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Review

Research Trends and Future Prospects of Constructed Wetland Treatment Technology in China

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Abstract: With the intensification of water pollution problems worldwide, constructed wetlands, as a green, efficient, and energy-saving wastewater treatment technology, have gradually attracted the wide attention of scholars at home and abroad. In order to better understand and master the research trends of constructed wetland treatment technology in China and promote its development, the literature from 2000 to 2023 in the CNKI database and the Web of Science (WoS) database (located in China) were selected as research objects. Then, CiteSpace software (6.2.R4) was used to visualize and analyze the literature, revealing the research trends and hot areas of constructed wetland treatment technology in China. Then, the optimized way of operation effect of constructed wetland was discussed to provide a theoretical and technical basis for the wide application of constructed wetland technology in our country. The results indicate that the annual publication volume of research on constructed wetlands in China is showing a rapid upward trend. Among them, the Chinese literature mainly focuses on how to improve the application effect of constructed wetlands on nitrogen and phosphorus removal of rural domestic wastewater by matching different wetland plants or developing combined processes. The English literature from the Web of Science (WoS) database mainly focuses on how to remove emerging pollutants, such as heavy metals and resistance genes in wastewater in China, by changing the filling matrix and microbial community structure or developing new processes, and the related mechanisms have been discussed. One of the hot spots for the future research of constructed wetlands in China is to vigorously develop microbial fuel cells, and try to overcome the problem of poor purification efficiency of constructed wetlands under complex conditions such as low temperature, low carbon-nitrogen ratio, and high pollution load. In order to strengthen its application, the specific optimization methods can be divided into two categories: self-optimization strategies such as increasing oxygen supply and transfer, providing electron donor matrix, preventing matrix blockage, and combination processes coupled with anaerobic treatment and other technologies.

Keywords: constructed wetlands; wastewater treatment; bibliometrics; research hotspots

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1. Introduction

Constructed wetlands, a novel wastewater treatment approach, are inspired by the water purification processes of natural wetlands. This method simulates natural systems artificially, involving processes like laying down matrix and planting aquatic vegetation. It leverages physical, chemical, and biochemical reactions to purify wastewater [1,2]. Unlike traditional wastewater treatment technologies, constructed wetlands are often more cost-effective and efficient in handling pollutants, including challenging ones like heavy metals and emerging contaminants [3,4]. Additionally, they offer ornamental and touristic value, contributing to regional development [5].

Since the installation of the first full-scale plant for treating domestic and industrial wastewater in the 1960s, constructed wetlands have undergone extensive research. Over the past two decades, researchers have conducted more studies to address the challenges of treating recalcitrant pollutants and improving the quality of discharged or reused water. They have explored the application of different types of materials as substrates in continuous water treatment to enhance the removal efficiency of target pollutants in wastewater [6]. Additionally, substantial work has been done in the laboratory and pilot-scale studies to investigate different types of macrophytes and determine the role of microorganisms in improving treatment efficiency in continuous water treatment [7].

Research related to operational factors such as changes in flow patterns, different aeration and recirculation methods, variations in depth, hydraulic loading rate, and hydraulic retention time has also proven to be significant in enhancing system efficiency and has received widespread attention.

While constructed wetlands as a standalone treatment technology may not always meet strict effluent standards, particularly when dealing with high organic and suspended solids' loading rates in wastewater, coupling and integrating them with other treatment processes have been proposed as a solution to address this issue [8]. Several novel approaches have been introduced, including the integration of constructed wetlands with algae ponds, photocatalytic oxidation processes, and anaerobic biofilters, among others [9]. These integrated systems have shown success in treating specific pollutants and, in some cases, even allow for energy recovery, making them economically viable and environmentally friendly approaches for wastewater remediation [10].

In recent years, China has increasingly applied constructed wetlands for treating various polluted water sources, including domestic wastewater, industrial wastewater, and contaminated surface water [11,12]. While the volume of research has grown rapidly, comprehensive combs and assessments of this field within China remain limited. Bibliometrics, a method introduced by Alan Pritchard in 1969, effectively evaluates the impact and value of research through keyword analysis [13]. Utilizing bibliometric techniques and CiteSpace software (6.2.R4), this study conducts a statistical analysis of the literature concerning constructed wetlands in China, spanning from 2000 to 2023. This study aims to assess the current research status, forecast future trends, and offer recommendations for the development of constructed wetlands in China.

2. Data Collection and Research Methods

2.1. Data Sources

This study focused on the Chinese and English scholarly literature on constructed wetlands, published in core database journals by domestic scholars since 2000. The Chinese articles were sourced from the CNKI core journal database, while the English articles were obtained from the WoS core collection database. The search timeframe spanned from January 2000 to July 2023. In the CNKI database, a "topic" search approach was employed with the terms "constructed wetlands" and "wastewater treatment", focusing on academic journals in Chinese. The WoS database search was conducted using the terms "TS = (constructed wetland OR artificial wetland) AND TS = (wastewater treatment OR waste water treatment)". This search included research papers, conference proceedings, reviews, and online publications in English, with a national focus on "CHINA AND TAIWAN". After meticulous manual review and screening, the study gathered a total of 2573 valid Chinese documents and 2194 valid English documents.

2.2. Research Method

This article employs statistical software to analyze data samples, focusing on identifying trends in the annual publication count, predominant journals, and key references in the field of constructed wetlands. Additionally, we utilize CiteSpace 6.2.R4, a visualization software, to visualize the keyword information from the articles. The analysis includes examining keyword co-occurrence, clustering, and emergence to provide insights into research directions and frontiers in wastewater treatment technology of constructed wetlands.

This approach not only highlights the current status of research, but also forecasts future research trends in this area.

3. Research Trends of Constructed Wetland in China

3.1. Mechanism of Pollutants Removal in Constructed Wetlands

In constructed wetlands, the synergy of aquatic plants, microorganisms, and matrix plays crucial role in wastewater purification. They work together to remove pollutants through physical, chemical, biochemical reactions, and synergistic effects between them [14]. Among them, the physical effects include filtration, sedimentation, and retention of suspended solids in the water by the matrix as well as plant stems, leaves, and roots [15]. Chemical effects include ion exchange, chemical precipitation, redox reactions, adsorption, antagonism, etc. These effects and reactions mainly depend on the characteristics of the matrix type [16]. Biochemical reactions refer to the action of aerobic, facultative anaerobic, and anaerobic microorganisms. They refer to the conversion of polymer pollutants in wastewater into simple small molecules, thereby achieving the decomposition of pollutants [17]. In constructed wetlands, plants, matrix, and microorganisms, each has individual purification capabilities [18,19].

3.2. Annual Number of Publications

As shown in Figure 1, since 2000, there has been a consistent annual increase in publications on domestic constructed wetlands, with a significant surge after 2005. This trend is closely linked to China's major national initiatives for water pollution control and treatment science and technology projects. The efficiency and low cost of constructed wetlands align well with China's national priorities, triggering continued in-depth research on constructed wetlands by domestic scholars. Notably, after 2015, the volume of English-language publications began to surpass those in Chinese, with the gap widening each year. In 2022, English-language publications reached a peak of approximately 273 articles. This shift may be attributed to the maturing understanding of constructed wetlands among domestic scholars and the deepening research in this field. Many domestic scholars are increasingly choosing to submit their work to international journals, thereby fostering enhanced global exchanges.

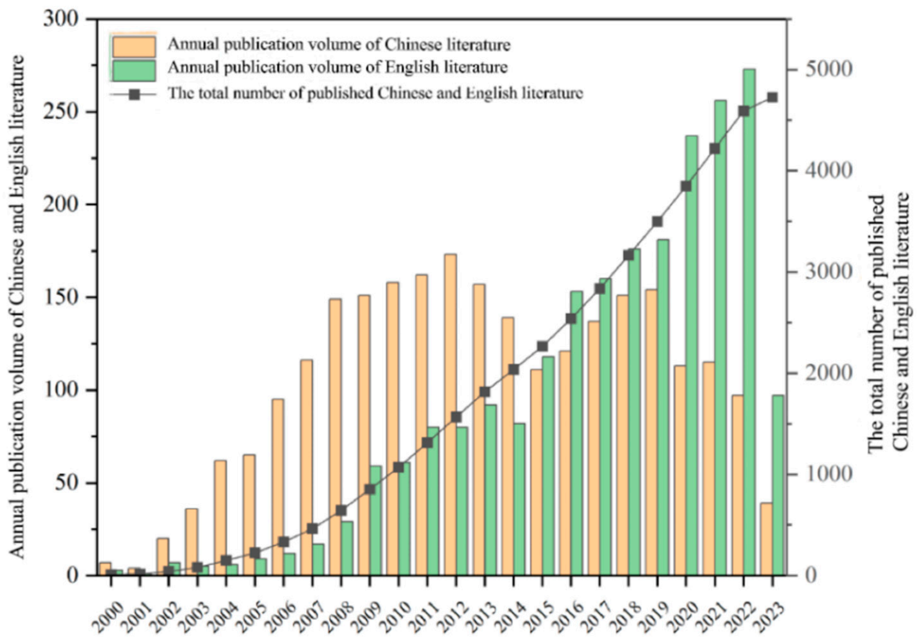

Figure 1. Comparison of the number of Chinese and English publications on constructed wetlands by Chinese scholars from 2000 to 2023.

3.3. Keyword Analysis

Analyzing and clustering keywords from the literature can reveal the current state of research in constructed wetland wastewater treatment technology and summarize research topics in this area [20]. Figure 2a,b illustrates a network co-occurrence analysis of keywords in the domain of domestic constructed wetlands. The betweenness centrality (BC) reflects the number of keywords strongly linked to others, with line thickness representing the connection strength [21]. A comparison between keyword co-occurrence maps of the Chinese and English literature reveals a sparser network with lower keyword frequency in the Chinese literature. For clarity, in comparison, Figure 2a highlights keywords with a frequency of 5 or more, while Figure 2b focuses on those with a frequency of 20 or more.

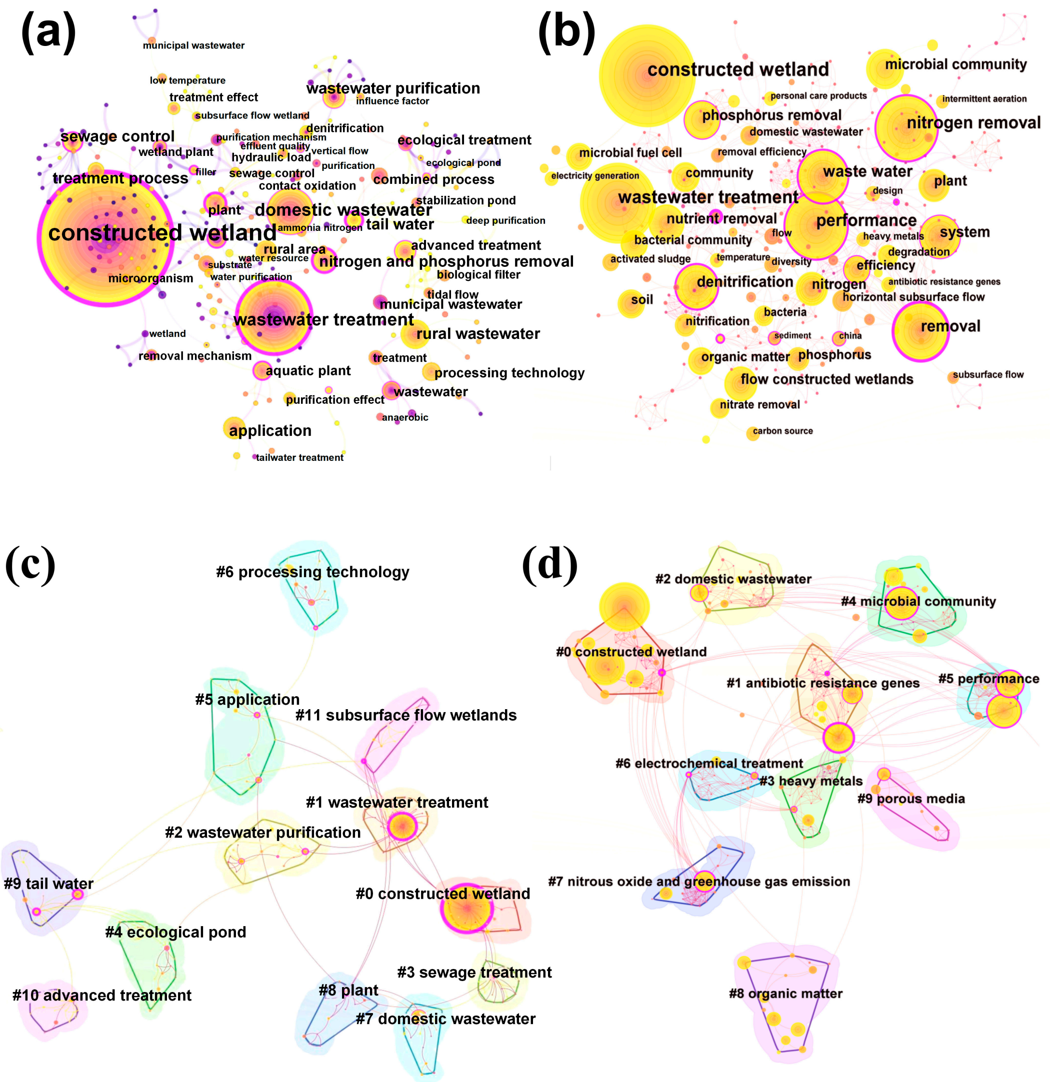

Figure 2. The co-occurrence and cluster network of keywords based on data from the Chinese literature (**a**,**c**) and the English literature (**b**,**d**).

Both the Chinese and English literature regard constructed wetlands as suitable for treating domestic wastewater. The Chinese literature shows that constructed wetlands are particularly suitable for rural domestic wastewater, possibly due to the dispersed nature of rural wastewater and the impracticality of extensive piping, long transport distance, and multiple pumping stations required for centralized treatment in traditional wastewater plants [22]. Additionally, the keyword co-occurrence map shows that both the Chinese and English literature are keenly interested in the wastewater treatment effect of constructed wetlands. The Chinese literature focus on enhancing nitrogen and phosphorus removal through combined processes, whereas the English literature focus on the removal of emerging contaminants through the development of new processes (such as microbial fuel cells).

After clustering high-frequency keywords in the domestic literature on constructed wetlands, according to Figure 2c,d, the research topics of domestic scholars on constructed wetland wastewater treatment technology since 2000 can be mainly summarized into the following categories, and these research topics show some differences in the Chinese literature and English literature:

(1) Research on the mechanism of pollutant removal by constructed wetlands. The three keywords cluster of "plants", "microbial community", and "porous medium" reveal the mechanism of pollutant removal in constructed wetlands, which uses the triple synergy of physics, chemistry, and biology of plants, matrix, and microorganisms [23,24]. Among them, the Chinese literature emphasize the crucial role of plants in pollutant removal, including cold-resistant breeding of wetland plants [25], the screening and matching of wetland plants, etc. [26,27]. At present, aquatic plants are mainly used in surface-flow wetlands; subsurface flow wetlands mainly use aquatic herbs, supplemented by hygrophytes [28]. The English literature mainly focuses on the two influencing factors of filling matrix and microorganisms. As for the matrix, recent research focused on the selection and the proportion of traditional matrix, such as gravel, zeolite, sand and gravel, etc. It also includes the development of a new matrix such as biochar, sponge iron, and carbonized slow-release fillers [29]. The leading roles in constructed wetland purification are mainly heterotrophic bacteria, autotrophic bacteria, fungi, and other types of microorganisms [30], so research has been carried out on functional genes such as nosZ, nirS, nirK, and anammox [31], as well as microbial community structure composition and diversity [32], to explore the mechanism of microorganisms in the transformation and mineralization process of nutrients and organic pollutants.

(2) Research on pollutant removal objects in constructed wetlands. Combined with the keywords co-occurrence map, both the Chinese and English literature concentrate on conventional pollutants such as "organic matter", "nutrient removal (denitrification and phosphorus removal)", and "heavy metal". However, the English literature placed gravity center of research on the removal of emerging contaminants "antibiotic resistance gene" and "personal care product" in the later phase. For instance, Chen's research on antibiotic removal in a mesoscale wetland, which combined artificial aeration and mixing, achieved an 87.4% reduction rate [33]. Koottep et al. selected different aquatic plants and iron-rich media to explore the removal effect of constructed wetlands on personal care products [29]. Overall analysis shows that the scope of targeted pollutant removal for constructed wetlands in China has been increasing, but the specific manifestations are reflected in major published the English literature.

(3) Research on optimization and application of constructed wetland process combination. Domestic scholars are further enhancing the potential of constructed wetlands to purify wastewater through developing combined processes and optimization technologies, such as traditional constructed wetland + ecological pond technology [34–36] and new constructed wetland + biofuel cell technology [37,38], and they appear in the Chinese literature and the English literature, respectively. The Chinese literature also delves into application aspects, the first is the application of water bodies. Considering that the technology of constructed wetlands in various wastewater treatment has become mature, in addition to applying it to conventional "domestic wastewater" and other wastewater treatment, it also includes the constructed wetlands to treat low-pollution-load water bodies, such as advanced treatment of "tail water" and "reclaimed water" [39]. The second is application conditions. Related research involves improving the pollutant purification effect of constructed wetlands under complex

working conditions such as low temperature, low carbon-nitrogen ratio, and high load [40–42].

(4) Research on coordinated regulation of water–air pollution in constructed wetlands. Constructed wetlands are both economical pollutant removers and potential greenhouse gas emitters, and there is a risk of converting "water pollution" into "air pollution". In the process of removing organic matter and nitrogen and phosphorus nutrients in constructed wetlands, the oxidation of organic matter and microorganisms, respiration of animals and plants, etc., will release CO_2. The anaerobic decomposition of organic matter will produce CH_4, and the nitrification-denitrification process will produce N_2O [43]. The theme of "nitrous oxide and greenhouse gas emission" shows that domestic scholars have carried out research on the key processes and mechanisms of harmful gas emissions from constructed wetlands, as well as emission reduction measures [11,44].

3.4. Research Hotspot

The sudden increase and bursty frequency of a certain keyword in a short period of time can reflect the frontier hotspots of a research field. In the field of constructed wetland wastewater treatment technology, the results of keyword burstiness analysis based on keyword co-occurrence are shown in Tables 1 and 2. According to the results of published papers, the analysis is carried out by taking 2014 as the boundary. In Table 1, the early Chinese literature was keen to study the impact mechanism of plants on the treatment efficiency of constructed wetland, and developed various combination processes to improve the wastewater treatment efficiency. The later Chinese literature focused on the application of constructed wetland technology in rural sewage, tail water, and other water bodies, as well as the specific purification effect of nitrogen and phosphorus removal. In Table 2, the research hotspots in the English literature have changed from strategies to improve the removal efficiency of traditional pollutants, such as nitrogen and phosphorus, to the removal of new pollutants, exploring the mechanism of microbial community structure for pollutant treatment and developing microbial fuel cells. Therefore, combining with the results of Tables 1 and 2, the future research hotspots and development trends of constructed wetlands in our country can be classified as follows:

(1) In terms of pollutant treatments, nitrogen, and phosphorus should still be used as an important indicator of effluent water quality evaluation standards, and heavy metals should be taken as the focus of attention among emerging pollutants.

(2) In terms of process combination and application, the combined form of constructed wetland + microbial fuel cell can not only improve the degradation efficiency of pollutants, but also achieve part of the energy recovery [38], which should be vigorously developed in the future. The main application object of constructed wetland should continue to be rural sewage, and further try to treat the tail water of sewage treatment plant. In the process of application, it is necessary to overcome the problem of poor purification effect of constructed wetlands under complex conditions such as low temperature, low carbon nitrogen ratio, and high load. Existing methods have been proved to include the allocation of different types of wetland plants [45,46], the addition of exogenous microorganisms [47], intermittent aeration [48], and the addition of carbon sources [49], etc. Based on the key words highlighted in the English literature, this article suggests focusing on carbon source supplementation and intermittent aeration to alleviate the above problems.

(3) In terms of research methods. With the rapid development of microbiology, genomics and other disciplines, the focus of future data analysis needs to be placed on the study of the structure, metabolic characteristics, and functional diversity of bacterial flora so as to improve the mechanism of decontamination and strengthen the decontamination efficiency from a microscopic perspective [50].

Table 1. The top 25 most frequently cited keywords in the Chinese literature. The blue line represents the base timeline, and the red part indicates the burst duration of each keyword.

Keywords	Year	Strength	Begin	End	2000–2023
plant	2000	8.07	2000	2006	
wastewater treatment	2000	7.81	2000	2005	
wetland	2003	2.98	2003	2005	
subsurface flow wetland	2004	3.68	2004	2005	
municipal sewage	2005	6.18	2005	2012	
sewage	2002	5.13	2005	2012	
purification mechanism	2003	3.74	2005	2007	
contact oxidation	2006	3.07	2006	2012	
ecological treatment	2003	3.43	2007	2014	
removal mechanism	2004	3.39	2007	2008	
handle	2002	2.79	2007	2014	
combined technology	2008	6.57	2008	2015	
treatment effect	2012	2.93	2012	2015	
anaerobic	2013	2.82	2013	2014	
tidal current	2014	4.43	2014	2016	
hydraulic load	2014	2.85	2014	2016	
matrix	2004	2.82	2014	2019	
biological filter	2015	5.52	2015	2018	
rural sewage	2007	13.84	2017	2023	
processing technology	2012	6.99	2017	2021	
apply	2007	3.61	2017	2021	
treatment technology	2000	3.6	2017	2023	
tail water	2014	5.22	2019	2023	
purification effect	2012	2.65	2019	2023	
nitrogen and phosphorus removal	2006	3.03	2020	2021	

Table 2. The top 25 most frequently cited keywords in the English literature. The blue line represents the base timeline, and the red part indicates the burst duration of each keyword.

Keywords	Year	Strength	Begin	End	2000–2023
effluent	2002	9.71	2002	2012	
subsurface flow	2004	9.83	2004	2016	
retention	2006	7.36	2006	2014	
removal efficiency	2007	14.63	2007	2016	
macrophytes	2008	8.21	2008	2015	
flow	2007	19.48	2009	2014	
vegetation	2009	9.55	2009	2014	
nutrients	2000	7.92	2009	2012	
phosphorus	2005	8.68	2010	2013	
accumulation	2010	7.58	2010	2015	
diversity	2009	13.19	2012	2017	
temperature	2006	7.19	2012	2014	
horizontal subsurface flow	2011	18.69	2014	2018	
sediment	2005	7.08	2015	2016	
china	2006	10.87	2016	2017	
activated sludge	2013	16.11	2017	2019	
nitrate removal	2014	13.94	2018	2020	
carbon source	2018	13.28	2018	2019	
intermittent aeration	2018	9.68	2018	2020	
heavy metals	2000	8.53	2018	2019	
bacterial community	2017	7.98	2019	2023	
degradation	2020	17.37	2020	2023	
bacteria	2007	9.47	2020	2023	
microbial fuel cell	2015	8.13	2020	2023	
electricity generation	2021	13	2021	2023	

4. Optimization Measures for the Operation Effect of Constructed Wetland Technology

4.1. Constructed Wetland Technology Optimization Strategy

The problems and optimization strategies faced by constructed wetland operations are shown in Table 3 [50]:

(1) Increase oxygen supply and transfer. The efficiency of constructed wetlands is often hampered by poor oxygen transfer rates. To counter this, artificial aeration introduces compressed air, boosting the oxygen transfer rate and thereby enhancing pollutant removal efficiency. Additionally, tidal flow wetlands present another effective solution to oxygen transfer limitations, where wastewater is cyclically injected and discharged into the wetland, acting as a passive pump to draw fresh air into the bottom through repeated cycles of wetting and drying [51].

(2) Combined with electron donor matrix. The availability of electron donors in constructed wetlands may not be sufficient to sustain pollutant removal. Many low-cost organic matrix from nature (including wheat straw, oyster shells, compost, organic wood mulch, rice shells, walnut shells, and sugarcane bagasse) and waste products from natural ores and industrial or mines (such as coal gangue, iron ore, and manganese ore) have been employed in benchmark and pilot-scale studies of chemical waste [52,53]. These matrix and wastes have notably enhanced both heterotrophic and autotrophic denitrification processes [54].

(3) Improve low-temperature performance. Plant physiology and nutrient absorption are directly controlled by temperature and solar radiation. Low temperatures stymie the growth and activity of most pollution-degrading microorganisms, leading to reduced purification efficiency [55]. The performance of low-temperature continuous water treatment can be improved by selecting cold-resistant plants, inoculating cold-resistant microorganisms, and adding insulation materials. However, potential ecological risks must be considered when using exotic species or microorganisms.

(4) Risk and prevention of substrate clogging. The primary operational challenge of constructed wetlands is substrate clogging. Clogging leads to water overflowing on the substrate surface due to reduced conductivity and porosity [56]. The biological approach of earthworm processing is able to reduce and repair clogging by ingesting particulate organic matter and converting refractory organic matter into easily biodegradable substances during the digestion process [57]. In addition, pretreatment reagents with strong oxidizing (such as hydrogen peroxide and sodium hypochlorite) can enhance the conductivity of the matrix through strong oxidation of organic matter, which can alleviate clogging [57]. While these methods are operationally effective, they require continuous monitoring and maintenance.

Table 3. Optimization strategies for the operation effects of constructed wetlands.

Limitations	Enhancement Strategies and Technologies	Intensification Performance
Oxygen limitation	The oxygen transfer rate in constructed wetlands has been increased, and pollutant removal rates improved through artificial aeration (intermittent and/or continuous aeration) [58,59]. Tidal flow wetlands have been constructed, where wastewater is cyclically injected and discharged in response to tidal operations. This repetitive wetting and drying cycle acts as a passive pump, allowing fresh air to be drawn into the bed [51,60].	Intermittent aeration COD RE: 97% NH_4^+-N RE: 95% TN RE: 80% Tidal operation Oxygen transfer rate: 350 g m^{-2} d^{-1} TN RE: 70%

Table 3. *Cont.*

Limitations	Enhancement Strategies and Technologies	Intensification Performance
Electron limitation	Low-cost organic substrates derived from natural waste materials, including wheat straw, oyster shells, compost, organic mulch, rice straw, rice husk, walnut shells, and sugarcane bagasse, have been added [52]. Additionally, other inorganic substrates derived from natural minerals and industrial or mining waste, such as coal gangue, iron ore, and manganese ore, have been used to provide electron donors and improve heterotrophic denitrification [61].	Organic-rich substrates COD RE: 73% BOD RE: 79% NH_4^+-N RE: 91% Inorganic electron donor substrates TN RE: 88% TP RE: 69%
Cold climate	Improving the performance of low-temperature continuous water treatment can be achieved by selecting cold-tolerant plants, inoculating with cold-tolerant microorganisms, and adding insulation materials [62,63].	Adding insulation material BOD RE: 95% (in winter) NH_4^+-N RE: 84% (in winter) TP RE: 88% (in winter) Inoculating cold-resistant microorganisms NO_3-N RE: 97% (in winter) Selecting cold-resistant plants NH_4^+-N RE: 94% (in winter)
Clogging risk	Improving system performance can be achieved through pre-treatment, the addition of organisms such as earthworms, and the use of highly oxidizing chemical agents such as hydrogen peroxide and sodium hypochlorite [64].	Adding earthworms Increases the hydraulic conductivity by more than 60% Adding reagent (sodium hypochlorite) Recovery to 69% of the original condition

4.2. Combination with Other Processes

In order to further stimulate the potential of constructed wetland to purify wastewater, the combined process and optimization technology of constructed wetland were raised recently (Figure 3).

First, some studies combine constructed wetlands with anaerobic treatment technologies, including anaerobic sequencing batch reactors, Upflow Anaerobic Sludge Blanket (UASB), adsorption biodegradation (AB), ultraviolet disinfection processes, and combined processes of septic tanks and constructed wetlands [57]. This approach has proven effective in treating chromium-rich wastewater, reducing energy consumption in brewery wastewater treatment, significantly lowering cytotoxicity and mutagenicity in wastewater, achieving high removal rates of total nitrogen and coliform bacteria. Additionally, the treated product offers some economic value.

Secondly, the process of combining constructed wetlands with microbial fuel cells is currently in the development phase. At present, most studies focused on the effects of electrode materials, plant species, matrix, and carbon sources on the treatment effectiveness [65,66]. A large number of existing research results show that this type of combined process can be used to treat antibiotics and refractory substances [67], and the clogging phenomenon of constructed wetlands has also been alleviated to a certain extent.

Finally, constructed wetlands are also being combined with technologies like photocatalysis [68], sand filters [69], the photo-Fenton advanced oxidation process [70], moving Bed Biofilm Reactors (MBBR) [71], and electrolysis technology [72]. These combinations have effective treatment effects on cadmium-containing wastewater, organic matter, drugs, and other refractory organic matter.

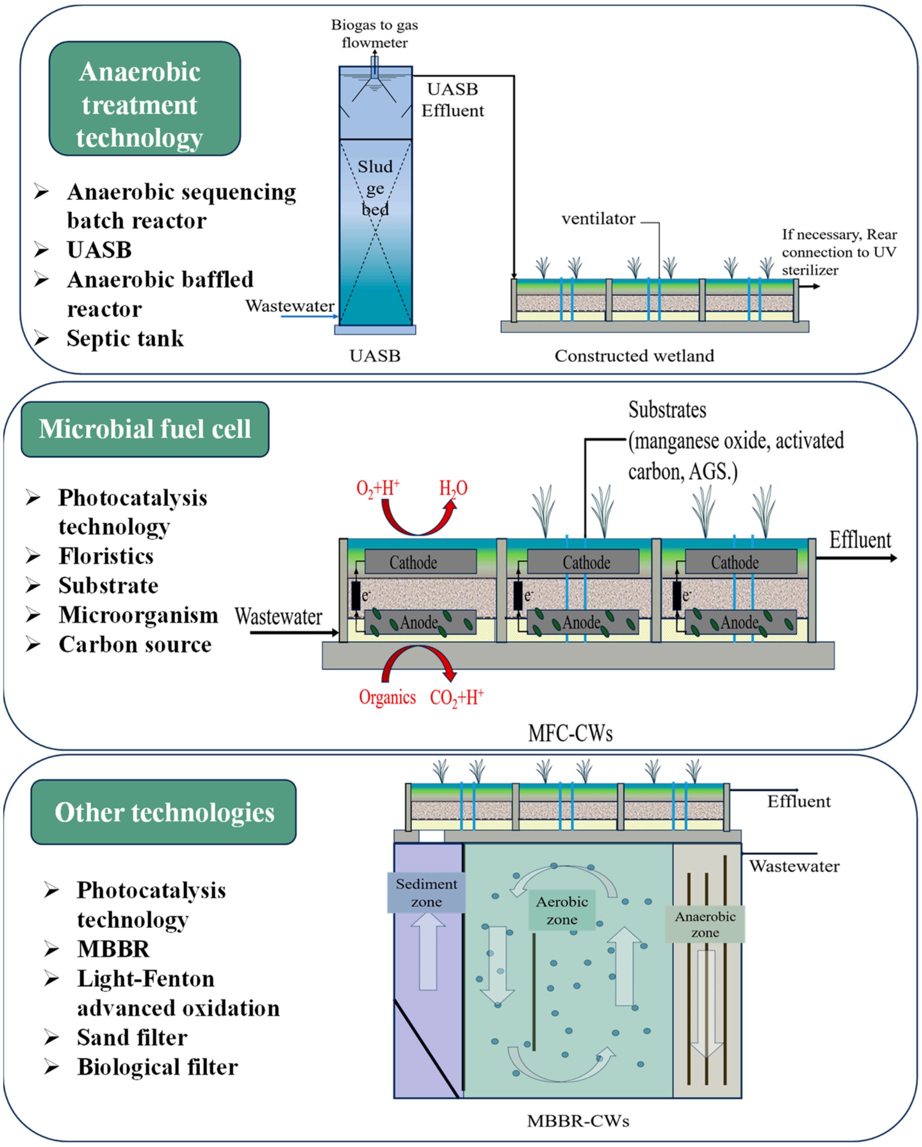

Figure 3. The combination of constructed wetland and other treatment processes improves the operation effect.

5. Conclusions

The main conclusions of this article are as follows:

(1) The primary focus areas in constructed wetland research in China encompass four categories: pollutant removal mechanism, pollutant removal objects, process combination optimization and application, and collaborative control of water–air pollution. Among them, the Chinese literature primarily explores enhancing nitrogen and phosphorus removal from rural domestic wastewater by combining different wetland plants or developing combined processes, with the aim of broader application across different water bodies. The English literature concentrates on removing emerging pollutants such as heavy metals and resistance genes by altering the filling matrix and microbial community structure or developing new processes (microbial fuel cells), while also considering greenhouse gas emissions during the purification process.

(2) Future research about constructed wetlands will focus on integrating microbial fuel cells to unify ecological and economic benefits in the purification process. Research efforts are directed towards trying to use the methods of adding carbon sources and intermittent aeration to overcome the problem of the poor purification effect of

constructed wetlands under complex working conditions such as low temperature, low carbon-nitrogen ratio, and high load. The goal is to apply these solutions in actual projects in a cost-effective manner.

(3) In order to enhance the application capabilities and effects of constructed wetlands, specific optimization measures can be summarized as self-optimization strategies such as increasing oxygen supply and transfer, providing electron donor matrix, and preventing substrate clogging. Additionally, it also combines with anaerobic treatment and other technologies to form a combined process.

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