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Research Article

Big Data Analysis of Water Saving Standard Based on Bibliometrics

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At present, water-saving standard is an important technical means to implement national water-saving actions and the strictest water resources management system. In order to analyze the development process and research fields of water-saving standards in China, this paper makes quantitative statistics and qualitative analysis on seven aspects of water-saving standards, such as annual publication, drafting unit, research fields, and progress. The results show that the annual release of water-saving standards generally showed a trend of first rising and then declining, and the release reached its peak in 2017. The contribution of China National Institute of Standardization to the development of water-saving standards is dominant. From the point of view of water department, the water-saving standards in the industrial field are comprehensive. Our finding are helpful to better understand the development process of water-saving standards and provide reference for further improving the water-saving standard system and building a water-saving society.

1. Introduction

More people and less water, uneven distribution of water resources in time and space, and prominent contradiction between supply and demand are the basic water conditions in China [1, 2]. Problems such as weak awareness of water conservation, extensive water use, water pollution, and large gap between the utilization efficiency of water resources in China and the international advanced level have aggravated the status quo of water resources shortage [3–5], which has become the bottleneck of ecological civilization construction and sustainable economic and social development.

Water conservation is the fundamental way to solve the problem of water shortage in China [6]. We should realize the importance of water saving from the strategic height of realizing the sustainable development of the Chinese nation and accelerating the construction of ecological civilization; vigorously promote water conservation in agriculture, industry, towns, and other fields; promote water saving in water-deficient areas. The CPC Central Committee and the State Council attached great importance to water conservation and issued a series of laws, regulations, and policy documents on water conservation management. In 2002, the Water Law of the People's Republic of China clearly stipulated "The state shall strictly save water, vigorously promote water conservation measures, popularize new technologies and processes for water conservation, develop water-saving industries, agriculture and services, and establish a water-saving society." This provides legal guarantee for the all-round construction of water-saving society. And a series of water-saving policies, such as "red line of water efficiency control," "combination of total amount control and quota management," and "ten actions of water saving for all the people" were launched. In the "National Water Saving Action Plan," the short-term and long-term goals of improving water use efficiency and controlling water consumption [7] are put forward.

With the proposal of water-saving policy, a number of water-saving standards covering many fields were drafted and released, so as to change the extensive use of water resources, curb unreasonable water demand, greatly improve the efficiency and benefit of water resources utilization, and strongly support the high-quality development of economy and society.

Although the water-saving standards are gradually increasing, few scholars discuss the development process of water-saving standards in China at present. The research mainly focuses on the single water-saving field of industry or irrigation, and there is little application of integration with high-end information technologies such as big data, so the traditional analysis method is not enough to intuitively reflect its evolution process [8]. Therefore, this paper takes the national water-saving standards as an example, adopts the bibliometric methods commonly used in big data analysis at present [9–12], makes visual research on water-saving standards from different angles with the help of CiteSpace software, identifies the emerging hot spots and frontiers in the field of water-saving more scientifically and accurately, summarizes the main subject categories, and makes qualitative and quantitative analysis, so as to better assist researchers to determine the future research direction.

2. Research Methods and Data Sources

2.1. Data Sources. In this paper, the National Standard Information Network and China National Knowledge Internet (CNKI) are selected as data sources, and the relevant water-saving standards in China are statistically analyzed. When searching in China Academic Journals and Magazines Publishing General Database (CNKI included), words such as "water saving, irrigation, sewage reuse, water fetching" are used as the keywords, and the searching time span is 2002-2021. In order to ensure that the original data is comprehensive, accurate, and highly credible, the database search results are processed by eliminating duplicates and abolishing standard deletion. Finally, 289 existing water-saving-related standards are obtained, and the standard level is the national standard.

2.2. Research Methods. This paper mainly uses bibliometric analysis to analyze water-saving standards, so as to describe, evaluate, and predict the development trends of water-saving standards [13, 14]. Common bibliometric analysis software includes CiteSpace, VOSviewer, Bibexcel, and NetDraw (all software is open source and can be used for free). In contrast, CiteSpace integrates the methods of cluster analysis, cooperative network analysis, multidimensional scale analysis, etc., and focuses on detecting and analyzing the development trend of research frontiers, the relationship between research frontiers and their knowledge bases, and the internal relations among different studies [15–17]. Therefore, with the help of CiteSpace 5.8.R2 bibliometrics visual analysis software, this paper makes statistical and visual analysis of water-saving standards from 2002 to 2021, draws a knowledge map [18], and shows the development law of the standard-making field through elements such as node size, network connection, and keywords.

3. Status Quo of Water-Saving Standardization

3.1. Time Series Analysis of the Annual Release of Water-Saving Standards. Since 2000, in order to adapt to the new situation of water resources and water pollution in China, the state has strengthened the work of water-saving standardization. After more than 20 years of efforts, the formulation of water-saving standards has made great progress.

According to the distribution of the annual publication quantity of water-saving standards by 2021, it can be seen that the annual publication quantity of standards generally showed a trend of first rising and then declining, and the annual release quantity reached its peak in 2017, accounting for 16% of the total release quantity (Figure 1). The concentrated release in 2017 is closely related to the *13th Five-Year Plan for the Construction of Water-saving Society* in which "improving the water-saving standard system" is clearly put forward. We should improve the water quota standards of agriculture, industry, service industry, and urban living industry in each provincial administrative region, speed up the formulation and revision of national water quota standards for industries and services with high water consumption, and implement mandatory water quota standards. Regularly organize and carry out water quota assessment and guide and promote all localities to revise the industry water quota in time; pay close attention to the formulation of water-saving basic management, water-saving evaluation, and other national standards; and improve the water-saving standard system. The standards released in 2017 cover water intake quota, water efficiency of products, water-saving enterprises, reverse osmosis water treatment equipment, sewage treatment, seawater cooling water treatment chemicals, and many other aspects.

3.2. Analysis of Water-Saving Standard Drafting Unit

3.2.1. Cooperation of Water-Saving Standard R&D (Research and Development) Units. Through the cooccurrence analysis of water-saving standard R&D units, we can identify the core units in this field and the cooperative relationship among them. CiteSpace is used to build the cooperation network of water-saving standard R&D units (Figure 2). The size of nodes in the figure represents the frequency of cooccurrence of core units. The larger the nodes, the more frequently the unit cooperate with other units. The number and thickness of lines represent the intensity and closeness of cooperation between units. The more and thicker of the connections, lead to the stronger the connection between units. It can be seen from the figure that there are 393 nodes and 1411 link lines, with a network density of 0.0183. The number of nodes and link lines is relatively large, and the density is relatively high. Therefore, it can be seen that there are many links between units, and the structure of cooperative networks among units is relatively tight, which indicates that the drafting of each standard needs the cooperation of multiple units. For example, the water intake quota of wool textile products was jointly drafted by China Textile Economic Research Center, Shandong Jining Ruyi Wool Textile Co., Ltd., China National Institute of Standardization, Zhejiang Jiaxing Xinlong Dyeing and Finishing Co., Ltd., China Wool Textile Association and

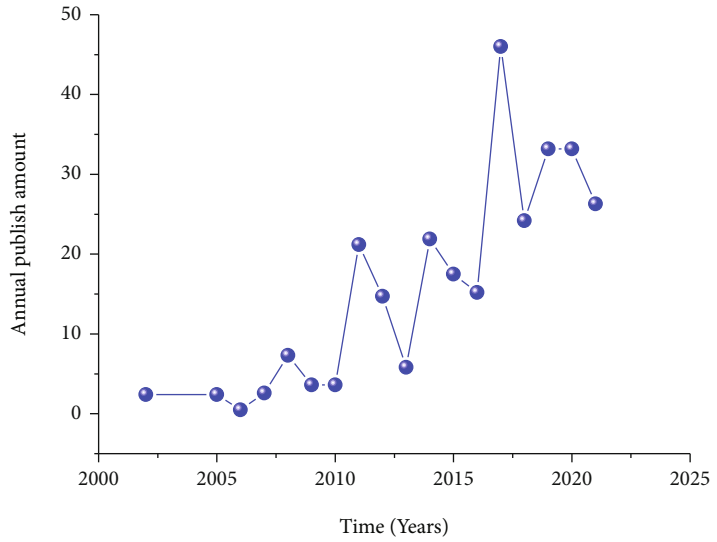

Figure 1: Release trend statistics of national water-saving standards (2002-2021).

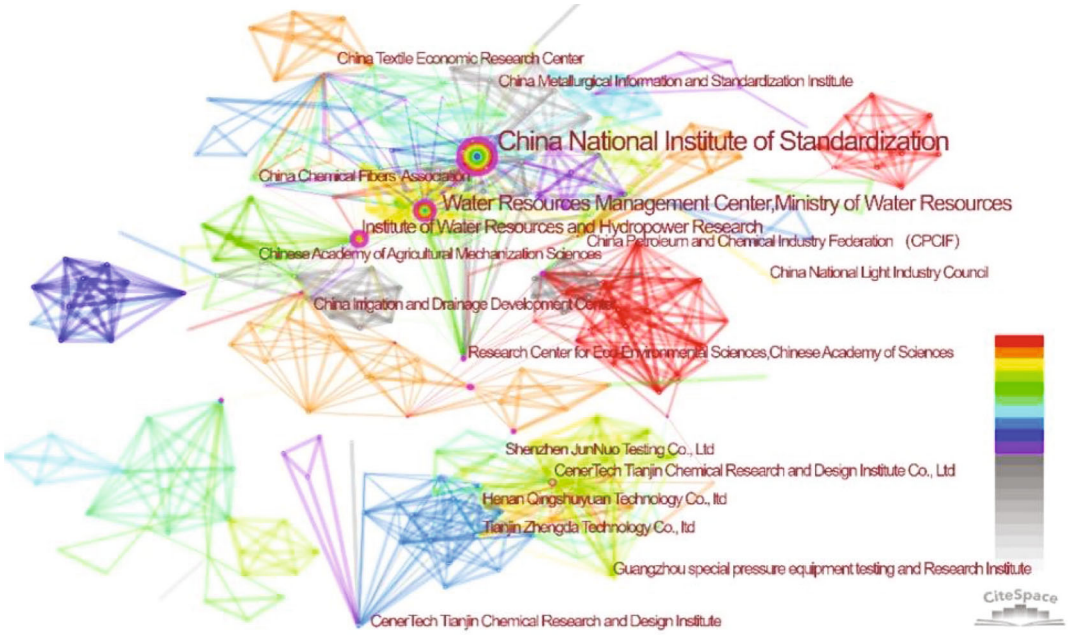

Figure 2: Cooperation diagram of national water-saving standard R&D unit.

Water Resources Management Center of Ministry of Water Resources.

In order to show the importance of each R&D unit in the field of water saving more intuitively, the statistics of the units with high frequency of occurrence and large intermediary centrality value (Table 1) show that the cooccurrence frequency ranking of R&D units is not completely consistent with the centrality ranking, mainly because of the different emphasis of cooccurrence frequency and centrality, with cooccurrence frequency focusing on the frequency of occurrence of R&D units and centrality focusing on the "importance" and "core position" of R&D units in the cooccurrence network. Among them, China National Institute of Standardization has the highest cooccurrence frequency (93) and centrality (0.62), which indicates that it plays a leading role in the development of water-saving standards. The water resources management center of the Ministry of Water Resources (49) ranks second in cooccurrence frequency and only ranks fifth in centrality (0.25). China National Institute of Standardization has the closest cooperation with China Petroleum and Chemical Industry Federation and Water Resources Management Center of Ministry of Water Resources, and most of the standards of water intake quota were drafted jointly with the above two units, respectively.

Table 1: Contribution frequency and centrality of water-saving standard R&D unit.

No.	Keyword	Frequency	Centrality
1	China National Institute of Standardization	93	0.50
2	China Institute of Water Resources and Hydropower Research	29	0.41
3	Research Center for Eco-Environmental Sciences, CAS	6	0.31
4	MCC Capital Engineering & Research Incorporation Limited	4	0.28
5	Water Resources Management Center of Ministry of Water Resources	49	0.25
6	Beijing University of Civil Engineering and Architecture	3	0.23
7	Shanghai Light Industry Research Institute Co., Ltd.	3	0.20
8	North China Municipal Engineering Design & Research Institute Co., Ltd.	3	0.20

3.2.2. Water-Saving Standard R&D Contribution Index. In order to quantify the contribution degree of the drafting unit in developing a standard, first, according to the ranking of the drafting unit of the standard, it is qualitatively divided into leading (ranking no. 1 in the drafting unit of the standard), presiding (ranking no. 2 and no. 3 in the drafting unit of the standard) and participating (ranking no. 4 and later in the drafting unit of the standard). Then, according to the degree of contribution, the top five in the drafting unit are assigned, respectively, and those ranked no. 6 and later are classified into one category for weight assignment (Table 2).

The contribution index of each drafting unit in the development of water-saving standards can be calculated according to the number of participants in different orders and the corresponding index weights. The formula is as follows:

$$\mathrm{CI} = \sum_{t=1}^{k} \lambda_t N_t \quad (\mathrm{t} = 1, 2, 3 \cdots, 6), \tag{1}$$

where CI represents the contribution index of each drafting unit, t represents the ranking of drafting units, λ_t is the index weight, and N_t represents the number of drafting standards.

The top 15 contributing units are listed in the following table (Table 3), and these units have made important contributions to the formulation of water-saving standards. China National Institute of Standardization ranked first with a contribution index of 84.4, with a total of 134 national standards developed, including 30 leading researches, 60 presiding researches, and 44 participating researches. The contribution index was much higher than that of the second-ranked Water Resources Management Center of the Ministry of Water Resources (19.9).

3.3. Research Field and Progress Analysis of Water-Saving Standards. Keywords of water-saving standard are the main induction and generalization of standard content. By clustering and cooccurrence analysis of keywords, we can understand the focus of standard development, so as to better analyze the research field and development trend of water-saving standard.

3.3.1. Research Field of Water-Saving Standards. The keywords of 289 water-saving standards are visually analyzed, and the keywords cluster map is obtained. As can be seen from Figure 3, water-saving standards are mainly divided into six categories: water intake quota, water treatment agent, urban area, reclaimed water, limited value, and cooling water, which reflects the research field of water-saving standards in China. Among them, the overlapping patches are reclaimed water and urban areas, which indicates that reclaimed water is mainly used in cities. The largest patch is the water intake quota, which indicates that the water-saving standard of water intake quota series accounts for a large proportion, so this paper takes the related research of water intake quota as an example to analyze.

Table 2: Ranking weight value of drafting unit.

Unit ranking	1	2	3	4	5	6
Weight	1	0.8	0.6	0.4	0.2	0.1

With the vigorous development of China's various construction undertakings and the increasing improvement of people's living standards, the exploitation and utilization of water resources in China have increased rapidly, and the problems of lack of water resources and water environmental pollution have become increasingly prominent [19]. The status quo of low efficiency, high growth, and heavy pollution of industrial water use in China is extremely incompatible with China's water resources conditions. Strengthening industrial water conservation and changing the backward situation of China's industrial water management is a very important and extremely urgent task, and it is also an objective requirement for China's deep-rooted reform of water-saving management under the conditions of market economy. In this context, the formulation of water intake quota standards for industrial enterprises has been carried out.

The number of water intake quota standards released was 61, accounting for 21.11% of the total number of standards, including a *General Principle for the Preparation of Water Intake Quotas for Industrial Enterprises* (hereinafter referred to as the "General Rules for Water Intake Quotas") and 60 water intake quota standards. The water intake quota for industrial enterprise products is the basic standard in China's industrial water use and water-saving standard system, one of the main indicators of the national assessment of the utilization efficiency of water resources in regions, industries and enterprises and the evaluation of water-saving levels, the control indicators for the purchase, management and distribution of national water resources supply and enterprise water resources

Table 3: Contribution index of water-saving standard R&D.

Ranking	Unit name	Contribution index
1	China National Institute of Standardization	84.4
2	Water Resources Management Center, Ministry of Water Resources	19.9
3	China Petroleum and Chemical Industry Federation	15.5
4	China Institute of Water Resources and Hydropower Research	15
5	Cener Tech Tianjin Chemical Research & Design Institute	11.3
6	China Irrigation and Drainage Development Center	10
7	He'nan Qingshuiyuan Technology Co., Ltd.	9.2
8	Guangzhou Special Pressure Equipment testing and Research Institute	7.4
9	Center Tech Tianjin Chemical Research and Design Institute Co, Ltd.	6.6
10	Institute of Seawater Desalination and Multipurpose Utilization, SOA (Tianjin)	6.6
11	Nanjing University	6.1.
12	Institute of Environmental Protection of Light Industry	6
13	China Metallurgical Information and Standardization Institute	6
14	The Institute of Seawater Desalination and Multipurpose Utilization, MNR (Tianjin)	6
15	Jomoo Kitchen & Bathroom Co., Ltd	5.2

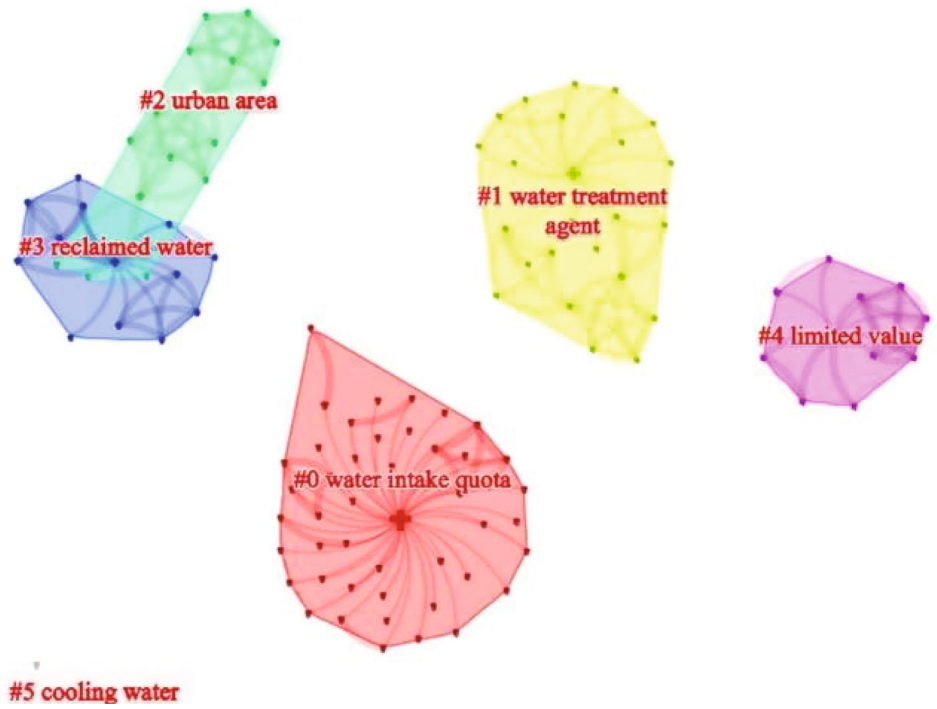

Figure 3: Main research field of water-saving standards.

plans, the indicators for evaluating the rational use of water and water conservation technologies of enterprises, and the basis for industrial enterprises to formulate production plans and water supply plans. The formulation of this standard will guide and standardize the revision of industrial water intake quotas, which is conducive to the formulation of a series of national standards for water intake quotas in related industrial industries and is conducive to strengthening the management of industrial water conservation. It was first released on August 29, 2002, implemented on January 1, 2003, and revised to be released again on June 16, 2011. The 60 national water intake quota standards are mainly formulated for high water use industries such as electric power, iron and steel, textile, paper, petroleum and chemical industry, food fermentation, nonferrous metals, coal, and medicine (Figure 4), which have played an important role in the country's water resources demonstration, planned water use and water withdrawal permit system, and achieved huge water-saving benefits.

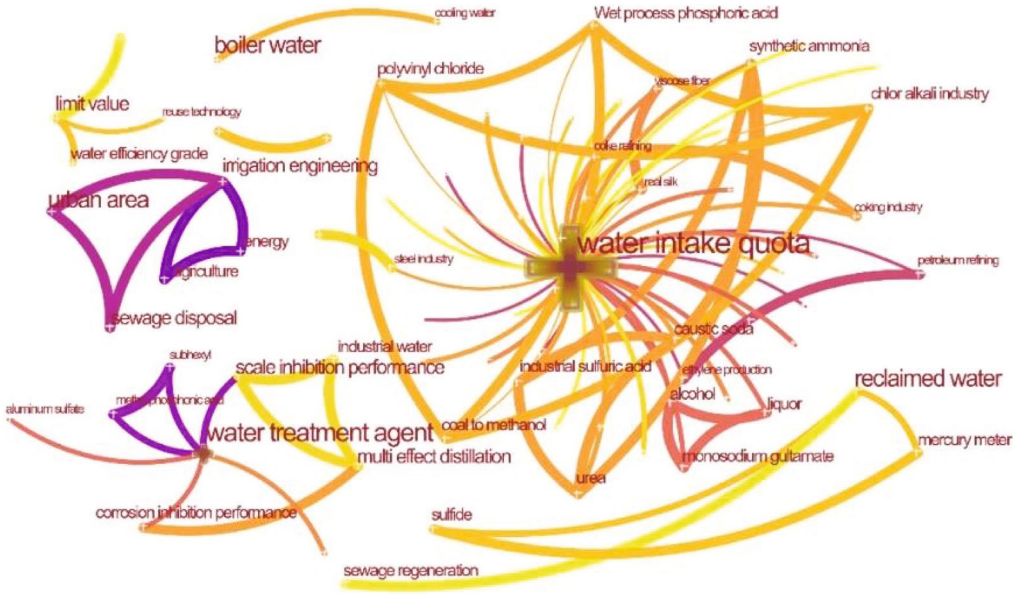

Figure 4: Relationship diagram of water conservation standard.

Top 20 keywords with the strongest citation bursts

Keywords	Year	Strength	Begin	End	2002-2021
City	2002	0.69	2002	2002	
Irrigation project	2002	1.33	2007	2012	
Agriculture	2002	0.88	2007	2012	
Water resources	2002	0.88	2007	2012	
Treatment agent	2002	1.33	2008	2008	
Sewage disposal	2002	1.1	2010	2011	
Iron and steel enterprises	2002	1.25	2011	2011	
Water intake quota	2002	1.77	2012	2012	
Technical guideline	2002	0.75	2012	2012	
Water treatment agent	2002	3.09	2014	2016	
Sea water desalination	2002	1.13	2014	2016	
Drip iriigation pipe	2002	1.15	2017	2017	
Steel industry	2002	0.91	2017	2017	
Reporting guide	2002	0.79	2017	2019	
Boiler water	2002	1.27	2018	2018	
Regenerated water	2002	1.88	2019	2021	
Management norm	2002	1.17	2019	2021	
Reuse technology	2002	1.05	2019	2019	
limit vaue	2002	0.82	2019	2019	
Scale inhibition performance	2002	0.78	2019	2021	

Figure 5: Water-saving standard keyword burst diagram.

3.3.2. Research Progress on Water-Saving Standards. The emergence of water-saving standard keywords indicates that the frequency of use of keywords in a short period of time has increased significantly, and the frontier of the research field can be judged according to the word frequency change of the emerging words. Through the sudden detection of keywords from 2002 to 2021, obtained a year ranking graph containing 20 keywords with strong bursts, in order to further understand the standard setting fields in different periods, according to the keyword start and end time shown

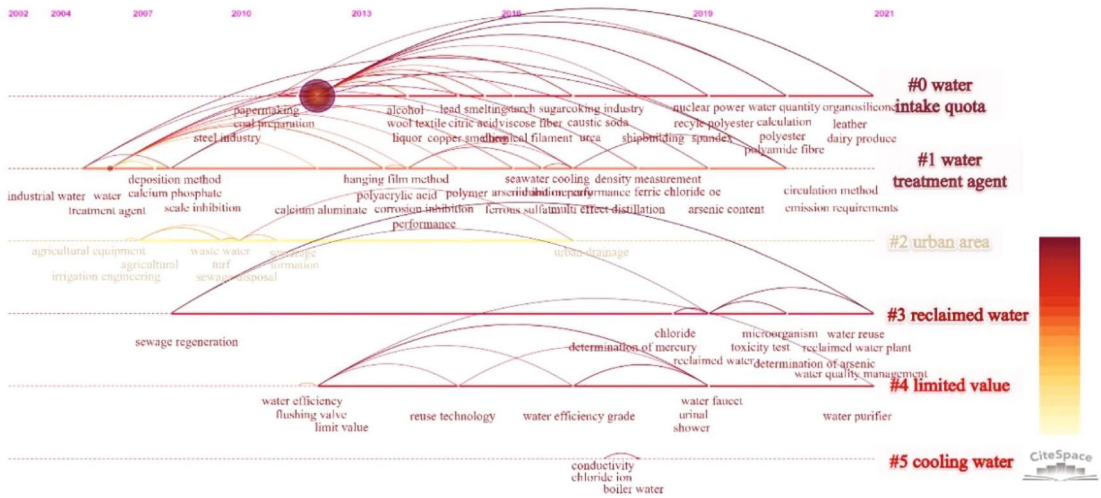

Figure 6: Timeline diagram of the water-saving standard research.

in Figure 5 and the relationship between each other, the frontier research progress of water-saving standard formulation can be divided into four stages. The first phase of the burst time is 2002, the prominence is "city," indicating that water-saving measures were first implemented in the city, and the second phase is 2007-2012, mainly for the development of water-saving standards for industry and agriculture, of which "agriculture" and "irrigation project" have the longest emergence time, and water conservation of agricultural irrigation has been committed to from 2007 to 2012 [20–22]. In addition, there is the release of technical guidelines, which mainly include terms, definitions, and technical basis, which provide reference for the drafting and compilation of relevant series of water-saving standards. The third phase is 2014-2019, in which the research on desalination was joined [23]. The fourth phase is 2019-2021, which focused on water conservation control from the aspects of water recycling and the use of reclaimed water [24, 25].

The timeline chart of water-saving standard keywords (Figure 6) can reflect the evolution of water-saving standard research over time, and the future development trend can be seen from the content of standard development in the past two years. For example, most of the standards in 2019 are focused on product water efficiency, including urinals and dishwashers, and this series of standards provides a standard basis for the establishment and implementation of water efficiency labeling of water products in China.

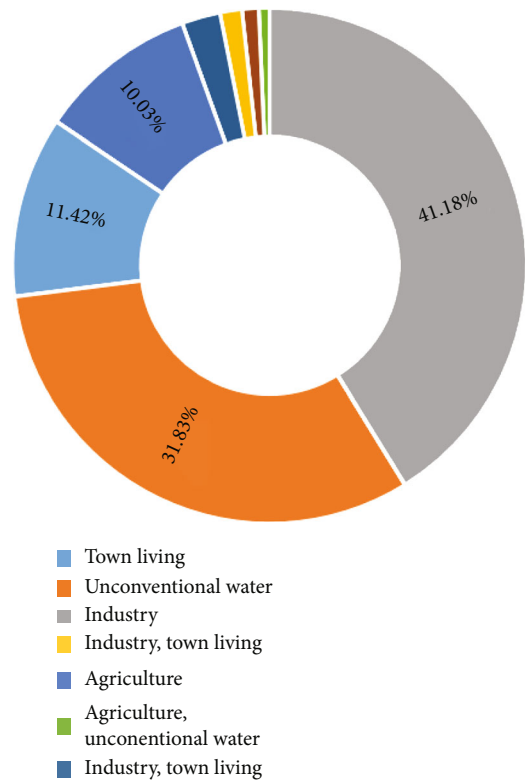

Figure 7: Distribution map of water-saving standards by fields.

3.4. Analysis of the Attribution of Water-Saving Standards

3.4.1. Field of Attribution of Water-Saving Standards. In the national water-saving standards released in 2002-2021, there were a total of 119 water-saving standards in the industrial field, accounting for 41.18%, ranked first in various fields, and the standards for industrial water-saving have been relatively comprehensive, respectively, the national standards for water intake quotas in 60 high-water-using industries such as thermal power generation, steel joint enterprises, petroleum refining, textiles, papermaking, nonferrous metals, and food fermented paper have been formulated; the number of unconventional water-related water-saving standards is 92, accounting for 31.83%, ranking second in various fields; the water-saving standards in the field of urban life is 33, accounting for 11.42%, ranking third in all fields. The specific situation is as shown in Figure 7. The category of water-saving standards is a more intuitive display of the research areas of water-saving standards.

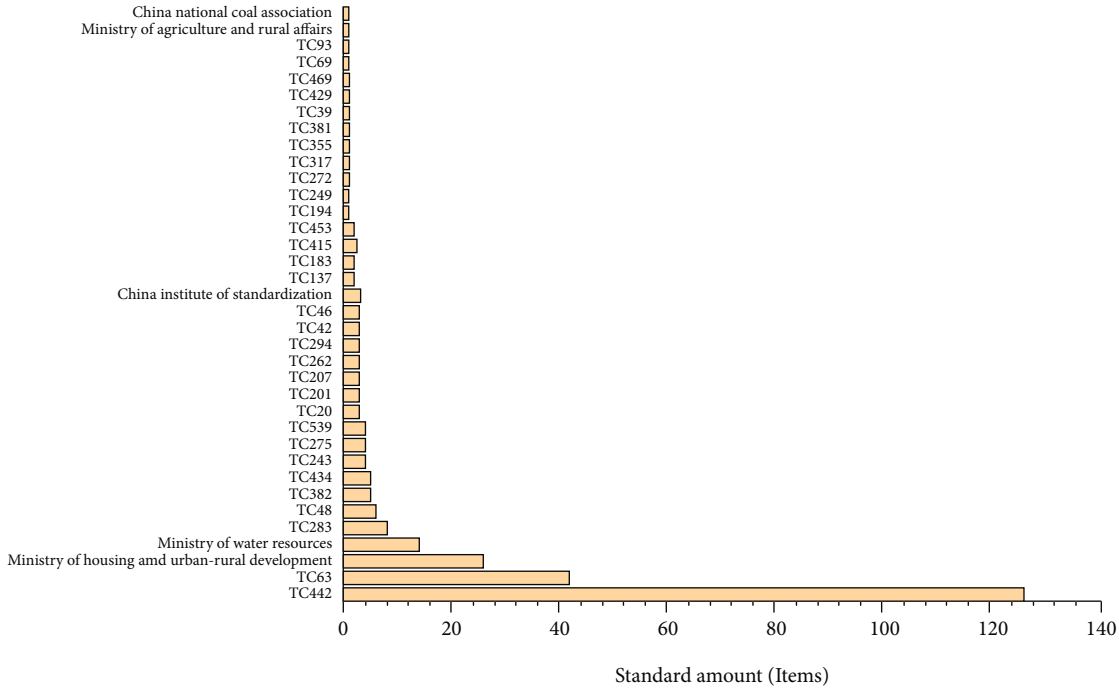

Figure 8: Distribution map of water-saving standard focal units.

3.4.2. Water-Saving Standard Focal Units. The largest number of focal units is the National Water-saving Standardization Technical Committee (SAT/TC 442), which proposes a series of standards such as water intake quotas and water efficiency evaluation of water-using units, which provides a technical basis for the formulation and implementation of policies such as water efficiency of water-saving enterprises and key industrial enterprises; followed by the National Chemical Standardization Technical Committee (SAC/TC63), which is responsible for the formulation of a series of standards for water treatment agents and reclaimed water quality measurement, a total of 31 items, accounting for about 74% of the total, which are applied in the field of unconventional water; The Ministry of Housing and Urban-Rural Development proposed standards about the main urban sewage recycling and building reclaimed water design, the latter clearly stipulates that when all kinds of buildings and residential buildings are constructed, their overall planning should include the comprehensive utilization of sewage, wastewater, rainwater resources, and the construction of reclaimed water facilities; the Ministry of Water Resources ranks fourth, and the scope of the standards proposed by it is mainly water-saving equipment, water-saving technology, evaluation, water quota, and basic common standards, although the number is relatively small, but it plays an important role. For example, the basic common standard is widely used in the preparation and revision of water-saving standards and water-saving work, which is the basis for other water-saving standards (Figure 8).

4. Conclusions

Through the analysis of the water-saving standard development units in the past 20 years, it is found that the relevant water-saving standards are mainly formulated by the China Institute of Standardization, and its development standards mainly include basic common standards such as industrial water-saving terminology, water-use statistics, water balance testing, and general rules for the compilation of water intake quotas, as well as specific standards such as water intake quotas and water-saving enterprises in various industries. The overall trend of first rising and then falling shows that with the gradual improvement of water-saving awareness, the gap in China's water-saving standards has been significantly improved. The formulation of water-saving standards has a great impact on China's industrial, agricultural, and domestic water sectors, in order to adapt to the development of China's modernization, we should improve the water-saving standard system as soon as possible.

Data Availability

All data can be obtained in current manuscript through contact corresponding authors Liu Yang.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Xue Bai and Meng Hao contributed equally to this work.

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