pollution

In addition to water shortage, China is also confronted with considerable wastewater discharge and deteriorated water quality of many water bodies. Over the last two decades, the annual GDP growth rate in China was 10.9% in average. Meanwhile, China's urbanization rate has also grown at a fast pace, reaching 54.8% in 2014. Given high-speed economic expansions and rising urbanization rates, the quantity of total wastewater discharge in China has been increased over the years, which is up to 69.5 billion m^3 in 2013 (**Hu *et al.*, 2015**). However, China's wastewater treatment development is uneven. Although cities achieved

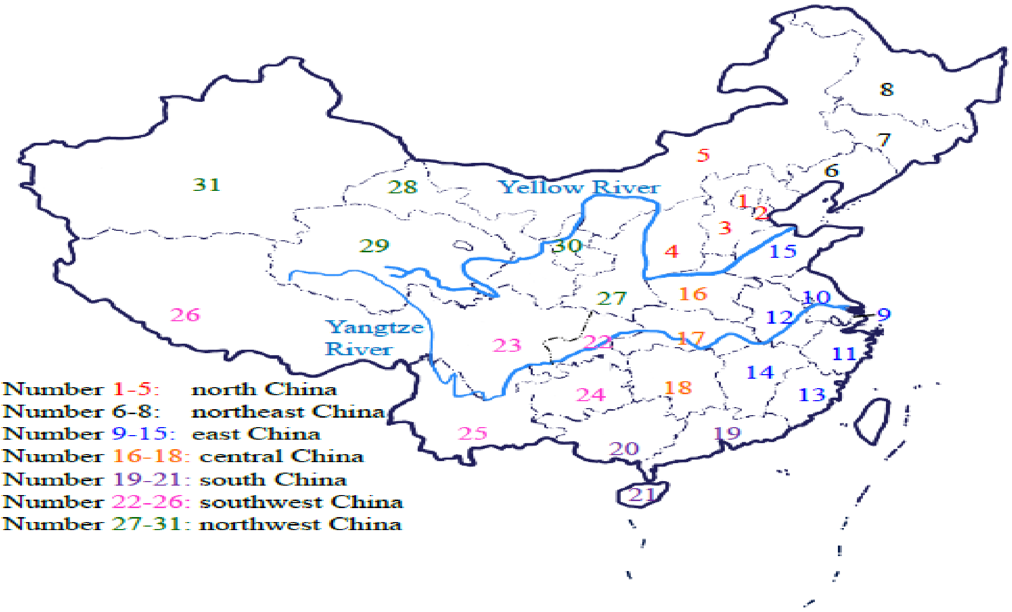

Fig. 1. Map of geographical locations of 31 provinces in mainland China

***Notes*:** **Each code number (1-31) represents a province in mainland China.**

Source: Sun *et al.* (2016)

The code number remains consistent in following figures

Number 1: Beijing; 2: Tianjin; 3: Hebei ; 4: Shanxi; 5: Neimenggu; 6: Liaoning; 7: Jilin; 8: Heilongjiang; 9: Shanghai; 10: Jiangsu; 11: Zhejiang; 12: Anhui; 13: Fujian; 14: Jiangxi; 15: Shandong; 16: Henan; 17: Hubei; 18: Hunan; 19: Guangdong; 20: Guangxi; 21: Hainan; 22: Chongqing; 23: Sichuan; 24: Guizhou; 25: Yunnan; 26: Tibet; 27: Shannxi; 28: Gansu; 29: Qinghai; 30: Ningxia; 31: Xinjiang.

a relatively high treatment rate of over 80%, the national treatment rate is only 69% in 2014. Besides, the 2014 Environmental Performance Index analysis reported a low wastewater network connection rate of 46.8% in China (**Hsu *et al.*, 2014**). Discharging excessive poorly treated or untreated wastewater into waterways, together with hazardous wastes and agricultural runoffs of fertilizers and pesticides, has posed serious health and environmental concerns (**Cheng *et al.*, 2009**). As a result, more than half of the country's lakes, reservoirs and groundwater aquifers are deemed of low water quality, which are unsuitable for human consumption (**MWR, 2015**).

Resources Utilization

Water reuse can be considered as an effective approach to address water shortage problems and water quality deterioration issues. Moreover, there is a development trend towards ultimate utilization of wastewater as a resource. Fig. 2 shows a novel concept of wastewater refining (**Hu *et al.*, 2015**). Having recognized these key challenges and opportunities on water use in China, it is essential to conduct systematic wastewater quality analyses for sustainable water management both locally and nationally. As an important part, strategies for further resources utilization such as water reuse and nutrient recovery should be provided.

Characteristics of Wastewater

Characteristics of wastewater are broadly classified into physical, chemical, and biological properties. They also stated that the liquid portion of the wastewater comprises a complex mixture of minerals and OM in many forms, including large and small particles, floating suspension, and colloidal. Wastewater has some poisonous elements, for example, arsenic, cadmium, chromium, lead, copper, zinc, mercury, *etc*. Among the organic substances existing in this water are pesticides, carbohydrates, fats, proteins, synthetic detergents, pharmaceuticals, and complex nitrogenous OM products (**Cizmas *et al.*, 2015**). These poisonous elements have hazardous

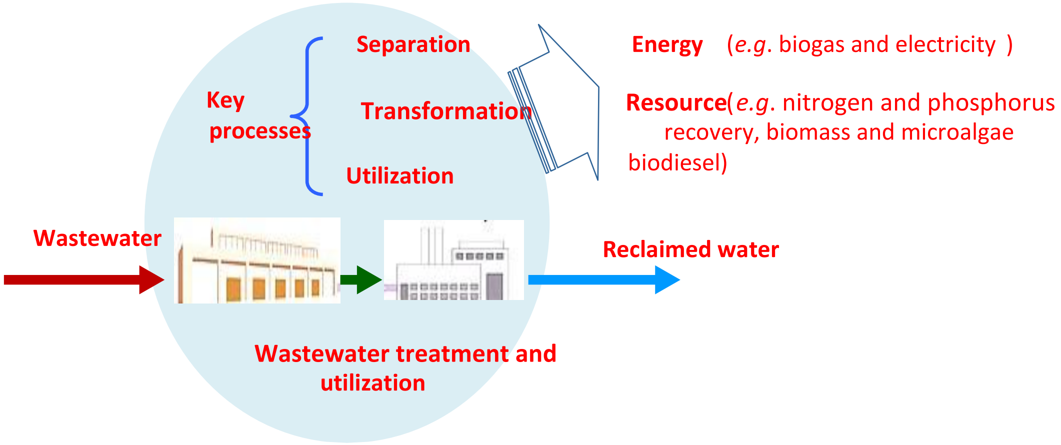

Fig. 2. The concept of wastewater refining toward the ultimate utilization of wastewater resources

Source : Sun *et al.* (2016)

effects on general health (**Wu *et al.*, 2015**). However, direct evidence of adverse human health impacts is still being discussed. Microplastics, polymer fibers, polyethylene terephthalate, polyethylene, polypropylene, and polystyrene are present in the wastewater (**Carr *et al.*, 2016**). Microplastics can have an inimical effect on the reproductive and vegetative growth of plants (**Ziajahromi *et al.*, 2017**). A large number of studies had stated that TW contains pharmaceutically active compounds (PhACs) (**Golovko *et al.*, 2014**). Conventional wastewater treatment based on activated sludge could not efficiently remove these compounds. As a result, many of these chemicals were later detected in soils watered with TW (**Biel-Maeso *et al.*, 2018**). Additionally, they mentioned that the ecotoxicological hazard of PhACs in the soil was very low. However, this is widely dependent on the PhACs, as shown by. The soil microorganism can be affected if these compounds accumulated for many years in the soil and can be moved to the crops and then to the food chain, probably risking humans. The chemical and biological constituents and the physical properties of wastewater and their sources are placed in Table1. Additionally, the important contaminants of interest in wastewater treatment are placed in Table 1.

Water Quality Analysis

DO, water temperature (Tw), pH, Chla, and TSS were measured in situ once every week using SEBA KLL-Q-2 Portable Water Quality Probes (Gewerbestr, CO, Germany). Water transparency (Tra) was measured with a Secchi disk at all sampling sites. Water samples were analyzed within 24 hr, according to standard methods (**Huan, 2002**). Water quality discharge standards refer to “Requirements for Water Discharge from Freshwater Aquaculture Ponds (SC/T9101-2007) in China.” All water quality indicators and corresponding monitoring methods, as well as discharge standards, are shown in Table 2.

Pollutant Removal by the FCETS

The water quality parameters (Tra, TSS, TN, NO3−-N, NH4+-N, TP, DP, COD Mn) of all sampling sites are summarized in Table 3. In the influent, Tra, TSS, TN, NH4+-N, TP, DP, and COD Mn of 29.0–36.0 cm, 99.0–114.0 mg/L, 7.2–8.1 mg/L, 4.0–4.8 mg/L, 1.5–1.8 mg/L, 0.9 –1.0 mg/L, and 35.8–41.2 mg/L were detected, respectively. In the effluent, Tra (Water transparency) increased to 62–70 cm, showing an improvement of 83.3–125.8%. The other six parameters were decreased in the influent to 52.0–64.0 mg/L, 3.5–3.8 mg/L, 1.8–2.1 mg/L, 0.2–0.3 mg/L, 0.7–0.9 mg/L, and 15.6–17.3 mg/L, respectively. These demonstrated reduction rates of 41.1–49.1%, 44.8–56.2%, 49.3–55.6%, 80.0–88.2%, 52.6–65.0%, and 52.0–61.5%, respectively. The parameters TSS, TN, and COD Mn met the second standard, as specified in the SC/T9101. As for COD Mn and

Table 1 . Physical, chemical, and biological characteristics of wastewater

Characteristic	**Source**
Physical properties	Domestic and industrial wastes, natural decay of organic materials
Color	
Odour	Decomposing wastewater, industrial wastes
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, inflow infiltration
Temperature	Domestic and industrial wastes
Chemical constituents:	
Organic	
Carbohydrates	Domestic, commercial, and industrial wastes
Fats, oils, and grease	Domestic, commercial, and industrial wastes
Characteristic	Sources
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic, commercial, and industrial wastes
Priority pollutants	Domestic, commercial, and industrial wastes
Surfactants	Domestic, commercial, and industrial wastes
Volatile organic compounds	Domestic, commercial, and industrial wastes
Other	The natural decay of organic materials
Inorganic	
Alkalinity	Domestic wastes, domestic water supply, groundwater infiltration
Chlorides	Domestic wastes, domestic water supply, groundwater infiltration, water softeners
Heavy metals	Industrial wastes
Nitrogen	Domestic and agricultural wastes
Acidity	Domestic, commercial, and industrial wastes
Phosphorus	Domestic, commercial, and industrial wastes natural runoff
Sulfur	Domestic water supply, domestic and industrial wastes
Toxic compounds	Industrial wastes
Gases	
Hydrogen sulfide	Decomposition of domestic wastes
Methane	Decomposition of domestic wastes
Oxygen	Domestic water supply, surface-water infiltration
Biological constituents:	
Animals	Open watercourses and treatment plants
Plants	Open watercourses and treatment plants
Bacteria	Domestic wastes, surface water infiltration, treatment plants
Archae	Domestic wastes, surface-water infiltration, treatment plants
Protista	Domestic wastes, treatment plants
Viruses	Domestic wastes

Source: (Hashem and Qi, 2021)

Table 2. Discharge standards of water quality indicators

Indicators	**Monitoring methods**	**SC/T9101-2007**	
		First standard	**Second standard**
COD_{Mn}	Potassium permanganate index method	15.0 mg/L	25.0 mg/L
NH_4^+-N	Na’s reagent spectrophotometry	unspecified	unspecified
NO_3^--N	Potassium persulfate oxidation spectrophotometry	unspecified	unspecified
TSS	Electrode fluorescence method	≤ 50 mg/L	≤ 100 mg/L
TN	Phenolic disulfonic acid spectrophotometry	3.0 mg/L	5.0 mg/L
TP	Potassium persulfate digestion	0.5 mg/L	1.0 mg/L

Source: Liu *et al.* (2022)

Table 3. Summary of water quality removal effects by FCEST

Treatment unit	**Tran (cm)**	**TSS (mg/L)**	**TN (mg/L)**	**NO_3^--N (mg/L)**	**NH_4^+-N (mg/L)**	**TP (mg/L)**	**DP (mg/L)**	**COD_{Mn} (mg/L)**
Inlets	29–36	99–114	7.2–8.1	4.0–4.8	1.5–1.8	1.8–2.1	0.9–1.0	36.7–41.2
SP	39–44	78–82	6.2–7.8	3.2–3.7	1.1–1.4	1.3–1.6	0.7–0.8	31.2–34.1
Removal rates (%)	17.9–30.5	18.2–30.7	15.5–18.8	3.7–17.3	25.8–44.8	15.8–35.0	11.1–22.2	12.5–20.6
AP	44–52	72–75	4.2–5.1	2.5–2.8	0.6–0.8	1.1–1.4	0.6–0.65	23.6–26.6
Removal rates (%)	5.8–19.1	6.4–8.9	14.8–17.3	17.7–44.9	3.8–21.2	12.5–20.0	7.1–18.8	18.6–27.8
EP	59–65	59–64	3.5–3.9	1.8–2.1	0.2–0.4	0.7–1.0	0.4–0.45	17.5–20.3
Removal rates (%)	18.5–25.0	14.7–20.3	14.0–34.6	15.2–25.5	23.6–28.3	28.6–36.4	25.0–33.3	14.0–34.2
Outlets	62–70	52–64	3.5–3.8	1.8–2.1	0.2–0.3	0.7–0.9	0.35–0.4	15.6–17.3
Total removal rates* (%)	36.6–49.5	41.1–49.1	44.8–56.2	49.3–55.6	53.4–64.8	52.6365.0	53.0–65.0	52.0–61.5

Source: Liu *et al.* (2022)

NH4+-N, it was AP > EP > SP, and for NO3−-N and DP, it was EP > SP > AP. Overall, FCETS could provide treatment robust to flow fluctuations and pollutant concentrations.

The chemical risks associated with wastewater usage are that it contains HM, OM, salt, nutrients, and toxic compounds.The chemical composition of wastewater is more varied and more concentrated and contains certain various acids, alkalis chemical contaminants, oil, coarse solids, and other constituents. Inorganic constituents include high concentrations of calcium, sodium, potassium, chlorine, phosphate, sulfur, bicarbonate, ammonium salts, and HM. TW contains many of the micronutrients that the plant needs, such as copper, iron, manganese, zinc, boron, molybdenum, cobalt, and nickel. Mentioned that the chemical characteristics of wastewater could adversely affect the environment in many different ways. Soluble organic can deplete oxygen levels in the stream and give taste and odour to water supplies, as well as toxic materials that can affect the food chain and public health. Reported that the properties of wastewater that can be identified by the human sense organs are termed the physical characteristics. The most important physical characteristics of wastewater are its solid content, as it affects the water’s aesthetics, clarity, and colour. Other physical parameters are temperature and odors and are not commonly altered in a wastewater treatment plant. The temperature of wastewater is important primarily because it affects aquatic and biological life in the receiving body of water. Higher temperatures decrease the dissolved oxygen solubility in the water. A considerable amount of dissolved solids may be added to water during its treatment and use. The term biological characteristics of water refers to the aquatic life and viruses found in water. The quality of water is significantly affected by these characteristics. Algae, for example, cause taste and odour. Some types of algae clog sand filters; others produce nuisance-causing slimy growths on equipment, tanks, and reservoir walls. Furthermore, some microalgae produce powerful toxic substances harmful to living organisms (**Casabianca *et al*., 2019**). Microbiological life in water, such as bacteria, viruses, and protozoa, can cause different diseases (**Uyttendaele *et al*., 2015**). The environment of wastewater considers an ideal environment for growing viruses, bacteria, and protozoa. The majority is harmless, but sewage also contains pathogenic microorganisms. Several researchers have indicated that biological oxidation systems that occur in the secondary treatment of sewage can remove most pathogenic bacteria from sewage. Biological wastewater characteristics can be derived with the help of measuring both COD and BOD). Organic waste usually requires oxygen for rapid and effective biological decomposition. Therefore, the greater the number of organic pollutants, the greater the oxygen demand. Hence, higher BOD and COD indicate higher pollutant content in wastewater. The BOD/COD ratio is widely used to decide the biodegradability of the wastewater (**Sun *et al*., 2016**). After wastewater treatment, the wastewater concentrations of BOD and COD decrease dramatically due to a notable reduction in biodegradable OM in TW (**Sun *et al*., 2016**). The BOD value is expressed in milligrams of oxygen consumed per L of a sample during five days of incubation at 20°C, and it considers a mirror of the level of water organic pollution and an indication for the possibility of polluted water or effluent to oxygen consumption. Stated that the master sources of OM affecting the BOD concentration are raw sewage wastewater and industrial wastes. Additionally, (**Sun *et al*., 2016**) they stated that unpolluted water typically has BOD values of 2 mg L^{-1}, and the raw sewage has a BOD value of about 600 mg L^{-1}, whereas treated sewage effluents have BOD values ranging from 20 mg L^{-1} to 100 mg L^{-1} according to the treatment level. Industrial wastes may have BOD values up to 25,000 mg L^{-1}. The COD test is an indirect indicator of organic compounds' contents in water, and it is commonly used to measure the sensitivity to oxidation of the organic and inorganic compounds that exist in water bodies and effluent from sewage and industrial plants (**Muthuraman *et al*., 2019**). It is expressed in milligrams of oxygen per L of water (mg L^{-1}). COD is a useful, rapidly measured variable for many industrial wastes. The ratio between COD and BOD will vary depending on the characteristics of the wastewater (**Abdalla and Hammam, 2014**). This ratio has been commonly used as an indicator for biodegradation capacity, the Wastewater Treatment Committee concluded that future wastewater treatment plants must achieve four primary objectives (sustainable water quality, resource recovery, energy neutrality, and environmental friendliness) collectively in what is known as the concept of wastewater treatment. China's water pollution control has made important achievements.

Reuse of Treated Wastewater

TW refers to municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for beneficial purposes. The worldwide wastewater releases around 0.4 trillion m^3 per year and contaminating around 5.5 trillion m^3 of water each year. Therefore, all countries should be concerned about treating these large quantities of wastewater, and then reuse it. The increasing demands for domestic water due to population growth, improvement in living standards, and the growing industrial sector will raise the amount of wastewater produced, promoting TW reuse worldwide. The major problems associated with this matter include public health and ecological perils plus technical, institutional, socio-cultural, and sustainability aspects. Thus, wastewater treatment and its usage will be highly essential. So, for example, the treatment rate of wastewater in China (the ratio of the TW amount to the total discharge amount of wastewater) increased to 86% in 2014, 3.4 times

Table 4. Important contaminants of concern in wastewater treatment

Contaminant	Reason for Importance
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged into the aquatic environment.
Biodegradable organics	Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most commonly in terms of BOD (biochemical oxygen demand) and COD (chemical oxygen demand). If discharged untreated to the environment, their biological stabilization can lead to the depletion of natural oxygen resources and the development of septic conditions.
Pathogens	Infectious diseases can be transmitted by the pathogenic organisms in wastewater.
Nutrients	Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.
Refractory organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused.
Dissolved inorganic solids	Inorganic constituents such as calcium, sodium, and sulfate are added to the original domestic water supply as a result of water use and may have to be removed if the wastewater is to be reused.

Source : (Hashem and Qi ,2021)

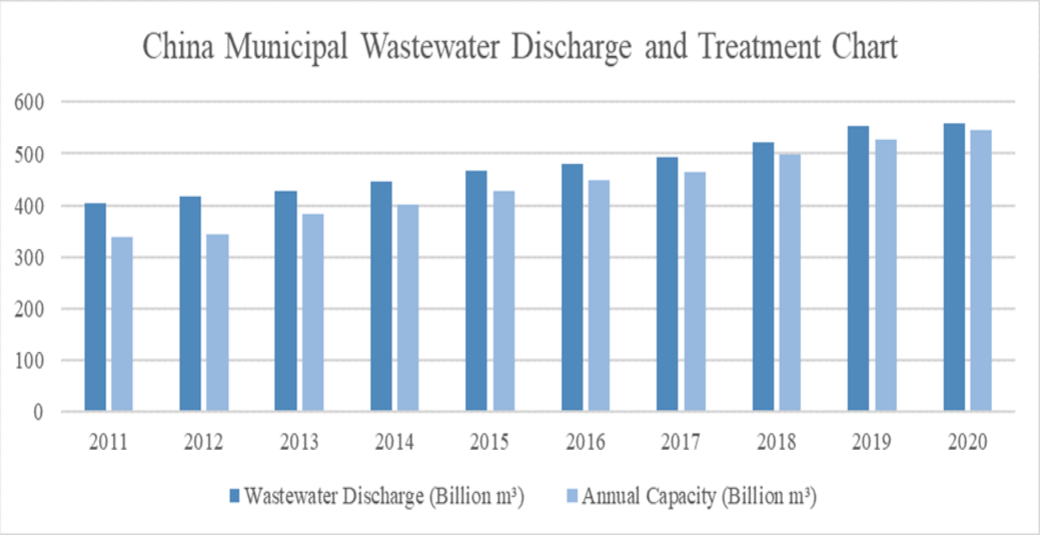

Fig. 3. Chinese municipal sewage disposal and treatment scheme 2011-2020

Source: Chinese Ministry of Environment 2021

Table 5. The wastewater generation, collection, treatment, and reuse for irrigation of crops in some countries in relation to the total cultivated area.

Country	Total Area (1000 ha)	Agricultural Area (1000 ha)	Total Agricultural Area (%)	Generated Municipal Wastewater (109 m3 year^{-1})	Collected Municipal Wastewater (109 m3 year^{-1})	Treated Municipal Wastewater (109 m3 year-1)	Treated Wastewater Used for Irrigation (109 m3 year^{-1})
Australia	774,122	47,307	6.11	-	-	2	0.28
Brazil	851,577	86,589	10.1	-	-	3.1	0.008
China	960,001	122,524	12.7	48.51	31.14	42.37	1.26
Germany	35,738	12,074	33.7	-	5.287	5.213	5.183
India	328,726	169,360	51.5	-	-	4.416	-
Italy	30,134	9121	30.2	3.926	-	3.902	0.087
Jordan	8932	322	3.6	-	0.115	0.113	0.103
Pakistan	79,610	31,252	39.2	3.06	-	-	-
South Africa	121,909	12,913	10.5	3.542	2.769	1.919	-
Turkey	78,535	23,944	30.4	4.297	-	3.483	-
UK	24,361	6279	25.7	4.089	4.048	4.048	-
USA	983,151	157,205	15.9	60.41	47.24	45.35	-
Canada	998,467	50,846	5.09	6.613	5.819	5.632	-
Sweden	44,742	2608	5.82	0.671	-	0.436	-

***Source* : (Hashem and Qi ,2021)**

Agricultural irrigation represents the largest currently TW user globally; hence, this offers significant future opportunities

that of 1999 (**Wang *et al.*, 2017**). Internationally, the TW irrigation has increased around 10–29% per year in Europe, China, and the US, and approximately 41% in Australia. Table 5 shows the whole wastewater generated, gathered, treated, and utilized for irrigation in some countries (**FAO, 2017**). The main treatment target is to supply TW with an appropriate and secure level of risk for the environment and public health, and this happens by reducing SS and OM plus removing wastewater chemical and biological constituents that might be harmful to crops and general health (**Seow *et al.*, 2016**).

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دراسة مرجعية حول خصائص مياه الصرف الصحى المعالجة المستخدمة فى الزراعة في الصين

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كانت المياه قضية مركزية على جدول الأعمال الدولي لعدة عقود باعتبارها أهم مورد للحياة. ومع ذلك، فإن يعتبر تلوث المياه مشكلة بيئية رئيسية في جميع أنحاء العالم، وخاصة في البلدان النامية، فإن إمدادات العالم من المياه العذبة النظيفة تتناقص بشكل مطرد بسبب الطلب الزراعي الواسع على الأراضي. في هذه الدراسة، تم القيام بتحليل البيانات المتنوعة طويلة المدى (مثل جودة المياه ومحطات معالجة مياه الصرف الصحي وتصريف الملوثات وما إلى ذلك) لفهم عملية التحكم في تلوث المياه بشكل منهجي في الصين في العشرين عامًا الماضية. أبرزت النتائج أن قدرة جمع ومعالجة مياه الصرف الصحي في الصين اقتربت من مستوى الدول المتقدمة، حيث تجاوزت معدلات المعالجة 90% في كل من المناطق الحضرية والقطرية. تم تحسين الجودة البيئية للمياه السطحية باستمرار، لكن مشاكل تلوث المياه ظلت في أحواض الأنهار بشرق الصين، مع تحقيق تقدم اقتصادي ملحوظ. كان النمو الاقتصادي السريع، وليس النمو السكاني، هو العامل المحدد للسيطرة على تلوث المياه في الصين. لذلك، يجب استخدام موارد المياه بكفاءة أكبر، ويجب زيادة استخدام موارد المياه غير التقليدية، مثل مياه الصرف الصحي المعالجة. يمكن أن تكون إعادة استخدام المياه المعالجة خيارًا بديلاً لزيادة موارد المياه. وهكذا، قررت العديد من البلدان تحويل المياه العادمة إلى مورد للري للمساعدة في تلبية الطلب الحضري ومعالجة نقص المياه. ومع ذلك، بسبب طبيعة تلك المياه، هناك مشاكل محتملة مرتبطة باستخدامها في الري. بعض المخاوف الرئيسية هي المخاطر الصحية وتراكم الملوحة ومخاطر السمية. وتتمثل أهداف هذه المراجعة الشاملة للأدبيات في إلقاء الضوء على أهمية استخدام المياه المعالجة في الري كمصدر بديل للمياه العذبة وتقييم آثار استخدامه على خصوبة التربة وخصائص التربة الأخرى والنباتات والصحة العامة. ومع ذلك، فإن الاستخدام غير المنضبط لمثل هذه المياه له العديد من الآثار غير المواتية على كل من التربة والنباتات، خاصة على المدى الطويل. لتقليل هذه الآثار غير المواتية عند استخدام المياه المعالجة في الري ، يجب اتباع الإرشادات المناسبة لإعادة استخدام مياه الصرف الصحي وإدارتها للحد من الآثار السلبية بشكل كبير.

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