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Research article

Institutional challenges and stakeholder perception towards planned water reuse in peri-urban agriculture of the Bengal delta

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ABSTRACT

The indirect, unplanned use of urban wastewater by peri-urban farmers in developing countries poses a severe risk to the environment and the farmers. Planned water reuse could contribute substantially to the irrigation water demand in peri-urban agriculture and minimize the risk. However, implementing such practice requires a thorough evaluation of stakeholder's perception and the scope within the existing organizational structures. This paper aims to assess the level of awareness, perception, and willingness of different stakeholders toward current practices and the prospect of urban water reuse in Khulna City - one of the most vulnerable cities located in the southwest of Bangladesh due to the consequences of rapid climate changes in the Bengal delta. Also, institutional arrangements and their functioning were analyzed to understand the current sectoral performance. One questionnaire with 385 respondents from the urban area, 32 in-depth interviews and one focus group discussion with farmers in the peri-urban area, and ten interviews with key informants from the government and non-government organization was conducted. Results indicate an overall positive attitude among major stakeholder groups toward planned water reuse for peri-urban agriculture. More than half of the citizens (53%) are willing to pay for the treatment of wastewater and majority of the farmers (66%) are willing to pay for the supply of better-quality irrigation water. However, the public sector responsible for wastewater collection and treatment requires adjustment in rules and regulations to implement planned water reuse. Interrelated factors such as lack of transparency and coordination, shifting responsibilities to other organizations, lack of required resources need to be addressed in the updated rules and regulations. Strategies to enforce current regulations and align all stakeholders are also crucial for collection and treatment of wastewater and its subsequent use for crop production.

1. Introduction

1.1. Background and objective of the study

The demand for good quality water in food production and industrial activities is proliferating in Bangladesh. However, the quality degradation of water resources and the threat of natural disasters (floods, cyclones) intensified by rapid climate change is limiting the availability of freshwater resources and thus threatening the existence of cities in this part of the Bengal delta. A large volume of wastewater generated in the urban area is discharged every day into the nearby rivers and canals and flows to the peri-urban agricultural lands. Peri-urban farmers are left with no other alternative than to use this polluted surface water; a practice termed as indirect-unplanned wastewater use (Drechsel et al., 2015; Jiménez and Asano, 2008). The reasons behind this practice are lack of quality irrigation sources, unavailability of adequate wastewater management infrastructure, inadequate financial resources, absence of adequate policy, lack of farmer's awareness and willingness to use untreated wastewater (Ensink et al., 2002).

Planned reuse can improve water circularity and ensure the optimum use of available resources (Agudelo-Vera et al., 2012; Wielemaker et al., 2018). However, public consent is essential for implementing planned water reuse, especially in agriculture. Evidence shows that the negative emotional response towards wastewater also known as '*Yuck Factor*' is one of the most critical factors that triggered the failure of wastewater

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Abbreviations

AOSED	An Organization for Socio-Economic Development
BADC	Bangladesh Agricultural Development Corporation
BELA	Bangladesh Lawyers Association
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DC	District Commissioner
DOE	Department of Environment
DPHE	Department of Public Health Engineering
ETP	Effluent Treatment Plant
FGD	Focus Group Discussion
KCC	Khulna City Corporation
KDA	Khulna Development Authority
KWASA	Khulna Water Supply and Sewerage Authority
LGED	Local Government Engineering Department
NWRC	National Water Research Council
O&M	Operation and Maintenance
PMO	Prime Minister's Office
WARPO	Water Resources Planning Organization
WTP	Willingness to pay

management plans (Gross et al., 2015; Hartley, 2006). Besides, trust and knowledge, related costs and benefits, attitudes toward the environment, and socio-demographic factors, also crucially influence the social acceptance of wastewater use (Drechsel et al., 2015; Po et al., 2003). Institutional arrangements also play a crucial role in planned water reuse in agriculture. Lack of coordination among national and local agencies for wastewater management, unclear institutional arrangements, and overlapping responsibilities across organizations make it difficult to have a functioning reuse scheme (Drechsel et al., 2015).

Institutional aspects and stakeholder perception of urban water reuse in Bangladesh are yet to be investigated. This paper aims to study the perception of major stakeholder groups (farmer, citizen, government officials) towards urban water reuse, through a questionnaire survey, interviews, and analysis of the existing governance structure. Additionally, we also explored the economic aspects of reuse through assessing willingness to pay by farmers to receive better quality irrigation water, and by citizens for treating domestic wastewater. Khulna, a coastal city, located at the southwest of Bangladesh, vulnerable to climate change impacts, has been taken as a case study.

1.2. *Urban water management in Khulna*

Khulna is the third-largest city of Bangladesh and is an administrative powerhouse of the region with more than 600 thousand inhabitants struggling to find an adequate supply of drinking water. Due to lack of good quality water sources in the city, recently, a drinking water purification plant has been inaugurated to collect surface water from *Modhumati River,* which is 58 km away from the city. However, most private residential users meet their daily water demand from deep tube wells as they are not connected with a centralized system. Water extracted from aquifers is consumed within the household as drinking water and used for domestic activities (bathing, washing) and is discharged as greywater into the nearby drainage network (Fig. 1). Blackwater originating from flushing the toilet is mostly collected in septic tanks, and often effluent gets mixed with surface water. The drainage network carries 50,000 m^3 of untreated greywater to the *Mayur river* located west of the city. The industrial wastewater is treated before discharge as this is required and enforced by the authority. The *Mayur* river separates the urban area from the peri-urban area and the majority of the farmers are connected to the *Mayur* river for irrigation purposes. The peri-urban farmers extract water from the river for irrigation during the dry period (mid-November to mid-April). As river water gets polluted with untreated wastewater, the farmers are indirectly using wastewater for irrigation. Study showed that river water quality deteriorates severely during the dry period and based on FAO irrigation water quality standards, this water is not suitable for irrigation (Haldar et al., 2020). However, the farmers are forced to use this polluted surface water due to lack of other available sources.

1.3. *Analytical framework*

1.3.1. *Framework for the analysis of stakeholders and institutional practices*

Stakeholder analysis is a pivotal tool to identify and classify the major stakeholder groups according to their interests and influence (Mendelow, 1981). The stakeholders related to urban water management are placed in the axis and divided into four different groups according to the degree of interests and influence: 'keep satisfied', 'manage closely', 'monitor', and 'keep informed'. Stakeholders in 'keep satisfied' group has little interest but quite some influence, 'manage closely' group has the highest level of interest and influence, the 'monitor group' has lesser interest and influence on the subject and finally 'keep informed' stakeholder group has high interest but low influence (Mendelow, 1981).

To analyze the institutional practices and outcomes of dealing with wastewater, a conceptual framework composed of structural variables and a set of dynamic factors is presented (Table 1). The structural variables describe the roles and duties of the actors involved in wastewater production, treatment and use, and their institutional resources (Hassenforder and Barone, 2019). The formal and informal actors involved in collecting, treating, monitoring and using wastewater have specific roles and duties. This relate to specific responsibilities, objectives, legal actions, institutional level, domain and geographical area; according to the water law and regulations (Wiering et al., 2015). Whether or not the actors can act according to these rules and duties depends on the capabilities and resources. Resources include access to financial means, information and time. Access to financial resources depends on the distribution of costs and benefits, imposed fees and fines.

The set of factors that influence institutional dynamics includes decision making, representation, accountability and credibility. Decision making is about who defines the objectives and the rules (there might be different factions within the public organizations) and how the stakeholders are represented in the decision-making platforms. Accountability of the state apparatus vis-a-vis the citizens is a vital mechanism to enforce rule-of-law. To circumvent accountability mechanisms

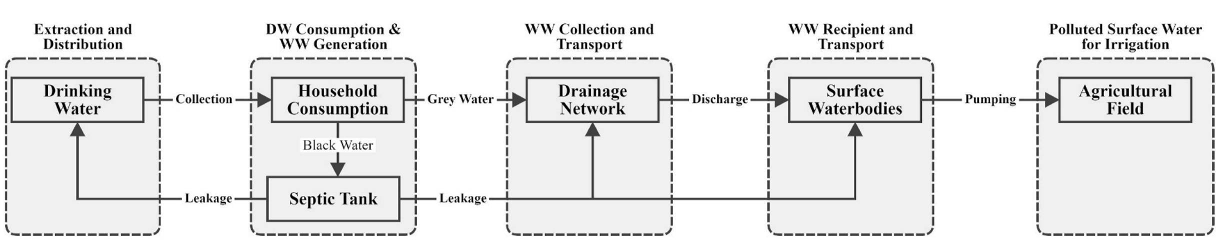

Fig. 1. Existing water chain in the study area.

Table 1
The common set of structural variables and factors used to analyze the institutional practices and outcomes (Hassenforder and Barone, 2019).

The common set of structural variables:
1. Actors that are involved (formal and informal)
a. Roles and duties of the actors
b. Capabilities, actionability and enforceability (How can the actors achieve outcomes, autonomy and dependence on others)
2. Resources
a. Financial resources (distribution of the costs and benefits, fees, fines, willingness to pay)
b. The information available (data generated, and access to information of others)
c. Time input available (staff time input)
The common set of factors of institutional dynamics:
3. Decision making and representation
a. Definition of objectives and regulations
b. Enforcement of regulations and sanctions (formal and informal authority)
c. Advocacy influence
4. Accountability
a. How the state apparatus is held accountable by citizens
b. How risks and damage are formulated, blame and responsibility shifted to others
5. The credibility of authority, policy and rules

organizations might shift responsibilities and blame to others (Bickerstaff and Walker, 2002). Authority, policies and rules will gain importance if they are accepted and credible (Jacobs and Matthews, 2017). Besides institutional structure and dynamics, actual outcomes of wastewater treatment are also influenced by the infrastructure available, climate, and the type and levels of contamination of the wastewater.

1.3.2. Water pricing and willingness-to-pay

Water pricing may be an incentive for the user group to use water more efficiently and raise funds to provide the drinking water service. However, high fees can exclude poor people from access to water. Similarly, citizens are generating and discharging wastewater that contaminates farmers' irrigation source. Charging for treatment could cover the costs of collection and treatment, but in Khulna treatment is not charged at the moment. The three most important concepts for water economies is the cost, value and price set by authorities (Rogers et al., 1998, 2002). Cost includes a wide range of aspects including O&M costs, capital cost, opportunity cost, cost of economies etc. whereas value and price can be defined by the benefit and value received for the service against the amount set by the socio-political system. The opportunity cost and economic externalities were assumed to be zero, as there is no shortage of supply and no alternative use (Rogers et al., 1998).

Willingness to pay (WTP) is a widely-used method where citizens and farmers willingness is estimated to implement services and can be compared to the Full Economic Cost of water and wastewater treatment (Akter, 2007; Markantonis et al., 2018; Saldias et al., 2016; Zakaria et al., 2014). To avoid the respondents strategic bias by deliberately exaggerating the amount they would be willing and could afford to pay (Carson et al., 2001; Zakaria et al., 2014) both groups were explained clearly the necessity of the treatment system and possible positive socio-environmental benefits. The average amount mentioned by the urban citizens and farmers was then used as an indicative amount that they are willing to pay for improved services.

2. Methodology

2.1. Questionnaire survey

A questionnaire survey was conducted in 2018 among the urban citizens to understand the awareness, perception and knowledge towards water reuse and related issues. During the questionnaire survey, urban residents were asked to indicate an open amount that they are willing to pay for the treatment of wastewater and improvement of existing drainage infrastructure. Correlation analysis of the associated socio-demographic factors (education, age, income) was calculated to validate the amount mentioned by the respondents. Besides WTP, the questionnaire included necessary demographic data, domestic water use, wastewater generation, attitude towards water reuse. The questionnaire was pre-tested and the finalized version was deployed in the digital data collection platform Kobo Toolbox. The total number of respondents was 385 and their basic demographic profile is presented (along with the details of area-specific sample size and locations) in the supplementary material. In the questionnaire, respondents were asked to rate different aspects of water from a scale of one to five, where one means negative or low responses and five means excellent or positive responses.

2.2. In-depth farmers interview and focus group discussion (FGD)

In-depth and structured interview questions were formulated to understand farmers' motivation and perception towards the existing indirect use of wastewater for irrigation. In addition to these, farmers were asked to indicate an open amount that they are willing to pay (per 0.134 ha *or locally termed as "1 Bigha"*) for receiving clean irrigation water instead of using polluted surface water. A pre-test was executed in the study area and necessary adjustments were made before finalizing the interview questions. The target group consisted of randomly selected farmers involved in irrigation by drawing water from the river *Mayur* during the dry period. In 2019, a total of 32 interviews were carried out in the southern and western part of Khulna city, which is dominated by peri-urban agriculture. Socio-demographic information of the interviewed farmers is added in the supplementary materials. One Focus Group Discussion (FGD) was held at the end of the fieldwork with the farmers to validate and elaborate on the preliminary findings as FGD should be used as a mixed methodological approach to avoid biases in response (William, 2012). Especially, the amount mentioned as the willingness to pay for improved irrigation water by individual farmers was further justified during the FGD.

2.3. Key informant interview

Based on the stakeholder analysis (Fig. 2), stakeholders related to wastewater management were identified, and among them, a total of 10 representatives of organizations were selected for the interview. High-level officials from government offices like Khulna Development Authority (KDA), Khulna City Corporation (KCC), Khulna Water Supply and Sewerage Authority (KWASA), Department of Environment (DOE), Department of Agricultural Extension (DAE), Department of Public Health Engineering (DPHE), Bangladesh Water Development Board (BWDB) and District Commissioner's (DC) office and two non-governmental organizations namely An Organization for Socio-economic Development (AOSED) and Bangladesh Environmental Lawyers Association (BELA) were identified as key informants for conducting the interview. Like other surveys, the interviews' main aim was to understand their organizational role, perceptions, and plans towards improving the surface water quality and planned reuse.

3. Results and discussion

3.1. Stakeholder analysis for urban water management

Several governmental and non-governmental agencies are directly or indirectly involved in implementation activities, policymaking, monitoring and enforcement related to urban water management in the study areas (Table 2). Concerned ministries in consultation with different advisory bodies, for example, the steering committee, planning commission, WARPO, and Prime Minister's Office (PMO); prepare policies, rules, and regulations related to water supply and sanitation. Local agencies like KWASA, KCC, DPHE, LGED, and BWDB are responsible for implementing water management projects. KWASA is responsible for

Table 2
Organizational involvement matrix in urban water chain in the study area (own elaboration).

Organization	Involvement[a] of organizations in Urban Water Chain				
	Water extraction and distribution	Water Consumption and Wastewater generation	Wastewater collection and transport	Wastewater discharge and river management	Pumping irrigation water
Concerned Ministries	+	+	+	+	+
District Commissioner's Office	-	-	-	+	-
Donor agency/INGO/NGO	+	-	-	+	-
Industries	-	+	-	+	-
Khulna Water Supply and Sewerage Authority (KWASA)	++	+	-	++	-
Khulna City Corporation (KCC)	-	++	++	-	-
Bangladesh Water Development Board (BWDB)	-	-	-	+	+
Department of Agriculture Extension (DAE)	-	-	-	-	++
Khulna Development Authority (KDA)	-	+	-	+	-
Department of Environment (DOE)	-	+	-	++	-
Research/knowledge institutions	+	+	+	+	+
Farmers	-	-	-	-	++
Local Government Engineering Department (LGED)	-	-	-	+	-
Bangladesh Agricultural Development Corporation (BADC)	-	-	-	-	++
Department of Public Health Engineering (DPHE)	+	-	-	-	-
Citizens of the urban area	-	++	-	+	-

[a] ++: Directly involved and responsible, +: indirectly involved and responsible, -: not responsible and lesser/no involvement.

supplying potable water in households and also responsible for the treatment of wastewater. Whereas, KCC being a municipal service agency, is responsible for providing a wide range of municipal services, including waste collection, street lighting, collection of holding taxes, trade license. KCC is mainly responsible for maintaining the drainage infrastructure which collects wastewater from residential, commercial and industrial areas. National and international donor agencies and concerned ministries provide the necessary funding to implement projects where NGOs and knowledge institutions generate knowledge, provides education and raises awareness among different stakeholders.

DAE and BADC carry out activities like meteorological forecasts, access to seeds, subsidy for pumping equipment, and advice on the use of pesticides. The District Commissioner's (DC) office monitors and takes actions against river and canal encroachment with local agencies' help. DOE is responsible for monitoring the surface water quality as well as the effluents from industries. Heavy industries must establish an Effluent Treatment Plant (ETP) to treat the effluent before discharge, by following the government's discharge standards. Urban citizens are the producers of greywater that affect the water quality in the rivers around Khulna city and do not pay for discharging greywater into the nearby drains.

The stakeholder analysis (see Fig. 2) shows that the ministries formulated policies at the national level and their input is essential for the change of current practices. Industries generate a considerable volume of wastewater which should be treated before discharge into surface water. However, the reality might be different than expected, and the industries have influence in setting standards for discharge and the enforcement of the standards. The '*Manage closely*' stakeholder group includes KCC, KWASA, DAE, BWDB and they have a high level of interest and influence. As the success of planned reuse depends on these

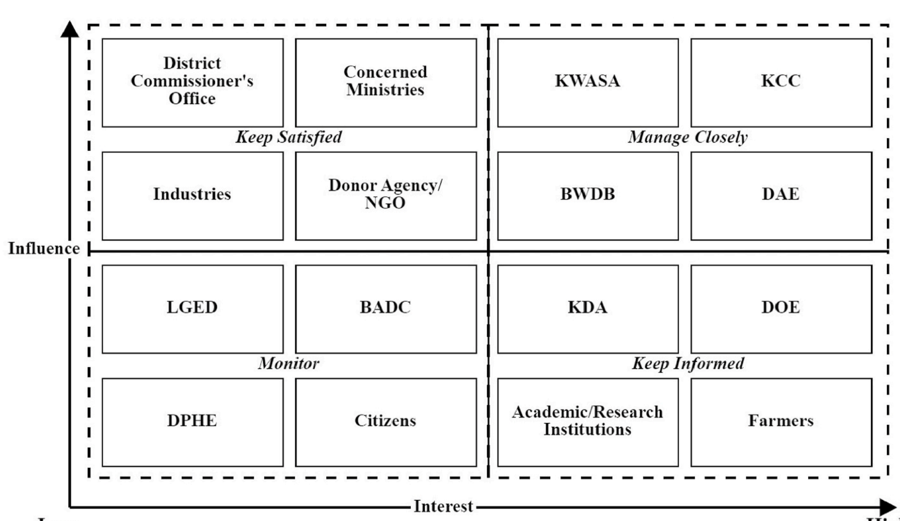

Fig. 2. Stakeholder matrix related to urban water management.

stakeholders, effort should be made to keep the stakeholder involved. Stakeholders in the '*monitor*' group (LGED, DPHE, BADC, Citizens) have a lesser interest and they require limited monitoring and evaluation with the issue. However, citizens are the greywater producers and thus should be included in further planning. The '*Keep informed*' group consists of farmers, DoE, KDA, and local knowledge institutions and are eager to improve the existing situation; however, their influence is limited.

3.2. Institutional aspects of a planned reuse

3.2.1. Important actors and their roles, duties, perception towards reuse

The Khulna Water Supply and Sewerage Authority (KWASA) was created in 2008 and activities are regulated through the Water Supply and Sewerage Authority Act, 1996. The Department of Environment (DoE) monitors the river water quality and their activities are regulated by several laws e.g. the National Water Act, 1999, the National Environmental Conservation Rules, 1997, the Sound Pollution Control Rules, 2006, and the National Waterbody Management Policy, 2009. The DoE periodically monitors river water quality in the region and publishes yearly online summary reports. Key informant interviews indicated that government organizations do not always have sufficiently trained staff and lack of intensive monitoring funds. The DoE generates revenue through imposing fines on polluting industries and fees for a clearance certificate on development projects. The summary reports of the periodic water quality monitoring program of DoE are available online, yet departments do not provide relevant information to other departments. Interviews revealed that all the organizations recognize the potential of planned wastewater use in the context of climate change in coastal Bangladesh and rated the idea of planned use as 'excellent'. However, they pointed out the cost and changes needed in infrastructure and policy as one of the main challenges to implement such practices.

3.2.2. Institutional dynamics regarding wastewater disposal in Khulna

Objectives and priorities for policies and policy implementation are usually taken at the National Water Research Council (NWRC), headed by the Honourable Prime Minister. In consultation with the steering committees and planning commission, different ministries set up policies based on objectives and priorities set by NWRC (Fig. 3). In contrast, KWASA has relatively more autonomy in defining its objectives and policies related to water supply and treatment, even though they rely on government funds for implementing large projects. Installing a proper sewage system and treatment plants would require a substantial increase in the service fee, which is not deemed feasible and collecting and treating wastewater is not regarded as a priority. The low priority of wastewater collection and treatment can be analyzed in the light of citizens' limited capacity to enforce government rules. Citizens suffer most from health effects borne from polluted water in the open gutters along the streets. Transparency International Bangladesh reports Patron-Client relations and office mismanagement to influence the low implementation of policies and enforcement of rules (KUET, 2015).

Rules and regulations on wastewater discharge are only partially enforced, and government organizations show low degrees of citizens' involvement and accountability, where this is key for effective environmental governance (Kochskämper et al., 2016). Different government organizations with functions regarding wastewater have limited cooperation (e.g. in exchange of information), and some seem to shift responsibilities to other organizations. This is because each organization has specific focus areas and not necessarily urban water issues are their primary area of interest. Similar trends of lack of coordination and prioritization among stakeholders are present in other international contexts (Hassenforder and Barone, 2019; Nhapi and Gijzen, 2004; Qadir et al., 2010; Reymond et al., 2020; Saldías et al., 2015). Such sectorization, i.e. polarization of water governance responsibilities distributed over different not adequately communicating organizations, hinders direct and effective measures to facilitate planned urban water use (Movik, 2012; Saravanan et al., 2009). Urban water issues are interrelated with other services and improved cooperation among different organizations is essential for yielding better results (Chowdhury, 2010). An intersectoral partnership among organizations where trust, continuous economic support and incentives for participation is ensured; can be a way out to overcome existing barriers in the urban water sector (Österblom and Bodin, 2012; Waddell and Brown, 1997).

3.3. Citizens awareness and perception towards planned reuse

3.3.1. Household water sources and quality perception

Access to safe, clean water for drinking and domestic activities is a

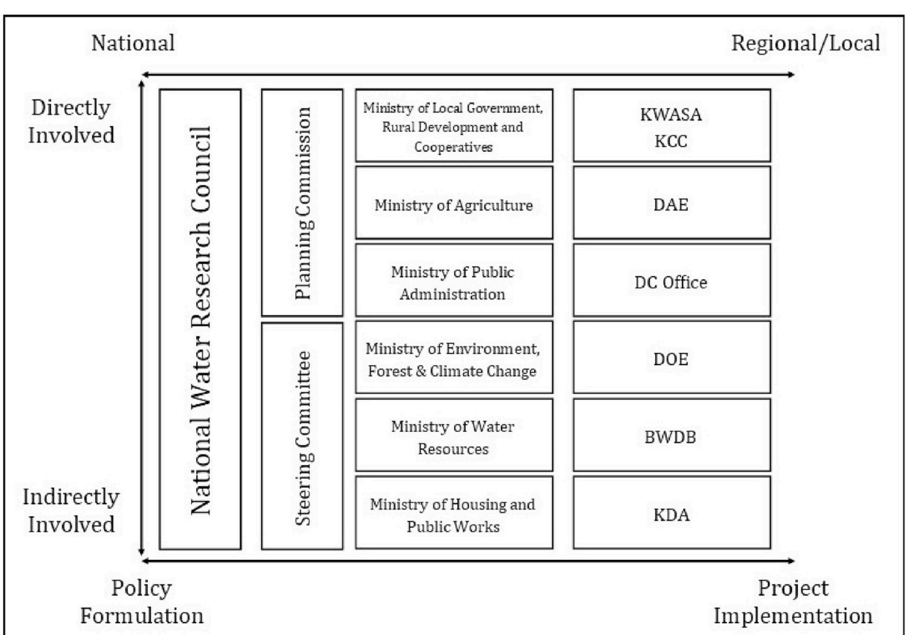

Fig. 3. Institutional dynamics related to planned water reuse (own elaboration).

challenge for people living in coastal areas. Salinity intrusion, presence of arsenic in groundwater, and lack of groundwater recharge have made the situation worse in the recent past (Abedin et al., 2014; Islam et al., 2019). However, the survey in Khulna indicated that, a major portion (90%) of the citizens has access to deep tube wells for drinking water. Other sources like water supply from KWASA and shallow tube wells are mainly used for domestic purposes. Rainwater harvesting is a popular method mostly in rural parts of the coastal area and only 1.3% of the urban citizens used rainwater for mostly domestic purposes. The survey indicated that the urban residents rated drinking water (extracted from deep aquifers at around 300 m) quality at 4.31 (out of 5), where the water quality for domestic purposes (extracted from shallow aquifers around 50 m) was 3.76. Laboratory analysis also indicated that deep tube-wells' water quality was better compared to the shallow tube wells (Datta et al., 2011).

Data analysis also indicated that more than 90% of the households were connected to a drainage network, where 75% had drainage adjacent to their house and 18% had access within 25 m from their house. The survey also showed that more than 64% of the respondents suggested the possibility of reducing the current water consumption and more than 88% of the respondents were willing to take necessary actions to reduce the consumption if necessary. More than 32% of the respondents indicated that they were consuming the required amount of water, thus did not see the need to reduce the current consumption. Previous studies found that water use habits and attitudes were linked with household water demand (Hoolohan and Browne, 2016; Manouseli et al., 2019). High water demand in the household, because of a large family or having a newly born baby was also indicated as primary reasons for not being able to reduce the consumption.

3.3.2. Awareness and perception towards pollution and wastewater treatment

Public perception towards different aspects of reuse scheme has become a critically important part of the implementation (Ross et al., 2014). The respondents perceived wastewater generated from the households to be relatively less polluted than the industrial and mixed areas (Fig. 4). Respondents thought that wastewater generated in the industrial areas is slightly less polluted than from the mixed area. The reason may be that the industries need to improve the wastewater quality before discharge into the open sewers. In contrast, there is no such treatment available in mixed areas, dominated by commercial activities. The majority (>70%) of the respondents rated positively (4 and 5) towards treated wastewater that indicates their understanding of the necessity of treatment. More than 80% of the respondents indicated that they were aware of the negative impact of direct discharge of wastewater, indicating awareness about the impact of untreated wastewater on the natural system.

3.3.3. Perception towards wastewater reuse

More than 78% of the respondents rated urban water reuse concept positively (4 and 5) (Fig. 4) and more than 75% of the respondents considered water reuse as a solution for combating the effects of climate change. Over the years perception towards planned water use has been positively changing which is evident in research from other areas of the world (Alhumoud and Madzikanda, 2010; Chen et al., 2015; Friedler et al., 2006; Garcia-Cuerva et al., 2016; Ravishankar et al., 2018). The respondents (38%) rated negatively (1 and 2) towards the current indirect wastewater irrigation in peri-urban agriculture. 'Irrigation water is dirty, polluted', 'harmful to health' and 'damaging for crops' were mentioned by the respondents explaining their rating on current irrigation practices. The majority of the respondents (83%) also pointed out agriculture as the most recommended area for reuse of treated wastewater followed by industry and households, considering the impact of climate change in coastal Bangladesh. This indicates rather good possibilities for implementing planned water reuse in this part of the delta. Climate change and rapid urbanization have reduced access to quality irrigation water and planned water reuse could be viable to mitigate that challenge (Gross et al., 2015).

3.3.4. Factors affecting citizen awareness and perception

Several studies have identified the factors affecting water reuse and pointed out several socio-economic-demographic factors related to water reuse responses (Chen et al., 2015; Fielding and Roiko, 2014; Po et al., 2003; Smith et al., 2018). The socio-economic background,

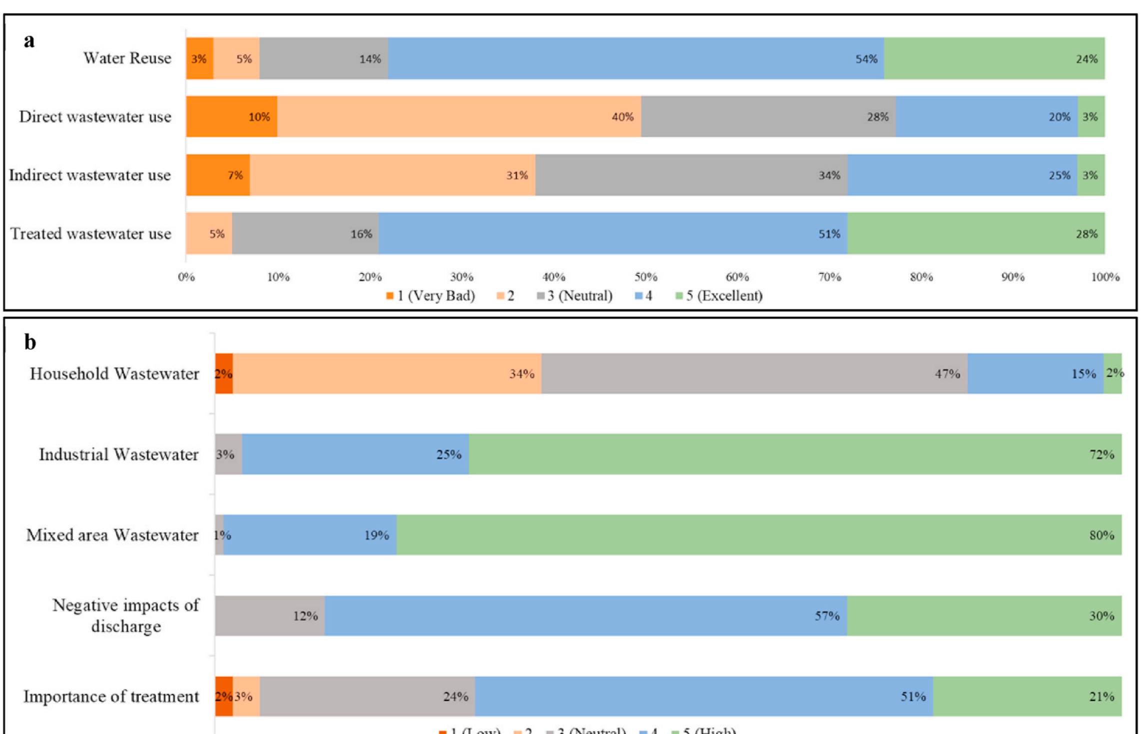

Fig. 4. Perception of citizens on a) different aspects of reuse and b) aspects related to wastewater.

especially the respondent's educational status, is one of the most influential factors related to the response to different aspects of water reuse (Po et al., 2003). A similar outcome has been found in the current study where monthly household income is the significant factor influencing the respondents' responses (Table 3). Gender is a vital factor in drinking water management in Bangladesh, as women are responsible for managing water within the household (Faisal and Kabir, 2005). A similar result has been reflected in this study as the rating of drinking water quality was significantly related to gender. Willingness to take measures within the household to reduce the water consumption primarily depended on the number of people in the family, monthly income and the type of house they live. People living in better housing types have access to more advanced facilities, making it difficult to change their habits in reducing water consumption and have higher expectations in terms of services and trust towards technology and the institutions.

The survey showed that awareness about the negative impact of wastewater discharge and service ratings of the existing drainage system was influenced by education, occupation, family income and house structure type. Residential buildings are well connected to the nearby drains, mostly covered, whereas, people living in slum/squatter do not have access to the proper drainage system or mostly earthen gutters. Willingness to pay for improved drainage systems and wastewater treatment systems was influenced by education and family income. The more income the household had, the more they were willing to spend on improving the system. It was also observed that the knowledge was vital for introducing new concepts, and providing information through education was one of the best ways to transfer new knowledge. Similar findings have been found in earlier research conducted in other areas of the world (Chen et al., 2015; Fielding et al., 2019; Saldías et al., 2016).

3.4. Farmers motivation and perception towards planned water reuse

3.4.1. Existing farming and irrigation practices

Interviews with peri-urban farmers of Khulna indicated that farmers cultivate one or two crops per year dominated by different rice varieties. Farmers also produce wheat or potatoes at different times of the year and some seasonal vegetables (radish, tomato, bitter cucumber) and fruits (bananas or melons). Interviews with farmers also revealed that the type and production of crops depended on farmers' financial situation and accessibility to land. During the dry period, agricultural activities are restricted by the water availability in the adjacent rivers as river water quality and quantity decreases.

On average, a farmer leases 0.98 ha from a landowner, following a '*Borgha*' structure, meaning during the dry season, the landowner will legally claim $1/3^{rd}$ of the benefit as lease transaction and rest $2/3^{rd}$ of the benefit will be for the farmer. During the rainy season, this ratio changes to $1/4^{th}$ for the landowner and $3/4^{th}$ for the farmer. About 60% of the interviewed farmers had a supplemental job such as day labour, construction worker and rickshaw or van pulling; besides their farming practices. Structural changes in the agricultural sector contribute to this development of full-time farming to part-time farming, especially in the peri-urban areas of big cities (Salam and Bauer, 2018). All the interviewed farmers used surface irrigation as the main irrigation technique and the majority (93%) of farmers are dependent on *Mayur* river for irrigation. Farmers are also not allowed to install deep wells, thus uses a shallow pump machine to extract water from the river and use pipes to supply irrigation water for distant crop fields.

3.4.2. Farmers motivation and perception for current practice

Farming has not been a profitable profession in the recent past, and farmers' financial capability determines their farming practices and irrigation sources. Even though the irrigation water quality is poor; 65% of the farmers were well aware of the nutrient presence in the current surface water and knew these nutrients are beneficial for rice growth. Water reuse, either planned or unplanned, has been a common practice among farmers due to the presence of nutrient and cheaply available options (Mojid et al., 2010; Owusu et al., 2012; Saldías et al., 2017). About 25% of the farmers responded by rating 1 (very bad) to irrigation water quality. They observed worms, insects, water hyacinths in surface water, and household wastes as quality deteriorating factors. Farmers also identified two leading causes for the bad water quality: the salinity intrusion from nearby rivers and the direct dumping of solid waste and effluents in the river which resonates with previous studies' findings (Haldar et al., 2020; Roy et al, 2015, 2018). In the context of the current practice, farmers saw planned wastewater use -with proper treatment and quality control-as an excellent option which could ensure quality irrigation water and protect their health.

3.5. Willingness to pay and economic aspects of reuse

Farmers' interviews indicated that over 34% of the farmers were willing to pay US$22[1] per cropping season for the current quality of the irrigation water if authorities decide to charge for water. Overall, 66% of the farmers were willing to pay for the irrigation water (Fig. 5). However, farmers were willing to pay $40 per cropping season for better quality irrigation water. The two most important factors behind their willingness to pay were farmers' inclination to obey the government regulations and mutual understanding with other farmers. Farmers also mentioned their current living conditions, land ownership, economic loss in farming in recent years, and increased production cost as factors for not willing or unable to pay higher prices for better quality irrigation water. On the contrary, citizens were less enthusiastic regarding payment for wastewater treatment and improved drainage infrastructure. Analysis indicated that only 53% of the citizens were willing to pay for wastewater treatment and 56% of the citizens were willing to pay for the improvement of the existing drainage infrastructure. The survey indicated that on average citizens were willing to pay $0.7/month/household for improving the current drainage infrastructure and an additional $0.7/month/household for the treatment of wastewater.

KWASA will establish a centralized wastewater treatment system for Khulna City in three phases and the expected investment cost in

Table 3
Socio-economic factors influencing awareness and perception.

Question	Significant Factor[c]
How do you rate the drinking water quality?	Gender[b], Household Head[a]
Are you willing to take necessary measures to reduce your current household water consumption?	Total Family Member[b], Total Earning Members[a], Monthly Income[b], House structure type[b]
How do you rate the current practice of direct discharge of wastewater and associated negative impacts on the environment?	Education[a], Family Income[a], *House structure type*[a]
How do you rate the existing drainage system?	Education[b], *House structure type*[a]
How much are you willing to pay for the improved drainage system and wastewater treatment?	Education[a], Family Income[a], *House structure type*[b]
How important do you think of proper wastewater treatment?	Education[a], Family Income[a], *House structure type*[a]
How do you rate the water reuse concept?	Education[a], Family Income[b], *House structure type*[a]
How important is it knowing the current irrigation practices for your agricultural products?	Education[a], Family Income[b], *House structure type*[b]
What are the possible water reuse sectors?	Education[b]
How do you rate your trust in technology in making water safe for reuse?	Education[a], *House structure type*[a]

[a] Correlation is significant at the 0.01 level (2-tailed).
[b] Correlation is significant at the 0.05 level (2-tailed).
[c] Italic means negative correlation.

[1] 1 US$ = 80 BDT.

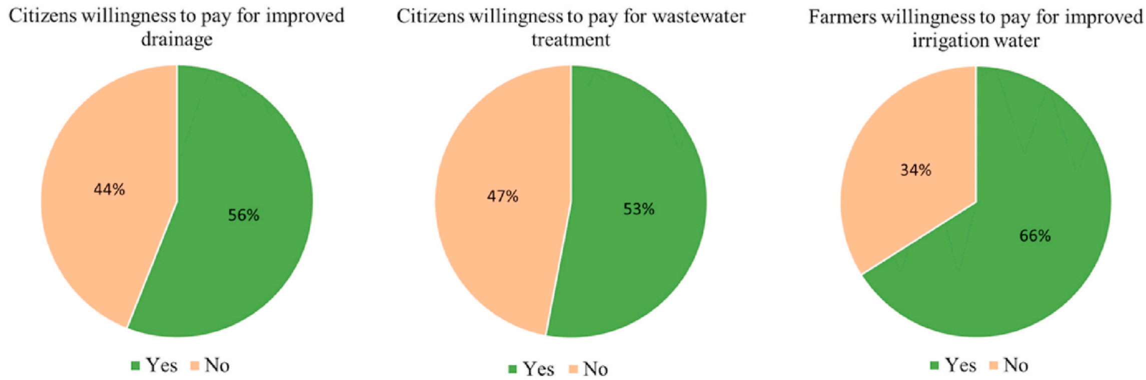

Fig. 5. Percentage of citizens and farmers are willing to pay.

immediate phase (2016–2023) is around $62 million, in the intermediate phase (2023–2029) around $54 million, and in the ultimate phase (2029–2035) around $42 million (KWASA, 2016). The government of Bangladesh and donor agencies are expected to finance the project and being able to provide services for the wellbeing of the population will be considered as an economically viable return (ADB, 2015; KWASA, 2016). The treatment system is expected to have a service span of 30 years and around $4.8 million annual Operation and Maintenance (O&M) costs that could be recovered from the system's beneficiaries. The system is expected to be completed by 2035 and annually treat 50 million cubic meters of wastewater (KWASA, 2016). Based on these numbers, the system's operation and maintenance cost will be $\$0.10/m^3$, and capital cost will be $\$0.11/m^3$ totalling the full cost of $\$0.21/m^3$ (Fig. 6). The capital cost will decrease over the years; however, the O&M cost is expected to increase as the system will require frequent maintenance.

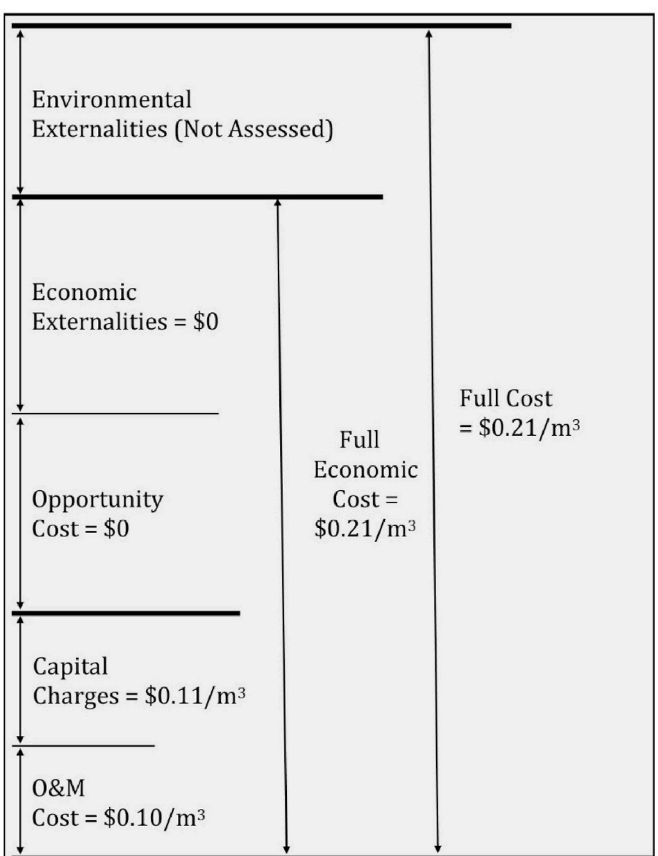

Fig. 6. Wastewater treatment cost in the study area.

Citizens are willing to pay $1.4/month/household for the whole system (drainage infrastructure improvement and treatment system) and annually around $2.4 million could be collected as water tariff which is around 50% of the annual O&M cost. The population in Khulna city is expected to grow due to increased economic activity in the region (ADB, 2020) and KWASA plans to adjust the current fixed tariff annually in the coming years to cover the O&M costs (KWASA, 2016). Progressive tariff system based on citizens' socio-economic condition or based on the volume of water consumed can be an interesting approach to replacing the current fixed tariff to cover the growing O&M costs (Klassert et al., 2018). During the questionnaire survey, more than 40% of the respondents mentioned economic constraints as the primary reason for not paying more for the treatment. Respondents also pointed out that providing infrastructural services is part of the government's responsibility and does not want to pay for it. They argued that industrial and commercial areas generate a greater volume of wastewater which causes severe pollution and those sectors should be paying more for the treatment of wastewater.

On average, a peri-urban farmer of Khulna would require around 3800 m^3 of irrigation water (Haldar et al., 2021) which would cost $380/cropping season (if only the O&M costs of the wastewater treatment are charged). Farmers are willing to pay $40 for clean irrigation water during the whole irrigation season, around 11% of the cost. The socio-economic consequences of charging for using natural resources like river water for agricultural activities on farmers livelihood should be further investigated before implementation. Overall, additional financing would be necessary to cover the rest of the O&M costs and concerned authorities should investigate whether instruments like polluters pay principle could be applied to other water users.

4. Conclusions

The peri-urban farmers of Khulna are heavily dependent on surface water for irrigation during the dry period. Due to the current direct discharge of untreated wastewater, the surface water is heavily polluted. In the context of climate change, reduced water availability with adequate quality will hinder farming in this area. Planned water reuse is a preferred alternative among the major stakeholders and this can contribute to the enhanced livelihood i.e. for farmers by maintaining their ability to produce food, and for citizens benefitting of the sustained food provision and improved living condition. However, adjustments in existing rules and regulations and setting up necessary discharge standards are crucial for planned water reuse in agriculture. Local government institutions need to be brought under an intersectoral partnership agreement to enhance collaboration. Additional financial and human resources should be allocated to monitor and to enforce such improved rules and regulations. Besides, participation, accountability and cooperation among all stakeholders should be ensured to create a more functional and sustained institutional arrangement. Progressive tariff system can be introduced for charging citizens for wastewater management as the study showed that the people with more income are willing to pay more for the treatment systems. This will safeguard the marginalized and poor communities living in slums and squatters of the city. Similarly, access to and clean irrigation water should be ensured so that marginalized farmer groups' socio-economic condition is not negatively affected. This research can be useful in formulating policies and strategies for effective water management in socio-demographically similar countries. Future research on water management should focus on the infrastructural aspects of collecting and treating urban wastewater and, finally, the supply of treated wastewater to the farmers for continuous food production in the region.

Credit author statement

Kamonashish Haldar: Conceptualization, Methodology, Data curation and Formal analysis, Writing – original draft. Katarzyna Kujawa-Roeleveld: Conceptualization, Methodology, Supervision, Manuscript Writing – review & editing. Marco Schoenmakers: Methodology, Investigation, Formal analysis, Manuscript editing. Dilip Kumar Datta: Conceptualization, Methodology, Supervision, Writing – review & editing. Huub Rijnaarts: Conceptualization, Methodology, Supervision, Writing – review & editing. Jeroen Vos: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2021.111974.

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