Reclaimed wastewater as an ally to global freshwater sources: a PESTEL evaluation of the barriers

S. Gul, K. M. Gani, I. Govender and F. Bux

ABSTRACT

Together with climate change, rising living standards throughout the world have put pressure on existing freshwater sources and increased global water scarcity. The reclaimed wastewater projects face obstacles in sustainable implementation. This paper reviews Political, Economic, Social, Technological, Environmental and Legal (PESTEL) factors that act as barriers to the successful implementation of the reclaimed wastewater. Owing to COVID-19, pandemic and presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in wastewater, future consequences on operations and public acceptance of reclaimed wastewater systems are discussed. This review will be useful for water experts, researchers and project planners for appropriate measures in future wastewater reuse projects.

Key words | barriers, perception, PESTEL, public acceptance, reclaimed water, wastewater reuse

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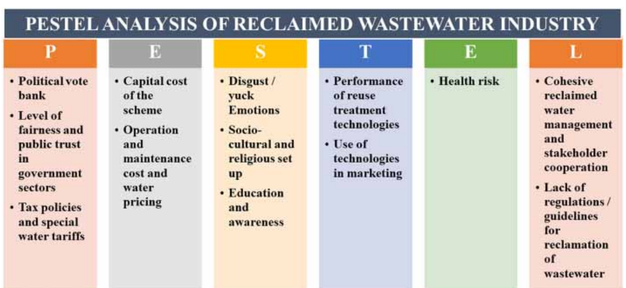
HIGHLIGHTS

- Public acceptance factors of reclaimed wastewater are reviewed by PESTEL analysis.
- Mean acceptance rate for drinking application of reclaimed wastewater is lowest.
- Contextualization of marketing message to the communities is necessary.
- Identification of desired attributes can augment branding of reclaimed wastewater.

GRAPHICAL ABSTRACT



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INTRODUCTION

Wastewater reuse has been identified as a key strategy in the conservation of water resources and solution for global water challenges (Wester *et al.* 2015). The governmental support, efficient technology, sufficient capital and public acceptance are among essential requirements for the success of wastewater reuse. Negative response from public is among main hurdles for the successful implementation of these wastewater reuse schemes (Nancarrow *et al.* 2008, 2009; Khan & Gerrard 2006; Chen *et al.* 2012; Baghapour *et al.* 2017). Public acceptance of reclaimed wastewater depends on several factors, as mentioned in Table 1 (Po *et al.* 2003a, 2003b). There has been tremendous positive output from the research efforts into the technical aspect of wastewater reuse which undoubtedly has made it possible to produce reclaimed water safe for human consumption. However, there is still a requirement of heavy research into social research and outreach regarding reclaimed water to ensure public acceptance (Villarín & Merel 2020). Therefore, proper planning is necessary to put reclamation wastewater projects into practice. Redman *et al.* (2019) reported that prior information about reclaimed water can be positive predictors for its acceptance. The main challenges are to identify public experiences, doubts, risks and cultural aspects associated with wastewater reuse which will help to address it through proper education and policy framework (Ricart *et al.* 2019).

Political, Economic, Social, Technological, Environmental and Legal (PESTEL) analysis is a strategic business tool to evaluate the Political, Economic, Socio-cultural, Technological, Environmental and Legal issues in a business which can provide strategic direction for its growth (Fahey & Narayanan 1986). It is used to assess, evaluate and organize the macro environment which can influence the current and future scenario of a business. Political factors may include the political conditions, rules and regulations by government. Economic factors include the effects of economic cycles, prices of commodity and labour markets that influence the industry. Social factors include the demographic patterns, tastes, cultural and religious values that align in the business setup of the industry. Technological factors include the effects of technology change, new processes and design. Environmental factors include how the industry interacts with the environment while performing its operations and its impact on

Table 1 | Various PESTEL factors reported in the literature, which are responsible for the acceptance of reclaimed water

Reference	Factors affecting the acceptability
Dillon (2000)	Risk perceptions
Dolnicar & Hurlimann (2009)	Risk perceptions, social factors, age, education, income
Nancarrow *et al.* (2009)	Trust in the agencies
Dolnicar *et al.* (2011)	Perceived knowledge
Fielding & Roiko (2014)	Providing information about the recycling process
Alhumoud & Madzikanda (2010)	Religious purity of the practice
Mankad & Tapsuwan (2011)	Risk perception, water culture and threat perception
Bakopoulou & Kungolos (2009)	Current or future water shortage
Robinson Robinson & Hawkins (2005)	Demographics like, elderly women, lower income and less education as an obstacle for acceptability of water reuse
Wester *et al.* (2015)	Females, having less education and particularly sensitive to pathogens
Gu *et al.* (2015)	Higher education and higher income levels
Chen *et al.* (2015)	Water resource managers, industrial sectors and researchers
Zhu *et al.* (2019)	Older people with higher qualifications
Baghapour *et al.* (2017)	Awareness of quality of reclaimed wastewater, level of education
Wilson & Pfaff (2008)	No fundamental religious objections to potable wastewater reuse either locally or internationally

ecology, farming and aquaculture. This factor is now becoming more crucial with recent global awareness about climate change. Legal factors include specific laws pertaining to occupation, health of employees and customer service, for which the industry is liable during production. The output from the analysis can be used in strategic planning processes and can help in market research (Sandberg *et al.* 2016). It provides an overall view of the external factors affecting the business and to spot new opportunities for sustainable growth (Stuiver *et al.* 2016). PESTEL analysis can help in planning, marketing and successful implementation of reclaimed wastewater projects.

The objective of this review is to perform a PESTEL analysis for the reclaimed wastewater industry to evaluate all relevant factors within the PESTEL framework that are obstacles in the successful implementation of reclaimed wastewater schemes and assess the new opportunities to prioritize future research directions.

GLOBAL SCENARIO OF RECLAIMED WASTEWATER

Globally, Namibia, the USA and Singapore have been successful in the implementation of reclaimed wastewater projects. The reclaimed wastewater project of Goreangab in Namibia has been a good model for experts to learn practical solutions related to the implementation of wastewater reuse. This plant meets around 24% of drinking water supply of the city, and it contributed to deal with the drought conditions in 2014–2016, when the local water reservoirs of Goreangab could meet only 10% of drinking water demand (Van Rensburg 2016). The largest wastewater reuse plant in the world located in Orange County, California, USA produces 379,000 m^3 of drinking water per day. In the USA, over 230 reuse projects are operating and the reclaimed water being used for irrigation, parks, school grounds, landscaping and industrial uses. Researchers have attributed its success to public engagement and awareness campaigns, which were adopted by Orange County Water District from the start of the project in 2008 (Tortajada & Van Rensburg 2020). In Singapore, the most effective reclaimed water project, NEWater, is considered as the upright example for wastewater reuse. It recycles the wastewater and is considered as the best and cheaper option (Po *et al.* 2003a, 2003b). NEWater is currently contributing to 40% of drinkable and non-drinkable water demand of Singapore with a target of 55% by 2060. Transparent communication between policymakers, public and technical managers has been reported as key drivers for its success (Tortajada & Nambiar 2019).

Among developing countries, China has almost 924 reclaimed wastewater treatment plants which have been constructed to supply reclaimed water for industrial, agricultural and landscape applications (Zhu *et al.* 2019). Jordan is a successful example with a strong community acceptability, achieved through proper education of its citizens about water scarcity and significance of wastewater reuse in agriculture (Al-Momani & Rasheed 2016). South Africa started a wastewater recycling plant in 2010 in Durban with a 45,000 m^3 capacity.

The reported public acceptance of reclaimed wastewater for drinking is lower than other direct potable applications (Figure 1). The acceptance rate is reported 5–42% (average of 15 countries as 28%) with minimum reported in Kuwait (5%) and maximum reported in Canada (42%) (Alhumoud & Madzikanda 2010; Velasquez & Yanful 2015). The order of acceptability was toilet flushing (87%) > landscape irrigation (86%) > cleaning (80%) > bathing (55%) > drinking (28%). Velasquez & Yanful (2015) reported an increase in acceptability of direct contact reuse applications (drinking and cooking) from 42 to 76% and from 51 to 80%, respectively, when the participants were asked to consider drought conditions. This indicates that the knowledge of water scarcity can act as an effective tool to increase the acceptance of reclaimed wastewater in direct contact applications. The studies being mostly from developed countries which indicate that the public opposition to use reclaimed wastewater for drinking is not confined to developing countries rather developed nations are still having this challenge. Among non-potable uses, toilet flushing and landscape irrigation are most favourable (Figure 2). In irrigation types, landscape irrigation is more acceptable than agriculture irrigation. Buyukkamaci & Alkan (2013) reported 55 and 50% acceptance rate for landscape and agricultural irrigation, respectively, in Turkey. Chen *et al.* (2015) reported 94 and 82% acceptance rate for landscape and agricultural

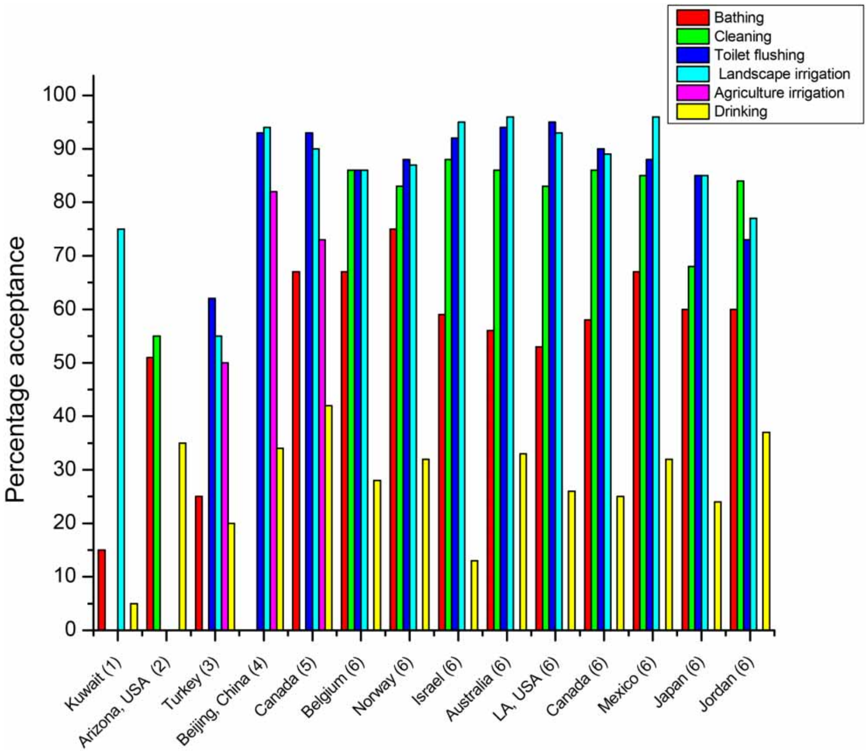

Figure 1 | Comparison of reported acceptance of reclaimed water for drinking purposes and other direct potable applications, from different countries across the world. 1 – Alhumoud & Madzikanda (2010); 2 – Rock *et al.* (2012); 3 – Buyukkamaci & Alkan (2013); 4 – Chen *et al.* (2015); 5 – Velasquez & Yanful (2015); 6 – Hurlimann & Dolnicar (2016).

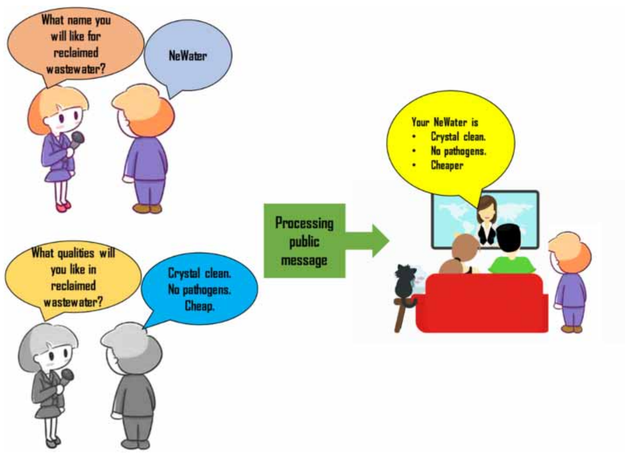

Figure 2 | Strategy to be adopted in order to design the message for circulation in public domain about reclaimed wastewater. The message should focus those attributes of reclaimed wastewater, which are important in public domain (author's own compilation).

irrigation, respectively, in China. Velasquez & Yanful (2015) reported 90 and 73% acceptance rate for landscape and agricultural irrigation, respectively, in Canada.

PESTEL ANALYSIS OF RECLAIMED WASTEWATER

Political factors

Political vote bank

Political factors have been influential in the success of reclaimed wastewater initiatives. Ross *et al.* (2014) reported about the resistance group CADS (Citizens against Drinking Sewage) in Toowoomba, Australia which started campaigning with an agenda of apparent health risks related with reclaimed water. It became politicized, created strong opposition which resulted in 62% of opposition votes. The initiative was suppressed even though there was a severe water shortage (Ross *et al.* 2014). The opposition groups in politics with the help of media can create a negative image of the reclaimed water that customers due to their political alignment oppose the reclaimed water schemes.

The media and politicians are interrelated with regard to escalation of the bad perception of reclaimed water. In order to gain political support from people, politicians usually support the sentiments of the people. Due to the negative perspective published by the *Los Angeles Daily News* about East Valley Water Recycling project in 2000, the local residents got worried about the safety of the water and local mayoral candidates politicized it. Consequently, the Los Angeles Department of Water and Power decided to implement the project for supplying reclaimed water in industry and agriculture instead of domestic reuse (US Bureau of Reclamation 2004).

The public opposition towards a 'Repurification Water Project' in San Diego was fuelled by the local newspaper, *The San Diego Union-Tribune,* by publishing a cartoon showing a man telling a dog to move over in order to drink water from a toilet (Hartley 2006). The newspaper even titled the news as *toilet to tap project* which fuelled the negative public emotions and resulted in political intervention to stop the project.

Level of fairness and public trust in government services

Most of the water utilities are government institutions. At times, the authority and their administrative processes have a significant influence on the opinion of community and acceptability of water reuse. Ross *et al.* (2014) studied the effect of fair procedures of water authority on the thinking of community members. The fair procedures or processes of the water authority perceived by the community members will eventually lead to the trust and credibility among users which is supportive towards the acceptance of the reclaimed water. Kramer & Tyler (1995) analysed that the good customer support and fairness in service delivery by the water authorities plays a role in accepting their decisions. The respect, fair procedures from the authorities help in building the trust with them and thus results in acceptance of their decisions.

Trust for reclaimed wastewater can be described as a multidimensional and psychological construct that drives the behaviour to agree with the risks in return to positive past expectations delivered by the service provider (Siegrist *et al.* 2000). According to Siegrist *et al.* (2000), decisions by some human beings are based on scientific research; however, in absence of information, their decisions are dependent on trust. Hurlimann *et al.* (2008) studied the relation between trust and public approval on potable water reuse. There should be trust between all the stakeholders, and the information conveyed must be simple, clear and reliable. Nothing should be hidden and proper transparency should be among all the stakeholders. It is important to develop a public participation process, two-way communication, with due flexibility. Allowing feedback or suggestion facilities for the public and willingness to include the public input into the process eventually leads into trust between the public and water service providers.

Tax policies and special water tariffs

Taxes are an important component that contribute to the internal costs of a reclaimed water project (Hernández *et al.* 2006). Reclaimed water rates are also dependent on existing tax policies for revenue generation. Exemption of user tax for the reclaimed water can encourage users towards its acceptance. An example includes the regulatory framework developed in Costa Brava, Spain that allows the elimination of tax on the consumption of reclaimed wastewater.

The government can devise new policies and regulations for the general public so that they can become aware and encouraged to use the reclaimed water. In US, water reuse has been promoted as a contributor towards environmental protection and resource conservation. Singapore used educational drives at community and school level and video documentaries to increase the public awareness of NEWater (Po *et al.* 2003a, 2003b). In China, the government provided special concessions in the form of subsidies and tax reductions to motivate public for using reclaimed wastewater (Zhu *et al.* 2019).

Economic factors

Capital cost of the scheme

Reclaimed water is priced to have the adequate sustainability in the operation and maintenance (O&M) of the scheme. Economic feasibility along with a comprehensive life cycle assessment of a reclaimed wastewater scheme is a precondition to ensure long-term successful operation of a wastewater reuse scheme. This is also a recommendation in the European Union Water Framework Directive for planning of a reuse scheme (European Union 2000). The cost of reclaimed water includes the extra investments for tertiary treatment to reach beyond the discharge regulations for the safe health in the communities and extra conveyance and pumping to the application location. The capital cost of the reuse scheme depends on the offsets, like conveyance system, level of treatment required and end use. Topography of the site has a good role in deciding the level of investment. A wastewater reuse scheme at higher altitudes can be cheaper in serving public there than pumping potable water from a freshwater scheme at low altitude. Depending on the local circumstances, discharging treated wastewater in a surface water body, which supplies a reservoir and drinking water treatment plant at downstream, is an economically wiser decision than installing a new tertiary system and a conveyance system for reclaimed water. Therefore, it is necessary to consider economic planning in design and construction of a reclaimed water scheme. This usually makes reclaimed water cheaper than the potable water. Average water prices (€/m^3) of reclaimed water for irrigation were 0.23–0.30, while as prices of the potable water supply scheme was 1.54 in French island of Noirmoutier (Atlantic coast) (Lazarova *et al.* 2013). The largest Dan Region Project in Israel having 120 million m^3/year capacity irrígates 16,000 ha with reclaimed water at prices of 0.36 €/m^3 (Angelakis *et al.* 2003). The cost factor can increase or decrease public acceptance of reclaimed water. Cheaper drinking water sources can increase public willingness for purchase and consumption. No change in tariff can shift public emotions to other factors such as disgust leading to lower acceptance of reclaimed water. Hartley (2006) reported that lower costs of water distribution network and installation are directly related to cost of the reclaimed water which can increase public acceptance of water reuse. However, the cost factor depends on various parameters and its value is attached to capital investments made by service provider and returns (Woolston & Jaffer 2005).

O&M cost and water pricing

Reclaimed water schemes add to the complexity of financing and costing of the water services. Instead of a continuous water source, reclaimed wastewater is an added source of water during scarcity of water from freshwater sources. The pricing schemes of conventional freshwater schemes based on cost recovery cannot be applicable with reclaimed water schemes. Pricing of the reclaimed water scheme should also focus on encouraging its acceptance. However, simultaneous focus of pricing of reclaimed water schemes on cost recovery, water demand management and increase in public acceptance is not feasible (Molinos-Senante *et al.* 2013). Therefore, apart from focus on cost recovery, the pricing strategy for a reclaimed water scheme should be based on the system-wide approach which involves all beneficiaries who receive a benefit after inclusion of reclaimed water in the water portfolio. This will create a shift from user pays principle to the broad beneficiaries pay approach (De Paoli & Mattheiss 2016).

On the cost side, the cost of additional wastewater treatment to make it safe for non-potable and potable reuse is an extra component compared with the regular water supply scheme. This can increase the water prices in a reclaimed water scheme resulting in reclaimed water being more expensive than regular freshwater supply. Together with health risk and yuck factor, this will reduce the acceptance of reclaimed water. Therefore, on the tariff side, cross subsidization can be implemented in which the price of reclaimed water is recovered from tariffs imposed on freshwater supply. This approach involves supply of freshwater at higher prices than its production and distribution investment, to accommodate the cost of water reuse and motivation for the public to accept low priced reclaimed water (Zayas *et al.* 2016).

As depicted from few case studies shown in Table 2, pricing based on consumption is the common tariff except few cases such as in Bora Bora for landscape irrigation, where a fixed rate is applied irrespective of consumption levels. Compared with the category of landscape irrigation, the water prices in case of groundwater (GW) recharge are lower (0.08–0.4 versus 0.13–2.18 €/m^3) (Table 2) which may be due to savings in costs associated with distribution systems. However, the water prices associated with GW recharge in case of Cyprus and California are too low to recover the O&M costs, indicating the presence of cross subsidization in water tariffs. From this comparison involving Cyprus and California, it may also suggest that potable

Table 2 | Case studies showing O&M costs of reclaimed water and pricing across the world (Lazarova et al. 2013)

Recycle application	Location	Source water	Treatment scheme	O&M costs	Recycle water price
Irrigation (Landscape)	Cyprus	Domestic wastewater	Activated sludge, denitrification, chlorine disinfection	0.46 €/m^3	0.15–0.21 €/m^3
	Bora Bora – French Polinesia	Domestic wastewater	Activated sludge, and membrane treatment	0.68 €/m^3	187 €/year (fixed) + 0.67–2.18 €/m^3
	Honolulu – USA	Domestic wastewater	Activated sludge, tertiary filtration, disinfection, reverse osmosis	0.48 €/m^3	0.13–0.47 €/m^3
Industry	El Segundo, California – USA	Domestic wastewater	Activated sludge, tertiary disinfection	N/A	0.56 €/m^3
	Honolulu – USA	Domestic wastewater	Activated sludge, tertiary disinfection	N/A	1.15 €/m^3
	Tianjin – China	Domestic wastewater	Membrane, ozone, reverse osmosis	0.29 €/m^3	0.32–0.33 €/m^3
GW recharge (Indirect potable use)	California – USA	Domestic wastewater	Activated sludge, tertiary disinfection, microfiltration, reverse osmosis	0.31 €/m^3	0.18 €/m^3
	El Segundo, California – USA	Domestic wastewater	Activated sludge, tertiary disinfection, reverse osmosis, advance oxidation	N/A	0.4 €/m^3
Irrigation (Agriculture)	Cyprus	Domestic wastewater	Activated sludge, denitrification, chlorine disinfection	0.46 €/m^3	0.05–0.07 €/m^3
	Noirmoutier – France	Domestic wastewater	Activated sludge, polishing lagoons	0.54 €/m^3	190 €/year (fixed) + 0.3 €/m^3
	Milan – Italy	Domestic wastewater	Activated sludge, multimedia filtration, ultraviolet disinfection	0.115–0.39 €/m^3	1,827 €/year (fixed) + 27,000 €/year for energy consumption (fixed)

Note: Source of reclaimed water in mentioned cases was domestic wastewater.

usages of reclaimed water will also attract cross subsidization to reduce recycle water tariffs and encourage its acceptance.

Social factors

Disgust/yuck emotions

The use of reclaimed water is opposed by a psychological barrier ('yuck factor' or 'disgust' factor), which give the impression of a disgust emotion, resulting from the thought of reusing wastewater. Po *et al.* (2003a, 2003b) reported that people prefer bottled water for drinking or filtered reclaimed water through a household filter. The public had associated reclaimed water with waste and portrayed a mental image of 'disgust'. The 'disgust emotion' refers to emotional discomfort that is produced when there is a close contact with a nasty stimuli. Thus, a disgust reaction is caused as people perceive reclaimed water as unclean or unpleasant. Therefore, current projects avoided terms such as 'treated wastewater' such that reclaimed water is termed as 'NEWater' in Singapore and 'Repurified water' in San Diego.

Socio-cultural and religious setup

Social and geographic factors influence the acceptance of reclaimed water. However, proper justifications based on these observations should be further supported while concluding and generalizing results from surveys (Po *et al.* 2003a, 2003b). However, public perception depends directly on the recognition of water scarcity by the public. However, the social setup and governance play a major role in the regions without water scarcity (Mesa-Pérez & Berbel 2020). Acceptability for water reuse has shown a direct correlation with men compared with woman (Dolnicar & Hurlimann 2009). In other studies, the age of participants is also related to public acceptance (Dolnicar *et al.* 2011). On the contrary, Jeffrey &

Jefferson (2003) reported no relationships between reclaimed water acceptance and socio-demographics in the United Kingdom. This may indicate that a representative sample for the survey should be chosen and justified with logical understanding rather than choosing a random geographical area.

Islamic faith was considered as one of the barriers for Muslims to reuse wastewater. Water recycling schemes are common in a number of Muslim-majority countries like Kuwait, Syria, Iran and Saudi Arabia. Arab nations are the leaders in the areas of wastewater recycling and reuse (Crook *et al.* 2005). The fraction of treated wastewater in the Arab regions is 54% that is higher than Asia (35%). Saudi Arabia issued a fatwa (Islamic ruling) regarding the use of water reuse in agriculture, recreation and ritual uses. Muslims in South Africa (Durban) resisted and protested against the wastewater reuse when eThekwini municipality announced the use of reclaimed water to supplement existing potable water supply in 2012. The community claimed the reuse water as unclean and un-Islamic. Similar findings were reported by Muanda *et al.* (2017) in South Africa that Muslim leaders indicated hesitation to the adoption of reclaimed water. However, proper analysis of religious scholars found that reclaimed wastewater is not prohibited in Islam (Muanda *et al.* 2017). Organization of the Eminent Scholars of Saudi Arabia, an eminent Muslim organization, has also approved reusing wastewater for religious applications (Faruqui *et al.* 2001). In summary, religion is a location-specific barrier which cannot be ignored and proper approach in terms of support from religious knowledge can be a strategic approach to deal with it. The literature about public acceptance of reclaimed wastewater in major global religious sectors such as Christians, Hindus and Buddhists is not available which indicate that future research directions should be to evaluate and comparatively assess the perceptions of these communities.

Education

The importance of public engagement increases with the increase in demand for wastewater reuse (Po *et al.* 2003a, 2003b). Information sharing, educational activities and awareness about the wastewater recycling support its acceptability. Information, knowledge about the processes and education are significant contributors in determining the perception of public. Psychological uncertainty among the public should be removed quickly otherwise it can influence the acceptability of water reuse. The mass media and government should disseminate information to the general public about scarcity of water resources, and need of recycling wastewater. Among different approaches establishing visitor centres at wastewater treatment plants for the public information, direct site visits to treatment plants, make the process understanding easier to the public (Saad 2019). The focus of public awareness should be to ensure public that the institutional setup, regulatory system and technological innovations working around wastewater reuse are capable to provide safe drinking water (Tortajada & Nambiar 2019). Velasquez & Yanful (2015) reported highest acceptance rate of 42% for application of reclaimed wastewater in drinking in Canada. The difference between this study and others shown in Figure 1 is that the sample site was a university where it is expected that the participants are educated, indicating support of education to the promotion of wastewater reuse.

The role of media in a substantial impact on public opinion cannot be ignored. A good relationship between public utilities and media will help to communicate the timely messages about the significance of water reuse in resourceful water management and its potential to provide reliable safe water during drought (Tortajada & Nambiar 2019). The focus of the public information towards technological innovations used in the reuse system will help to build trust and confidence among public. The head of Orange County Sanitation District described the reuse process by using phrases such as 'world's largest advanced water purification system', 'three-step advanced process' and 'sophisticated process' during a legislative address, which delivered a positive message to the public (U.S. Government Publishing Office 2016). Policymakers, public and media are mainly concerned with health aspects of reclaimed water schemes; therefore, the message content should be proper explanations for these concerns.

Technological factors

Performance of reuse treatment technologies

Efficient treatment technology for the treatment of wastewater increases the public acceptance of reclaimed water.

Fielding & Roiko (2014) reported that informing the public about the treatment technologies involved in wastewater reclamation improves the public acceptance. Water experts (scientists and utility managers) can be the suitable presenters while disseminating the information about the reuse treatment technologies to the public (Chen *et al.* 2015).

Upgradation of existing wastewater treatment plants is a major investment in a reclaimed water scheme. The government policies can help in finance of upgradation, for example, amendment of Water Protection Act by the Swiss parliament, to introduce a new tax of nine euros for financing of upgradation of 100 wastewater treatment plants to removal of micropollutants (Thevenon 2017).

Recent COVID-19 pandemic has led to (as of 19 May 2020) 4,735,622 confirmed cases, 316,289 confirmed deaths and 216 countries with confirmed cases and nationwide lockdown over many countries (WHO 2020). The novel virus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been found in the stools of infected people which may result in its occurrence in wastewater (Gao *et al.* 2020). Although not a viable SARS-CoV-2 virus, its ribonucleic acid (RNA) copies have been detected in wastewater in the Netherlands, Australia and the USA (Medema *et al.* 2020; Wu *et al.* 2020). The lipid covered viruses such as SARS-CoV-2 are easily removed by any oxidant like chlorination. Until now, there has been no confirmed transmission of COVID-19 through sewerage systems (WHO 2020), and water experts are expecting that the risk of transmission of SARS-CoV-2 through water systems is very low. Structure similarity of SARS-CoV-2 with previous viruses indicated that like other viruses, this can be removed in existing water and wastewater treatment processes. However, there are future implications for the water and wastewater experts to consider such pandemics with regard to design and operations of our water systems. Although there are no confirmed reports of its effective removal in water and wastewater treatment processes, a recent study done in the Netherlands confirmed non-occurrence of SARS-CoV-2 RNA in the effluent of wastewater treatment plants. It can be assumed that current treatment processes are enough to stop its spread through water systems and the technical challenges for water experts are low. However, there are focus areas where this ongoing pandemic will put an extra task to the water professionals in formulating new strategies to ensure water security and public acceptance of wastewater reuse.

The difference in COVID-19 and other viruses is that the pandemic is global in nature and every individual suffered directly or indirectly due to it. This has created a sense of fear across the world and this may lead to avoid doubtful behaviours like using recycled wastewater for direct potable applications. Therefore, service providers have to design new approaches to develop confidence among the public. Wide screening of the virus in the effluent of a wastewater reclamation plant and updating the public for a considerable period during the demonstration phase of the project can be an approach to be adopted. Installation of a necessary barrier for the removal of virus is essential in reuse plants. The presence of emerging contaminants (ECs) in water and wastewater at the concentration levels of nanograms per litre can be gauged in a similar manner. Two decades back, the EC concern was not significant but with public awareness, it is becoming mandatory for wastewater reuse utilities to remove a certain group of ECs. It can be expected that similar developments will occur with respect to SARS-CoV-2. Combatting the COVID-19 pandemic needs extra water security to ensure adequate water supply for maintaining public health and hygiene. One of the recommendations for public health safety during the COVID-19 pandemic is hand washing, which needs an adequate supply of safe water.

Use of technologies in marketing

Appropriate marketing strategies need to be adopted by municipalities for the successful implementation of reclaimed wastewater schemes. Marketing interventions can be tested to explore their influence on the acceptance level of recycled water. Adapa *et al.* (2016) and Adapa (2018) suggested public response should be explored towards marketing aspects such as price and process of production of reclaimed water. This can eventually recognize critical obstructions towards the acceptance of reclaimed water. The realization of water scarcity among water users can be triggered by making people aware about it by means of the internet, social media and television (Abdelrahman *et al.* 2019).

Deliberate exposure to the reclaimed water is a form of customer engagement that can increase confidence and personal experience with reclaimed water. Hills *et al.* (2002)

reported the acceptance of reclaimed water was higher among those participants from England who had been exposed to reclaimed water intentionally or unintentionally. In this study, those participants showed higher acceptance who had seen signage of reclaimed water in water exhibitions or used the toilets where reclaimed water was used for flushing. Saad (2019) also reported that the gradual establishment of direct human contact with reclaimed wastewater will help to tackle its wrong perception. This can be done by first introducing reclaimed wastewater for indirect applications (irrigation, firefighting and toilet flushing) and then direct uses such as drinking water. The final usage of reclaimed water can effect public acceptance of reclaimed water. Acceptance level is generally greater when there is minimal human interaction (Hartley 2006), which further led to a higher acceptance of using reclaimed water for industrial applications (Po *et al.* 2003a, 2003b). Dolnicar *et al.* (2011) reported that 92% of respondents agreed to use reclaimed water for irrigation; however, only 36% confirmed for drinking water.

Branding the reclaimed wastewater is one of the strategies which depend upon identification of desirable and undesirable attributes of water in public perception. It is also necessary to identify what images of tap water, bottled water and desalinated water are in the local community, thereby focusing on those water attributes during branding. This will also help in formulating the directions of marketing campaigns for the reclaimed water as illustrated in Figure 2. Dolnicar & Schafer (2009) compared the public beliefs for the different water sources, reclaimed, desalinated, tap, bottled and rain water. More than 80% of the respondents believed in the environment-friendly image of reclaimed water in terms of reducing the pollution of beaches, reducing the water scarcity and decreasing level of pollution. These positive attributes can be used to argue in a positive direction for the promotion of reclaimed water. On the other hand, a large portion (35–45%) of respondents perceived reclaimed water as disgusting, 56–60% perceived it as a health concern for drinking, and 52% perceived its taste as not good. These negative images of reclaimed water are also to be addressed; however, advertising is not an option for it. Khan & Gerrard (2006) and Hurlimann (2008) suggested that these negative images can be addressed by extensive public consultations, public exposure to the reclaimed treatment plants, providing opportunities to the public to have hands on experience with reclaimed water.

Environmental factors

Health risk

The primary concern of reclaimed water is the associated health risk after consumption (Hartley 2006). The level of public acceptance may increase if the water quality complies with international standards (Hartley 2006). A survey by Sydney Water (1999) reported 59% of respondents consider that health risk in reclaimed water cannot be avoided. Fear of health risk is related to the level of trust maintained by the service provider among their consumers (Nancarrow *et al.* 2009; Ross *et al.* 2014). Hartley (2006) identified the safety of public health and its assurance to the public as an underlying factor to gain public support for reclaimed water.

Trust and health risk are interrelated by causal-chain and associationist outlook (Eiser *et al.* 2002). According to the causal-chain view, factors such as trust and risk are inter-related for any decision making, in other words, trust depends on the assessment adopted by the public towards the information about the health risk. This may assist in shaping the decision to accept or decline the technology. Whereas, an associationist view holds independent characteristics of trust and risk perceptions. The associationist model plays a significant role in water reuse, as the trust and risk perceptions play individual roles. Therefore, trust, risk and the emotional reaction can be the strong predictors in deciding the behaviour of public for water reuse.

Legal factors

Cohesive reclaimed water management and stakeholder cooperation

The management of water in an integrated method is still a challenge in most regions of the world (Bouwer 2000; Furlong *et al.* 2016). Adoption of a national legislation towards water management will set up a means to integrate expertise and skills towards a common goal of a sufficient potable water supply. Legislations such as Water Framework Directive in Europe establish standard guidelines for the sustainable water governance, but there is a need to establish the means at local level that can include water reuse in their integrated water management plans.

Water reuse needs cooperation between water supply and sanitation compartments. Most often, the respective sectors are operated and maintained by two different organizations which result in poor institutionalization on the water management especially on water reclamation. This also contributes to the lag between feasibility studies and actual practice of the obtained results.

Bixio *et al.* (2006) reported four types of ownership structures in reclaimed water management which are single entity (water and sewerage under single responsibility), water company managing the reclamation project, wastewater company managing the reclamation project and *ad hoc* project structures developed as per local circumstances. The authors reported that the issue is the access and liability of financial and cost allocation. *Ad hoc* project structures can avoid the delays in the absence of transparent financial allocations. For example, in case of Tilburg reclaimed water project (the Netherlands), where service providers together formed as *ad hoc* water Reuse Company under a legal and administrative framework having tax advantages. This facilitated joint management of the reclaimed water scheme, allocation of funds at low interest rates and benefit from both technical specialists with the wastewater service provider managing the treatment scheme and the water supply provider looking after distribution services and customer service (Bixio *et al.* 2004).

Lack of regulations/guidelines for reclamation of wastewater

For the compliance of wastewater reuse, there is still lack of guidelines to decide when to reuse and what is the criteria for the reuse. Reclamation of wastewater is not always a good option depending on the local circumstances. In most locations, the quantitative analysis of available water resources and local demand is not available which interfere in wise decision making regarding the end usage of reclaimed water. Lack of regulations on reclaimed water quality can force administration to take conservative decisions (Bixio *et al.* 2006). Most commonly World Health Organization (WHO) criteria for water reuse is implemented in the absence of local regulatory criteria which can be over or under sensitive to local environmental conditions.

The paradox is that the river water quality at some places does not comply with the international irrigation guidelines and there is less concern about it. However, a lot of attention is focused on treated wastewater to comply with international guidelines. For example, suspended solid (mg/L), turbidity (NTU) and *E. coli* (CFU/100 mL) in Ter river in Torroella de Montgrí, Spain were 33.2, 19.3 and 38, respectively (percentile 90, year 2007) while as the Spanish regulations for these parameters are 20, 10 and 100. On the other hand, respective water quality parameters in reclaimed water were 6.6, 2.3 and 27 and public administration was more concerned about using reclaimed water for irrigation. Therefore, there is a need to have water reuse regulations that considers local circumstances as well.

QUANTITATIVE ASSESSMENT OF PESTEL FOR RECLAIMED WATER INDUSTRY

The PESTEL analysis of the reclaimed water industry is a precondition analysis which can help in strategic decision making for the implementation of reclaimed water. However, PESTEL analysis should provide a quantitative assessment of the situation leading to the proper decision making and weightage of each PESTEL factor. These factors may be put into an analytical and systematic framework by application of analytic hierarchy processes (AHP) making it possible to analyse the relative importance of each factor or sub-factors while implementing reclaimed water. This will also help in the integrated evaluation of PESTEL factors for the reclaimed water.

The various steps in this process may be the following:

- Gaining information about each PESTEL factor and sub-factors that are influencing the implementation of reclaimed water. These factors may vary from region to region depending on the local circumstances.
- Identification and mapping of interdependencies of these PESTEL factors by structural modelling approaches such as Decision Making Trial and Evaluation Laboratory (DEMATEL).
- Determination of local weights and inner dependence matrix of the identified PESTEL factors based on the DEMATEL analysis.

- Calculating the interdependent and sub-factor weights by analytic network process (ANP) and AHP, respectively.
- Determination of global weights by multiplication of interdependent and sub-factor weights from the previous step.
- Evaluation of the level of each PESTEL sub-factor that is calculated by multiplying global weights and scale values of evaluations. Based on the level of each PESTEL factor, the decisions can be made accordingly. A value of 0.6–1 is considered supportive, 0.4–0.6 as moderately supportive and less than 0.4 as not in favour (Yüksel 2012).

CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

The review did a comprehensive PESTEL analysis of all factors that are influencing public acceptance of reclaimed wastewater for direct potable reuse. A PESTEL analysis will be helpful in strategic planning and consideration of all factors in the preplanning stages of wastewater reuse initiatives. Main conclusions and future research directions drawn from this review are as follows:

- Mean acceptance rates for drinking applications of reclaimed wastewater are lowest compared with other application which are in the acceptability order of toilet flushing (87%) > landscape irrigation (86%) > cleaning (80%) > bathing (55%) > drinking (28%).
- Political vote bank impacts the water reclamation initiatives and predominantly the opposition is triggered by political parties ruling in opposition. The relaxation of taxes for reclaimed water users can encourage users towards adopting reclaimed water. A ruling political party amid controversies of corruption can negatively impact the trust among users. For the success of a wastewater reclamation project to materialize, it should be implemented during ruling of an honest political party. Future research should comparatively assess long-term impacts on success of wastewater reclamation projects during the rule of different political parties and develop strategic frameworks to deal with this barrier.
- Cheaper drinking water sources can increase their willingness for purchase and consumption. No change in tariff can shift public emotions to other factors such as disgust leading to lower acceptance of reclaimed water. In addition to focus on cost recovery, the pricing strategy for a reclaimed water scheme should be based on the system-wide approach which involves all beneficiaries who benefit from the presence of reclaimed water in the water portfolio. On the tariff side, cross subsidization can be implemented in which the price of reclaimed water is recovered from tariffs imposed on freshwater supply, to accommodate cost of water reuse and motivation for public to accept low priced reclaimed water.
- Service providers have to design new approaches to develop confidence among the public with respect to the presence of SARS-CoV-2 in wastewater. Wide screening of the virus in the effluent of a wastewater reclamation plant and updating public for a considerable period during the demonstration phase of the project might be a possible resolution.
- Religion is an influencing factor to accept reclaimed wastewater for direct contact applications. A proper guidance from religious scriptures can avoid this factor. The questions and concerns from the religious sensitive communities should be addressed at planning stage of the reclamation project rather than after implementation. This makes contextualization of the marketing message to the communities rather than one message for all. The literature about public acceptance of reclaimed wastewater in major global religious sectors such as Christians, Hindus and Buddhists is not available which indicate that future research directions should be to evaluate and comparatively assess the perceptions of these communities.
- The role of media is essential to disseminate the information and the timely knowledge about the importance of wastewater reclamation in efficient water management and its potential to provide reliable safe water during drought.
- Branding the reclaimed wastewater is one of the strategies which depend upon identification of desirable and undesirable attributes of water in public perception. A research requirement is to identify which attributes users want to be visible in the reclaimed wastewater which will help in formulating the directions of marketing campaigns for the reclaimed water.

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DATA AVAILABILITY STATEMENT

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

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