On the factors influencing public knowledge and acceptance of reclaimed water from a survey of three cities in northern China

Zhongfan Zhu, Hongrui Wang and Aihua Li

ABSTRACT

In this study, we analysed the survey results regarding the level of public knowledge about, and general attitudes towards, reclaimed water in Jinan, Weifang, and Yantai, three cities in northern China that experience serious water shortages. The objective is to identify the factors influencing public knowledge and acceptance of reclaimed water and determine the hurdles of water reuse applications. The results showed that: (1) educational background was moderately correlated, and age and monthly income were weakly correlated, with the respondents' knowledge about water resources and use; (2) gender, occupation, and economic income were not related to public attitudes toward reclaimed water, and older people and those with higher educational backgrounds were more willing to accept the use of reclaimed water than were other respondents. This study could provide a valuable reference in other regions of China and developing countries facing similar issues of reclaimed water. The knowledge of this study will help to overcome public acceptance hurdles in other projects.

Key words | case study, northern China, public acceptance, public knowledge, reclaimed water, water reuse

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INTRODUCTION

China experiences serious water shortages. It is one of the 13 countries with the lowest water availability worldwide, and the per capita water availability in China is about a quarter of the global average. Because of its rapid economic growth and urbanization in recent decades, the demand for water in China has increased dramatically (Cheng *et al.* 2013), and it has been estimated that China's water demand will reach 6.6×10^{11} m^3 by 2020 (Cheng *et al.* 2013). With a long-term annual precipitation of 660 mm, groundwater and surface water resources in China are limited. However, wastewater discharges are high and, according to the Statistical Yearbook of China, reached 735.3×10^8 tons in 2015, which caused a deterioration of the aquatic environment in some rivers, lakes, and reservoirs, thereby reducing the supply of fresh water resources (Lyu *et al.* 2016). To address the disparity between water demand and the supply of fresh water, the government in China is attempting to ensure efficient use of fresh water resources by, for example, diverting surface water, groundwater, and transferring water from the Yellow and Yangtze Rivers to water-scarce areas. The government is also striving to develop alternative sources of water, such as reclaimed water (reuse of recycled water), rainwater harvesting, and seawater desalination. Of these alternatives, reclaimed

doi: 10.2166/wrd.2018.049

water has an important role. Locally available, reliable, and, compared with other alternative water resources, relatively low-cost, reclaimed water is used in many areas of China (Yi *et al.* 2011). Many recently constructed wastewater treatment plants (WWTPs) and water reclamation plants now supply reclaimed water for various applications, such as industrial cooling water, agricultural irrigation, and landscape watering. According to statistical data provided by the Water Management Centre of the Chinese Ministry of Water Resources, 924 WWTPs have been constructed all over the country and the total utilization quantity of reclaimed water reached 56.9×10^8 m^3 by the end of 2015. Moreover, to promote the development of reclaimed water, the government in China has released many policies and regulations to encourage its production, use, and management and, for example, will give specific subsidies or tax exemptions to various stakeholders and control the amount of water for some applications. As a result, reclaimed water is making an increasingly important contribution to water resources management in China.

Successful implementations of reclaimed water programmes depend heavily on public involvement and attitudes, as public opposition may hinder the advancement of reclaimed water projects (Hartley 2006; Hurlimann & Dolnicar 2010). For example, to alleviate shortages in the fresh water supply, Toowoomba City Council in Queensland, Australia proposed a 'Water Futures Initiative' in July 2005, which included the construction of an advanced water treatment plant to provide potable-quality reclaimed water that would meet much of the region's demand. However, because of increasing public opposition in Toowoomba, a referendum was announced to ask the residents whether they were supportive of the water futures project in March 2006. Despite the efforts of the Toowoomba City Council to rescue the initiative from March 2006 onwards, the majority (62%) of Toowoomba's residents voted against the proposed project in July 2006, with the result that the scheme was finally abandoned. Many reclaimed water projects have failed in various countries because of a lack of community support (Hurlimann & McKay 2004; Hartley 2006). Therefore, it is very important to understand the public perception of, and attitudes towards, reclaimed water to ensure the success of reclaimed water programs.

Public perceptions and attitudes toward the use of reclaimed water have been investigated in the USA (Sims & Baumann 1974; Ormerod & Scott 2013), Australia (Fielding & Roiko 2014; Fielding *et al.* 2015), UK (Jeffrey & Jefferson 2003; Aitken *et al.* 2014), Middle East (Carr *et al.* 2011), and Africa (Adewumi *et al.* 2010). Some results indicate that the public prefers to use reclaimed water in low- and intermediate-body-contact applications, such as garden irrigation, landscape irrigation, and firefighting, and public support for using reclaimed water and the degree of body contact of reclaimed water are negatively correlated (McKay & Hurlimann 2003; Fielding *et al.* 2015; Hurlimann & Dolnicar 2016). From a survey of five US and Australian cities, Marks (2006) reported that, while the public were generally highly receptive towards the use of reclaimed water in industrial cooling processes and irrigation of golf grounds, public acceptance of using reclaimed water in vegetable crops and household garden irrigation was variable (Marks 2006). The distribution of positive information and specific education activities may help to increase public acceptance of reclaimed water use (Alhumoud *et al.* 2003; Tsagarakis & Georgantzis 2003). Moreover, some studies have explored how socio-demographic attributes influenced public acceptance of reclaimed water. Friedler *et al.* (2007) carried out a survey in Israel and showed that the gender, age, marital status, educational level, and income of those surveyed was not related to their support for reclaimed water reuse with medium-body-contact. In the USA, Cuervaa *et al.* (2016) reported that ethnicity, education, metro/non-metro status, and income of survey respondents influenced their degree of acceptance of reclaimed water reuse, but that gender had no significant effect on the survey responses. Some studies also found that, of all respondents, those more than 50 years old were the most unwilling to accept water reuse schemes, and highly educated people were more likely to use reclaimed water (McKay & Hurlimann 2003; Tsagarakis & Georgantzis 2003).

As a developing country with a unique culture and tradition, people's perceptions and attitudes toward reclaimed water in China are still not well developed. In recent decades, the Chinese Government has considered the technology, costs, and benefits of reclaimed water projects, and the environmental or health risks, but has tended to ignore the public perception and acceptance of reclaimed water.

With rapid developments in economic growth and public media (such as television and the internet), the Chinese public has become more knowledgeable about reclaimed water, and has expressed concern about the environmental aspects of reclaimed water projects (Chen *et al.* 2015). Therefore, so that reclaimed water schemes can be successfully implemented, there is an urgent need for policy-makers in China to understand public perception of, and the degree of openness towards, reclaimed water.

Recently, Zhu *et al.* (2018) conducted a questionnaire survey regarding public knowledge and perception toward reclaimed water in 13 cities in Shandong province, northern China. The results showed that the people in Shandong lack a general understanding of water resources, and the people show a low receptivity toward the application of reclaimed water as domestic potable water. However, a deep analysis and discussion regarding the influence of different factors on the public knowledge and acceptance toward reclaimed water were not presented in their study, and furthermore the question regarding which factors seem to be the hurdles of water reuse applications still remain unclear. In this study, we focus on the factors influencing public knowledge and acceptance of reclaimed water by analysing the survey results in three representative cities in Shandong province, namely Jinan, Weifang, and Yantai located near the western, middle and eastern part of the province. These three cities are under different levels of economic development but all of them experience serious water shortages because of rapid economic development and population growth. In these cities, reclaimed water has an increasingly important role in addressing water issues. Further, while the use of reclaimed water is steadily increasing in these three cities, this resource remains underused and is still in its initial stages, which, as shown by statistical data provided by the Water Management Centre of the Chinese Ministry of Water Resources, closely resembles the overall development situation of reclaimed water across China.

The socio-demographic characteristics of the participants and the questionnaire design toward reclaimed water uses are outlined in the Materials and methods section. The relationships between socio-demographic attributes of the respondents and their knowledge of, and attitudes towards, reclaimed water and a further discussion are presented in the Results and Discussion sections, respectively. Finally, concluding remarks are provided in the Conclusions.

MATERIALS AND METHODS

The study area

The geographic locations of Jinan, Weifang, and Yantai are shown in Figure 1. This study had 600 participants, 200 from each city. Of the respondents, 62.5% were male and 37.5% were female. Those aged between 21 and 30, younger than 20, and between 40 and 50 accounted for 52.2, 18.2, and 10.5% of the respondents, respectively. The monthly incomes of 34.5, 30.0, and 22.5% of the respondents were between 2,000 and 4,000 RMB, less than 2,000 RMB, and between 4,000 to 6,000 RMB, respectively. Statistics for Shandong Province for 2015 indicated that province-wide, 15.1% of the population was aged from 0 to 14 years, 75% was between 15 and 64 years, and 9.9% was older than 65 years. The respondents for this survey were randomly chosen from different areas of Jinan, Weifang, and Yantai, including urban and rural areas, public places, and residential living areas.

Questionnaire

The questionnaire was comprised of three parts. The five questions in Part I were designed to obtain information about the socio-demographic backgrounds of the respondents, including gender, age, educational background, occupation, and monthly income. Part II comprised six questions with multiple choice answers, designed to determine what the general public knew about water resources in Jinan, Weifang, and Yantai. Respondents were asked for information about the main water source, the largest water consumer, the water shortage situation, the largest sewage source, where wastewater was mainly discharged, and if they used reclaimed water in their daily life. The attitudes of the respondents towards different uses of reclaimed water were tested in Part III. In this part, 12 different uses of reclaimed water were investigated. They were classified into five groups, including landscape reuse; industrial reuse; urban non-potable use; agricultural, forestry, and

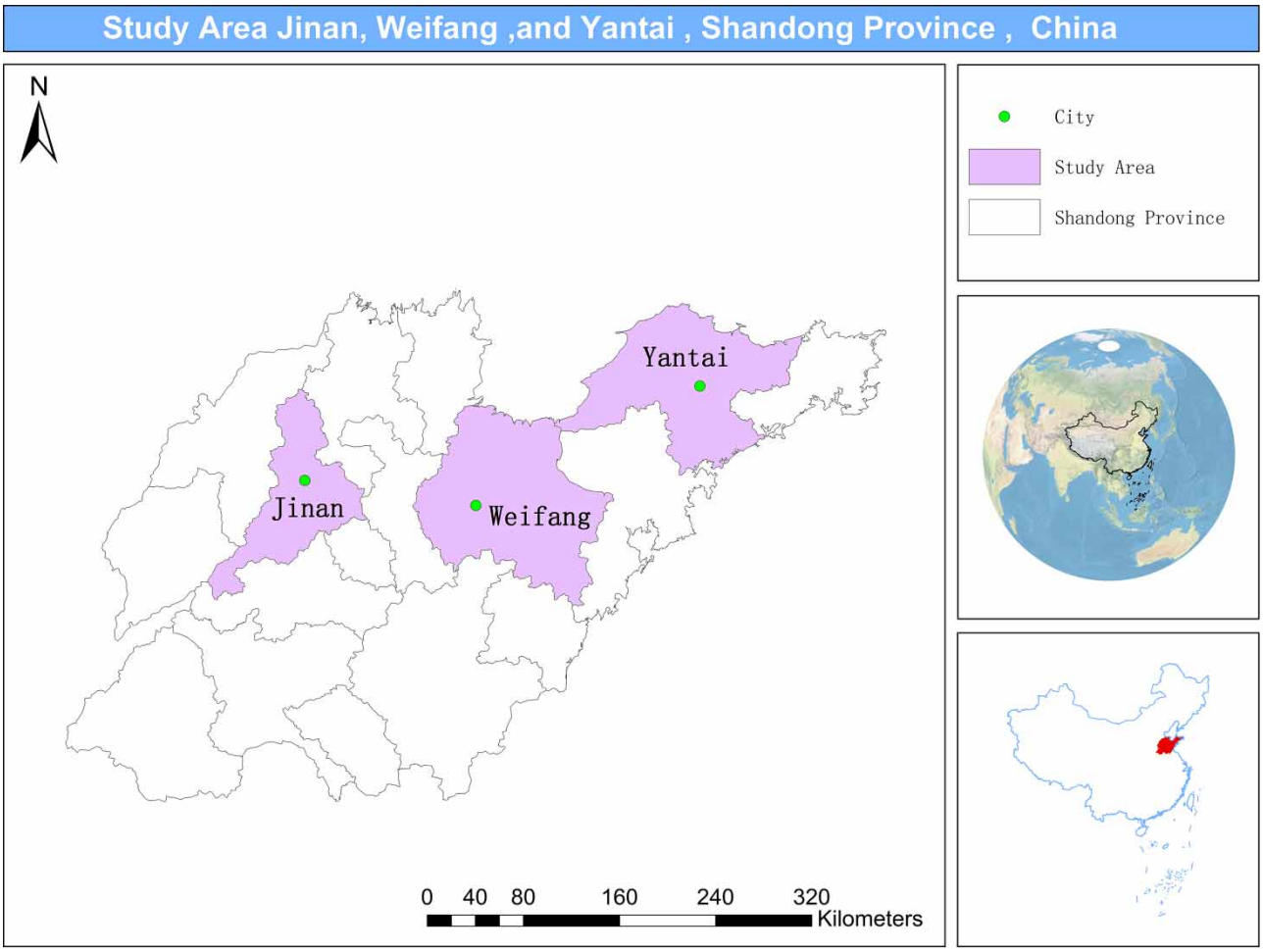

Figure 1 | Geographic locations of Jinan, Weifang, and Yantai, China.

animal husbandry reuse; groundwater recharge, and domestic potable and non-potable water. Further, the questionnaire also explored whether the respondents were willing to accept using reclaimed water in daily life, accept rainwater reuse, pay for sewage treatment, and accept a water price adjustment.

The questionnaire tested its reliability among almost 100 participants before distributing it to the respondents. The results of the preliminary test showed that the questionnaire was consistent and appropriate, and that it could provide reliable information. During the interviews, our students had face-to-face interviews with each respondent (the places were randomly chosen from different areas of Jinan, Weifang, and Yantai, including urban and rural areas, public places, and residential living areas). Each respondent was asked to choose one answer for each question and they were not given any hints or suggestions. After the interview, our students checked the answers for each questionnaire. In total, 601 questionnaires were distributed, and finally 600 questionnaires were validated (only one questionnaire contained some uncompleted contents). The content of the questionnaire can be found in Zhu *et al.* (2018).

RESULTS

The relationship between the ages of the respondents and their knowledge about water resources is shown in Figure 2. This shows that the people younger than 40 years (the groups including those younger than 20, between 21 and 30, and from 31 to 40) were much more knowledgeable about the main sources of water than those older than

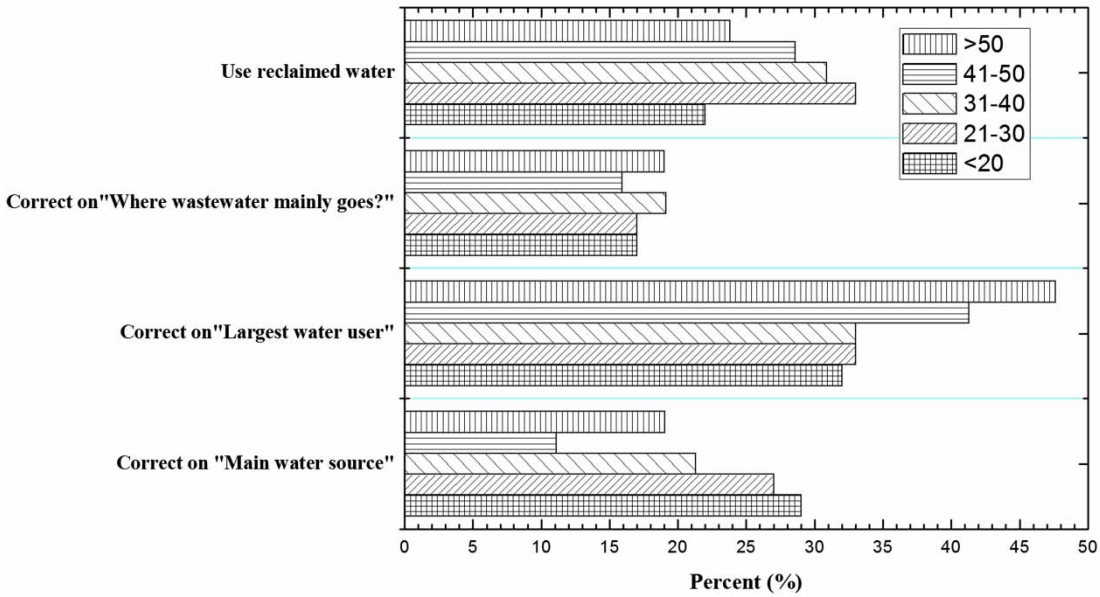

Figure 2 | Responses to selected questions by age group.

40 years, which included those between 41 and 50 years and those older than 50 years. There was no significant difference among the age groups younger than 40 years for the question about the largest water user, but the group over 50 years was the most knowledgeable. The respondents from 31 to 40 years were most likely to know where wastewater mainly went, whereas those between 41 and 50 years knew little. Of all the groups, the younger respondents, between 21 and 30 years, were the most willing to use reclaimed water, whereas of all the groups, the old people over 50 years were the most resistant to using reclaimed water.

The influence of educational background on the knowledge of the respondents about water resources is shown in Figure 3. Those educated to Bachelor degree level had much more knowledge about the main water source than the other educational groups. With the exception of those with high school degrees, the higher the education background, the more knowledgeable the respondents were about the largest water user and where wastewater mainly went. The highly educated respondents were generally more willing to use reclaimed water.

The relationship between the monthly incomes of the respondents and their knowledge about water resources is shown in Figure 4. Those with monthly incomes under 2,000 RMB and from 2,000 to 4,000 RMB were the most knowledgeable about the main source of water. Middle-income respondents (those with incomes from 4,000 to

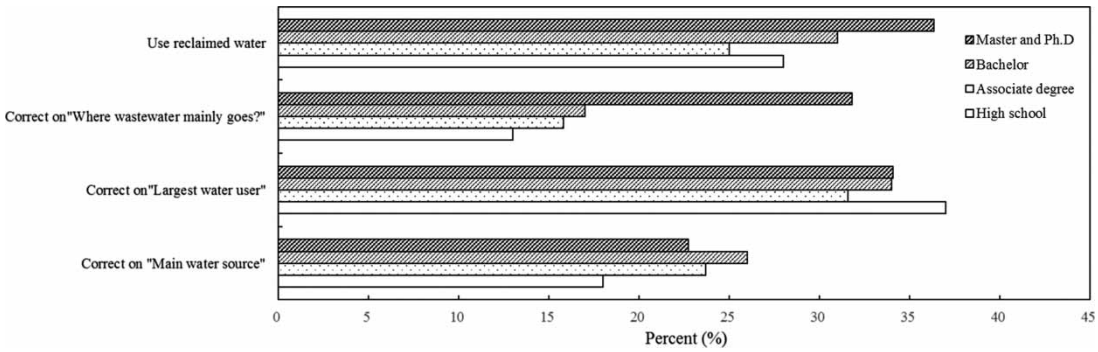

Figure 3 | Responses to selected questions by educational background group.

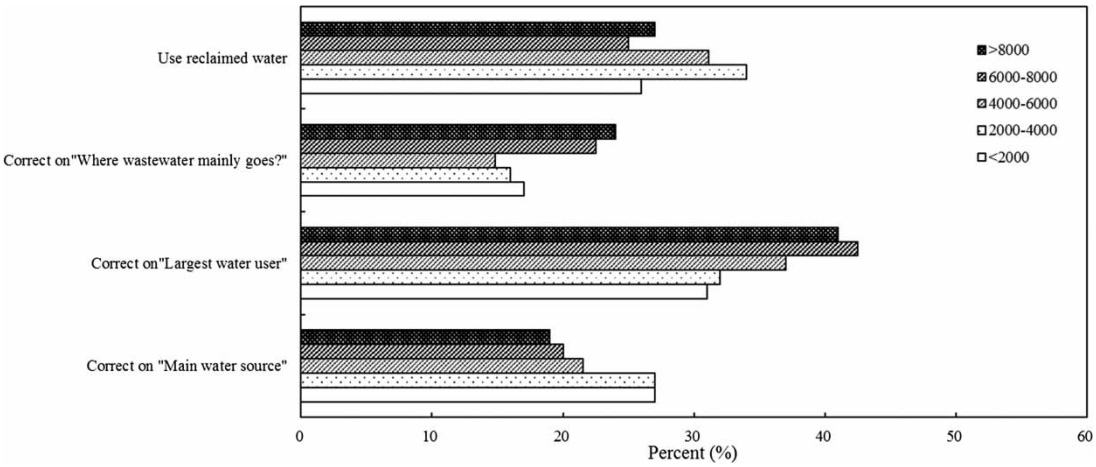

Figure 4 | Responses to selected questions by monthly income (RMB).

6,000 RMB and from 6,000 to 8,000 RMB) knew more about the largest water user than other people. Of all the respondents, those with incomes of between 4,000 and 6,000 RMB knew least about where most sewage went. Those with incomes between 2,000 and 4,000 RMB and between 4,000 and 6,000 RMB were much more willing to use reclaimed water than those with the lowest incomes (under 2,000 RMB) and those with the highest incomes (between 6,000 and 8,000 RMB and more than 8,000 RMB).

The responses of different age groups to the selected questions are shown in Figure 5. Those over 50 years old were always the most willing to accept reclaimed water and rainwater reuse, and to use reclaimed water for non-potable purposes. While older people were generally more willing to accept the use of reclaimed water as a source of domestic non-potable water, those older than 50 years old were the most resistant towards using reclaimed water as domestic potable water. Apart from the 21 to 30 age group, the older the respondents, the more willing they were to pay for sewage treatment. The respondents older than 50 were also the most supportive of water price reform.

The relationship between the educational background of the respondents and their acceptance of the use of reclaimed water is illustrated in Figure 6. People with a higher educational level were more willing to accept reclaimed water, use it as a domestic potable water source, and pay for sewage treatment. Highly educated respondents (with Bachelor, Masters, and PhD degrees) were more willing to accept rainwater reuse, use reclaimed water for domestic non-potable purposes, and accept water

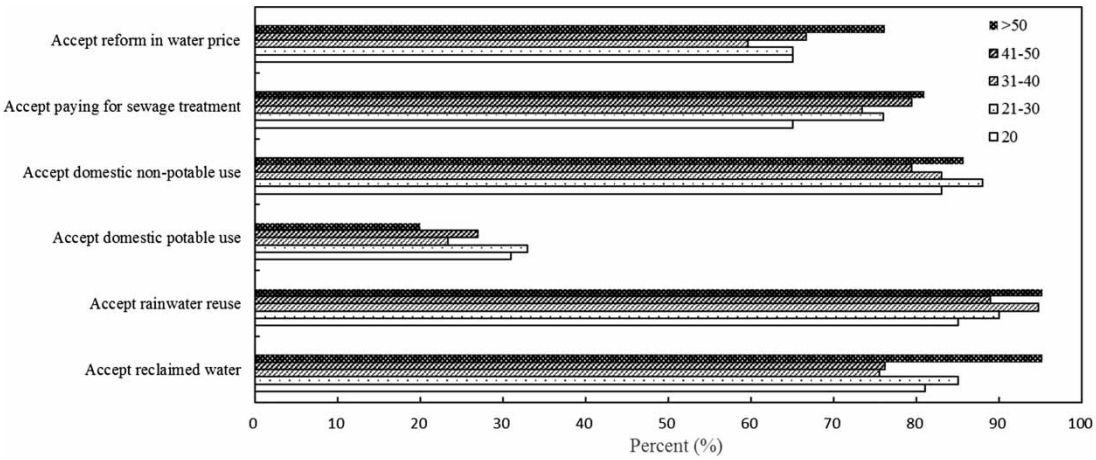

Figure 5 | Public acceptance of reclaimed water uses by age group.

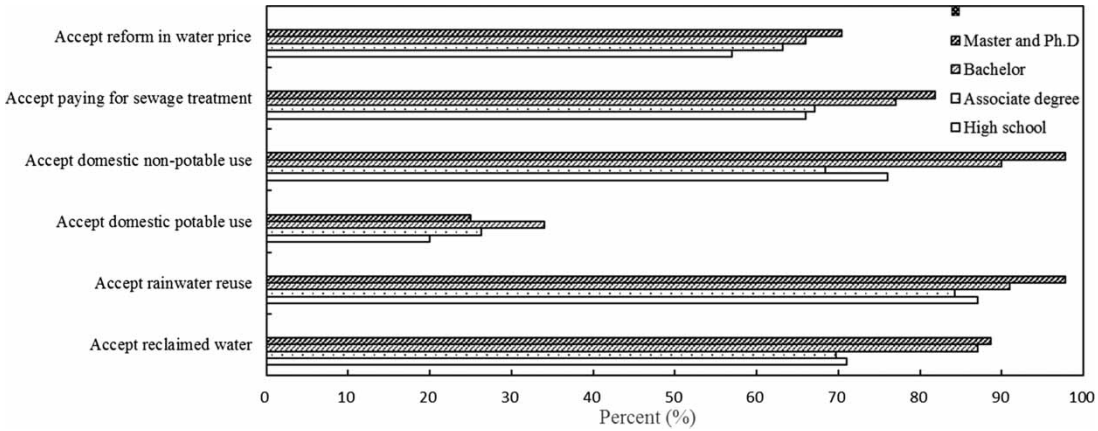

Figure 6 | Public acceptance of reclaimed water uses by educational background.

price reform than those with a high school education or associate degree.

DISCUSSION

Identifying public concerns about reclaimed water plays an important role in better implementation of reclaimed water projects. While such projects are developing rapidly in China, there are insufficient studies of people's perceptions and attitudes towards reclaimed water. In this study, a questionnaire survey was used to investigate public knowledge about, and attitudes towards, reclaimed wastewater in Jinan, Weifang, and Yantai in northern China.

The results showed that the people in Jinan, Weifang, and Yantai strongly agreed to using reclaimed wastewater in some applications, such as toilet flushing, flushing road dust, landscape purposes, washing cars, fountains, and industrial cooling water. Respondents were generally more accepting of non-potable applications of reclaimed water, as shown in other studies. For example, Dolnicar & Schäfer (2009) in their survey in Australia, showed that the public strongly agreed with using reclaimed wastewater in some non-potable applications, such as toilet flushing, watering the garden, firefighting, irrigation of sports fields, and car washing, and Friedler *et al.* (2007) also reported a similar result.

The results show that the public was not receptive to using reclaimed wastewater to irrigate agricultural land, recharge groundwater, or to supplement rivers and lakes. In most communities, municipal wastewater is the main source of reclaimed water. The low acceptance of wastewater to irrigate agriculture and recharge groundwater may reflect people's concerns about biological and chemical pollution. The low acceptance of using wastewater to supplement lakes and rivers may reflect public concerns about aesthetic problems, such as odour, colour, turbidity, and health issues. Higgins *et al.* (2002) concluded that people are mainly concerned about health issues, such as pathogens and chemical agents, related to reclaimed water. Pham *et al.* (2011) also showed that health issues and concerns about odours from reclaimed wastewater were the main reasons for opposing the use of reclaimed water in Australia.

Skin contact with reclaimed water is an important factor that influences the public's willingness to use reclaimed water in different applications. Many studies have shown that the public's willingness to use reclaimed wastewater is inversely correlated with the level of skin contact. Therefore, for applications such as bathing, washing clothes, and swimming, the receptivity is reduced. Consistent with other previous studies (Miller & Buys 2008; Pham *et al.* 2011; Zhang *et al.* 2012), the respondents in this study were least receptive towards using reclaimed wastewater as domestic potable water.

Wester *et al.* (2015) showed that older people could see more risks with reclaimed wastewater than other people, whereas Friedler *et al.* (2007) and Baghapour *et al.* (2017) found that age and receptivity to reclaimed water were not correlated. This study showed that the age of respondents was weakly related to their knowledge about water

resources, and that older people were more willing to accept reclaimed water for different applications than other people. This may be because the older people had more experience of drought in northern China and so had deeper feelings about severe shortages of water resources than younger people, which perhaps motivated them to accept reclaimed water as an alternative water resource. People who have experienced water shortage conditions are generally more willing to use reclaimed wastewater. Pham *et al.* (2011) also showed that the awareness of the people about water resource shortages and their willingness to use reclaimed wastewater were significantly correlated.

Gu *et al.* (2015) showed that people with higher income levels were more inclined to use reclaimed wastewater and were more willing to pay for it than others. In this study there were no significant differences between the different income groups.

Chen *et al.* (2015) reported that the beneficial use of reclaimed water was admired by water resource managers, industrial sectors, and researchers, who strongly supported progress in the reuse of reclaimed water. However, some other stakeholders showed concerns about the potential risks of using reclaimed water. The results of this study showed that the occupations of respondents were not related to their acceptance of reclaimed water use.

Some studies have shown that educational level and acceptance of reclaimed wastewater reuse were correlated. For example, Gu *et al.* (2015) found that people with a higher level of education were more inclined to use reclaimed wastewater and were more willing to pay for reclaimed water than those with a lower level of education. Wester *et al.* (2015) showed that people with lower levels of education were more uncomfortable with reclaimed water reuse in the USA, while Alhumoud & Madzikanda (2010) found that people with higher educational levels were more interested in reusing wastewater. The results of Dolnicar & Schäfer (2009) and Baghapour *et al.* (2017) were similar. This present survey also showed that people with a higher educational level were more receptive to using reclaimed water in many applications than those with a lower educational level. In general, people with a higher educational background have more information and knowledge about reclaimed water, especially about the benefits and risks of reclaimed water, and have more opportunity to participate in reclaimed water projects than those with lower levels of education. These people, therefore, may be more willing to use reclaimed water in a wider range of applications than those with lower education levels.

Wilson & Pfaff (2008) pointed out that ideological opposition sometimes prevented wastewater reuse. There is also controversy about whether religious beliefs affect people's receptivity toward reclaimed water; some researchers have shown that religious beliefs were related to acceptance of reclaimed wastewater reuse, while other researchers denied the existence of this relationship (Alhumoud & Madzikanda 2010; Wester *et al.* 2015; Cuervaa *et al.* 2016). The religious beliefs of respondents were not considered in this survey, and may be worth considering in future studies.

The survey results show that the inhabitants of Jinan, Weifang, and Yantai lack basic knowledge about their water resources. If the public is to make rational decisions about water supply issues, they need to have a better understanding of the basic facts about water supply as, with better understanding, people will be motivated to take reasonable actions. The public is generally not very accepting of domestic uses of reclaimed water, and negative feelings increase when potable use is considered. By sharing more positive experiences of, and information about, the quality of reclaimed water, attitudes should improve. The mass media and government are responsible for disseminating information about water resources and the quality and benefits of using reclaimed wastewater. Also, specific actions could be taken to help build public confidence about the quality and benefits of reclaimed water. For example, direct site visits to WWTPs, seeing the effluent from such facilities, and making the public more familiar about how reclaimed water is used in settings for which positive attitudes already exist, could play an important role in increasing public acceptance of reclaimed water use (Gu *et al.* 2015; Baghapour *et al.* 2017).

CONCLUSIONS

In this study, we analysed the survey results regarding public knowledge and public acceptance towards reclaimed water reuse for a variety of applications in three representative cities: Jinan, Weifang, and Yantai, northern China,

conducted by Zhu *et al.* (2018). The objective is to identify the factors influencing public knowledge and acceptance of reclaimed water and determine the hurdles of water reuse applications. The analysis results show that the educational background of respondents was related, whereas age and monthly income were only weakly related, to the respondents' knowledge about water resources and use. The gender, occupation, and economic income of the respondents were not related to public attitudes towards reclaimed water, but older people and those with higher educational background were more willing to accept the use of reclaimed water. This result may be useful for other regions of China and other developing countries where reclaimed water is used to alleviate water shortages.

It would be interesting to expand the areas and the number of the respondents (with different socio-demographic characteristics) covered by the survey in future studies. Comparing public perception and acceptance in different regions (or countries) all over the world will be valuable to help the managers tackle the hurdles of water reuse projects across the world, among which the study of Hurlimann & Dolnicar (2016) is a good example.

ACKNOWLEDGEMENTS

This research was supported by the National Natural Science Foundation of China (Number: 51479003). The authors would like to thank those students who helped with the survey and the data analysis. Interested readers may contact the authors for the original data of the survey in this study.

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First received 11 July 2018; accepted in revised form 27 September 2018. Available online 25 October 2018