Water Footprint for the Hotel Industry as a Tool of Sustainable Water Management: a Case Study of Region X, China

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Abstract: To alleviate the problem of water scarcity, studying the hotel industry's water footprint becomes critical. Based on the two aspects of hotel water consumption compared with residential water consumption and competition in the international hotel industry market, the hotel service industry of Region X was taken as a case study destination to perform quantitative measurement and feature analysis on the need for water conservation in the hotel industry. Further, a hybrid Life Cycle Assessment (LCA) model was employed to calculate the hotel industry's water footprint. The calculation results determine the water footprint economy. This information is used to judge the hotel, as well as the benefit value, water self-sufficiency rate, water import dependence, water footprint growth index, available water resource growth index, water sustainability index, and other hotel industry water resources sustainable development evaluation indicators, such as the state of sustainability of industrial water resources. The quantitative research reveal that the guestroom department's water footprint has a rapid growth trend, followed by the catering department's water footprint, and that of other departments is a stable trend. Both the total water footprint and direct water consumption of the three-star hotel service subsector are the largest.

1. Introduction

Water is the most important source of material and energy for human production and life. A regional social economy's stable development cannot be separated from the continuous and adequate supply of water resources. With the global population expanding and the continuous expansion of the industrial production scale, water resources continue are increasingly utilized and consumed, and the contradiction between fresh water supply and demand has become increasingly prominent. The use of water resources is closely related to human consumption: On the one hand, the consumption of water resources is mainly reflected in the amount of water consumed directly; on the other hand, because water resources are the basic resources for the production of many agricultural products, industrial products and service products, a large amount of water is in an "invisible" form embedded in the production process of various products and services. When these products and services are consumed, water resources are consumed in the form of a water footprint [1–3].

The service industry is the general term for various industries that provide service-oriented labor to society through certain places, equipment and tools. The most basic feature of the service industry's economic activities is the close integration of the production, exchange and consumption of service products. For example, the hotel service industry's comprehensive services also require the cooperation of multiple services such as communications, transportation, catering, laundry, shopping and medical treatment [4].

As a high-consumption living and entertainment venue, the hotel service industry is essentially a high-consumption, high-waste, and high-pollution industry, and its operations are based on the serious consumption of resources and environmental pollution. The average daily water consumption per room of a three-star hotel is 1 to 1.2 tons, which is equivalent to 3 to 5 times the water consumption of ordinary residents. This water resources waste is quite serious. The recovery and development of the tourism industry after the new crown pneumonia (COVID-19) epidemic is particularly important. COVID-19 has spread across the country. On January 24, 2020, the

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first-level response to public health emergencies was launched. The tourism industry entered a dormant period. The epidemic has seriously impacted the entire service industry, especially the large tourism industry including tourist attractions, rural tourism, travel agencies, accommodations, catering, etc. [5–6]. The hotel industry and its tourism industry have been hit hard by the pandemic. During the COVID-19 epidemic, hotel companies are required to fully consider their impact on the environment and resources in their business activities, and integrate environmental protection into the entire process of business management. To adapt to the requirements of the times and its own development, it is an inevitable choice to implement environmental behavior management for enterprises. Therefore, it is very important to study the hotel industry's motivation to implement a sustainable development plan for water resources.

2. Analysis on the Hotel Industry's Motivation on Implement Water Resources Sustainable Development Plans

2.1 The Necessity of Saving Water in the Hotel Industry

2.1.1 Hotel Water Consumption is Larger Than Residential Water Consumption

Hotel room water has always been the main part of hotel water, accounting for 40% of hotel water, followed by kitchen water, accounting for 30%, in addition to central air-conditioning water, greening and other water. Moreover, in the eyes of ordinary people, a hotel is a high-consumption place, and it is often associated with profligacy and the excessive pursuit of material comfort. Water is inevitable when you go out to stay in a hotel. However, many travelers do not pay attention to saving water when washing and bathing. For example, a passenger in the same room as the author would take a shower for extra-long periods of time, every time. Hearing the sound of running water was really distressing. In fact, a bath for ten minutes to a quarter of an hour is more than enough. Of course, even if two tons of water are used in an hour, it is not worth much-about 1% of the housing price. However, in China where water resources are increasingly scarce, especially in cities, it is not just draining water, but also money [7]. In fact, for the people who use water in the hotel lavishly, their reason as to why they do this is probably because of the idea of "do not use it for nothing". Since all hotels (including tourists and guest houses) across the country probably have no restrictions or quotas on the water the tourists use, tourists can use however much they want. Some tourists also unceremoniously turn on the big taps, and some even let the water run in vain. In addition, room supplies are cleaned a lot.

2.1.2 International Hotel Industry Market Competition Needs

The hotel industry in China has been the most smoothly integrated with the international market since China's reform and opening up in 1979. It was the first to integrate with the international market. Especially after joining the World Trade Organization (WTO), it means that my country's hotel industry must follow the rules and practices of the international tourism market and has no choice but to embark on it. It must compete with the world's major hotel groups and excellent hotels, and participate in the competition in the international market. Therefore, hotels must take the lead in accepting international environmental awareness, and their understanding of water resources is better than other industries. However, in view of the actual national conditions of the current poor awareness of sustainably developing water resources, we can only proceed step by step, starting with the water resources that everyone directly contacts every day. This is also an effective starting point for management [8]. However, the hotel has a large floating population every day and a large amount of information dissemination. It advocates water conservation and allows guests and the hotel to create a water-saving green hotel. Through the guest's evaluation and approval of the creation work, water conservation is the first to become a trend in the hotel industry and is driving others. The industry follows suit and promotes water-saving actions for the whole society. Therefore, whether it is from the contradiction between water supply and demand and the concrete implementation of the government's sustainable development strategy, or from the perspective of the hotel's own interests and the protection of nature, it is very necessary to carry out large-scale

water-saving activities in the hotel industry to create water resources, to lay the foundation for sustainable development.

2.2 Calculation Method of Hotel Industry Water Footprint

Based on the above analysis of the necessity of implementing water-saving practices in the hotel industry, a hybrid Life Cycle Assessment (LCA) model is adopted to calculate the water footprint of the hotel industry.

2.2.1 Water Footprint

The water footprint is used to measure the real demand and actual occupation of water resources from the perspective of human consumption of products and services that water resources provide. The water footprint collaboration network system is based on the basic framework of the LCA method. The steps are divided into the following: setting goals and scope, water footprint accounting, evaluating water footprint sustainability, and formulating water footprint response plans. The research content of the water footprint accounting mainly includes: First, quantifying the evaluation done of the water footprint of the production process, product, producer or consumer; second, evaluate the environmental, social and economic sustainability of the water footprint; and third, formulate water resources management plans. The research objects of water footprint accounting mainly include: the water footprint of a specific process in the production chain or the water footprint of the final product; the water footprint of consumers, products or a certain economic sector; the analysis from a geographical perspective, as well as the water footprint of the study area at different spatial scales [9].

At present, water footprint accounting research focuses on both agricultural and industrial products. The calculation methods are basically similar. They are all based on the cumulative summation method of the production process or the product's stages. The calculation method of the hotel industry's water footprint is also based on the water footprint calculation method that is also combined with services. The characteristics of industrial consumption activities are accounted for. The hotel industry's water footprint refers to the total amount of water consumed in the entire the hotel industry process, that is, the hotel industry's "virtual water content". Since the hotel industry in a region does not completely rely on local water consumption, it is possible to transfer the water resources from other regions to meet local and final consumption needs after consuming the water resources from other regions. Therefore, the hotel industry's water footprint mainly includes two aspects: internal water footprint (products are produced locally, consuming local water resources) and external water footprint (products are produced in other places, consuming foreign water resources). The consumption water footprint mainly includes directly the amount of water consumed (direct water footprint) and the amount of water hidden in products and services (indirect water footprint) [10].

2.2.2 Calculation Method of Hotel Industry Water Footprint Based on Hybrid Lca Model

To analyze the use of water resources in the hotel industry, it is necessary to collect the relevant data and then make an in-depth analysis of the data. Usually, the data collection method of water resources usage in the hotel industry consists of investigation, which mainly investigates the total number and distribution of local hotels, keeping records by filling out questionnaires, checking on-site usage, measuring water quantity, measuring water pressure, installing water-saving appliances, etc., and contacting the water supply company to obtain water quantity data, on the basis of which data mining and analysis are realized.

The water footprint calculation method based on the hybrid LCA model consists of two parts: process-based LCA (P-LCA) and economic input-output LCA (EIO-LCA). P-LCA is a bottom-up analysis method that collects material and energy inputs at each stage of the product production process through field surveys, monitoring or second-hand statistical data, and can record in detail the production, transportation and packaging of the product life cycle. Direct input into consumption or discharge can accurately analyze the environmental impact of a specific product or service throughout the life cycle, obtain the input and output data list of the research object through

the analysis of the full life cycle inventory, and then calculate the water footprint of the research object in the life cycle. The P-LCA method is advantageous in that it is highly pertinent, but it can only calculate physical inputs. The consumption and emissions of product production and service provision processes based on intangible inputs such as currency, labor and indirect consumption cannot be evaluated [11].

On the other hand, EIO-LCA creates a top-down life cycle accounting method based on the input-output analysis model. A department's corresponding consumption or output is obtained from the cost input of the economic department, which is generally expressed in unit currency. The EIO-LCA method first uses the input-output table to calculate the energy consumption and emission levels at the departmental level, and then evaluates the environmental impact of specific products or services through the corresponding relationship between the evaluation object and the economic sector. Then, the input-output analysis method uses indirect accounting. The advantage of decomposing specific products into their corresponding industry sectors in the input-output table is to improve the application of input-output analysis for specific product life cycles. On this basis, one can analyze the direct and indirect effects of selected products in the entire economic system, which results in the environmental impact [12].

By combining P-LCA and EIO-LCA, the hybrid LCA can not only reduce errors, but also strengthen the pertinence of specific evaluation products. At the same time, it can also incorporate the direct and indirect consumption of products into the scope of evaluation. The P-LCA method is correct. The direct and downstream material energy input of the product is analyzed, while the EIO-LCA method is used to analyze the upstream natural resource extraction, production and processing, and facility manufacturing and the product transportation [13–15]. Compared with the first two methods, the hybrid LCA is more complicated, requiring researchers to have a deeper understanding of the input-output table, and the requirements for matrix operations are also high, but it can avoid the problem of double calculation.

The formula for calculating the hotel industry's water footprint as based on the P-LCA analysis method is:

$$M_P = RA \times y \quad (1)$$

In the formula, M_P represents the hotel industry's water footprint in the P-LCA part, R represents the hotel industry's water consumption matrix per unit, A represents the input coefficient matrix, and y represents the final demand vector.

The formula for calculating the hotel industry's water footprint as based on the EIO-LCA analysis method is:

$$M_{EIO} = R(I - A')^{-1} \times y \quad (2)$$

In the formula, M_{EIO} represents the hotel industry's water footprint of the EIO-LCA part, and A' represents the direct consumption coefficient matrix.

The direct consumption coefficient is the direct consumption of the relevant department's products by the department's production unit. A' represents the direct consumption of the department *i*'s products by the department's production unit of *j*. The calculation formula is as follows:

$$A' = \frac{x_{ij}}{x_j} (\ i,j = 1,2,\ldots,n) \quad (3)$$

The Leontief inverse matrix reveals the intricate economic relationship between various sectors of the economy. B is also called the complete need coefficient matrix. It reflects the demand for the total output of each department to obtain the final product of the unit, including direct demand. The calculation formula of indirect demand and final demand I is as follows:

$$B = (I - A')^{-1} \quad (4)$$

The formula for calculating the hotel industry's water footprint as based on the hybrid LCA analysis is:

$$M_H = M_P + M_{EIO} \quad (5)$$

2.3 Determination of Evaluation Indicators for Sustainable Development of Water Resources in the Hotel Industry

Based on the above-obtained results of the hotel industry water footprint accounting, the evaluation indicators for the sustainable development of hotel industry water resources are determined.

(1) Economic benefit value of the water footprint

The hotel industry's water footprint economic benefit value is the ratio of the GDP of the product (industry) to the total water footprint value, WF. This indicator reflects the level of economic benefits that the water footprint consumption creates. The higher the index value, the greater the economic dependence and the higher level of water utilization. It is calculated as follows:

$$\text{Economic benefit value of water footprint} = \frac{GDP}{WF} \quad (6)$$

(2) Water resources self-sufficiency rate

The self-sufficiency rate of water resources in the hotel industry is the ratio of the internal water footprint to the total value of the water footprint. This indicator reflects the degree of water resources within a region. The larger the percentage, the higher the product's or region's dependence on the region's water resources.

$$\text{Self sufficiency rate of water resources} = \frac{\text{Internal water footprint}}{WF} \quad (7)$$

(3) Import dependence of water resources

The hospitality industry's water import dependence is the ratio of the external water footprint to the water footprint's total value. This indicator reflects the extent to which a region depends on external water resources. The larger the percentage, the higher the product's or region's dependence on imported water resources. It is calculated as follows:

$$\text{Import dependence of water resources} = \frac{\text{External water footprint}}{WF} \quad (8)$$

(4) Water footprint growth index

The water footprint growth index is the percentage of the difference between the total water footprint value WFR_2 of the previous year, the total water footprint value WFR_1 of the previous year and the water footprint of the previous year. This indicator reflects the extent of changes in water consumption in the study area during a certain time period, and indicates the speed at which the water footprint increases or decreases. It is calculated as follows:

$$\text{Water footprint growth index} = \frac{WFR_2 - WFR_1}{WFR_1} \quad (9)$$

(5) Available water resources growth index

The available water resources growth index is the percentage of the difference between the available water resources WAR_2 in the previous year, the available water resources WAR_1 in the previous year and the available water resources in the previous year. This indicator reflects the range of changes in the amount of water resources available in the study area during a certain time period, and indicates the speed at which the available water resources in the study area increase or decrease. It is calculated as follows:

$$\text{Available water resources growth index} = \frac{WAR_2 - WAR_1}{WAR_1} \quad (10)$$

(6)Water resources sustainability index

The water resources sustainability index is the ratio of the absolute value of the water footprint growth index to the absolute value of the available water resources growth index. This indicator reflects the strength of the sustainable use of water resources in a study area. It is calculated as follows:

$$\text{Water resources sustainability index} = \frac{|WFR|}{|WAR|} \quad (11)$$

The water resources utilization evaluation index system as based on the water footprint theory is shown in Table 1:

Table 1 Water Resources Utilization Status of Hotel Service Industry

Water footprint assessment structure	Water footprint evaluation index	Meaning	Water footprint assessment structure	Water Footprint Evaluation Index	Basic meaning
Water footprint benefit index	Economic benefits of water footprint	Water footprint of ten thousand yuan GDP	Water footprint benefit index	Economic benefits of water footprint	Water footprint of ten thousand yuan GDP
Water footprint structure index	Self-sufficiency rate of water resources	Degree of consumption of local water resources	Water footprint structure index	Self sufficiency rate of water resources	Degree of consumption of local water resources
	Import dependence of water resources	Extent of consumption of external water resources		Import dependence of water resources	Extent of consumption of external water resources
Water footprint sustainability indicators	Water footprint growth index	Change range of water consumption	Water footprint sustainability indicators	Water footprint growth index	Change range of water consumption
	Available water resources growth index	The change range of the water resources' available amount		Available water resources growth index	The change range of water resources available amount
	Indicators of sustainable utilization of water resources	Status and capacity of sustainable utilization of water resources		Indicators of sustainable utilization of water resources	Status and capacity of sustainable utilization of water resources

2.4 Judgment of the Sustainable State of Hotel Industry Water Resources

To judge the hotel industry's water resources sustainability, it is necessary to evaluate the water footprint. Water footprint evaluation refers to the evaluation of the input, output and potential environmental impact of water the product process or organization uses. Firstly, to determine the water footprint evaluation goal, it is necessary to clearly state the research intention, the reason for the research, the research object, etc.; secondly, to determine the system boundary, it is necessary to use the LCA method to evaluate the water footprint of the product as a whole, and the direct and indirect water generated in the whole life cycle; finally, a water footprint evaluation is carried out from different angles according to the purpose and scope.

Specific steps are as follows:

(1) Determine the goal: As the water footprint accounting mainly focuses on agricultural products and industrial products, there are few studies on the water footprint of service products, such as the hotel service industry water footprint research.

(3) Determine the scope: the direct consumption in the hotel operation process mainly includes the service phase and the cleaning phase; the service phase is mainly the room check-in and providing catering services, which directly causes water consumption; the cleaning phase is mainly the housekeeping department and the catering department doing cleaning preparations for the next guest. The indirect consumption in the hotel operation process mainly includes the preparation phase and the equipment operation phase. The preparation phase is mainly the hotel service industry construction phase, decoration and purchasing service products such as furniture and electrical appliances. The equipment operation phase mainly uses the water caused by the guest room department's and the catering department's equipment. The hotel industry's life cycle system

boundary is shown in Figure 1.

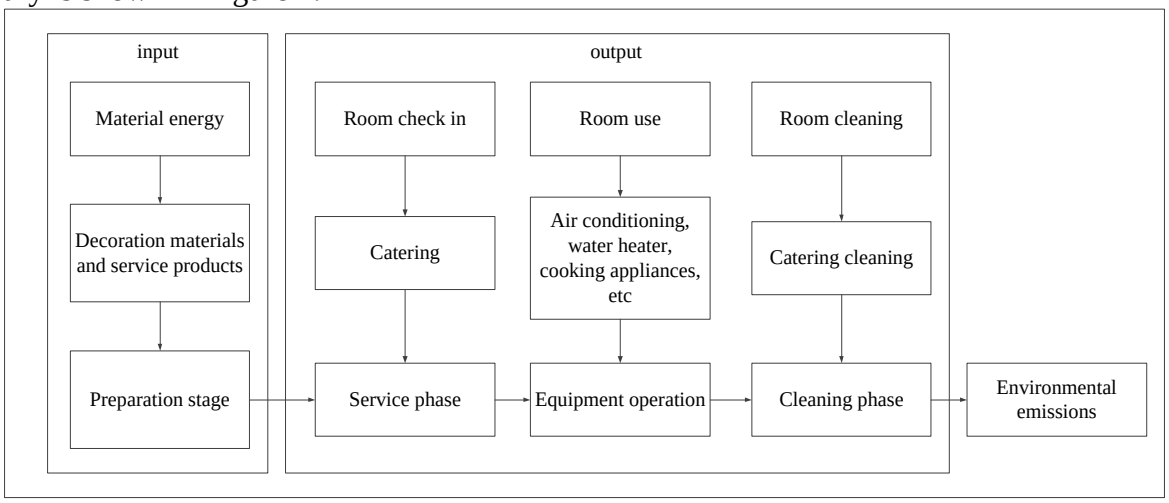

Fig.1 The Life Cycle System Boundary of the Hotel Service Industry

The water footprint inventory analysis includes the input and output of each unit process in the research system. The hotel service industry inventory analysis refers to the quantitative analysis of resource consumption and environmental emissions in all processes within the hotel service industry's life cycle system. The specific steps are included in the process of collating the data list:

(1) Design a questionnaire survey.

(2) Draw a specific process flow chart.

(3) Describe the process of each unit in detail.

(4) List the input and output of each operation stage.

Therefore, the water footprint is determined through analyzing the life cycle inventory, the input and output of water usage, material energy consumption and environmental emissions in each stage of the hotel service industry (input includes preparation stage, output includes service stage, equipment operation and cleaning stage).

The water footprint impact assessment includes the potential environmental impact that the changes in water consumption and water footprint changes in the research system cause. The hotel service industry evaluation model is divided into 3 steps: classification, characterization and quantification.

(1) The classification is based on the analysis of the life cycle data inventory and divides it into different impact types that can more clearly reflect environmental issues. According to the target definition, scope determination and inventory analysis, the data list provided will affect the hotel service industry and the guest room department. The environmental impact the water consumption process of the Food and Beverage Department causes is classified.

(2) Characterization is to use the environmental load index method to summarize different impact factors under the same impact type for the purpose of obtaining each impact type's comprehensive environmental load.

(3) Quantification is the comparison of various types of environmental impacts, with the purpose of further interpreting and synthesizing the data of environmental impact assessment, and the proportion of water pollution emissions in each stage of the hotel service industry.

The hotel service industry impact evaluation can be divided into economic impact and environmental impact. The economic impact is mainly the cost of the preparation stage and the operating cost of the equipment operation stage; the environmental impact is the relationship between the research data, the accounting principle of the water footprint and the use of water resources, as well as the benefits, structure and sustainability of the water footprint are selected as evaluation indicators to evaluate the utilization of water resources in the hotel service industry.

Through the hotel industry impact assessment, the state of the water resources' sustainability is judged, as shown in Figure 2.

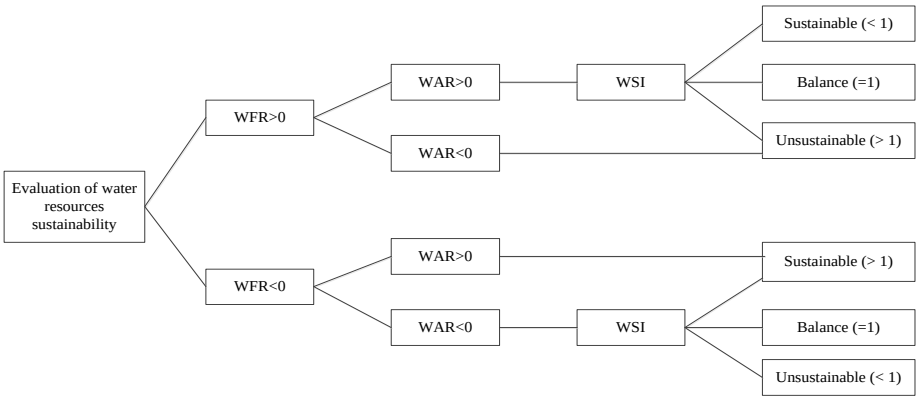

Fig.2 The Process of Judging the Sustainable State of the Hotel Industry

(1) When WFPR<0 and WAR<0, it means that the amount of available water resources is greater than the water footprint of the area. When WSI<1, the tendency of unsustainable water resources utilization is stronger; on the contrary, when WSI>1 , Water resources show a stronger trend of sustainable utilization; when WSI =1, the sustainability of water resources is in a balanced state. When WFPR<0, WAR>0, it is directly considered that the water resources are in a sustainable state.

(2) When WFPR>0, WAR>0, it means that the increase in water footprint exceeds the increase in available water resources in the area. When WSI>1, the tendency of unsustainable water resources utilization is stronger; otherwise, when WSI < At 1 o'clock, the water resources show a stronger trend of sustainable utilization; when WSI =1, the sustainability of water resources is in a balanced state. When WFPR>0 and WAR<0, it is directly considered that the water resources are in an unsustainable state.

3. Simulation Result Analysis

To verify the effectiveness of the hotel industry's motivation for implementing the sustainable development plan of water resources in practical applications, a simulation experiment analysis was carried out. The hotel service industry's water consumption is obtained through the research. The survey plan mainly includes: the hotel's basic situation (number of rooms, number of beds, occupancy rate, and operating income), water consumption of various hotel departments, the hotel's annual water consumption, its monthly water consumption, the basic situation of service product consumption, and the situation of hotel sewage discharge and treatment.

The survey focused on Region X, which is located in the underdeveloped dryland part of China. As of 2019, there were 47 gazetted hotels in this region, including two one-star hotels (Subsector A), 67 two-star hotels (Subsector B), 171 three-star hotels (Subsector C), 73 four-star hotels (Subsector D), and two five-star hotels (Subsector E). Considering the sustainable evaluation of water resources, a representative hotel with a longer operating life and better data preservation is selected as a case analysis. Through in-depth investigation and interviews with previously cooperated hotels, according to the accuracy of the data, the forementioned five subsectors of gazetted hotels have been selected to obtain the basic data of water consumption through field investigation, and conduct simulation experiment analysis.

The water footprint analysis of each department of the five hotel service subsectors from 2015 to 2019 is shown in Figure 3.

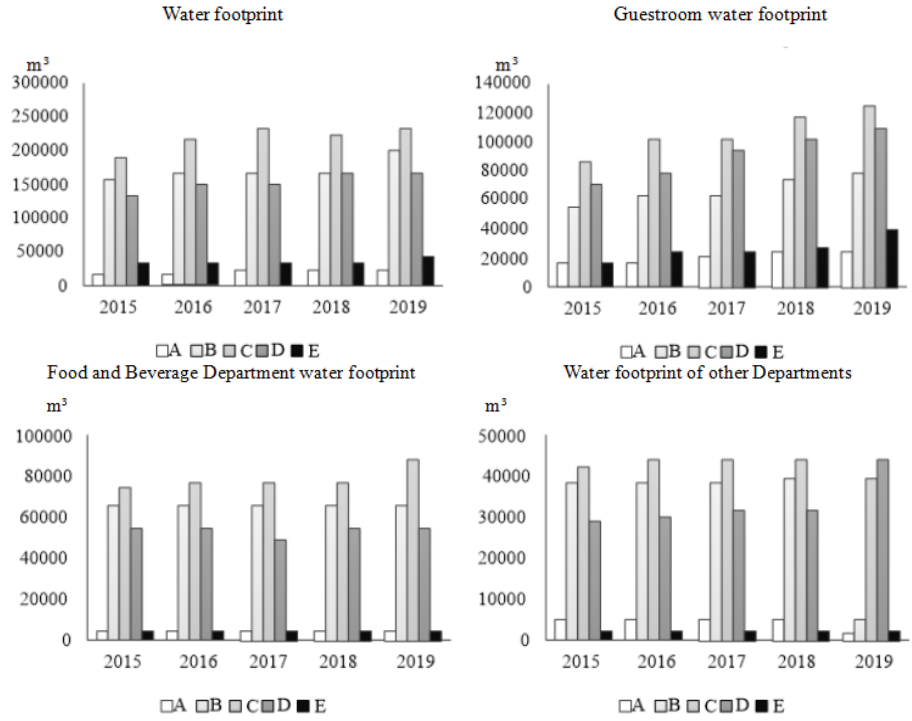

Fig.3 Water Footprint Analysis of Each Department of the Five Hotel Service Subsectors from 2015 to 2019

On the whole, the water footprint of each of the five hotel service subsectors in 2015–2019 has shown an upward trend. The water footprint of guestroom department has a prominent growth trend, followed by the water footprint of the food and beverage department, and the water footprint of other departments is in a stable trend. The guestroom department and the catering department have had accounted for the main water consumption of this industry. Secondly, other departments consume the an increasingly large amount of water resources. The main reason may well get rooted in the cleaning stage in the service stage. In particular, the laundry activities tend to consume a huge amount of water.

The total water footprint analysis of the five hotel service subsectors from 2015 to 2019 is shown in Figure 4:

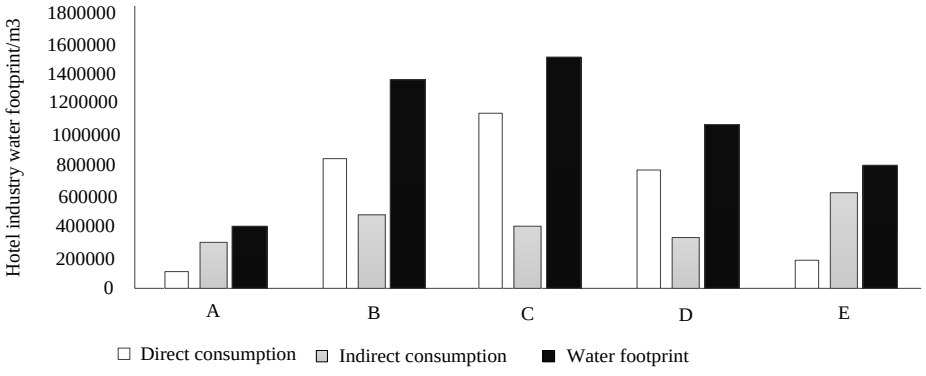

Fig.4 Analysis of the Total Water Footprint of the Five Hotel Service Subsectors from 2015 to 2019

According to the calculation of the hotel industry's water footprint, that of different subsectors of the hotel service industry is also different. As seen in Figure 4, the total water footprint of the three-star hotel service industry is the largest, and the direct water consumption is also the largest, followed by four-star hotels and two-star hotels; the indirect water footprint of the five-star hotel service industry is the largest, followed by three-star hotels and two-star hotels. Therefore, the factors that affect the hotel service industry's water footprint mainly include the tier of the hotel, the consumables invested in the preparation phase, facilities and equipment, the number of tourists received, and the quality of service.

4. Conclusion

The hotel industry is usually a large consumer of water resources. Under the situation of increasingly tight water resources, saving water energy consumption of large consumers is conducive to not only improving their own economic benefits, but also the rational deployment of social resources. This paper studies the hotel industry's motivations to implement the sustainable development plan of water resources and provides different ideas for alleviating the problem of water scarcity.

First, the hotel service industry should focus on investigating the entire life cycle of the hotel service industry during the operation process, from the preparation stage to the end, and every room and bed must engage with water-saving management; secondly, it should establish a hotel environmental management system. Analyzing and counting the water consumption of various departments at all stages, carrying out water-saving activities, and regarding water-saving as an important indicator for evaluating the environmental management system of the hotel service industry is a must. In addition, agricultural, forestry, animal husbandry and fishery products are an important indirect consumption sector of the hotel service industry, and implementing a diversified path of virtual water strategy has a positive effect on the hotel industry's water saving and water efficiency improvement. Finally, based on the research on the water footprint of service products, this research aims to make up for the lack of quantitative research on the water footprint of service products and provide a scientific reference for the socialized management of water resources.

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