

Domestic water use and water-saving countermeasures in the process of urbanization in 2021: Jiaozuo City case study

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ABSTRACT

Water-saving scientifically proved measures are crucial to reduce the use of decreasing fresh water resources. In this study, we investigate the current situation of residents' domestic water use, analyze the current situation of residents' water-saving measures, the current situation of residents' water-saving consciousness and its influencing factors. We performed a questionnaire survey and data obtained by relevant water supply departments, this paper used SPSS 19.0 and Excel 2020 software to conduct statistical analysis of survey data. Our results show that: (1) overall, the water consumption of urban residents in the central plains suburb is 18% higher than that of the original urban residents. (2) Among the residential water structures, washing, washing clothes and flushing toilets are the most frequent tasks, accounting for 87.3% of the total water consumption. (3) The implementation of water-saving measures by the original urban residents is better than that of the original suburban residents. (4) It is necessary to increase effective water-saving facilities and measures for urban water use.

Key words: domestic water use, Jiaozuo City, random survey, urbanization, water consumption distribution

HIGHLIGHTS

- The water consumption of urban residents in the central plains suburb is 18% higher than that of the original urban residents.
- Among the residential water structures, washing, washing clothes and flushing toilets are the most frequent tasks, accounting for 87.3% of the total water consumption.
- The implementation of water-saving measures of the original urban residents is better than that of the original suburban residents.

INTRODUCTION

Although the total amount of water resources in China is large, the amount of water resources per capita is extremely low, and it is one of the 13 countries with the poorest water resources in the world according to the United Nations, as the distribution of water resources is extremely mismatched with the layout of arable land, population and economy. As urbanization progresses, the scale of cities and towns continues to expand and the population continues to grow, resulting in a significant increase in non-agricultural water use, further exacerbating the contradiction between urban and rural areas, production and living, and other aspects of water use. This study takes Jiaozuo City in Henan Province as a typical area, and through a survey and research on the current situation of residential household water use, it clarifies the main factors affecting residential household water use and puts forward corresponding water-saving measures or suggestions (Zhang *et al.* 2009, 2010, 2019; Yu *et al.* 2015).

In the context of growing global urbanization, the interannual trend of residential domestic water use has become more and more complex, and more and more scholars have been conducting research on the topic of urban residential water use. Anderson (2014) in Australia predicted the daily water consumption of urban residents in Melbourne through a time series model and achieved good results; Zhou *et al.* (2000) compared the hourly and daily water consumption models by building a time series model; May & Lott (1992) used meteorological factors such as precipitation and average annual temperature as May & Lott (1992) constructed a regression model between medium- and long-term factors and water use under the premise of constraint conditions, and the model achieved more satisfactory results in the medium- and long-term water

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use prediction in Texas, USA. Liu *et al.* (2013) analyzed the main influencing factors of urban domestic water use, analyzed the evolution mechanism of urban domestic water use indexes, and established a model for calculating urban domestic water use indexes considering climate, economic development level and other factors. The average error of the model was 6.5%, which is relatively accurate in prediction, but there were individual parameters that were empirically taken and, in fact, the real values of these parameters can be obtained through surveys. In addition, the structure of household water use considered in the model is laundry water, bathing water and toilet flushing water, but not household drinking water and household cleaning water, which are essential parts of life although they do not consume much water (Li *et al.* 2014; Hai *et al.* 2018). In addition, urban water resources mainly involve urban water supply rivers and urban groundwater, and urban climate change and precipitation conditions directly affect water supply security. Wang & Wang (2018) conducted a study on drought warning and emergency dispatch for urban water supply. These studies for urban water resources utilization and investigation have obtained many valuable conclusions from different perspectives using different methods, which provide different degrees of assistance to urban water resources management.

To date, most of the global and international studies on water use by residents of different urban areas have focused on qualitative descriptions of survey data and simple generalizations using models (Chi *et al.* 2006, 2019), with fewer quantitative methods used to describe the differences in water use between residents of formerly urban and formerly suburban areas due to urbanization (Bao & He 2017; Meng *et al.* 2020). However, as cities continue to expand, the dramatic changes in housing prices and living environments in urban areas have led to a large influx of residents from former main urban areas to suburban areas (Che *et al.* 2015; Lu *et al.* 2018), resulting in a change in the structure of urban residents, with the number of suburban residents gradually increasing in proportion to urban residents, thus affecting water use differences (Li *et al.* 2012; Shi *et al.* 2015). In this paper, a random household survey was conducted in Jiaozuo City, Henan Province, based on a questionnaire, and statistical analysis was used to study the current situation of water use, awareness of water conservation and water conservation measures of these two types of residents (urban and suburban residents) in the urbanization process, in order to provide a scientific reference for the authorities to optimize the allocation of water resources, ensure the normal use of residents and the sustainable use of water resources. The study will provide a scientific reference for the authorities to optimize the allocation of water resources and ensure the normal use and sustainable utilization of water resources.

EXPERIMENTAL

The generality of the study region

Jiaozuo City is located in the northwest of Henan Province, between latitude 34°48'55"–35°29'59" and longitude 112°33'40"–113°38'42", it has four municipal districts (Jiefang district, Shanyang district, Zhongzhan district, Macun district), four counties (Xiuwu County, Wuzhi County, Wen County, Boai County), a provincial high and new technology industrial development zone, hosting two county-level cities (Qinyang, Mengzhou). The built urban area is 90 km², with a total population of nearly 3.54 million, among which the urban population is about 835,000, and the urbanization rate is 52.02% (Wang *et al.* 2005).

Jiaozuo has a warm temperate continental monsoon climate, with an average annual temperature of 14.5 °C, an average annual sunshine of 2,300 h, an average annual precipitation of 585 mm and an average annual evaporation of about 1,850 mm. Jiaozuo has abundant surface water resources, including 23 rivers with a drainage area of more than 100 km², and large reservoirs such as Qunying reservoir and Qingtian-river reservoir. Not only that, Jiaozuo is also a natural groundwater collection area, with proven groundwater reserves of 3.54 billion cubic meters, which is crowned with the reputation of 'underground reservoir' (Wang *et al.* 2019).

However, due to the influence of monsoon climate, the seasonal precipitation is uneven, and several rivers are cut off for a long time. The Qunying river and Puji river, which were originally used to discharge the flood in the urban area, have now been transformed into sewage discharge rivers. In recent decades, the continuous advance of urbanization, the increase of urban residents' population and the improvement of residents' living conditions have caused the urban residents' water consumption and industrial water consumption to increase substantially. Moreover, Jiaozuo City is a typical coal city. Large amounts of coal mining result in a large area of water table decline and a large area of funnel area. In addition, the improper treatment of industrial waste and household waste causes large areas of surface water pollution. It further aggravates the contradiction between supply and demand of water resources (Cui *et al.* 2020).

Research methodology

Based on the questionnaire survey method, this paper randomly selected some residential areas in the old downtown area of Jiaozuo center and the urban periphery to conduct the survey. In order to reduce the errors in the survey process and ensure the quality of the obtained questionnaire, we conducted the survey in the form of field visit. The contents involved in the survey can be divided into the following aspects: (1) demographic indicators such as gender, age, education background, income and family resident population; (2) the water used by the respondents in terms of water consumption, personal hygiene, diet, toilet flushing, laundry, etc.; (3) respondents' awareness of water saving, water-saving measures and use of water-saving equipment; (4) the respondents' motivation to save water and the survey of changes in household water use.

The data adopted in the survey were sorted and input into the computer software SPSS 19.0 and Excel 2020. Firstly, descriptive data statistics were made by software to analyze the demographic indicators, water-use status and water-saving measures of residents. Then, using relevant statistical methods, the paper systematically studies the domestic water consumption of the original suburban residents in terms of water consumption, water-saving awareness and water-saving measures. Finally, the correlation analysis method SPSS 19.0 was adopted to analyze the main factors affecting the difference of household water consumption of the two types of residents and the degree of influence of each factor.

The survey was conducted from the end of October 2014 to the end of November 2014, and the respondents were the original urban residents and the original suburban residents in the central and peripheral urban areas of Jiaozuo. The questionnaire was distributed by cluster sampling and simple random sampling. The original urban residents of Jiaozuo City distributed 98 copies and recovered 86 copies. The original suburbanites distributed 106 copies and recycled 95. The total effective recovery rate was 82.7%, excluding invalid questionnaires (partially filled, perfunctory answers, etc.).

RESULTS

Demographic indicators of respondents

Through the survey statistics of demographic indicators such as gender, age and education of the former urban and former suburban residents, the results are shown in Table 1, the income of the former suburban residents was mostly concentrated in (RMB 1,500–2,999) middle and low income and (RMB 3,000–4,999) middle income, while the income of the former urban residents in the middle and high income was 11.9% higher than the former suburban residents, and the education level of the respondents was 17.5% higher than that of the former suburban residents. The education level of the former urban area residents receiving higher education was 17.5% higher than the former suburban area residents, the former urban area residents from the proportion of permanent household population to the former suburban area residents of the elderly cases was slightly higher than the former suburban area residents.

Results of the survey on the current situation of domestic water consumption of residents

Water consumption and water charges

The monthly water consumption statistics of residents are shown in Figure 1 below: the water consumption of former urban residents is mostly concentrated below 13 m^3 as high as 90.1%, which is 20.3% higher than that of former suburban residents; among former suburban residents who exceed 13 m^3 , they are mostly concentrated in the range of $14\text{--}20 \text{ m}^3/\text{month}$, and are much higher than that of the former urban residents; the proportion of former suburban residents who exceed $20 \text{ m}^3/\text{month}$ is slightly higher than that of former urban residents. In general, the water consumption of residents in the former suburbs is more than that of residents in the former urban areas. In the statistical results of residents' water consumption structure (Figure 2), it is easy to find that the largest proportion of water consumption is for washing, with both categories of residents exceeding 35%, while laundry and toilet flushing also occupy a larger proportion. Washing, laundry and toilet flushing together account for 87.3% of the total water used by urban residents.

Since November 2010, Jiaozuo City has adopted a two-step water tariff: 2.4 yuan/ m^3 for households with less than 13 m^3 and 3.1 yuan/ m^3 for those with more than 13 m^3 . The survey results show that the monthly water bill for households in the former suburbs is higher than that for residents in the former urban areas. Here the water bill accounts for a smaller proportion of residents' income, only 0.7%, which is less inhibitory on residents. In China's Ministry of Construction 'urban and rural water shortage research' research report, water costs accounted for the effect of different household income on the residents and the different psychological impact of water use, less than 1% of residents found it less inhibitory, when more than 2% of income, the residents experience a greater psychological impact of water use.

Table 1 | Resident demographic data

Gender of interviewee			Age of interviewee			Average education years of interviewee			Household composition			Monthly income		
Gender	The original city	The original suburbs	Age	The original city	The original suburbs	Year	The original city	The original suburbs	Person	The original city	The original suburbs	Yuan	The original city	The original suburbs
Male	56.8	40.4	<16	0	1.8	<6	5.4	9.4	<16	30.5	26.5	<1,500	14.3	22.2
			16–29	5.4	8.8	6–9	10.8	22.2				1,500–2,999	32.4	46.4
			30–49	51.3	61.4	10–12	27.1	29.6	16–55	32.6	39.7	3,000–4,999	28.3	18.2
Female	43.2	59.6	50–59	27.1	15.8	13–16	51.4	38.8				5,000–10,000	17.9	13.1
			>60	16.2	12.2	>16	5.3	0	>55	37.9	33.8	>10,000	7.1	0

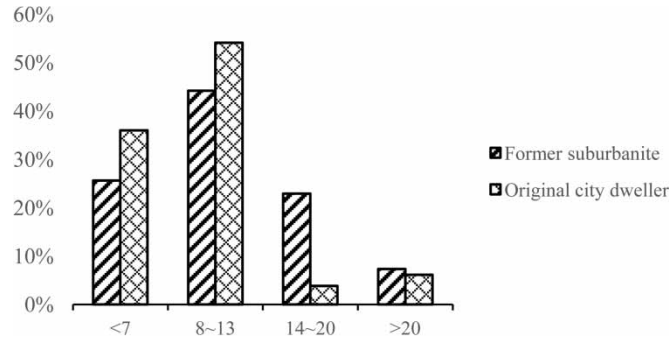


Figure 1 | Monthly water consumption for both types of residents.

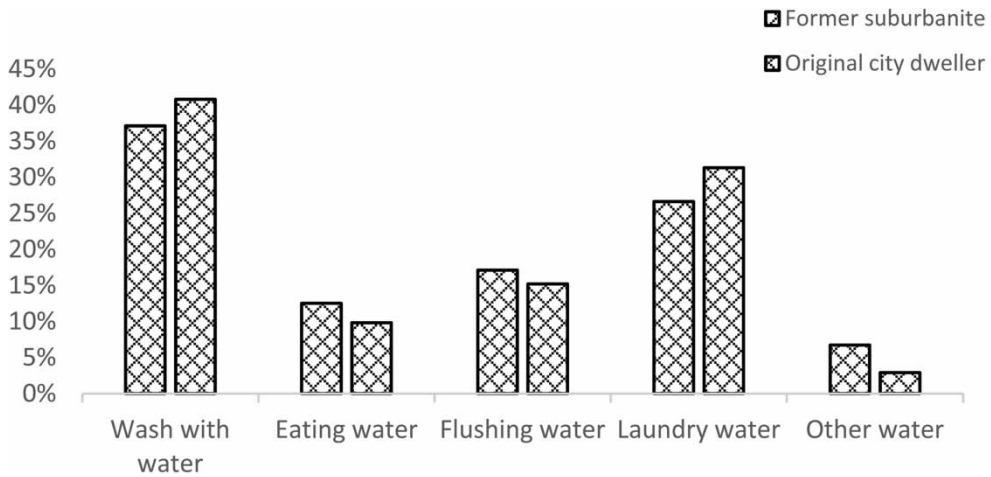


Figure 2 | Water structure comparison between the two groups of residents.

Water for washing and washing

As people’s disposable income continues to increase, the amount of water equipment in households continues to increase, and the ownership rate of household water heaters basically reaches 95% in both categories of residents, with some households owning more than one water heater. Figure 3 shows the results of the survey of water heater ownership in both

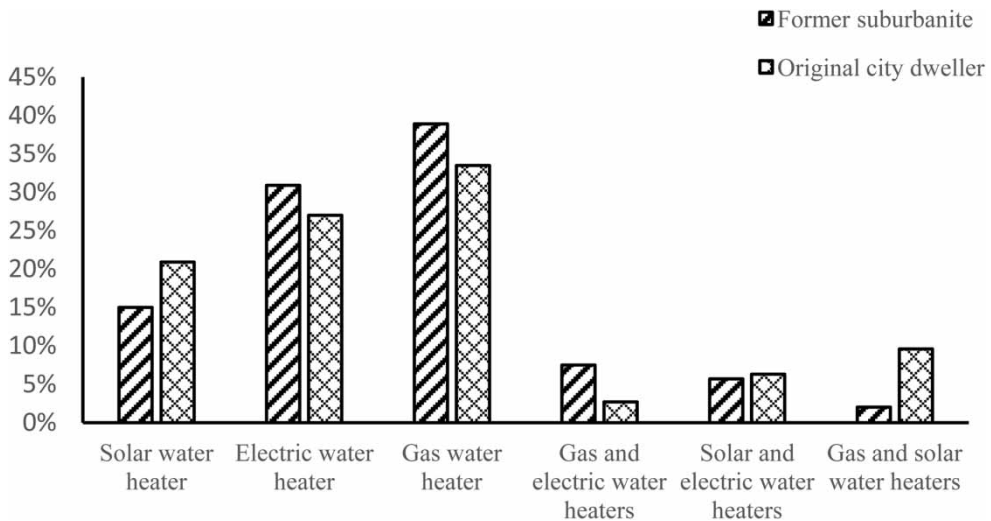


Figure 3 | Water heater ownership.

categories of residents. We can see that close to 80% of former suburban residents use gas or electric water heaters, and former urban residents also use these two types of water heaters most extensively, thus making it more convenient and stable when it comes to hot water supply.

According to the survey results (Figure 4), there are three main types of water heater use, bathing, kitchen pass-through hot water for washing dishes, and washstand pass-through hot water for washing faces. Among them, the proportion of the former suburbs for bathing are more than 90%, and only 5.7% for kitchen and washstand through hot water. From the viewpoint of the diversity of hot water use, the residents of the former suburbs have a more convenient supply of hot water.

In the winter bathing frequency survey (Table 2) as can be seen, the original suburban residents frequency distribution is more even, while the original urban residents concentrated in 5–9 times/month more than half of the residents, the two types of residents compared to the original suburban residents bathing frequency in 10–19 times/month ratio more than twice the original urban residents, according to the survey it can be seen that the main reason for this phenomenon, the original suburban residents more than 50% of the residents are also home bathing in winter. The main reason for this phenomenon is that more than 50% of the former suburban residents bathe at home in winter, while most of the former urban residents bathe outside. This is inevitably related to the more convenient hot water supply facilities for former suburban residents. The amount of water used by individuals for washing their face and teeth is small, less than 0.5 m³ per capita. In terms of personal water consumption for washing hair and feet, the per capita water consumption of residents in the former suburbs is less than that of residents in the former urban areas due to their personal habits.

Laundry situation

Washing clothes in residential water is another major water consumption item, accounting for 29.3% of the total water consumption. Therefore, the results of an in-depth survey on residents’ laundry frequency, washing machine ownership rate and washing machine use frequency are shown in Table 3 below: more than 50% of residents in the former urban and former suburban areas use automatic washing machines, while the ownership rate of water-saving washing machines is low, and the promotion of the use of water-saving washing machines is bound to save a lot of water resources.

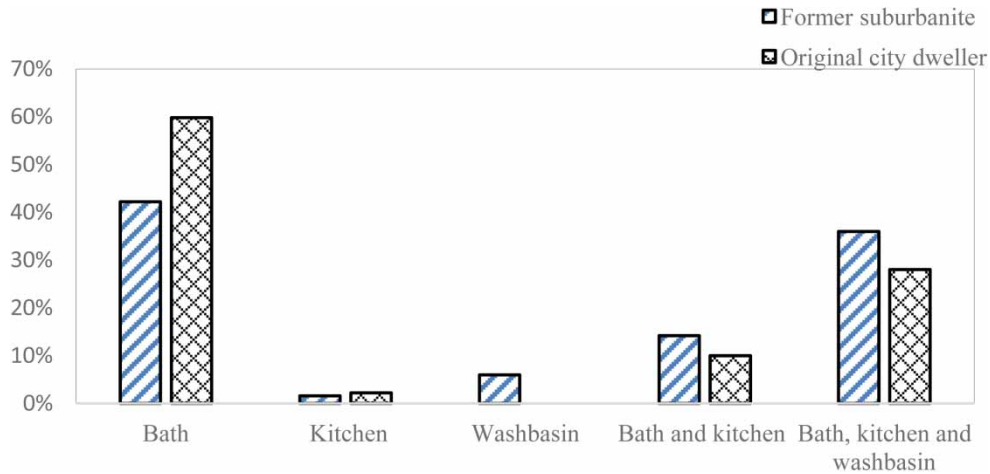


Figure 4 | Water for domestic hot water system.

Table 2 | Bathing frequency residents statistics

Baths (times per month)	The original suburbs	The original city
<5	28.20%	21.70%
5–9	21.80%	50.50%
10–19	44.60%	18.90%
>20	5.40%	8.90%

Table 3 | Winter laundry situation residents category

Type of washing machine	Residential washing machine ownership rate			Weekly laundry frequency of residents			Residents use washing machines weekly	
	The original city	The original suburbs	Laundry frequency	The original city	The original suburbs	Washing machine frequency	The original city	The original suburbs
Full automatic	51.40%	50.80%	< 3	72.20%	70.10%	< 3	78.40%	59.60%
Semi-automatic	43.20%	38.60%	3–5	13.90%	10.40%	3–5	16.20%	21.20%
Roller	2.70%	10.60%	5–7	11.10%	17.90%	5–7	2.70%	19.20%
Full automatic and roller	2.70%	0.00%	>7	2.80%	1.50%	>7	2.70%	0.00%

Residents weekly laundry frequency of three times/week was more than 70%, respectively, 72.2%, 70.1%, however, the frequency of washing machine use by residents of the original urban area was nearly 20% higher than the original suburban area, washing clothes more frequently residents. The use of washing machines followed frequently, and from the two types of residents in the frequency of washing machine use, the original suburban area residents washed more frequently. The main reason for this phenomenon is that most residents of the former urban areas are double workers, who are not at home during the day, and their clothes are mostly washed in the washing machine on weekends. While the former suburban residents include more women at home to do housework, laundry in time to wash, more often in the winter to use the washing machine to wash.

Flushing water situation

According to the survey results, the water consumption of household flushing accounted for 17.2% of the total water consumption. The statistics of the flushing survey results are shown in [Table 4](#): the type of commode is mostly bidets, and the difference between the daily flushing frequency of the two types of residents of the individual respondents is small; however, in the household flushing survey, the daily flushing frequency of the former urban residents is significantly higher than that of the former suburban residents, and from the statistics of the household information of the respondents, it is easy to find that the proportion of the elderly population is higher among the residents of the main former urban area, and it is relatively reasonable for this phenomenon to occur. However, the survey on the water consumption of flushing found that the residents of the former suburbs used more water than the residents of the former urban area. This was still due to the fact that most of the former urban residents are double-income workers, and the water used in using toilets cannot be expressed in the domestic water consumption of households.

Water-saving measures for residents

For the survey of residents' water conservation measures, items were set up in many aspects such as washing, laundry, toilet flushing, household hygiene and kitchen water use, and the residents were graded into five levels according to their compliance with water conservation measures, so as to understand the situation related to residents' water conservation measures. We also investigated residents' suggestions for water conservation measures and their motivation for saving water.

From the results of the survey, the implementation rate of water conservation measures for residents in the former urban area was higher than that of residents in the former suburban area, especially in the areas of centralized washing of clothes,

Table 4 | Flushing of toilets statistics types

Urinal type	The original suburbs	The original city	Number of individual flushing times (times per day)	The original suburbs	The original city	Number of household flushing (times per day)	The original suburbs	The original city
			<4	24.40%	22.60%	<6	27.30%	26.90%
Sitting	89.70%	86.50%	4–6	48.90%	45.20%	6–10	57.60%	38.50%
			7–10	22.20%	22.60%	11–20	12.10%	26.90%
Squat	10.30%	13.50%	>10	4.40%	9.70%	>20	3.00%	7.70%

washing of greasy kitchen utensils after wiping off the grease, and reuse of wastewater, etc. The proportion of residents who chose the five levels of compliance was 15% higher. In terms of shortening the bathing time to save water, the level of compliance for both types of residents is relatively low, as people take personal cleaning as a starting point and do not intentionally shorten the bathing time to save water. In terms of mopping, residents in the former suburbs are more likely to use more water than residents in the former urban areas, both in terms of frequency and water consumption. Here, 65.3% of the former urban residents will reduce the frequency of mopping by increasing the frequency of sweeping or using vacuum cleaners. Mainly mopping is more troublesome, while most of the former downtown residents need to work and cannot mop frequently. When it comes to checking for plumbing leaks, 78.3% of former urban residents check frequently, while only 41.7% of former suburban residents do so. In the survey, we learned that this is mainly because former suburban residents, who live in neighborhoods built in the last decade or so, are newer in various aspects such as decoration and do not need to check for leaks frequently.

The questionnaire set up not only assumed scenarios for residents to investigate water conservation measures, but also set up a number of questions for residents on water conservation measures suggested by residents to popularize water-saving facilities in the water conservation measures for statistics as shown in Figure 5 on the right: more than 75% of residents believe that water conservation measures through the use of water-saving appliances, sewage reuse, etc. can more effectively promote residents' water resources. Residents' motivation to save water was found through the survey that 43.2% of the residents in the former suburban areas were motivated by economic factors to save water and 37.4% were motivated by environmental factors, while only 28.7% of the residents in the former urban areas were motivated by economic factors and 45.7% were motivated by environmental awareness; the combined effect of the two factors was 10.2% and 8.5% respectively; the remaining part of residents' motivation to save water was caused by other factors.

Residents' awareness of water conservation and its influencing factors

In the process of investigating whether residents are aware of water conservation, the awareness of water conservation was investigated side-by-side by using a survey similar to that of water conservation measures, assuming water use scenarios and setting different water use behaviors for respondents to choose from, divided into five levels from high to low according to the degree of water conservation. In total 12 scenarios were set, resulting in a total of 60 points for awareness of water conservation. Regardless of the mean value of the scores, the plurality (Figure 6), the former urban residents have higher water conservation awareness scores than the former suburban residents.

Chinese scholars have studied the awareness of water conservation among urban residents in various ways; Jiang *et al.* (2007) used questionnaires to directly understand the factors influencing residents' awareness of water conservation, Mu *et al.* (2014) conducted a study of residents' water conservation behavior by establishing model variables, and Yang *et al.* (2013) used a nonparametric λ_2 statistical method to analyze the influence of rural residents' awareness of water conservation factors. In this paper, the correlation analysis method based on the data obtained from the questionnaire using SPSS 19.0 software was used to reflect the residents' awareness of water conservation through the degree of influence of the

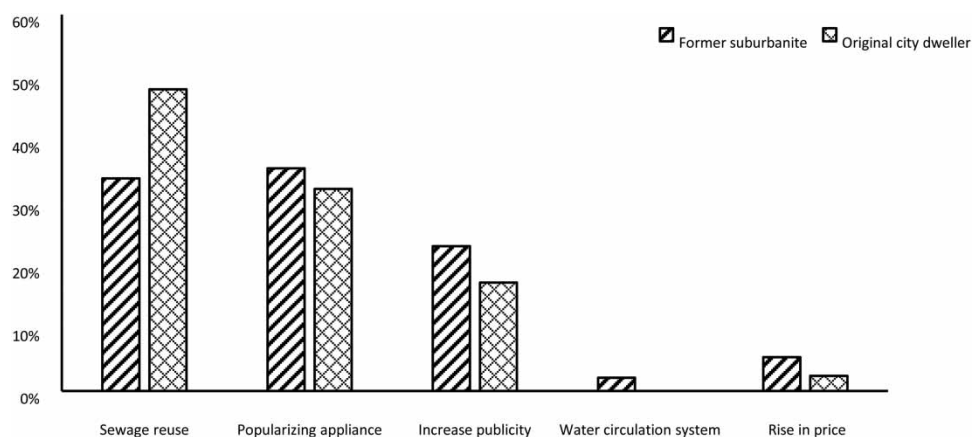


Figure 5 | Residents' suggestions on water-saving measures.

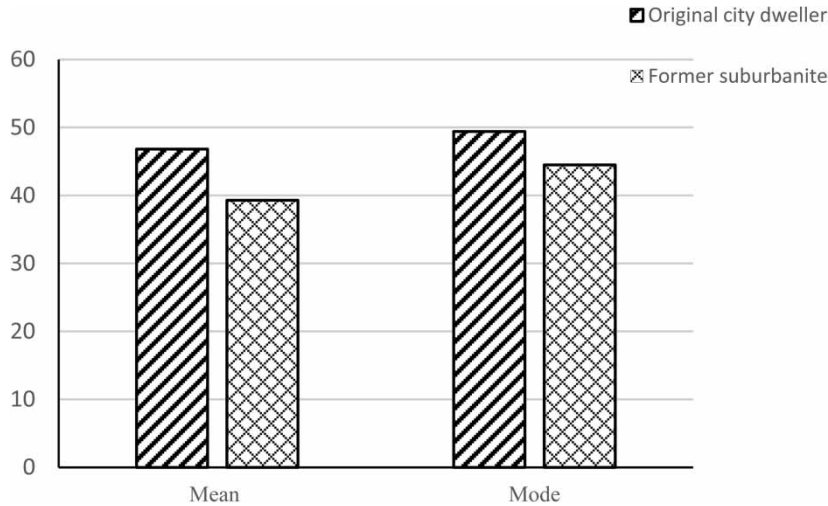


Figure 6 | Investigation of residents' awareness of water saving.

respondents' scores on their water conservation behavior in terms of their age, years of education, income, and years of moving to the former suburban areas.

The results of the correlation analysis of water conservation awareness (Table 5) showed that education had the most significant effect on residents' awareness of water conservation, and the longer the education received, the higher the awareness of water conservation.

Change in water consumption

In China, there are more results on the changes of urban residents' water consumption. Zeng *et al.* (2008) used differential hysteresis model and neural network model to forecast urban water supply; Li *et al.* (2014) studied the minimum standard of urban residents' water consumption; Tao *et al.* (2005) studied urban residents' water consumption by studying the current situation of urbanization; Zhang *et al.* (2010) predicted urban demand based on the Engel's coefficient based on and Hoffman's coefficient to forecast urban demand from a macro perspective. This paper investigates the changes in residents' water consumption in recent years and their own predictions of water consumption in future years.

According to the results of the survey (Table 6), 51.3% of the residents in the former suburbs think that their water consumption has increased in recent years, 36.5% have remained the same, and 12.2% have decreased; 27.1% of the

Table 5 | Main influencing factors of residents' water-saving consciousness

	Former suburbanite Pearson correlation coefficient	Original city dweller Pearson correlation coefficient
Average education years		
Age	0.313	0.341
Move to a fixed number of year	0.297	—
Income	-0.021	-0.005

Table 6 | Changes in water consumption in recent years and projections of water consumption in future years

	Former suburbanite		Original city dweller	
	Recent years	The coming years	Recent years	The coming years
Increase	51.3%	18.4%	27.1%	7.2%
Unchanged	36.5%	71.5%	66.7%	57.7%
Decrease	12.2%	10.1%	6.2%	35.1%

residents in the former urban areas have increased, 66.7% have remained the same, and only 6.2% have decreased. The increase in water consumption of former suburban residents is mainly due to the increase in electrical appliances, changes in living habits and the increase in population, while the decrease in water consumption is considered to be mainly due to the decrease in resident population and the constraint of water charges. The increase in water consumption of former urban residents is mainly due to an increase in the number of permanent residents in the household, while the decrease in water consumption is mainly due to an increase in awareness of water conservation and a decrease in population.

Residents in the former suburbs forecasted an increase of 18.4%, no change of 71.5%, and a decrease of 10.1% in water consumption in the next few years, while residents in the former urban area increased by 7.2%, no change of 57.7%, and a decrease of only 35.1%. The increase in water consumption of former suburban residents is mainly due to changes in living habits, improvement in living conditions and increase in population, while the decrease in water consumption is considered to be mainly due to the decrease in resident population and awareness of water conservation. The increase in water consumption by residents of the former urban areas was mainly due to the increase in the resident population of households, while those households that saw a decrease in water consumption were mainly due to an increased awareness of water conservation and a decrease in population.

DISCUSSION

China's urbanization is in a rapid development stage and the scale of cities is expanding, leading to an increasing pressure on urban water supply. According to the survey, the per capita water consumption of urban residents in Jiaozuo City, Henan Province is 153 L/d higher than the urban residential domestic water consumption standard (Ministry of Construction of the People's Republic of China. GB/T 50331-2002 2002), especially the per capita water consumption of residents in the former suburbs is higher, and the potential for water saving is even more considerable. This paper is based on a survey of residents' domestic water consumption in Jiaozuo City, along with an analysis of the influencing factors. The results show that with the increasing level of urbanization, people's living conditions continue to improve and many other factors influence the residents' water consumption. On the whole, residents in the former suburbs use more water than residents in the former urban areas.

The largest proportion of water consumption is for washing, while laundry and toilet flushing also account for a large proportion. The main influencing factors are, in descending order, the frequency of washing and bathing, the degree of water conservation in laundry, education level, income level, personal habits, age, and water costs. Compared with residents in the former suburbs, residents in the former urban areas use less water because they bathe less frequently, wash their clothes more centrally and use washing machines more frequently, sweep or vacuum more often and mop less frequently, and so on.

Residents in the former suburbs are motivated to save water mainly for economic reasons, and the implementation rate of water conservation measures is relatively low, while residents in the former urban areas are motivated by environmental awareness, and the implementation rate of water conservation measures is higher, especially in the areas of centralized washing of clothes, washing of greasy kitchenware after wiping off the grease, and reuse of sewage. Therefore, it is particularly important to raise residents' awareness of environmental protection. In addition, there is a positive correlation between the time of education, age and years of moving in and residents' awareness of water conservation, with education having the most significant effect on residents' awareness of water conservation, with residents in the former urban areas having higher education than residents in the former suburban areas, and therefore having higher awareness of water conservation than residents in the former suburban areas.

Most of the former suburban residents believe that the increase in water consumption in recent years is mainly due to the increase in electrical appliances, changes in living habits and the increase in population, while some former urban residents predict that water consumption will decrease in the next few years due to the increase in awareness of water conservation and the decrease in population. To a certain extent, this indicates that the pressure on urban water supply is gradually increasing and that water conservation by residents is an important means to solve the current water stress.

Based on the above study, recommendations for residential water conservation are made in the following areas:

1. The survey results show that residents are prone to water wastage mainly in the areas of washing, laundry and toilet flushing, accounting for 87.3% of total water consumption, which has a large potential for water saving. Residents should be encouraged to use bath tubs and increase the popularity of water-saving devices for toilets and dishwashing. In addition,

since the current ownership rate of water-saving washing machines in households is low, there is a need to promote the use of water-saving washing machines, which will save a lot of water resources;

2. Government departments should strengthen the publicity of residents' water conservation and enhance residents' awareness of water conservation. Due to the positive externality of water-saving behavior to society, according to Pigou theory, appropriate subsidies should be given to residents who use water-saving appliances, comprehensively promote the reasonable water price system, and stimulate residents to make rational use of water resources.
3. Strengthen the maintenance and improvement of aging pipe network, increase the rational utilization and development of rainwater and sewage, and government departments increase the investment and management of secondary water facilities, so as to ensure the normal supply of domestic water for residents.

Due to time constraints, the survey scope and analysis methods in this study affected the accuracy of the prediction results to a certain extent. In future studies, the analysis of urban residents' domestic water demand should not only rely on the results of literature and questionnaire surveys, but also introduce the parameters of relevant water demand prediction models and evaluate the applicability of the models. We should study the differences in the hierarchical water demand of residents in different regions, and forecast the domestic water demand at different levels in the region and analyze its reasonableness, taking into account the future regional economic and social development scenarios.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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