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Review

Effective Solutions to Ecological and Water Environment Problems in the Sanjiang Plain: Utilization of Farmland Drainage Resources

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Abstract: The Sanjiang Plain stands as a pivotal grain-producing region in China. Faced with population growth and the imperative of ensuring food security, the rapid expansion of agricultural land in the Sanjiang Plain has led to escalating ecological and water-environmental challenges, hindering the sustainable development of regional agriculture. This research aims to explore and propose practical measures for utilizing agricultural drainage resources to address the ecological and water-environmental issues resulting from agricultural expansion in the Sanjiang Plain, striving to achieve harmonious and sustainable economic and environmental growth. The discussion revolves around the potential alleviation of water quality, water quantity, and ecological health issues in the Sanjiang Plain through the proposed approach. Considering regional characteristics, the focus is on potential environmental drawbacks resulting from the improper application of the method. Building on these findings, effective strategies are presented to enhance the systematic operation of agricultural drainage resource utilization in the region. In conclusion, addressing ecological and water-environmental challenges stemming from local agricultural development is imperative for the Sanjiang Plain to realize sustainable development for the economy and the environment.

Keywords: agricultural drainage; wastewater irrigation; Sanjiang Plain; pollution treatment; ecological water environment

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1. Introduction

The Sanjiang Plain is widely recognized for its distinctive wetlands and farming landscapes, which are characterized by an abundance of ecological assets. The region in question is recognized as a significant area for grain production in northeast China [1]. Nevertheless, the Sanjiang Plain has experienced alterations in land use and land cover, resulting in the growth of agricultural land, a decline in wetland areas, and the emergence of persistent challenges pertaining to water supply and water quality [2]. According to statistical data, there has been a notable decline in wetland areas over the years, coinciding with the expansion of agricultural land and the degradation of wetlands. Specifically, between 1990 and 2000, wetland areas experienced a reduction of 7395 square kilometers. Subsequently, from 2000 to 2015, there was an additional decrease of 3238 square kilometers [3–5]. The primary purpose of groundwater extraction in the Sanjiang Plain is for agricultural irrigation. Over the period from 2000 to 2017, there was a notable increase in groundwater supplies, rising from 51.0 billion cubic meters to 101.9 billion cubic meters [6]. The intensification of farming practices has led to an increase in water contamination resulting from agricultural activities. Reports indicate that in nitrogen load testing in the Songhua River Basin, pollution from non-point sources, mainly agricultural fields, accounted for 74% of the pollution [7]. The aforementioned concerns not only have implications for the sustainable development of regional agriculture but also pose a significant threat to the equilibrium and well-being of the local ecosystem. Hence, it is crucial to implement strategies aimed at mitigating these issues and attaining sustainable management of water resources. Based on regional characteristics and development planning, the resourceful utilization of agricultural drainage offers a promising solution to the ecological and environmental issues in the Sanjiang Plain.

The resourceful utilization of agricultural drainage is an effective solution aimed at preventing further environmental degradation. As illustrated in Figure 1, the land use patterns in the Sanjiang Plain in 2021 indicate a prevailing presence of agricultural land, with a notable allocation of water resources towards agricultural activities, namely the cultivation of rice, which serves as the primary staple crop [8,9]. In recent times, there has been a notable increase in rice production within the Sanjiang Plain. This expansion has led to a significant challenge in managing agricultural drainage, resulting in the over-extraction of groundwater and the exacerbation of surface water pollution issues [10]. The resourceful utilization of agricultural drainage involves the recognition and exploration of agricultural drainage as a non-conventional water resource. When well controlled, it has the potential to optimize agricultural water usage, mitigate water scarcity, and concurrently enhance the ecological environment [11]. Hence, the utilization of agricultural drainage for irrigation has become a topic of growing interest in grain-producing regions like the Sanjiang Plain. This is primarily due to its significant contribution in addressing ecological, water, and environmental issues in the region. The fundamental principle underlying this approach involves considering agricultural drainage as an unconventional water resource. By implementing appropriate treatment and utilization methods, this water can be effectively employed for agricultural purposes. Consequently, this approach enhances water efficiency, alleviates strain on surface water and groundwater reserves, and mitigates the adverse environmental effects of wastewater.

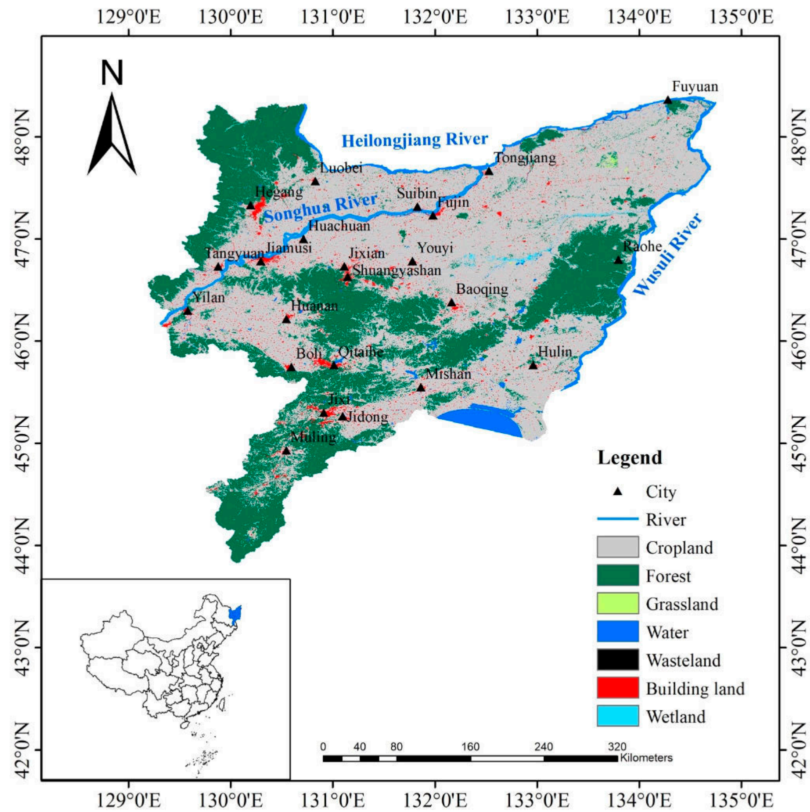

Figure 1. Land use situation in the Sanjiang Plain in 2021.

Building upon the foundation laid by the aforementioned article, this paper aims to conduct a thorough exploration of the environmental effects and impacts associated with the resource utilization of agricultural drainage. Correspondingly, we propose effective measures to address these issues. As elucidated, the resource utilization of agricultural drainage has significant positive effects on mitigating the contradictions between water supply and demand, controlling non-point source pollution in regional agriculture, and maintaining the health of the regional ecological environment. Conversely, there are negative environmental effects, including soil pollution, crop yield reduction and pollution, and potential hazards to human health. To maximize the potential of resource utilization from agricultural drainage, we emphasize the importance of formulating relevant guidance policies, constructing artificial wetlands, introducing sewage stabilization systems, and adopting drip irrigation systems. These measures are anticipated to achieve comprehensive and sustainable resource utilization of agricultural drainage in the realm of agricultural water resource management.

2. Positive Environmental Effects of Farmland Drainage Resource Utilization

As depicted in Figure 2, a multitude of nations worldwide have used wastewater recycling strategies in order to address the prevalent problem of global water scarcity. The present discourse seeks to elaborate on the notion of resourceful utilization of agricultural drainage by placing significant focus on the effective gathering, utilization, and administration of agricultural drainage as a primary resource. The primary objective of this procedure is to attain water conservation, nutrient recovery, and the prevention of surface water and groundwater pollution, among various other advantages [12]. The primary task of utilizing farmland drainage resources is to achieve the effective recovery and treatment of water resources [13]. Therefore, it is necessary to design a reasonable drainage system to achieve efficient water transport. Typically, drainage facilities use pipeline drainage or underground drainage, ensuring both the rational transport of farmland drainage and meeting the requirements for drainage [14]. Secondly, wastewater treatment is essential because using untreated wastewater may pose risks of disease or death [15]. Generally, wastewater treatment includes preliminary treatment (physical, mechanical), primary treatment (physical–chemical, chemical), secondary treatment (biological, chemical), tertiary treatment (physical, chemical), and advanced treatment [16–19]. Among these, tertiary and advanced treatments enable safe use for various purposes, including garden irrigation and crop irrigation [20,21]. Subsequently, selecting appropriate water storage facilities, such as reservoirs or underground aquifers, is essential for storage [22]. Finally, upon entering the recycling system, the treated water is effectively utilized, including for irrigation and aquaculture [23,24].

The reuse of agricultural wastewater can be traced back to ancient China, around the Yin Dynasty in approximately in the 11th century BCE, when people began utilizing wastewater for aquaculture [25]. In the Chinese setting, there have been instances in history where the practice of agricultural drainage has been utilized as a method of irrigation for a prolonged duration. The city of Nanning, situated in China, has implemented the practice of agricultural drainage for a duration of 54 years. The efficacy of this approach in promoting irrigation has been demonstrated, resulting in a significant improvement in wheat and barley production, with yields increasing by a factor of three to four times the initial output [26]. In specific areas of Gansu, China, such as the Jinghe Irrigation District, agricultural drainage is used as a strategy when the water supply from the Yellow River is insufficient for irrigation purposes. The primary objective is to sustain an optimal level of crop yield [27]. Furthermore, there are specific regions, such as Yinchuan in Ningxia [28] and Baoji Li in Shandong, that continue to utilize agricultural drainage as a method of irrigation. The utilization and recycling of agricultural drainage not only offer potential opportunities for generating revenue within the agricultural industry, but also have a positive impact on the conservation of groundwater resources [29]. The effective and strategic application of agricultural drainage presents a potential solution for addressing ecological and environmental issues in the Sanjiang Plain area. Additionally, it can contribute significantly to the sustainable management of water resources, environmental preservation, and the reduction of excessive groundwater extraction.

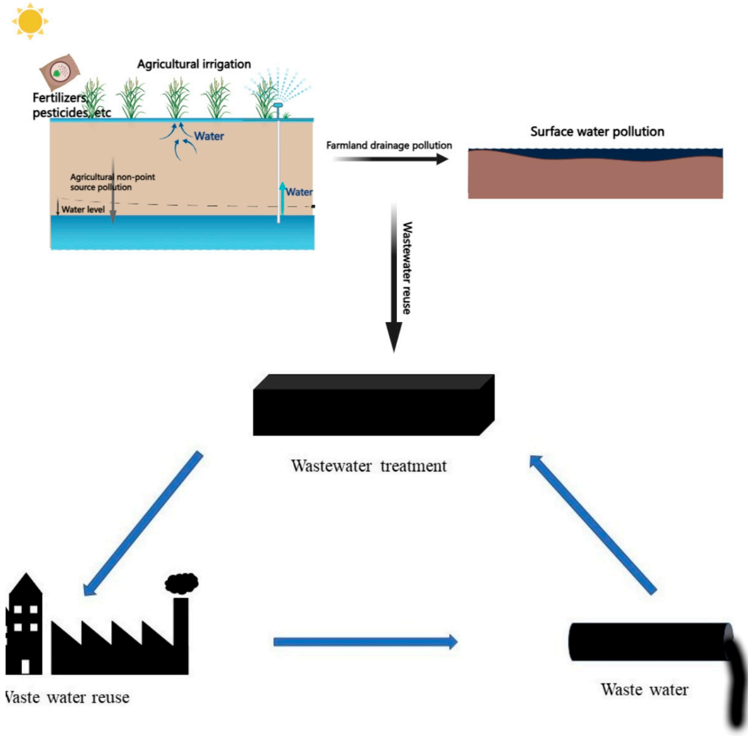

Figure 2. Wastewater recycling.

2.1. Alleviating the Contradiction between Regional Water Supply and Demand

The Sanjiang Plain experiences a significant disparity between water availability and demand, principally attributed to the rapid expansion of agricultural activities and limited use of surface water resources [30]. Due to the dominant agricultural industry in the Sanjiang Plain, its primary objective is food production. Additionally, agriculture provides employment opportunities and income sources for the local rural population [31]. Based on survey data, it was observed that between 2004 and 2015, the percentage of water used for agricultural purposes saw an upward trend, rising from 71.8% to 88.0%. Additionally, the overall volume of surface water storage in the wetlands of the Sanjiang Plain exhibited a decline, decreasing from 14.46 billion metric tons to 4.70 billion metric tons by the year 2010 [32]. According to the water resource report of the Songliao River Basin, there was a notable change in the supply structure of water resources in the Sanjiang Plain from 2000 to 2017. During this period, the proportion of groundwater supply increased from 50.1% to 63.1% of the total water supply. Consequently, the supply structure shifted from a combination of surface water and groundwater to mostly relying on groundwater as the primary source of water supply [33]. The use of efficient agricultural drainage practices yields numerous advantages for both the environment and the agricultural sector. The practice of reusing agricultural drainage is a significant strategy for effectively addressing potential water resource scarcity concerns in the future [34]. According to statistical data, the use of wastewater for agricultural irrigation accounts for 70% of the overall agricultural water consumption. This practice facilitates the recycling and reuse of water resources, hence mitigating the need to take water from environmental sources [35–38]. Moreover, under some circumstances, agricultural drainage irrigation proves to be a more dependable water source in comparison to alternatives like rainfall and surface water. This enables farmers to provide a consistent water supply for their crops throughout the entire year [39]. A study conducted in an Arab region revealed that the utilization of treated wastewater for agricultural purposes resulted in a significant conservation of 70% of groundwater resources [40].

Hence, the implementation of efficient agricultural drainage practices in the Sanjiang Plain region would have a positive impact on the restoration of groundwater levels and the enhancement of groundwater recharge. Consequently, this would facilitate the promotion of comprehensive water resource management [41]. This approach successfully mitigates dependence on freshwater resources and mitigates the strain of excessive groundwater extraction [42].

2.2. Controlling Regional Agricultural Non-Point Source Pollution

The agricultural non-point source pollution encountered in the Sanjiang Plain commonly refers to ecosystem pollution caused by the excessive use of fertilizers and pesticides in the process of agricultural cultivation [43]. Research findings indicate that the utilization rates of nitrogen and phosphorus fertilizers in paddy fields are significantly low, with values of approximately 27.1% and 13.7%, respectively. Agricultural drainage results in the loss of residual fertilizers, hence contributing to soil pollution and serving as a significant driver of non-point source pollution in agriculture [44]. In order to mitigate the agricultural non-point source pollution challenges, it is imperative to explore novel approaches aimed at enhancing the ecological water environment inside the Sanjiang Plain. In this context, the effective utilization of agricultural drainage presents a possible answer.

Using treated agricultural wastewater for irrigation is an effective strategy for reducing the reliance on chemical fertilizers [45,46]. As depicted in Figure 3, following comprehensive treatment, the utilization of wastewater for irrigation purposes can contribute essential nutrients to the land. Multiple studies have provided evidence indicating that the use of irrigation rates at approximately 4000 m^3/ha, along with treated wastewater concentrations ranging from 30–180 mg/L, might result in a notable enhancement in the soil's sodium (Na) fertilizer value, with potential increases ranging from 100–720 kg/ha [47–49]. Consequently, the strategic application of agricultural drainage can effectively decrease reliance on chemical fertilizers, thereby limiting the potential for water pollution resulting from fertilizer usage. Hence, reducing fertilizer utilization is a crucial strategy for mitigating wetland degradation in the Sanjiang Plain [50].

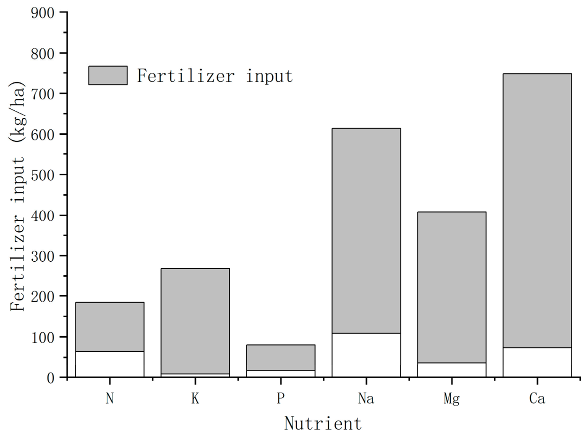

Figure 3. Fertilizer value provided by wastewater irrigated soil.

2.3. Maintaining Regional Ecological Environment Health

According to statistical data, there was a significant decline of 80.06% in the overall wetland area inside the Sanjiang Plain during the period spanning from 1955 to 1980 [51]. Moreover, due to the substantial water requirements for agricultural purposes on the Sanjiang Plain, surface water needs to be improved, leading to excessive groundwater extraction. Between 2000 and 2014, the Sanjiang Plain's groundwater resources experienced extreme extraction, resulting in an average yearly decline of 313 million cubic meters in groundwater storage [52]. Water eutrophication has been observed as a consequence of the widespread application of chemical fertilizers and pesticides. When the phosphorus concentration in water reaches a level of 0.02 mg/L, it has the potential to induce significant algal proliferation, ultimately resulting in the process of water eutrophication [53]. The substantial nitrogen content present in wastewater serves to effectively diminish the reliance on artificial fertilizers, augmenting soil production and mitigating the adverse effects of river eutrophication and freshwater ecosystem degradation. The implementation of wastewater for agricultural irrigation in the Mexicali Valley resulted in significant enhancements in soil productivity. This practice contributed organic matter and essential nutrients to the soil, benefiting around 85,000 hectares of agriculture. Moreover, it led to a notable reduction of 50% in river eutrophication [54].

In conclusion, the utilizing of unconventional water resources emerges as a vital alternative for safeguarding and mitigating the ongoing degradation of the natural water environment in the Sanjiang Plain. Resourceful utilization of agricultural drainage reduces the demand for chemical fertilizers in agriculture and increases the content of conventional ions in the soil, benefiting plant and crop growth. Moreover, it mitigates water contamination from the excessive application of fertilizers and offers assistance in safeguarding groundwater and wetland ecosystems.

3. Negative Environmental Effects of Reirrigation of Drained Farmland

Reirrigation of agricultural drainage water has become a common practice globally due to the oversupply of water resources caused by population growth and agricultural development. However, the use of untreated or improperly treated wastewater for irrigation in agriculture can have serious human health and environmental impacts [55], including the contamination of crops [56], the presence of pathogens and heavy metals [57], an increase in the risk of waterborne diseases [45], impaired soil health and fertility [45], and the contamination of groundwater.

3.1. Contamination of Soil

Untreated or improperly treated farm drainage water used for irrigation may lead to a reduction of organic matter in the soil [58], the accumulation of deleterious elements [59], changes in soil parameters [48], effects of microbial communities [60], and soil salinization problems [61,62]. According to a study conducted by [63], it was observed that pH levels exhibit variations at different depths within the soil profile. Specifically, the highest pH values were recorded between the 0–30 cm depth range, while the lowest were found within the 60–90 cm depth range. These findings highlight the significance of pH in influencing both plant growth and soil chemistry. Furthermore, it has been observed that this phenomenon also has an impact on the efficacy and bioavailability of the microbial population present in the soil [64]. Consequently, the significant increase in soil pH following irrigation with wastewater poses a considerable concern. This is primarily due to the fact that as pH rises, the organic matter included in the wastewater undergoes substantial dissolution, resulting in the production of black alkali on the soil surface [65].

The pH of the tertiary-treated wastewater at the West Melbourne Treatment Plant falls within the acceptable range of total dissolved solids (TDS) of 800 to 1500 mg/L. However, it is essential to note that the wastewater contains elevated levels of sodium and chloride, which necessitates careful management to mitigate the risks of soil salinization and acidification [12]. This phenomenon can be attributed to the possibility of a higher concentration of soluble salts within these substances or the occurrence of solidification processes [24].

3.2. Crop Yield Reduction and Pollution

The use of treated farm drainage water in irrigation has been observed to have a positive impact on crop growth and yield. However, the use of untreated farm drainage water may have detrimental effects on plant growth due to its interference with crucial biochemical processes, including metabolism, respiration inhibition, photosynthesis weakening, and stomatal opening obstruction [24,66]. In the case of radish plants that were irrigated with wastewater that had been previously utilized, it was seen that the highest concentration of iron was found in the roots, reaching approximately 1835 mg/kg. Similarly, the leaves of these plants exhibited a maximum iron accumulation of around 1247 mg/kg. Furthermore, other metallic elements such as manganese, zinc, nickel, copper, and cadmium were also detected in varying amounts [12]. While certain metals, like Cu, Ni, Zn, and Fe, have the potential to enhance plant growth to a certain degree [48], their excessive supply and uptake can have adverse effects on plants [48]. The absorption of excessive zinc in the soil by crops can lead to a range of negative consequences, including reduced seedling germination, leaf yellowing, and the gradual wilting of mature leaves [67]. Several research studies have indicated that the use of untreated wastewater for irrigation has resulted in a decrease in maize biomass [68]. The global annual consumption of antibiotics is anticipated to exceed 100,000 metric tons, posing a potential risk of sub-lethal antibiotic concentrations in irrigation water used for vegetable cultivation. The presence of antibiotics in the edible component of food crops might lead to the accumulation of resistant bacteria, hence increasing the risk. Consequently, it is imperative to establish minimum acceptable antibiotic criteria for water used in the irrigation of these crops [69,70].

Therefore, if wastewater is not treated correctly, the contaminants contained therein may adversely affect crop yields or lead to the accumulation of toxic substances in crops, thus posing a potential risk to human health.

3.3. Human Health Hazards

Untreated wastewater has the potential to harbor pathogenic microbes and hazardous compounds, posing a significant risk to human health [71,72]. Various microorganisms, such as Escherichia coli, fecal coliform, and Enterococcus, can be present in inadequately treated wastewater, potentially leading to the transmission of diseases such as Ascaris infection, cholera, typhoid fever, shigellosis outbreaks, nonspecific diarrhea, and other related health issues [55,73–76]. The consumption of vegetables that are irrigated with inadequately treated wastewater has the potential to elevate human exposure to persistent *E. coli* derived from wastewater irrigation, thereby amplifying the related risk [76].

As of 28 June 2018, a total of 36 individuals had been admitted to hospitals throughout several states in the United States as a result of contracting an *E. coli* infection. This infection has been traced back to the Yuma growing area, where samples of irrigation water were found to be contaminated with the bacteria [77]. Since 1994, the European Union (EU) has implemented a restriction on the use of antibiotics. However, it is worth noting that a significant proportion (up to 50%) of *E. coli* isolates found in irrigation water inside EU member states, including Belgium, continue to exhibit resistance to antibiotics [78]. Following experimentation, it was shown that the concentration of parasites in untreated wastewater surpassed the established threshold. This outcome has the potential to result in the contamination of soil and crops subsequent to irrigation. The quantity of parasite eggs in the soil was measured to be 750 eggs per 100 g, while the concentration of cysts was found to be 2.8×104 per 100 g. Additionally, the concentration of Giardia cysts in crops was seen to reach as high as 6.6×103 per kilogram [79].

Improper treatment of agricultural wastewater can pose serious threats to human health, including the risk of transmission of pathogenic microorganisms and parasites. Therefore, it is necessary to strengthen the quantitative assessment of microbial risk in the process of resource utilization in farmland drainage, especially in the measurement and evaluation of worm concentration. This will help to ensure the proper treatment of wastewater in order to maintain the safety of the environment and public health.

4. Effective Measures to Promote the Utilization of Farmland Drainage Resources

While the use of treated field drainage for crop irrigation brings obvious benefits, it also comes with some potential drawbacks. In order to maximize the benefits of drainage irrigation, human interventions are needed to reduce possible negative impacts.

4.1. Formulate Relevant Guidelines and Policies

The establishment of rules pertaining to the safe and suitable utilization of agricultural wastewater is of utmost importance in order to mitigate the occurrence of eutrophication and uphold the integrity of ecosystems 84]. It is imperative to consider the many types and distributions of pollutants present in wastewater, such as microorganisms, inorganic chemicals, and organic compounds, when formulating guidelines [80]. Furthermore, there is a need to enhance the quantitative evaluation of microbial risk, particularly in terms of measuring and assessing the concentration of worms [81]. It is recommended to engage in proactive involvement in public campaigns aimed at mitigating the potential health hazards associated with the transmission of diseases caused by contaminants present in wastewater [82]. Farmers and agricultural workers are required to implement a set of preventive measures while handling wastewater in order to minimize direct exposure to wastewater and thus mitigate potential health hazards [83].

In order to safely and effectively reuse treated wastewater, the World Health Organization (WHO) has published a four-volume series and provided accurate wastewater guidelines for local decision-makers [84]. As early as 1918, the California State Health Commission issued the first guidelines for wastewater reuse, expressly prohibiting the use of untreated wastewater for irrigating crops [85]. The new regulations for the minimum requirements of wastewater used in agricultural irrigation, released by the European Commission on 25 May 2020, have now come into effect. The latest guidance policies are expected to be implemented starting 26 June 2023. Table 1 outlines the quality requirements for wastewater reuse in agriculture [86].

Table 1. Quality requirements for wastewater reuse in agriculture [86].

Reclaimed Water Quality Class	Indicative Technology Target	Quality Requirements			
		Escherichia coli (*E. coli*) (No./100 mL)	Biochemical Oxygen Demand (BOD_5) (mg/L)	Total Suspended Solids (TSS) (mg/L)	Turbidity (NTU)
A	Secondary treatment, filtration, and disinfection	≤10	≤10	≤10	≤5
B	Secondary treatment, and disinfection	≤100	In accordance with Directive 91/271/EEC		-
C	Secondary treatment, and disinfection	≤1000			-
D	Secondary treatment, and disinfection	≤10,000			-

4.2. Artificial Wetland

Artificial wetlands are considered an ecological type of wastewater treatment system, comprising multiple treatment modules, including biological, chemical, and physical components. As a result, artificial wetlands have been successfully employed to treat various types of wastewater, including agricultural, urban, and industrial wastewater [87]. Artificial wetlands represent an effective environmental treatment method capable of assisting in the removal of pollutants from wastewater. The primary mechanism for wastewater treatment in artificial wetlands relies on large plants and microorganisms present in the wetland, thereby achieving the removal of pollutants and high-load nutrient substances from the wastewater [88]. Research findings indicate that created wetlands have the capacity to eliminate 90% of the biochemical oxygen demand (BOD) present in wastewater over a span of 24 h. Consequently, these wetlands are widely recognized as an environmentally sustainable method for treating wastewater [89]. The integration of biological and physical filtering techniques enhances the efficacy of pollutant removal from wastewater [90]. Upon doing an analysis of the treated wastewater in the wetland, it was shown that the presence of pharmaceuticals was diminished by around 80%, hence preventing their release into adjacent rivers [91]. When treating wastewater using wetlands, calcium iron oxide particles can be added, and research indicates that this can reduce the phosphorus content in wastewater by 98% [92]. Wastewater treated through artificial wetlands may potentially lower the risk of pathogen transmission [93]. Additionally, it contributes to the elimination of antibiotics in wastewater [94]. The aforementioned practice aids in the preservation of water resource sustainability and facilitates the efficient safeguarding of such resources. Hence, to enhance the efficacy of wastewater reuse, it is imperative to integrate created wetlands with complementary technologies, thereby facilitating the amalgamation of farmland drainage resource utilization and environmental treatment approaches. This comprehensive application has the potential to effectively address the requirements of farmland drainage on the Sanjiang Plain, thereby ensuring the sustainable management and efficient conservation of water resources.

4.3. Sewage Stabilization System

The sewage stabilization pond system is a technology used to treat wastewater through sedimentation and sunlight, primarily for the removal of viruses and insect eggs in water [95,96]. Studies indicate that the extent of virus removal is closely related to the hydraulic retention time in the water, but sedimentation is not universally applicable for virus removal, and the sunlight-mediated mechanism depends on the characteristics of the water body [96].

To further enhance the efficiency of wastewater treatment, microorganisms such as algae or activated sludge can be introduced into the sewage treatment process to facilitate the degradation of organic and inorganic pollutants [97]. This microbial-based wastewater treatment approach is applicable to various pollutants present in wastewater. Additionally, introducing aerobic and anaerobic wastewater treatment processes can effectively remove biological micropollutants from wastewater [98]. Under aerobic conditions, microorganisms can oxidize and degrade some organic substances, while specific microorganisms can further degrade organic substances in the absence of oxygen. Therefore, combining sewage stabilization pond system technology with other wastewater treatment techniques can significantly improve the efficiency and effectiveness of wastewater treatment.

4.4. Drip Irrigation System

Drip irrigation, particularly underground drip irrigation, is widely recognized as an ecologically sustainable approach to sewage irrigation due to its ability to substantially mitigate potential environmental hazards and successfully decrease rates of nitrate leakage [36]. The main principle is to transport wastewater through pipelines to the roots of crops and then drip the water into the root zone of the plants. The advantage of drip irrigation systems lies in their ability to significantly reduce the contact between crops and recycled water, thereby effectively protecting the health of both farmers and consumers [99]. This irrigation technique is especially well-suited for the above-ground edible portions of plants, resulting in a more significant reduction in the impact on crops and soil [36]. However, drip irrigation devices are prone to clogging, and the main reasons for this issue may be suspended solids and microbial growth in wastewater. Regular maintenance and cleaning are crucial to addressing this problem [100]. In conclusion, the successful management of farmland drainage resources is a crucial undertaking that necessitates the efficient recycling and treatment of water resources, alongside careful consideration of nutrient supply and pollution removal. By employing a range of treatment technologies, including sewage treatment, artificial wetlands, phytoremediation, sewage stabilization ponds, and drip irrigation systems, it is possible to achieve a more sustainable utilization of wastewater. This approach serves to safeguard water supplies and ecosystems while simultaneously mitigating environmental and health hazards. Nevertheless, it is imperative to acknowledge that many systems possess inherent limitations and necessitate integration in order to enhance the caliber and effectiveness of wastewater reuse. By means of scientific direction and effective dissemination, collaborative efforts can be made to attain the safe and sustainable utilization of agricultural wastewater, thereby fostering the sustainable development of agriculture. The incorporation of microorganisms, such as algae or activated sludge, has been proposed as a significant factor in the treatment of wastewater. Microorganisms possess the ability to efficiently decompose both organic and inorganic contaminants found in wastewater, thereby enhancing the quality of water and mitigating detrimental impacts on the environment [101]. Simultaneously, cultivating crops that exhibit high rates of transpiration contributes to the secure and sustainable utilization of wastewater [102].

5. Conclusions

The implementation of farmland drainage resources presents a viable approach to addressing the ecological and water environment challenges in the Sanjiang Plain. The utilization of treated farmland drainage in agricultural irrigation not only enhances the overall efficiency of agricultural water usage but also presents several issues in terms of environmental and health considerations. This review aims to emphasize the varied character and intricate complexity of the aforementioned aspect. Utilizing farmland drainage as a resource presents a potential solution to address the conflict between regional water supply and demand. Additionally, it offers an effective means to manage agricultural non-point source pollution and uphold the overall ecological well-being of the region. The aforementioned positive impacts play a vital role in promoting the sustainable development and effective management of water resources in the Sanjiang Plain. Nevertheless, inadequate wastewater treatment can also result in adverse environmental consequences, such as soil contamination, diminished crop yields, pollution, and significant risks to human health. The effective promotion of beneficial environmental outcomes through the utilization of farmed drainage resources hinges on the recycling and treatment of drainage. Consequently, it is imperative to implement a range of efficacious strategies, includeing the development of pertinent guidelines and policies, the establishment of drainage recycling and treatment mechanisms, the construction of artificial wetlands, the adoption of sewage stabilization systems, and the promotion of drip irrigation systems. Overall, when appropriate risk protection measures are implemented, the practice of farmland drainage shows promising potential as a scientifically and practically viable substitute for traditional sources of irrigation water.

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