

Article

Perceptions of Different Stakeholders on Reclaimed Water Reuse: The Case of Beijing, China

Weiping Chen ¹, Yanying Bai ^{2,*}, Weiling Zhang ¹, Sidan Lyu ¹ and Wentao Jiao ¹

¹ State Key Laboratory for Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China;

E-Mails: wpchen@rcees.ac.cn (W.C.); zhangweiling10@mails.ucas.ac.cn (W.Z.);

lvsidan01@163.com (S.L.); wtjiao@rcees.ac.cn (W.J.)

² Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

* Author to whom correspondence should be addressed; E-Mail: baiyy@igsnr.ac.cn;
Tel./Fax: +86-10-6488-8202.

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Abstract: Public involvement is critical to the successful implementation of reclaimed water reuse programs. Based on the participatory research method, we studied the attitudes of the stakeholders who are involved in reclaimed water reuse in Beijing, China. Results showed that the general public's knowledge on water resources was poor, while their awareness on reclaimed water reuse was high. The general public showed a strong acceptance of non-contact and non-potable reclaimed water reuse, but their acceptance of the three major water reuse types of river water supplement, park water supplement, and agriculture irrigation was not high. The beneficial use of reclaimed water was admired by water resource managers, industrial sectors, and researchers, and these stakeholders strongly supported the advancement of reclaimed water reuse. However, some of the stakeholders showed concerns about the potential risks from reclaimed wastewater reuse. Among them, risks from waste water treatment facilities were the biggest concern. Stakeholders' perception of reclaimed water was influenced by their social-economic attributes. This study will enrich the current survey findings on public perception of reclaimed water reuse, particularly in developing countries.

Keywords: public awareness; stakeholder willingness; wastewater reuse; water resource; risk management

1. Introduction

As the urban water shortage grows and water purification technologies advance, municipal wastewater is being reclaimed and reused in increasing volumes and for more purposes around the world [1]. Beijing, China has a successful urban water reuse program. Its annual reclaimed water reuse has risen rapidly from 260 million tons in 2005 to 800 million tons in 2013 [2]. The amount is expected to exceed 1000 million tons by 2015 [3]. The municipality strives to make reclaimed water a key component of the water resource management scheme, accounting for 20% of the total water supplies.

Besides the public health, environmental, and economical concerns, successful water reuse programs also depend on acceptance and support from the general public [4]. As the ratepayers will be directly impacted and eventually have to pay for the costs, public opposition may potentially be an obstacle to advance reclaimed water reuse projects. In 1994, San Diego (California, USA) proposed that reclaimed wastewater undergo tertiary treatment processes including coagulation-precipitation, granulated activated carbon filtration, microfiltration, and UV disinfection so that the treated water can be used as part of the supply for the city's source water storage reservoir. While the proposal gained the support of technical experts and regulatory approval by the California Department of Health Services, the plan failed to materialize due to public opposition and local politics [5].

The public attitudes toward urban wastewater reuse have been surveyed in the U.S. [5], Australia [6–8], Africa [9], Crete [10], and Thailand [11]. Outcomes of a survey in Israel showed that among 21 reclaimed water reuse options, 95% of the public supported those with low and intermediate risk of human contact, such as landscape irrigation and fire protection, while less than 15% of the public supported those with high risk for human contact, such as processing food and recharging potable water aquifers. Despite the seemingly low risk of human contact, merely 50% of the public in Israel would support irrigating field crops and orchards with reclaimed water [12]. Marks [13] showed that there were high levels of public acceptance of non-potable water reuse in industrial processing, and irrigating golf courses, public parks, and school grounds in five surveyed U.S. and Australian cities. However, the extent of public acceptance varied for non-potable reuse in irrigating vegetable crops and household gardens. For three California cities (Monterey, Irvine, and San Jose), the public acceptance levels varied from 47%–74%, while in Sidney, Australia, it exceeded 95%. The yuck factor, exacerbated by the media's use of ambiguous terms such as “recycled sewage” and “toilet-to-tap” in characterizing reclaimed water, is a significant negative image to augment reclaimed wastewater reuse, especially for potable and agricultural production purposes [14]. Positive information sharing and outreach education activities can increase the public support of water reuse [5,15,16].

As a developing country with a unique culture, the public's perspectives on water reuse in China are difficult to fathom. In the past decades, the general public simply accepted such plans decreed by the authorities. However, after years of modernization and economic expansion, especially rapid development in public media including TV, cell phones, Internet, *etc.*, the general public has become knowledgeable

and shows greater environmental concerns. While public opposition does not have the same role that it does in regions like California and Australia, the public acceptance and support have become more and more important in successful implementation of the national water reuse policy. The opposition of residents for the reuse of toilet flushing had led to the failure of many community reclaimed water reuse projects [17]. So far, the attitudes of the Chinese general public and professionals on reclaimed water reuse are unclear. In addition, it is unknown how their perception would be affected by socio-economical attributes, and whether or not there is a significant difference between the developed country and developing country, as well as between the western and eastern country.

In this research, we took Beijing as an example to study the attitudes of both the general public and stakeholder professionals towards reclaimed water reuse. Two sets of questionnaires were developed to examine the awareness of different stakeholders on reclaimed water reuse and risk concerns from stakeholder professionals. Factors affecting stakeholders' attitudes on reclaimed water reuse were discussed. This study will also enhance current findings on public perceptions on reclaimed water reuse, especially in developing countries where few studies have been done.

2. Methodology

2.1. Questionnaire Design

With different sources of knowledge, the attitudes of stakeholders related involved in reclaimed water reuse, including the general public, managers, manufacturers, operators, and researchers, varied greatly. Two sets of questionnaires were developed. One was intended to test the public's knowledge on Beijing's water supplies and reclaimed water reuse, designated hereafter as Questionnaire I. The second was specifically aimed at probing viewpoints of water reuse stakeholder professionals in Beijing, designated hereafter as Questionnaire II. The survey instruments were designed according to the basic principles of and followed the seven-step protocol for formulating social survey questionnaires, which included design preparation, structure plan, pretest, questionnaire evaluation, finalizing a manuscript, appearance design, and coding.

Questionnaire I consisted of three themes, namely perception in water consumption and wastewater generation, cognition in reclaimed water reuse, and willingness to use reclaimed water with 13, five, and 14 multiple choice questions, respectively in each theme. Among the 32 questions, seven were objective, and 25 were subjective questions in Questionnaire I.

Questionnaire II included three themes on perception, willingness, and risk identification of reclaimed water reuse with three questions in each theme. The questionnaire was designed for the stakeholder professionals, namely administrators/managers of water reuse programs and researchers who specialize in wastewater reclamation and water reuse.

In both questionnaires, demographical attributes of respondents including gender, age, education, occupation, and personal income were recorded.

2.2. Survey Methodology

Questionnaire I was aimed at the general public in metropolitan Beijing. Questionnaires were distributed to randomly selected subjects in 14 public areas across the city during May and June, 2013.

The survey sites covered parks, transportation stops, and housing complexes. The survey was conducted based on the participatory research method. About three quarters of the invited subjects agreed to complete the survey form. In total, 714 questionnaires were collected. The gender, age, education, occupation, and personal income of the subjects are summarized in Table 1. The gender and age distributions of the surveyed population were similar to the demographical profile of Beijing.

Table 1. Socio-economical attributes of surveyed population (N = 714).

	Personal attributes	Distribution (%)
Gender	Males	42.05
	Females	57.95
Age	<25	23.62
	25–35	28.01
	35–45	14.29
	45–55	13.01
	>55	21.07
Education	High school or less (≥ 12 years)	26.38
	College graduates (12–14 years)	25.51
	University graduates (12–16 years)	36.30
	Advanced training (> 16 years)	11.81
Occupation	Unemployed	18.65
	Company employees	41.61
	Self-employed households	9.47
	Civil servants and enterprise workers	8.90
	Retired	21.38
Monthly income in RMB (Yuan)	<1500	21.59
	1500–2500	26.54
	2500–3500	25.04
	3500–4500	13.49
	>4500	13.34

Questionnaire II targeted wastewater reclamation and reuse stakeholder professionals in Beijing, including those associated with the Beijing Water Authority, Beijing Drainage Group LTD, Beijing Hydraulic Research Institute, and academic and scientific research entities. Fifty-seven questionnaires were distributed to 10 individuals with management responsibilities, 25 individuals with marketing and operations responsibilities, and 22 individuals with research and development responsibilities, respectively. Fifty-four questionnaires were returned. Each response was followed by in-depth one-to-one interviews and e-mail correspondences for clarification.

2.3. Data Analysis

Survey data were tabulated in Microsoft Office Excel format and statistically analyzed using the SPSS software (SPSS 17.0). To obtain the average response of investigated people to a certain subject without distorting the original data, a scale weighting factor was assigned to each category of

willingness or favor. The weighing factor for the j^{th} question on willingness to accept reclaimed water was assigned to be 4, 3, 2, and 1 for categories of strongly willing, acceptable, unwilling, and no opinion, respectively. The overall public's intent to the j^{th} question (W_j) was the weighted average of the responses that:

$$W_j = \frac{(S_{j4} \times 4 + S_{j3} \times 3 + S_{j2} \times 2 + S_{j1} \times 1)}{S_{j1} + S_{j2} + S_{j3} + S_{j4}} \quad (1)$$

where S_{j1} , S_{j2} , S_{j3} , and S_{j4} represent the number of subjects that answered the j^{th} question in “no opinion”, “unwilling”, “acceptable”, and “strongly willing” categories, respectively.

Similarly, a five-point scale with weighing factors ranging from “5” for strongly in favor to “1” for strongly in opposition was used to judge responses of the reclaimed water stakeholder professionals. The overall degree of recognition for the i^{th} survey question (R_i) is calculated as:

$$R_i = \frac{(A_{i5} \times 5 + A_{i4} \times 4 + A_{i3} \times 3 + A_{i2} \times 2 + A_{i1} \times 1)}{A_{i1} + A_{i2} + A_{i3} + A_{i4} + A_{i5}} \quad (2)$$

where A_{i1} , A_{i2} , A_{i3} , A_{i4} , and A_{i5} represent the number of subjects that answered the i^{th} question ranging from strongly in favor to strongly in opposition, respectively.

3. Results and Discussion

3.1. Public Awareness on Water Resources and Reclaimed Water Reuse

According to the survey, the residents of Beijing are cognizant of the city's water supplies and wastewater treatment situations: 75% of the respondents realize that the city is facing a severe water shortage; 70% of the respondents are aware of the massive municipal wastewater collection and treatment infrastructures; and 97% of the respondents recognize the public health hazards and needs of properly treating and disposing of municipal wastewaters (Table 2). However, 76% of respondents do not know the sources of Beijing's water supply, 60% do not know the primary generators of Beijing's wastewater, and 97% do not know which sectors in the city consume the largest volume of water. The public inclines to blame the industrial sector for causing the water shortage and water pollution. Additionally, 42% and 55% of the respondents thought industries are the biggest water consumers and the primary sources of municipal wastewater in Beijing, respectively. In reality, Beijing's population of over 20 million residents by default consumes more water and generates a greater volume of wastewater than any other socio-economic sectors. Overall, the public lacks accurate knowledge on the water resources of Beijing and there is room for improvement.

Table 2. The public's responses to the posted questions on water resources and uses in Beijing.

Question	Preferred option	Correct option
Main water source	Surrounding rivers or reservoirs (56.16%)	Groundwater (24.47%)
Largest field of water consumption	Industry (41.57%)	Irrigation (2.86%)
Water shortage or not	Severe water shortage (75.07%)	Same as preferred option
Main wastewater source	Industrial wastewater (54.58%)	Domestic water (39.73%)
Where municipal wastewater goes	Sewage treatment plant (70.12%)	Same as preferred option
Sewage needs treatment or not	Yes (97.47%)	-
Household waste water or not	No (71.07%)	-
Community waste water or not	Yes (63.59%)	-
Be able to reduce water consumption	Yes (78.96%)	-
Would like to reduce water consumption	Yes (81.07%)	-
Would like to pay for water treatment	Yes (73.88%)	-

About 70% of the respondents feel that domestic consumptions are essential and the users are not responsible for the shortages in the city, but the majority of them feel that they can conserve water (79%) and would like to reduce water consumption (81%). Meanwhile, 64% of respondents hold the viewpoints that public uses such as landscaping irrigation and street cleaning are excessive and wasteful. These findings suggest that there is room for conserving water, the public is not well informed regarding water uses, and their viewpoints about various water users may be biased. As the capital of China, Beijing may represent the optimistic case in public awareness on water resources and reclaimed water reuse. The government has not paid much attention to public outreach until recent years. Thus, public opinions may be distorted by unofficial media.

Water rates may influence domestic water consumption and may be a means to encourage water conservation. The majority of the respondents feel that the current rate is reasonable (40%) or somewhat high (38%). A small portion of the respondents view the current rate being either very high (6%) or too low (10%) (Figure 1a). With increasing water prices in recent years, residents pay more attention to water conservation, and managers of parks and companies show higher interest in using reclaimed water. Water price is critical in expending the water reuse. Currently, the reclaimed water price is kept at 1 RMB per ton, roughly 17% of that of the city's public water, far from adequate to recuperate capital investments and operation costs of the water reuse system. Reasonable water rates are necessary for promoting water saving and water reuse.

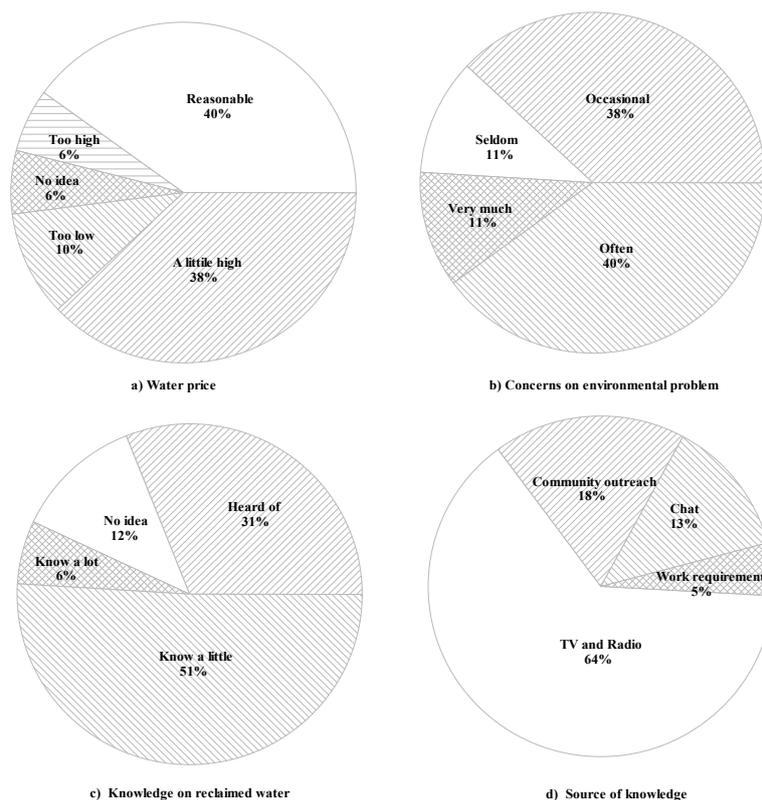


Figure 1. The public's knowledge on water supply and wastewater in Beijing.

Further developments in water resources may cause adverse environmental impacts. Approximately 11% and 40% of the respondents express strong and intermediate commitment, respectively, to environmental protection, while 38% and 11% of the respondents show successively less enthusiasm toward protecting the environment (Figure 1b). If the public's perspective and consciousness on environmental protection becomes more favorable, it may be an incentive in promoting the water conservation and reclaimed wastewater reuse.

Beijing over the years has made great efforts to disseminate information on water reuse. The overall public awareness on water reclamation is high. About 90% of the respondents are aware of the ongoing wastewater reclamation and reuse (Figure 1c) and point to the fact that reclaimed water may be used for toilet flushing, car washing, landscape irrigation, *etc.* The majority of the respondents (64%) acquired the knowledge through public information messages from television and radio media. Less effective, though, 18%, 13%, and 5%, of the respondents, respectively, learned about water reuse through community outreach, personal contacts, or other means (Figure 1d).

The individual's willingness to accept non-body contact and non-potable reuse of the reclaimed wastewater is overwhelming (Table 3). Over 90% of the respondents are willing to accept or strongly endorse reclaimed water for toilet flushing, fire protection, landscape irrigation, street cleaning, industrial cooling, ornamental lakes, and car washing. Even crop irrigation and domestic uses (except for drinking and food preparation) are acceptable to 82% of respondents. Collectively, the support based on the aggregated willingness scores according to Equation (1) ranges from 3.51 to 3.04, between the score of 4 for strongly agree and the score of 3 for acceptable. The public is less enthusiastic about the potentially potable reuse options, especially for supplementing the domestic water supply, which is deemed unacceptable by 63.3% of the respondents.

Table 3. The public's acceptance of reclaimed water reuse options.

Reuse Category	Strongly agree (%)	Acceptable (%)	Unwilling (%)	No comment (%)	Aggregated willingness factor ^(a)	
Non-body contact and non-potable reuses	Toilet flushing	63.17	29.84	1.6	5.39	3.51
	Firefighting	59.24	34.93	0.58	5.24	3.48
	Landscape irrigation	58.22	35.66	0.58	5.53	3.47
	Street cleaning	59.68	32.31	2.18	5.82	3.46
	Industrial cooling water	57.93	35.08	1.31	5.68	3.45
	Landscape fountain	55.17	36.54	3.2	5.09	3.42
	Car cleaning	55.9	33.19	6.26	4.66	3.4
	Park water supplement	46.29	40.47	8.01	5.24	3.28
	Agriculture irrigation	42.07	40.17	14.12	3.64	3.21
	Non-potable and non-cooking domestic uses	26.93	56.48	10.04	6.55	3.04
Potentially potable reuses	River flow supplement	44.69	35.08	16.3	3.93	3.21
	Groundwater recharge	34.93	35.37	24.6	5.09	3.00
	Supplementing drinking water supply	8.44	25.04	63.32	3.2	2.39
Average	28.09	61.43	7.42	3.06	3.15	

Notes: ^(a) Calculated by Equation (1).

Overall, the extent of Beijing residents' willingness to accept reclaimed wastewater reuse in their community is remarkable. The results were in line with other findings that willingness to reuse appears as a descending trend as reclaimed water use transits from public to private [8,14,18,19]. Improving renewable water quality and expanding the knowledge-related publicity are effective ways to increase the degree of willingness to use recycled water.

3.2. Perception of Stakeholder Professionals on Reclaimed Water Reuse

The stakeholder professionals including managers, producers and operators, and researchers are overwhelmingly positive about the reclaimed water reuse. Among them, 81% strongly believe the benefits of water reuse and the remaining 19% of the respondents feel that the reclaimed water reuse is acceptable (Figure 2a). They overwhelmingly (96% of the respondents) support technology advancements of wastewater reclamation (Figure 2c). On the prospect of reclaimed water (Figure 2b),

the responses are: 50% strongly confident, 46% slightly optimistic, 2% unsure, and 2% pessimistic about the future of water reuse.

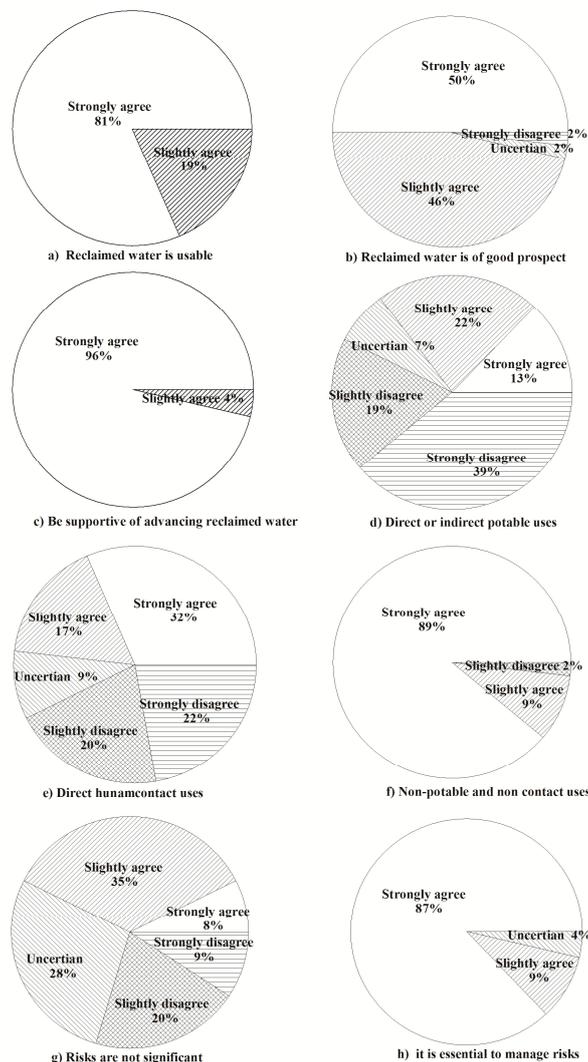


Figure 2. Responses of Beijing’s water reuse professionals to questions on recycling reclaimed water.

We employed a 1-to-5 scale to probe the aggregate viewpoints of professionals on water reuse with 5 being strongly in favor and 1 being strongly in disagreement (Table 4). From the professional point of view, the stakeholders understand the critical need for developing new water resources for Beijing and collectively feel that recycling reclaimed wastewater is beneficial for the city (aggregate score = 4.78). They are optimistic toward the official water reuse program (aggregate score = 4.44), and support advanced technology developments for recycling water (aggregate score = 4.95). In comparison to manufacturers and operators, researchers were more optimistic on reclaimed water reuse, which may be due to their closer contact with the latest environmental developments and their good understanding about the urgency of water scarcity and pollution. The reason that manufacturers and operators had lower confidence in the future of reclaimed water reuse may be because they were quite familiar with the current situation of water reuse and promotion in Beijing, knowing the difficulty of advancing reclaimed water very well.

Table 4. Average degree of recognition and willingness of different stakeholder professionals on reclaimed water.

Question	Manager	Manufacturer and operator	Researcher	Mean value ^(a)
Reclaimed water is usable	4.60	4.73	5.00	4.78
Reclaimed water is of good prospect	4.50	4.27	4.55	4.44
Be supportive of advancing reclaimed water	4.90	5.00	4.95	4.95
Risks are not significant	3.70	2.68	3.27	3.22
It is essential to manage risks	5.00	4.73	4.86	4.86
Direct or indirect potable uses	3.50	2.27	2.32	2.70
Direct human contact uses	3.90	3.32	2.64	3.28
Non-potable and non-touching uses	4.60	4.95	4.86	4.81

Notes: ^(a) Calculated by Equation (2).

The stakeholders of water reuse programs incline to favor non-body contact and non-potable reuse options, and avoid those having the potential risk implications of potable reuse (Figure 2d–f). The managers, producers and operators, and researchers exhibit different perspectives on cost effectiveness, system performances, and environmental sustainability [11]. Those in managerial positions who are promoting and implementing the policies tend to be more optimistic and are willing to push the water reuse programs further, especially for body-contact and potentially potable reuses. The researchers, producers, and operators who are at the frontlines dealing with research and development issues and reuse process routines tend to be more cautious and considerably less enthusiastic of the body-contact and potable reuses (Table 4).

3.3. Perception on Risks Associated with Reclaimed Water Reuse

Stakeholders are aware of the public health and environmental pollution risks that come along with water reuse, and view risk control as essential in the implementation and management of water reuse projects (Table 4). Furthermore, 43% of the stakeholder respondents feel that health and environmental risks are not significant issues, with the remainder divided between those uncertain of the risks and those who view the risks as being serious (28 % vs. 29%) (Figure 2g), and the overwhelming majority of the respondents (87%) agree that steps to minimize risks are imperative (Figure 2h).

The water reuse program in Beijing is unique in that the effluents of the municipal wastewater treatment systems are through a contractual agreement turned over and sold to a revenue-supported intermediary entity, which is solely responsible for upgrading and marketing the reclaimed water to users across the city. The stakeholder respondents identify four areas in the water reuse programs where potential public health and environmental risks may arise (Table 5). Additionally, 66% of the respondents are concerned that reclaimed water producers and marketers often fail to deliver the water of promised quality to the downstream. Risks may also stem from the inappropriate uses by those acquiring the reclaimed water (an issue raised by 59% of the respondents) and inadequate quality controls during the course of quality upgrading operations (an issue raised by 54% of the respondents). Finally, the conveyance and storage stage of reclaimed wastewater may also result in contamination due to cross connections, leakages, and accidental spills (an issue raised by 41% of the respondents). Judging from

the responses, although the water reuse stakeholder professionals in Beijing are committed to the idea of reusing reclaimed wastewater, they are not entirely comfortable with the reliability and effectiveness of the wastewater treatment and reclaimed water marketing operations that are the backbone of a successful reuse program (Table 5). These results are closely related with stakeholders' roles in water reuse development and their understandings of water reclamation.

Table 5. Sources of public and environmental risks of using reclaimed water in Beijing, according to the opinions of local water reuse professionals.

Source	Responded Positive (%)	Cause	Responded Positive (%)
Wastewater	66	Origin of wastewater	83
		Treatment efficiency and reliability	48
End uses	59	Quality of reclaimed water	72
		End use categories	46
Production/operation	54	Treatment technology	83
		Accidental spills	44
		Equipment malfunction	35
Conveyance and storage	41	Cross-connection	59
		Pipeline leakage and corrosion	46
		Backflow	19

3.4. Factors Affecting Public and Stakeholders Awareness on Reclaimed Water Reuse

The general public and stakeholder professionals' responses to different survey questions are affected by their social-economic backgrounds (Table 6). Occupation is a significant factor (at $p < 0.01$) for the general public in correctly answering three of the six questions about knowledge of Beijing's water resources. Those holding public sector jobs appear to pay more attention to such activities than those working in the private sectors or who are self-employed. The respondent's awareness of the water resource issues is also significantly affected (at $p < 0.01$) by age, income, and education factors. Older, higher-income, and well-educated individuals are better informed and have more reasonable expectations of what the water supply system can deliver to them. Gender does not appear to affect the outcomes.

The general public's viewpoints on how water is used throughout the city are divided (at $p < 0.01$ or $p < 0.05$ significant levels) by age, gender, occupation, income, and education factors. Older, less-educated, female, and self-employed respondents tend to feel that water is being wasted across the spectrum. Older respondents (at $p < 0.01$) especially feel that there is room for water conservation in the city. When asked to reduce their water consumption, the female (at $p < 0.01$), higher-earning (at $p < 0.05$), and more educated (at $p < 0.05$) respondents are more willing to participate than the others. Again, older (at $p < 0.01$), more educated (at $p < 0.01$), higher-income (at $p < 0.01$), and public sector (at $p < 0.01$) respondents are concerned more about the environmental impacts of water resource development and express greater willingness to pay for the water. The younger, less educated, and lower-income respondents appear to be indifferent one way or the other in terms of water reuse.

Table 6. Social-economic factors that affected views on water reuse.

Category	Question	Significant Demographic Factor ^(a)
Public's knowledge on water resources	Regarding to Beijing's water sources	Age ** Occupation **
	Regarding to water consumption trends in Beijing	None
	Regarding to Beijing's water shortage	Education ** Occupation ** Income **
	Regarding to Beijing's wastewater production trends	Occupation ** Education *
	Where does municipal wastewater go?	Income *
	Do municipal wastewater need treatment?	Age *
Public's opinion on water uses	Is your household wasting water?	None
	Is Beijing wasting water?	Age *, Occupation *, Education*
	Can Beijing's water consumption be reduced?	Age **
	Would you like to reduce water consumption?	Gender ** Education * Income*
	Are you willing to pay for water treatment?	Income ** Education * Occupation *
	Are you concerned about environment problems?	Age ** Occupation **
	Is the water rate high?	Age ** Education ** Income **
Public's perception on reclaimed water	Are you aware of the reclaimed water reuse in Beijing?	Education ** Income ** Occupation *
	Where do you get the information from?	Age ** Occupation * Income *
Public's willingness to use reclaimed water	Drinking water supplement	Age ** Income **
	River supplement/Groundwater recharge	Age *
	Non-potable household uses/firefighting	Income ** Education *
	Park water supplement/agriculture irrigation/car cleaning	Income *
	landscape irrigation/road cleaning/public toilet flushing/industrial cooling water/landscape fountain	Education ** Income **
Stakeholder's perception on reclaimed water	Role of reclaimed water	Education ** Income ** Gender*
	Prospect of reclaimed water	Education * Occupation *
	Support of reclaimed water	-
Stakeholder's opinions on risks of reclaimed water	Risk significant or not	Occupation ** Age **
	Build-up of risk management system	-
Stakeholder's willingness to reclaimed water reuses	Non-potable and non-touching uses	-
	Direct touching uses	Income *
	Direct or indirect potable uses	Occupation *

Notes: ^(a) Linear correlation between the response of each investigation participant and their demographic factor was conducted. Statistical inferences: * and ** denote the factor earmarked is correlated to the question at $p < 0.05$ and $p < 0.01$ significant levels, respectively.

Allowed to choose how the reclaimed water would be used, the respondents have strong preferences toward non-body contact and non-potable water reuse options (Table 6). Respondents with higher incomes, more education, and who are older (age 35 to 55) are more optimistic about the future of water reuse, but they are less supportive of the riskier potable reuse options. A survey from the San Diego County Water Authority showed that there was a shifting of public opinion on the potable reuse of reclaimed wastewater between 2004 and 2011. Those who “strongly oppose” using reclaimed water that has received advanced treatment to augment the drinking water supply dropped from 45% in 2004 to 11% in 2011 [20] through unyielding public outreach efforts. Beijing undoubtedly must wage credible outreach efforts to convince the population to embrace water reuse.

The water reuse professionals are more realistic and practical in terms of the roles of reclaimed wastewater in Beijing. Their perceptions and expectations are less likely to be influenced by social-economic factors such as personal income, gender, and occupation. However, the technical knowledge (reflected in the education levels) and experience (reflected in the age factor) are significant factors (Table 6). This group occupies the management and technical decision-making positions in the water reuse programs. As a result, despite the official policy push to implement water reuse, the implementation approach has been cautious and progress has been slow.

4. Conclusions

Reclaimed water reuse is a national policy and Beijing has the largest-scale and most successful water reuse program in China by far. We investigated attitudes of both the general public and professionals towards reclaimed water reuse in Beijing. The outcomes reveal that: (1) The majority of the respondents, although keenly aware of the water shortages and quality issues, have misconceptions about the city’s sources of water supply, the biggest consumers of public water supplies, and the biggest generators of wastewater in the community; (2) most residents consider themselves conscious in conserving water resources yet there is room for water conservation because others are wasting water (nonetheless, they are willing to reduce their water consumption); and (3) respondents are knowledgeable about wastewater reclamation and are strongly willing to use reclaimed water except for potable use. Nonetheless, the respondents shy away from supporting augmenting river flows, groundwater recharge, and directly or indirectly augmenting the public water supplies. In all, the residents of Beijing are willing to accept reclaimed water, but their knowledge needs to be improved through targeted information dissemination coupled with properly set water rates to promote water conservation and encourage water reuse.

The survey of water reuse professionals showed that: (1) Beijing’s water reuse professionals recognize the positive roles that reclaimed water may play in the city’s water supply and they strongly support technological development to promote water reuse, yet a few of them are pessimistic about the future of recycling reclaimed wastewater; (2) the overwhelming majority of the professionals hold the opinion that risk aversion and management are imperative in reclaimed water reuse; and (3) they are aware of risks that may arise at the reclaimed wastewater treatment and production phases due to upstream water quality issues, operation errors, equipment failures, and accidental spills, or at the utilization phase due to cross connections and mismatches of uses and water quality.

The general public's and stakeholder professionals' perceptions on reclaimed water reuse are affected by their social-economic backgrounds. It is necessary to improve stakeholders' understanding of reclaimed water in order to smooth the implementation of water reuse.

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Author Contributions

Weiping Chen analyzed the data and completed the first draft, Yanying Bai designed the questionnaires and revised the manuscript, Weiling Zhang & Sidan Lv collected the data, Wentao Jiao made the graphs and went through the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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