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Acceptability of reclaimed municipal wastewater in cities: evidence from India's National Capital Region

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ABSTRACT

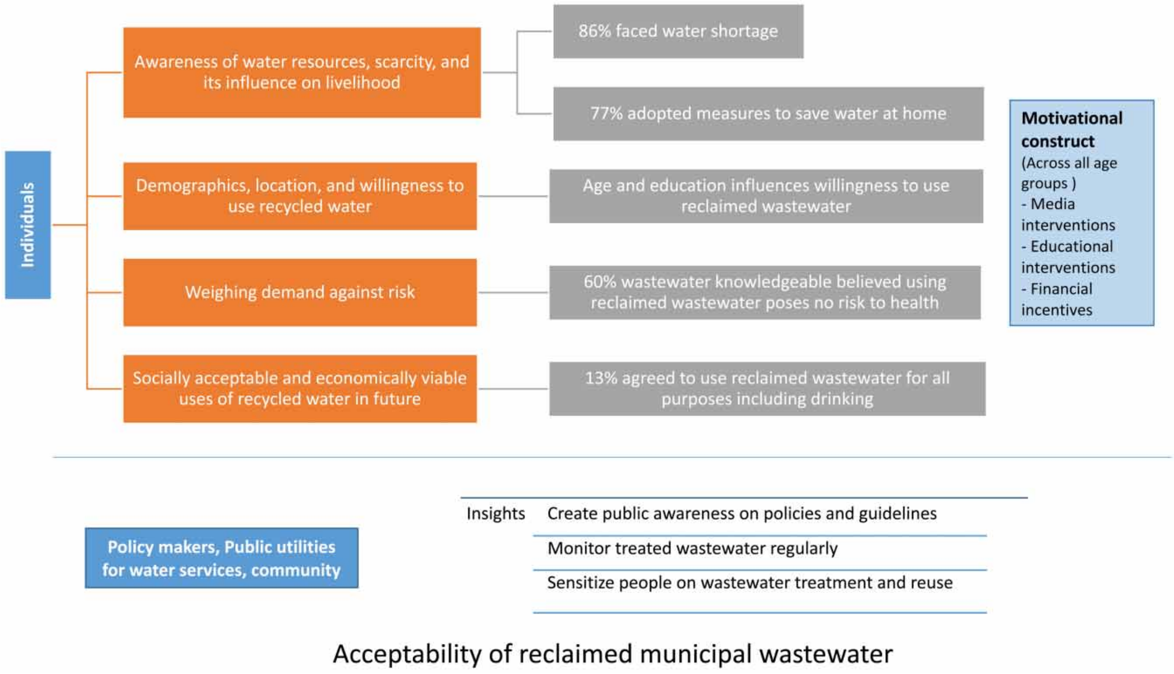
Willingness to reuse reclaimed municipal wastewater was ascertained through a questionnaire completed by 424 respondents, opinions of 17 experts, and interviews with 15 farmers. Information was collected to assess their knowledge of water scarcity and to determine the influence of demographics, correlation to perceived risk, willingness, challenges, and barriers related to the acceptance of reclaimed water. Most respondents were receptive to the idea of using it for purposes other than drinking, and 'water conservative' individuals were inclined towards using it even for drinking. Farmers were concerned about its quality and implications for the health of using it for irrigation. Effective communication between authorities and end-users can promote the idea of reusing greywater and reclaimed water for domestic use, and, eventually, for drinking. These findings will be useful in developing an integrated, practical, and strategic framework for treating wastewater for reuse in other cities not only in India but also in other developing countries.

Key words: Stakeholder perception, Urban communities, Wastewater reuse, Water-use behaviour

HIGHLIGHTS

- Water-conserving people are more inclined to use reclaimed water for drinking.
- The quality of water supply is a major concern by all stakeholders in the study region.
- Effective information dissemination positively influences the perception of reclaimed water.
- A significant percentage of urban residents are aware of water sustainability risks.

GRAPHICAL ABSTRACT



INTRODUCTION

The world's urban population is projected to grow by 2.5 billion between 2018 and 2050, and nearly 90% of that growth will be in Asia and Africa. In Asia, India will add the most, with an estimated 814 million of its people living in cities by 2050 (UN, 2019). This developmental exodus together with migration from rural areas puts increasing strain on the resources at hand to meet the rising demands for water, especially freshwater. The all-around scarcity of water and increasingly contentious transboundary agreements for sharing water make it imperative to explore new water resources – of which reclaimed wastewater (RW) is one.

Treating RW as potable is not a new initiative. People in Australia, Namibia, Singapore, and some states in the USA (California, Virginia, and New Mexico) are already drinking RW. However, despite a choice of proven technologies, many projects aimed at using RW have been abandoned because the public at large was averse to it and it is becoming increasingly clearer that perceptions of general public must be taken into account in designing the measures to overcome water scarcity and in shaping policies related to water (MoJS, 2021). Public perception is made up of the thoughts, beliefs, and values of individuals who constitute the public. For example, in Toowoomba, Australia (Price *et al.*, 2012), a majority of people who initially supported a scheme to use RW opposed it later, and the scheme had to be closed. In San Diego, USA, the initial plan to use RW as potable water was rolled back to use RW only for other uses in the 1990s but the original plan was revived in the mid-2000s after public engagement (City of San Diego, 2013).

For the present study, global case studies between 2010 and 2020 were reviewed briefly for a better understanding of public perception related specifically to the use of RW as potable water. The sociodemographic variables that potentially govern public perception in using RW for potable purposes include age, gender, education, income, nationality, and level of public awareness (Gu *et al.*, 2015; Mohammad *et al.*, 2017). Some studies considered factors like attitude towards reclaimed water use (Zhu *et al.*, 2019), size and location of residence community (Eck *et al.*, 2019), willingness and consumer satisfaction (Mohammad *et al.*, 2017), and trust in health officials, utilities, media, government, politicians, and race or religion (Crampton & Ragusa, 2016).

The following sociodemographic factors were considered in the present study: gender, age, education, geographic location, type of dwelling (rented house, flat, etc.), and monthly income. Knowledge of water resources emerged as a decisive factor in many studies. Research on public perception of RW in Asia – except Singapore, with its NEWater scheme – is limited, especially with reference to developing countries.

Currently, Indian cities are short of water, the average daily supply per capita being about 70 litres, barely half of the norm of 135 litres for domestic use (MoJS, 2020). At the same time, the income per capita is INR 98,435 in cities and INR 40,925 in villages (MoSPI, 2018). These numbers make it obvious that Indian cities are not only in dire need of the alternative and new sources of water but also lack the capital needed to invest in them. Indian cities have started to use RW for watering plants; for rejuvenating ponds, lakes, and streams; and for putting out fires when required. Many states in India have started formulating appropriate policies on disposal and reuse of wastewater, building the required infrastructure to treat wastewater, and drafting appropriate regulations on standards and on mandatory use of RW for some purposes. For example, the state of Gujarat introduced the 'Reuse of treated wastewater policy' in May 2018 that makes the use of treated wastewater mandatory by all power plants and major industries within 50 km of a sewage treatment plant (STP) (Parikh, 2019). Similar projects and policies have been developed in several Indian cities including Chennai (Vishwanath, 2019), Nagpur (World Bank Group, 2019), Bengaluru (Ravishankar *et al.*, 2018), and Hyderabad (Starkl *et al.*, 2015) but none has considered public perception and acceptance. In India, the use of RW as potable water is evolving; at present, the emphasis is more on industrial and agricultural sectors (Kumar & Goyal, 2020). In the context of public perception, it is important to understand that the general public is not a homogeneous entity: individuals who make up the general public are influenced by a range of complex interests and factors such as education and past experiences unique to them. Although some motivational factors such as closer engagement by the policy-makers with citizens will remain constant, understanding these factors can be immensely useful in promoting widespread use of RW in cities. With India's ever-increasing population, it is imperative for policy-makers to understand the various limitations and opportunities to mobilize public acceptance of RW in cities and to recalibrate policies accordingly to bring about a sustainable change.

The main objective of the present study was to assess public attitude towards the use of RW in India as potable water, using it as a case study of the National Capital Region (NCR). More specifically, the study sought to (1) evaluate existing knowledge and awareness of water scarcity and determine the reflexive impact of water resources and its scarcity on the lives and livelihoods of the residents of the NCR, (2) determine the influence of demographics on the likelihood of people accepting the use of RW and the trends and patterns within homogenous locations, (3) examine the relation between demand or need and perceived risk in the use of RW, (4) identify the potential large-scale uses of RW and its social and economic acceptance, and (5) identify the challenges to such use and the barriers in devising suitable policies, regulations, and frameworks to overcome those challenges.

MATERIALS AND METHODS

Description of study region

India was selected because being a middle-income country, it faces many challenges that are common to many other low- and middle-income countries and also because India has demonstrated its technological competence and leadership to represent the collective conscience of the emerging economies. Within India, we chose Delhi, the country's capital city and also the world's second-most populous urban agglomeration. The NCR is the planning region centred upon the National Capital Territory (NCT) of Delhi spread over 55,098 km², which encompasses such satellite cities as Faridabad, Gurugram, Ghaziabad, and Noida. The region attracts migrants not only from other parts of India but also from other countries because of the many employment opportunities and better civic amenities it offers. As a result, its population continues to increase – as does the demand for water. The total annual water inflow in the Delhi region (including water imported under the existing interstate agreements) is 2,095 MCM (million cubic metres), whereas the discharge is 1,621 MCM. The share of centralized supply in the total water supply is 67%. Although rainfall can meet only 65.3% of Delhi's current water needs, its potential is not harnessed due to the lack of rainwater harvesting and storage facilities (Ghosh *et al.*, 2019). The total annual groundwater recharge by rain and urban infiltration is 338.3 MCM, and groundwater withdrawal is 428.3 MCM a year. This explains the decline in the water table beneath the surface in Delhi. Annual water demand and supply gap in Delhi is estimated to be 2.02 MCM (GNCTD, 2021), making Delhi a water-insecure city. Daily domestic wastewater generated in the Delhi region is estimated at 11.69 MCM, 30% is transported through the underground sewer network, and the remaining through open drains (Singh & Kansal, 2018). The wastewater treatment capacity is about 2.7 MCM but only 2.3 MCM is treated, as the STPs are utilized at only 88%. Out of the treated wastewater, only 0.4 MCM is reused (GNCTD, 2021). The treated wastewater is used at various locations, including the Delhi International Airport, the Feroz Shah Kotla Stadium, and the Ambedkar Stadium for heating, ventilation, and air conditioning, for flushing toilets, for watering landscaped gardens and parks, and for washing the coaches of Delhi Metro and buses of the Delhi Transport Corporation. The National Green Tribunal has drawn up a plan for using the water treated in STPs for watering the plants in all the parks within 5 km from the STPs. Several institutions and corporate houses that treat the wastewater they generate and use it for gardening include the Imperial Hotel on Janpath, the Maurya Sheraton in Diplomatic Enclave, the Netaji Subhash Institute of Technology in Dwarka, and the India Habitat Centre on Lodhi Road. Treated wastewater is also being used in the water parks in Gurugram.

The present study is based on evidence from an urban conglomerate, namely a part of the NCR comprising Delhi and its two satellite cities, namely Gurugram and Ghaziabad.

Data collection and analysis

The approach used in the present study was an amalgam of both quantitative and qualitative approaches (Figure 1): the quantitative approach, through a questionnaire survey, was used for estimating the influence of socio-economic and -demographic factors on the willingness to use RW, whereas the qualitative approach, through semi-structured interviews, was used for obtaining better insights into the challenges in accepting RW. The norm activation model is a quantitative assessment method, which helps to understand people's behaviour towards the environment. Three distinct behavioural aspects are personal norms, awareness of consequences, and ascription of responsibility. Moral obligations such as opting for public transport, conserving resources, and recycling are a few personal norms (Lind *et al.*, 2015); perception of the risk of adverse consequence shows awareness of consequences (Saphores *et al.*, 2012); and accountability for pro-environmental behaviour indicates ascription of responsibility (Jansson, 2011).

The questionnaire survey was administered, using both English and Hindi, through face-to-face meetings to ensure that all the questions are answered. The survey design commenced in April 2019 and a pilot survey was carried out in May 2019, followed by a review during June, and the full-scale survey was carried out between June and December 2019. We approached over 1,100 potential respondents, of which 424 agreed to participate: the rest either did not wish to participate or said that they could not spare the time. The data sets were

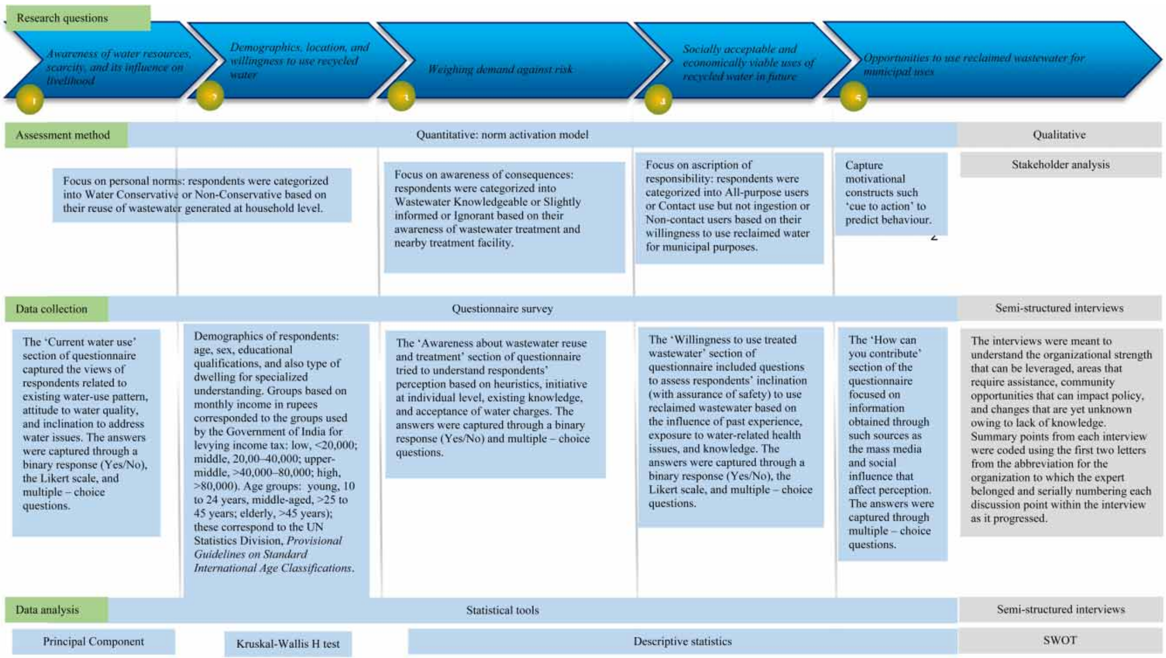


Fig. 1. | Methodological approach to assess the acceptability of reclaimed municipal wastewater in cities.

numerically coded for statistical analysis using a spreadsheet (Microsoft Excel), and the statistical tests were conducted using SPSS ver. 16.0. To achieve a better understanding of the distribution and spread of the data, the descriptive statistics were computed across the variables, and to compensate for the lack of normal distribution, a non-parametric test, namely goodness-of-fit (Jarque–Bera), was used.

The survey questionnaire was designed using a five-step protocol, namely design preparation, structure plan, pre-test, evaluation, and finalization. The formulated survey was then pilot-tested on 15 respondents' representative of the target demographics. Most of the respondents found the list of possible uses of water to be too long but not informative enough. Accordingly, we reduced the possible uses to only three categories, namely for drinking, for uses other than drinking that involved direct contact with water (such as bathing or washing up), and other uses (such as watering plants or flushing toilets). The final questionnaire was designed to capture the views of respondents on the topics listed below (the full questionnaire is reproduced as part of the Supplementary Material):

- Demographic details such as age, gender, education, and income.
- Water usage and awareness of water scarcity.
- Knowledge and awareness of wastewater treatment and its potential reuse.
- Willingness, most acceptable use of wastewater, and the reasons for these choices.

Cronbach's α reliability test was performed on the entire set of survey questions consisting of both dichotomous and Likert-scale questions for measuring the internal consistency of the scores, taking 0.70 as the minimum score for reliable and internal consistency.

During the initial testing, which involved exploratory analysis, the correlations between most of the independent variables were seen to be statistically significant. Therefore, to understand the behaviour of the respondents with reference to the current status of water supply, water scarcity, and use of untreated wastewater, we used such techniques for analysing multivariate data as principal component (PC) analysis (Equation (1)) to transform the initial set of variables into groups of PCs to separate the most important variables from the least important variables.

$$Z_{ij} = a_{i1}x_{1j} + a_{i2}x_{2j} + a_{i3}x_{3j} + \cdots + a_{im}x_{mj} \tag{1}$$

where z is the component score, a is the component loading, x is the measured value of the variable, i is the component number, j is the sample number, and m is the total number of variables.

To understand the relation between the sociodemographic factors and other variables, we used the Kruskal–Wallis H test, a rank-based non-parametric test to determine if there are statistically significant differences between groups of independent and dependent variables. Dependent variables as age, gender, income, and education have multiple categories, and we used the test to ascertain whether the difference between independent and dependent variables, if any, was statistically significant.

The participants in the qualitative assessment, which was undertaken through in-depth interviews, were selected based on their involvement in the treatment or use of wastewater at the national, state, or city levels and included officials from government agencies, members of think tanks and research organizations, other experts on water, and technology providers, as well as individual water users including farmers and representatives of resident welfare associations. The interviews, conducted observing the due process and obtaining informed consent from the interviewees, lasted about 45–60 min each and were focused on three points, namely the status of wastewater reuse, motivational strategies adopted to encourage the use of RW, and challenges and barriers in terms of differences in the degree of acceptability of RW for municipal uses.

The questions were designed to enhance our understanding of six elements, namely leadership vision; planning and collaboration with various organizations; regulation and legislation; citizen and stakeholder engagement; finance and financing; and culture, knowledge, and capability.

The notes made during the interview were shared with the interviewees and revised where necessary so that the final version was approved by them. Seventeen interviews and two group discussions with seven and eight farmers in each group were conducted during September 2020–March 2021. The data were coded and a SWOT analysis (strengths, weaknesses, opportunities, and threats) was conducted to confirm the challenges to the municipal use of RW because a SWOT analysis makes it easier to identify the association between action and performance-based planning.

RESULTS

Demographic data

Of the 424 respondents, 224 were men and 200 were women; roughly 60% were at least graduates and approximately 28% had either completed their school education or had a diploma; and the sample was evenly distributed in terms of age, the young (10–24 years old), the middle-aged (25–44 years old), and the elderly (45 years or older) each accounting for roughly a third of the total. A third was from the middle-income group; approximately 13%, from the low-income group; and about 10%, from the high-income group. Table 1 gives a summary of the demographics.

Cronbach's α reliability test score was 0.804, suggesting that the variables were highly correlated.

Awareness of water resources, scarcity, and its influence on livelihood

Nearly 86% of respondents faced water shortage and 77% adopted some measures to save water at home.

Table 1. | Demographics of respondents (n=424).

		Education												
		Literate (no formal education)	Matriculate				Senior secondary/diploma				Graduate and above			
		Income group[a]												
Age group	**Gender**	**Low**	**Low**	**Middle**	**Upper middle**	**High**	**Low**	**Middle**	**Upper middle**	**High**	**Low**	**Middle**	**Upper middle**	**High**
Young (10–24 years)	Women	0	2	32	4	0	4	2	3	0	16	12	5	4
	Men	0	2	8	0	0	12	2	5	0	20	4	3	0
Middle-aged (25–44 years)	Women	3	4	0	0	0	4	4	0	0	8	16	5	4
	Men	1	4	0	0	0	8	36	0	0	20	28	7	0
Elderly (≥45 years)	Women	12	4	0	0	1	0	8	0	3	4	5	8	23
	Men	0	8	0	0	3	0	16	0	13	4	11	4	5

[a]Monthly income in Indian rupees: low, $<$20,000; middle, 20,000–40,000; and upper-middle, $>$40,000–80,000; high, $>$80,000.

Piped water through state-owned pipelines was the main source (for 68% of the respondents), 13% used submersible pumps to withdraw groundwater from privately owned wells, and 19% used both these sources. Although about 70% were satisfied with water quality, 81% within that group preferred purified or bottled water, which shows lack of trust in the safety of water provided by the state. About 75% paid for the water and 71% within that group considered the charges to be adequate, which shows that most of the consumers were comfortable with paying for water or could afford to pay for it.

The PC analysis identified four PCs (with eigenvalues greater than 1) as significant drivers of consumer behaviour and attitude (Table 2).

The more important personal norms that shape people's perception of the current water supply are the quality of water, its source, possible ways to cope with water shortage if water is not available for purposes other than drinking, use of untreated wastewater for those purposes, and the cost of water.

A large majority (87.7%) of the respondents adopted some measures at home to conserve water to meet their requirements. These respondents were categorized as 'water conservative'. A small proportion (8.5%), who although claiming that they save water, were unable to mention any specific measure, whereas 75% who said they did not save water were actually doing so regularly. The rest (12.3%) were categorized as 'non-water-conservative'.

Among the age groups, approximately 77% of the young, 92% of the middle-aged, and 94% of the elderly were water conservative. This indicates that experience in life is an important influence that favours conservative behaviour. More than three-fourths (77.4%) in that group pay for water and less than 15% consider the charges excessive, whereas only about 55% of the non-water-conservative pay for water, and approximately 43% of them consider the charges exorbitant. This split shows that the water conservatives appreciate water as a valuable resource.

Demographics, location, and willingness to use recycled water

The relationship between behaviour or attitudes (factors that affect personal norms) and the attributes of water quality and supply as seen in respondents sharing a homogenous environment was ascertained by using the Kruskal–Wallis H, the results of which are shown in Table 3.

Table 2. | PCs (eigenvalues greater than 1) of water quality and supply driving consumer behaviour and attitudes.

Variable	PC 1	PC 2	PC 3	PC 4
Source of supply	0.045155	−0.006756	**0.574847**	**0.547563**
Water colour	**0.425182**	−0.05619	0.374982	0.255212
Water taste	**0.402788**	−0.382995	0.156062	−0.167106
Water smell	**0.465635**	−0.00774	−0.35754	−0.152734
Overall water quality	**0.494691**	−0.274069	−0.085353	−0.083379
Water purification	0.053992	**0.451058**	0.003367	0.020559
Water shortage	0.295136	**0.501937**	−0.085727	−0.035749
Steps to address water shortage	0.269465	0.288088	0.099433	−0.034899
Conservation measures to save water	−0.049193	0.06707	**0.4061**	−0.555477
Untreated wastewater for domestic use	0.044637	−0.115023	−0.432618	**0.506382**
Water charges	0.162373	**0.467783**	−0.011902	0.094554

PC 1 was based on individual perception of water quality in terms of colour, taste, and smell.
PC 2 included water shortage, mode of purification required to make it suitable for drinking, and water charges.
PC 3 included water supply and measures to conserve water adopted at the household level.
PC 4 included water supply and the use of untreated wastewater for other uses (such as watering plants or flushing toilets).
Bold values indicate the significant drivers of PC.

Table 3. | Results of the Kruskal–Wallis H test on the relationship between consumer behaviour and attributes of water supply.

		PC 1				PC 2			PC 3		PC 4	
Variable	**Statistic**	**Water colour**	**Taste**	**Smell**	**Overall quality**	**Purification**	**Water shortage**	**Water charges**	**Source**	**Measures to save water**	**Source**	**Use of untreated wastewater for domestic activities**
Age	χ^2	1.276	0.069	2.778	4.793	2.749	0.887	0.590	5.216	8.944	5.216	5.453
	P-value	0.528	0.966	0.249	0.091**	0.253	0.642	0.744	0.074**	0.011	0.074**	0.065**
Gender	χ^2	4.274	0.121	1.515	0.283	5.560	0.002	1.013	3.181	1.153	3.181	1.584
	P-value	0.039*	0.728	0.218	0.595	0.018*	0.967	0.314	0.074**	0.283	0.074**	0.208
Education	χ^2	4.766	4.775	3.818	1.642	10.166	4.708	16.507	4.766	7.474	4.766	12.088
	P-value	0.190	0.189	0.282	0.650	0.017*	0.194	0.001*	0.190	0.058**	0.190	0.007*
Income	χ^2	2.149	4.355	6.129	2.707	26.446	6.576	11.227	2.149	12.960	2.149	3.188
	P-value	0.542	0.226	0.105**	0.439	0.000*	0.087**	0.011*	0.542	0.005*	0.542	0.364

*Significant at 95% confidence interval; **significant at 90% confidence interval.

Variables such as ways of water purification, water charges, and measures to conserve water are influenced by income and education, whereas variables such as source of water and reuse of RW for other uses at the household level are correlated to age and education. These associations indicate that groups of people who value water, irrespective of their income, prefer purified water for drinking and adopt measures to conserve water but whether such people would go far enough to be willing to use RW is a function of their age and education. The gender influences such variables as the response to the colour of water, method of purifying water, and the source of water because, by and large, it is women who are mainly responsible for water-related domestic chores and therefore plays a decisive role and is concerned about its source and quality, including colour and odour.

Weighing demand against risk

Nearly 30% of the respondents were categorised as 'wastewater knowledgeable'; 50% as 'wastewater slightly informed'; and the rest 20% as 'wastewater ignorant'. Among the knowledgeable, 38.9% were at least graduates; in terms of age, approximately 43% among the young were in that category, as were 63% of the middle-aged and slightly over 50% of the elderly. This group also accounted for roughly two-thirds (63.6%) of those from the upper-middle-income group, whereas approximately 70% of those who were slightly knowledgeable belonged to the middle-income group and among the ignorant, approximately 43% belonged to the lower-income group. When asked whether they were aware of government policies related to water, approximately 71% of the knowledgeable, 56.6% of the slightly so, and only 27 of those categorized as wastewater ignorant replied in the affirmative.

A majority (about 60%) of the knowledgeable believed that using RW poses no risk to health; about the same proportion of the slightly knowledgeable were unsure; and a much larger proportion (nearly 82%) of the wastewater ignorant were either unsure or believed that using RW is risky.

In the first two categories, nearly half (49%) of those with education beyond secondary school said that what they knew about water was what they had learnt at school or college and 24% of them named various informational campaigns as the source of their knowledge, whereas of those who had studied only up to secondary school, 57% acknowledged school as the source of knowledge, 29% acknowledged their family, and none cited campaigns as the source. These figures indicate that knowledge makes RW more acceptable and imply that endorsing its use through both formal and non-formal channels of information will pay rich dividends.

Socially acceptable and economically viable uses of recycled water in future

Approximately 13% of the respondents agreed to use RW for all purposes; 41%, agreed for contact use of RW but not ingestion; and the remaining accepted RW for non-contact purposes.

Only a small minority (approximately 6%) of the young as compared to about 20% of the elderly were willing to use RW for all purposes, as were approximately 18% of those from the upper-middle-income group and 36% from the high-income group. A larger proportion of women (60%) than that of men (48%) were willing for using RW for all purposes except ingestion, whereas with respect to education, approximately 44% of those with a bachelor's degree or higher were comfortable with the contact use of RW but not its ingestion and 13% were happy to use RW for all purposes.

The response was also governed by other factors: approximately 39% could not say when they would be open to the idea of using RW for all purposes, whereas about 30% said they would be comfortable with the idea if other people around them accepted it and the rest (approximately 22%) insisted on quality assurance from state authorities. Approximately 46% of the total were unwilling to pay more for better quality of water or for longer hours of supply.

To understand the limiting factor and the willingness of different categories of respondents to use RW for municipal uses in future, we calculated the mean score for the various factors. Health (with a score of 4.3) emerged as the major limiting factor for women (for men, it was 3.93), whereas men were more sensitive to public criticism (2.3) than women (1.88) were. Lack of trust in government authorities was a major limiting factor but changed with education (2.0 in the case of the literate with no formal education and 3.26 in the case of those who were at least graduates). The limiting factor for religious prohibition decreased with education (from 3 for respondents with no formal education qualification to 1.8 for respondents who were at least graduates). Apart from health, the yuck factor (3.02) emerged as a prominent limiting factor.

Education, age, gender, and income were the factors that influenced the respondents' willingness to use RW. Overall public receptivity towards using RW for uses other than drinking was high, with health being the crucial limiting factor. Women, the elderly, and those in the middle-income or higher-income group proved more willing than the rest. However, willingness to use RW for drinking was low, and those from the low-income group said they would use RW for drinking only if they had no other choice.

Opportunities to use RW for municipal uses

The participants were divided into three groups of stakeholders, namely policy-makers, public utilities for water services, and community. Such that, 5 officials from government agencies dealing with water at city/state levels were categorized into policy-makers; 4 water experts and 2 technology providers were clubbed as public utilities for water services; and 3 water professionals from think tanks, 15 farmers, and 3 resident welfare associations were combined as a community. The major discussion points of the various 32 stakeholders are summarized in Table 4.

The consolidated responses were also used for SWOT analysis (strengths, weaknesses, opportunities, and threats) as summarized in Figure 2.

The above analysis of responses from the stakeholder offers some deeper insights, mainly about the need to

- make people aware of relevant guidelines, government policies, and framework,
- monitor treated wastewater regularly at the community level and to train local residents in conducting quality checks to build enough confidence in people about the technology and the quality of water, and
- sensitize people to the need to use treated water and to educate them through campaigns to promote the use of reclaimed municipal wastewater and the existing infrastructure.

These insights were derived from analysing what motivates people to act: the analysis showed that 71% of the respondents across all age groups prefer to receive information through television, radio, and newspapers. It is noteworthy that the young no longer trust celebrity endorsements: only 11% of the young prefer such endorsement, whereas the corresponding proportion was 24% in the elderly and 13% in the middle-aged. On the other hand, only about 25% among the young would prefer to attend workshops or to verify the information by visiting the treatment plant or the demonstration units, whereas 33% among the elderly preferred community workshops and 52% preferred site visits. Upon being asked how public understanding of the use of RW can be increased, 66% of the respondents believed that this can be achieved through education; 33% suggested financial incentives; and 26% said that appropriate state policies can help. Among the respondents who were at least graduates, 61% believed education to be the most important, as did 64% of the elderly. Appropriate state policies were chosen by 43% of those who were at least graduates and by 55% of the elderly.

DISCUSSION

Residents of the NCR conserve water and use it judiciously either to deal with water scarcity or as a way of life in the interest of the environment – those who conserve water today are more likely to become willing users of RW in future, although most would avoid it for drinking: only 13.2% were willing to do so, whereas 40.6% were willing to use RW even for uses that involved direct contact with RW (e.g. bathing or washing up) but not for

Table 4. | Discussion points with various stakeholders as clubbed into three groups on wastewater reuse.

Discussion points	Policy-makers	Public utilities for water services	Community (including think tanks, farmer, and Resident Welfare Associations)
Regulation and legislation	Standards are regularly met apart from the monsoon season, when treatment capacity can be overwhelmed, leading to untreated wastewater being discharged.	Only in locations where STPs are working at full capacity.	Farmers complained that quality was not constant and that every few days, the water would be smelly. Unaware about discharge standards and their fulfilment.
Culture, knowledge, and capability	Using tertiary-treated wastewater to add to the natural flow in river. Rejuvenating water bodies in Delhi, and water parks in Gurugram. Using treated wastewater for watering plants in parks and gardens near wastewater treatment plants.	Using in-house facilities available with industries to treat municipal wastewater – which is much easier and cheaper to treat than many other effluents – to make up for irregular supply of water.	Those living in housing societies use RW for flushing toilets and for watering plants. Water for washing pavements and other open spaces. Supplying treated water to farmers to irrigate crops.
Citizen and stakeholder engagement	Campaign in form of informal education and use children as agents of change are being organized. Way to educate the masses is equally essential and required. Working with focussed groups to enhance different reuse purposes.	Need to launch a movement to persuade people, over time, to extend the use of RW to drinking. Local solutions derived from global successful case studies need to be highlighted through local radio channels and cable TV to reach the public at large. The relevant educational curricula need to be revised. First-hand data need to be collected to create awareness and to involve the general public in framing policies.	Policy changes are required to ensure capacity building: those involved in implementing the relevant policies should have the capacity to do so. Regular monitoring of TWW quality and sharing of results with users.
Finance and Financing	Connecting parks and gardens to the nearest wastewater treatment plant. Setting up of decentralized STPs/customised TWW for specific utilization.	A movement that can be facilitated by using dual pipelines colour coded to mark the source of water. Installing such pipelines right from the beginning in areas being connected to a sewerage system for the first time.	Yield and quality of the farm produce suffered owing to the poor quality of RW.

(*Continued.*)

Table 4. | Continued

Discussion points	Policy-makers	Public utilities for water services	Community (including think tanks, farmer, and Resident Welfare Associations)
Political leadership in new innovations, planning, and collaboration with various organizations	Lack of coordination among different agencies dealing with issues related to water, wastewater, health, and sanitation, resulting in mismanagement and wastage of funds. Capacity building of employees and regular certification are required.	Political will to enforce inter-department coordination as shown by two national missions, namely the 'Jal Jeevan' mission and the 'Swachh Bharat' mission. Instead of RW, terminology like recycled water can be used to help the process of public acceptance.	Provision of financial incentives for the general public should be sorted. Involvement of members of resident welfare associations in regular monitoring and evaluations of treated wastewater units.

drinking; and 46.2% were willing to use it only for uses that did not involve direct contact with the body (e.g. toilet flushing and watering plants). These results indicate that the closer the contact with RW while using it, the greater the reluctance to use it.

Thus, considering water scarcity in cities and the need to meet growing demand, it is clear that users should be made aware of the feasibility of reusing greywater. The World Health Organization maintains that 25 litres of water a day is sufficient to meet all the basic sanitation and food needs of one person. Reusing greywater, because it is estimated to constitute 43–70% of the total volume of domestic wastewater, can help a great deal in reducing the total demand for freshwater in cities. Brazil has been able to reduce water consumption by 29–35% by using greywater for flushing toilets (Ghisi & Ferreira, 2007); in Australia, the state offers financial incentives for treating and reusing treated greywater at the household level; in Tokyo, the reuse of greywater is mandatory for buildings of specified sizes; and local regulations in Spain make installing the systems to reuse water obligatory in all new buildings (Domenech & Sauri, 2010). A cost–benefit analysis of greywater reuse for flushing toilets and watering gardens in Madhya Pradesh, India (Godfrey *et al.*, 2009), revealed that the internal and external benefits of greywater reuse were substantially higher than the internal and external costs. Although these interventions entail some costs for the required infrastructure, as freshwater becomes increasingly scarce and the infrastructure to supply it, especially in cities, continues to be stretched, the easiest way to reuse water is to reuse the light greywater collected from reverse osmosis filtration units and AC ducts for uses other than drinking, such as watering plants, cleaning, and washing. Using such water for purposes other than drinking is the first stage of water reuse in cities and is more likely to be acceptable to those whose personal norms include careful use of water. The next stage is to use recycled grey water even for drinking, and the final stage is to use appropriately treated blackwater for all purposes.

Overall responses to using RW are the result of a complex interplay of age, income, education, and gender. Although the young in our sample knew less about the use of RW, that is the age at which behavioural and attitudinal changes are being formed and their current perceptions can probably change. The present study revealed that the elderly are more likely in future to be willing to use RW even for drinking, a finding in line with Gu *et al.* (2015) reporting that people's environmental concerns change with age. As people in different age groups are born and bought up in different historical periods with distinct values and orientations, such changes are only to be expected.

Another finding from the present study, namely that respondents who were at least college graduates showed greater awareness of wastewater issues than that shown by others who were less educated, is also echoed by Akpan *et al.* (2020), who found that people with higher education were more willing to reuse wastewater.

Fig. 2. | SWOT analysis about the use of RW for municipal uses from stakeholder responses.

The present study also found that health concerns made women more reluctant to use RW and that social criticism did the same for men. This difference can be explained by Ajzen's theory of planned behaviour, namely that an individual's behaviour can be predicted from their behavioural intentions. The theory was supported by Dolnicar *et al.* (2011), who maintained that an individual's prior attitude influences the individual's perception and response to information. Therefore, knowledge needs to be fortified with hands-on experience if behaviour and attitudes are to be changed. The results of our survey show how well-devised communication along with setting up demonstration units can be the principal drivers to change the behaviour to promote the reuse of RW as a viable source of drinking water in the future.

Respondents from the middle-income and high-income groups were more willing to pay more for the maintenance of the infrastructure for reuse, as was reported earlier (Abdelrahman *et al.*, 2019). Also, those with a conservative attitude to water do not consider charges for water as high, indicating a pro-environment behaviour shaped by some understanding of the availability – and of growing scarcity – of water.

Of the total number of respondents, only about 30% had such knowledge, which points to the need for wider and more effective dissemination of information by authorities on the use of RW and the existing infrastructure created for that purpose so as to create a pool of informed citizens who will be motivated to take reasonable actions. Better dissemination of information can be achieved through creatively designed resource materials, visits to wastewater treatment plants (Gu *et al.*, 2015), and so on. Also, state authorities should work with manufacturers of reverse-osmosis devices, air conditioners, washing machines, and other such appliances that produce greywater to provide information on how that water can be reused. This measure will reduce the overall demand for water across the country.

Lack of trust in state machinery and the consequent concerns about quality and health are obstacles to be overcome. Such lack of trust has been reported in many studies to be influenced by various factors including sociodemographic variables, involvement of communities, level of awareness, availability of and access to water, health issues, and the intended use of water (Dolnicar *et al.*, 2011). Religious prohibition was another major limiting factor for the less educated, indicating that ideological opposition can dissuade people from reusing RW (Massoud *et al.*, 2018).

Farmers have their separate concerns over RW and need reassurances and information on regular monitoring at the local level to ensure uniform quality of water, safety measures to be adopted while using tertiary-treated wastewater for irrigation to avoid adverse impacts on health, and to maintain the quality of produce. Farmers are generally willing to reuse RW but to make them use it, more effective communication between water authorities and end-users is required.

CONCLUSION

Successful expansion of the use of reclaimed municipal wastewater depends on the attitude of the public and what it knows about such use. The present study offers policy-makers just such knowledge in the form of useful and first-hand data on what the public knows about water scarcity and how demographics influence, and correlate with, perceived risk and willingness to use reclaimed municipal wastewater. The data were collected through a questionnaire survey and semi-structured interviews with experts and other stakeholders in India's NCR. The survey and the interviews were designed to ascertain the willingness of people to use RW and the challenges and barriers that make people unwilling to use it. The findings provide a base for developing an integrated, practical, and strategic wastewater framework for cities in developing countries. Most of the respondents in the region were conserving water and receptive to the idea of using treated wastewater but remained averse to using it for drinking. The reuse of water can be promoted at the household level through focused educational campaigns and will eventually persuade people to use such water for drinking as well.

Focusing on those in their middle-school years will pay rich dividends because, eventually, it is the younger generation that should be persuaded to use reclaimed municipal wastewater in future.

DATA AVAILABILITY STATEMENT

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

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