Exploring Effects of Public Perception in Jordan on Wastewater Treatment Technology Use

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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STS Research Paper

Introduction

Jordan is the second most water scarce country in the world and relies extensively on groundwater aquifers and rainwater collection to supply the population's water needs (Denny et al., 2008; UNICEF, n.d.). These aquifers are being depleted faster than they can be replenished given more intermittent rains and one of the highest population growth rates in the world (Denny et al., 2008; UNW-DPC, 2014). One potential solution to tris trend is wastewater treatment technology, which processes wet biowaste, primarily municipal sewage, to produce drinking water. Although this technology has become increasingly popular globally owing to benefits, such as lower cost than desalination, abundant feedstock, and pollution mitigation, it is not a technology used in Jordan to diversify its water sources. Key factors holding back the use of wastewater in Jordan are a cultural belief that the water is dirty and religious teachings that prohibit its use.

Islam is the predominant religion in Jordan, and it is against Islamic belief to drink treated wastewater. As is stated in The Quran (25: 48) "... We sent down from the heaven tahur water." which refers to water directly from rain, snow, springs, seas and other naturally occurring groundwater as *tahur*, or 'pure'. Once this water is mixed with pollutants, including anything that would change its color, taste or odor, the water is no longer pure, and cannot be consumed even after treatment (Amery & Haddad, 2015). In the past, Jordan has relied on what Islam considers 'pure' water resources such as groundwater aquifers to supply water to its population (Amery & Haddad, 2015). However recently Jordan has begun to import water from desalination plants in Israel to supplement the depleting local sources. This practice is unsustainable and has a

much higher comparative cost to waste water treatment (Amery & Haddad, 2015; Hambright et al., 2006).

Understanding the relationship between Islamic beliefs and water treatment methods is imperative to find a culturally sensitive solution to Jordan's water crisis. Two analytical frameworks, technological momentum and the social construction of technology (SCOT), will be used to answer the following research question: How does the public perception of wastewater treatment in Jordan impact the potential technological solutions to the ongoing water crisis of this region?

Geographic and Technological Context

Severe water scarcity is defined as 500 cubic meters of water per person annually and Jordan has less than 100 cubic meters (UNICEF, n.d.). Jordan relies on groundwater aquifers and rainwater collection to supply the majority of its water (Denny et al., 2008). Recent droughts have had serious consequences to agriculture and livestock, with severe impact on social and economic growth (UNW-DPC, 2014). Projections indicate that the Middle Eastern region will continue to face unpredictable rainfall, rising temperatures, and accelerated ground water evaporation as a result of global climate change, directly reducing Jordan's primary source of water (Whitman, 2019). Furthermore, Jordan has the ninth highest population growth rate globally, exacerbated by persistent refugee inflows, so demand for water is only growing (Denny et al., 2008). Consequently, Jordan needs to develop technological solutions to diversify its reliable sources of water.

One potential additional source of water is treated industrial and municipal wastewater. Modern technologies can treat wastewater to produce potable water at a competitive price.

Wastewater typically consists of sewage, as well as industrial processing effluent, but in a wastewater treatment plant is cleaned using various intense filtration processes and chemical disinfectants. Water leaving the treatment process is clean and would comply to the local drinking water cleanliness regulations. Wastewater treatment has proven to be economically beneficial, and in areas where water is such a valuable commodity, this technology should not be neglected. Jordan is an example of a country where wastewater treatment could be successfully to recycled and support conservation of Jordan's limited and valuable water resources. However, the sociotechnical complication that prevents Jordan from fully adopting this wastewater treatment is that Islam is the primary religion, and it is against Islam to drink treated wastewater. Instead, Jordan must source its water from what The Quran states as 'pure' resources such as the groundwater aquifers (Amery & Haddad, 2015). These aquifers, however, are being depleted faster than they are replenished (Whitman, 2019).

Sociotechnical Frameworks

As Jordan is forced to consider changes in their water technology and infrastructure, the relationship between Jordanian society and wastewater will become vital to understand so that a culturally sensitive technological solution can be achieved. Two STS frameworks will be used to analyze this relationship between society and technology: technological momentum and the social construction of technology (SCOT). First, the concept of technological momentum describes how social development both shapes and is shaped by technology and how this relationship change over time. Specifically, that new technology is more influenced by society, but as time passes and a technology matures, momentum will form from larger sociotechnical systems (Dyson et al., 2021). This framework was defined by Thomas Hughes as an alternative

to technological determinism. This framework puts emphasis on the influence of social structures to a system, as well as the technical ones (Povlock, 2016). Critiques of this framework suggest that it falls short in fully addressing the complexities of technological and social change (Colarossi, n.d .). The Actor Network Theory is used to combat this critique and help describe the complexities of social perceptions of wastewater treatment in Jordan and as an organizational tool to respond to the research question.

Technological momentum has been used in previous literature by Robert Kirman to analyze the ethics of metropolitan growth (Kirman, 2004). Specifically, Kirman defines suburban landscapes as technological systems, which involves the technical structure, including streets, buildings, water systems, etc., as well as the social components, including homeowners, businesses, academic institutions, and the government. This study puts emphasis on the influence of technology and the physical environment on the growth of metropolitan areas. An example given is the implementation of public transit in a growing suburban setting. Suburban areas are low density, with disconnected neighborhoods, and have alternating residential and commercial areas. To implement public transit, radical infrastructural changes and zoning restrictions must occur. However, the more radical the change, the more resistance will come from the community and the less likely the change will occur, and thus technology influences social outcomes.

The second framework to support the following analysis is the social construction of technology. This framework describes how human action and society shape technology. The SCOT framework was defined by Trevor Pinch and Wiebe Bijker in 1987 and has since been heavily used in research (Klein & Kleinman, 2002). The component of SCOT most notably used in the following analysis is relevant social groups. A relevant social group describes a group where all members of a certain social group share the same understanding of a specific artifact,

in this case water. The relevant social groups researched include refugees, the general Jordanian public, and farmers. A general criticism of SCOT is that the approach places too much emphasis on agency while neglecting the various structures in society (Klein & Kleinman, 2002). Specifically, it does not put enough emphasis on structural influences, such as class, institutions, economic and political systems (Prell, 2009). This criticism will be combated by the added focus to the wider context during this analysis to better encompass all of the parties involved.

An example of the SCOT framework being used for water management is the research by Julie Trottier who researched the social construction of water management in a region of international conflict (Trottier, 2013). Specifically, Trottier researches the Palestinian village of Al Auja in the Jordan valley. Six relevant social groups were listed in Trottier's research, namely the various demographics of the inhabitants of Al Auja, including descendants of Bedouin families, descendants of refugees, and inhabitants who purchased land in the past 10 years (including corporations) (Trottier, 2013). By using SCOT Trottier determines that local water conflicts are associated with international conflict, and cannot be solved with the proposed solution of attributing a fixed quantity of water to West Bank regions, and instead require more developed local management (Trottier, 2013).

Methods

The methods that are used to answer the research question include documentary research, historical case studies, interviews, and discourse analysis. Documentary research and discourse analysis are both used to analyze historical and modern literature in order to gain more information on the wider context of wastewater technologies in Jordan. Historical case studies are used to understand how Jordanian society has influenced or been influenced by water

treatment technologies in the past which may indicate how society will react to change in the future. Finally, interviews helped to explore the current public perception of wastewater in Jordan and how it may vary regionally. A preliminary list of research questions is found in Appendix A. These methods form a comprehensive understanding of the public perception of water in Jordan. To maintain the scope of this research, key words include: Islam, The Quran, water scarcity, wastewater treatment, local and regional public perception of water, technological momentum, and social construction of technology.

Results and Discussion

Although Islam dictates that the consumption of treated wastewater for drinking is not allowed, the following analysis shows that there are other ways to implement wastewater treatment technologies, and support Jordan's current water crisis, without going against cultural values. Both historical and more modern case studies are provided which express the significant impact that the relevant social groups of Jordan's society have had on regional water technology. These case studies show that although Jordanians have very little trust in new water-providing technologies, this trust can be built through the help of various actors, which provides support required for the development of these new technologies.

Access to water has always dictated where and how Jordan's inhabitants live. Jordan is an arid country, with a desert covering 83% of its land (Al-Ansari et al., 2013). Despite the seemingly inhospitable conditions of the desert, civilization in Jordan has thrived for thousands of years and has seen some of the most exciting and innovative water collection and treatment technology developments. The first settlers in Jordan were hunter-gatherers dating back to the Paleolithic period. These first settlers used rudimentary water storage systems in the natural

sand-stone formations of Jordan (Suleiman, 2003). The Jordan river also provided water for what is considered the oldest city in history, Al-Jalil, now known as Jereicho (Suleiman, 2003). Over time, as Jordan's population grew, more innovative technology was adapted to catch and hold water for more people, livestock, and agriculture. Exciting technological advancements were made in water collection and distribution engineering to accommodate a continuously increasing population in the dry conditions. The most famous of these advancements were the extensive water canals and catchment systems designed and built by the Nabateans to provide water year-round for the ancient city of Petra, originally known as Raqmu (Mays, 2014). Channels, basins, aqueducts, dams, and cisterns were carved into the sandstone rock to provide water year-round to Petra. At its peak population, Petra's impressive water infrastructure served 20,000 inhabitants for consumption, hygiene, livestock, agriculture, wine and beer making, and even decadent roman baths for the wealthier population. This rich history is a point of pride for Jordanians, and places water at the center of their cultural frameworks.

Today, Jordan has a population of approximately 10.2 million people (United Nations, 2020). This population is concentrated in the northeastern highlands, including the capital city of Amman. Groundwater and surface water have remained the two main sources of Jordan's water, with the technology remaining relatively consistent in the modern era, although infrastructure has increased with population. Groundwater accounts for approximately 54% of the water supply in Jordan, collected from 12 groundwater basins (Al-Ansari et al., 2013). There are 16 surface water basins, and these account for approximately 37% of the water supply (Al-Ansari et al., 2013). The remainder of the water supply comes from treated wastewater. Using treated wastewater as a supply of water is a relatively new technology in Jordan, with the first wastewater treatment plant beginning operations in 1968 (Amery & Haddad, 2015). The

continued reliance on groundwater and surface water infrastructure may be a result of technological momentum. As ground and surface water technology has been successful in the past, the infrastructure has grown and built momentum. The consequences of this momentum are that changes to the infrastructure become more difficult and social resistance to change is more likely.

Relying on groundwater and surface water has historically been successful, with consistent rainwater replenishing these sources, but this is no longer the case. In 1948 the per-capita water availability was 3600 m^3 and it is now under 60 m^3 (Al-Ansari et al., 2013), (GIZ, 2021). International water standards state that less than 500 m^3 of water per person is severe water scarcity (UNICEF, n.d.). In fact, following 1948 there has been substantial exploitation of the natural groundwater and surface water sources, meaning the natural basins filled from groundwater and rain have been unable to refill fast enough to match the rate of extraction (Suleiman, 2003).

There are a few reasons for this exploitation. The first is climate change, which has decreased the overall amount of rainfall in Jordan. Specifically, from 1970 to 2013 the rate of the decrease of rainfall is more than 0.4 mm/yr (Rahman et al., 2015). This is a steady decrease of the amount of rainfall entering groundwater and surface water basins, which are no longer being refilled fast enough. The second reason for the exploitation of Jordan's natural water sources is the societal factors accompanying an unusually high population growth which has required the higher usage of groundwater and surface water sources to provide drinking water. The population has increased at a rate consistently higher than the world average, growing from 5.9 million in 2006 to 10.2 million in just 6 years (Maxmen, 2017). This leap in population is much

higher than the predicted population growth, that is, in 2008 the population of Jordan was predicted to be 7.8 million people in 2022, not 10.2 million (Al-Ansari et al., 2013).

Refugees as a Relevant Social Group

Refugees entering Jordan have caused these unpredictable and sharp increases in population. Mass influxes of refugees have occurred numerous times since the 1940s, and as of 2016 one third of Jordan's residents are non-Jordanians (Salameh & Al-Alami, 2021), (Hajjar, 2016). These refugees are coming from neighboring countries in conflict and include returnees from the Gulf States, Lebanese, Iraqis, Palestinians, and most recently Syrians (Salameh & Al-Alami, 2021). More than 90% of these refugees are Muslim, and therefore require naturally sourced water for drinking and religious practice (Salameh & Al-Alami, 2021). The religious requirements of this social group determined the technology Jordan was able to use to accommodate the increase in population, and is an example of the social construct of water technology in Jordan.

Jordan's water management strategy involved developing both groundwater and surface water sources, as well as slowly increasing the use of wastewater treatment for reuse in areas such as agriculture (Suleiman, 2003). If the population of Jordan would have followed a normal population growth curve, this initial management strategy would have been more successful, and Jordan would not be facing as big of a water crisis as it is today (Suleiman, 2003). However, with the influx of Muslim refugees, the demand on the groundwater and surface water sources increased significantly. Refugees do not carry out farming or other agricultural activities so they have no use for treated wastewater, as they cannot consume it or use it for hygiene. Therefore, the increase of demand on natural water sources was much greater than the demand for

wastewater treatment (Suleiman, 2003). This disproportional demand for natural water sources impacted water technology in Jordan in multiple ways. First, more technology was developed for extracting water from natural basins, to include digging deeper wells to accommodate for the lowering water table, as well as additional dams and weirs to capture and accumulate surface water to attempt to reduce evaporation (Al-Ansari et al., 2013). Second, investments in desalination technology have been made, specifically in a partnership with Israel to trade electricity for desalinated water in 'The Green Blue Deal for Prosperity' (Esoh, personal communication, January 17, 2022), (Bromberg et al., 2020). Water desalination is the act of removing salt from sea water to produce potable water. Desalination is much more expensive than wastewater treatment, and requires more energy, however in the view of Islam it is a natural source of water whereas wastewater is not (Cooley & Rapichan Phurisamban, 2016).

Jordanian General Public as a Relevant Social Group

The public perception of water in Jordan has always played a significant role in the shaping of the water technology in the region. To analyze the relationship between the public perception of water and water technology in Jordan, the general perspective of the public must first be defined. First, it is important to illustrate how well informed the Jordanian public is about water use in Jordan. Water is incredibly important to Jordanians, not only for the obvious reasons of drinking and hygiene, but also for two pillars of Islam: praying and pilgrimage (Amery & Haddad, 2015). Before prayer, a religious ablution is performed, or the ceremonial act of washing parts of the body in a mosque. Islam requires pure water to be used for these acts, so Jordanian Muslims (approximately 95% of the population) are very aware of where their water comes from to ensure this is the case (Al-Ansari et al., 2013). The following two case studies

give evidence for the impact of the Jordanian general public as a relevant social group on wastewater technology in Jordan.

The first case study is an event that occurred with the Zai water treatment plant in 1998. This water treatment plant was a major supply to the capital of Amman's municipal tap water (Bellefontaine, 2015). The treatment plant malfunctioned, and a treated water stream leaving the plant was mixed with and was contaminated by a non-treated wastewater stream (Bellefontaine, 2015). This malfunction caused water coming out of the taps around Amman to smell, and have a dark color. Panic arose, as well as a deep mistrust of the water utilities. Ever since this event very few people in Jordan drink straight from the tap, even though there is no longer contamination and the World Health Organization has declared the tap water safe to drink (Esoh, personal communication, January 17, 2022). Instead, Jordanians either drink bottled water or have an additional filtration system in their house to ensure there are no contaminations to the water they are drinking.

The second case study is the use of greywater for irrigation purposes. Greywater is defined as relatively clean wastewater that is not contaminated with toxic chemicals or excrement, which includes water from sinks, showers, baths, washing machines, etc. In a project by the German Agency for International Cooperation, or GIZ, mosques were retrofitted with technology to reroute greywater to irrigation systems for gardening of native trees around the mosque (Häberelein, 2020). Reuse of greywater would save water, and provide trees and shade to the mosque grounds. However, when this construction began, locals protested and expressed that using greywater for irrigation was unclean and did not know if it should be allowed (Alayed & Häberlein, personal communication, February 13, 2022). In order to continue with the implementation of the greywater irrigation, the Iftaa’ Department of Jordan had to release a

statement, called a fatwa, claiming that this technology should be allowed. The General Iftaa' Department, or GID, is a council that judges situations, usually social, and provides the Islamic view on the matter in a fatwa, in other words a non-binding legal opinion (GID, n.d.). These fatwas are tools to deal with issues not explicitly mentioned in The Quran by looking at evidence from Islam and applying it to modern situations (Alayed & Häberlein, personal communication, February 13, 2022). The fatwa released considering the greywater reuse systems for implementation in mosques claims that Islam does not prevent the use of greywater for irrigation, nor does it prevent eating the fruits from irrigated plants (Abulbasal et al., 2015). In fact, this fatwa quotes the opinion of Imam Nawawi, who is a respected religious leader and academic of Islam, that "As the al Imam al Nawawi have been asked before can we eat from crops and fruit that irrigated from unclean water or used animal feces as fertilizer, he answered yes we can. But we must always follow the health instructions announced to be sure it's safe…" (Abulbasal et al., 2015). This fatwa is a very important release as it allows greywater to be used to irrigate crops and that the fruits and vegetables grown as a result are safe to eat under Islam, which is still not the widely accepted opinion of the public (Alayed & Häberlein, personal communication, February 13, 2022).

Farmers as a Relevant Social Group

Despite having high standards for water quality and a general mistrust for water from non-natural sources, like wastewater or greywater, Jordanians are aware of the current water crisis and are becoming less stringent over time (Esoh, personal communication, January 17, 2022). Drinking water produced by wastewater treatment is not permitted in Jordan, even with tertiary treatment which is becoming more common in western societies (Amery & Haddad,

2015). However, treated wastewater is used for agriculture, which has greatly reduced pressure on the groundwater and surface water supplies, but this use is still regulated. First, in Jordan treated wastewater can only be used to grow crops that will be cooked, which excludes a large portion of the exported vegetables (Abdel-Jabbar & Seder, 2011). Second, treated wastewater must be mixed at certain ratios with fresh water in order to be used for agriculture (Abdel-Jabbar & Seder, 2011). The main users of treated wastewater are farmers, and because of the increasing need to water crops, their perception of wastewater treatment has improved over time (Esoh, personal communication, January 17, 2022). Farmers are still willing to pay more for 'higher quality' water, or water that has a higher freshwater to treated wastewater ratio, however they have accepted that their older standards cannot be met in the current climate (Esoh, personal communication, January 17, 2022). As a result of this social group accepting treated wastewater for agriculture, more wastewater treatment plants have been developed in Jordan, which in turn has increased the availability and usage of treated wastewater. Although the use of wastewater is still minimal, the impact of the farmers is not, and shows the potential impact that future social change can have on technology in Jordan.

The Actor Network Theory

If the general perception of wastewater treatment in Jordan was better, it is very likely the technology would be more widely accepted. Similarly to the increase in usage of treated wastewater for farming, if Jordanians had a better understanding of the technology, they might be less opposed to wastewater and greywater reuse. The success of the fatwa promoting greywater reuse for irrigation, as well as the consumption of the fruits and vegetables produced, shows the direct impact the public perception of a technology can have on its realization. The

fatwa used a well-known religious figure to reassure the public that it is not against Islam, and conveyed the water-saving benefits of the technology. In this way, religious actors have proven their ability to impact public acceptance and therefore impact technological advancements. However, there are many more actors involved that influence water technology in Jordan who are not acting from a religious standpoint. The actors that have the biggest impact on water technology include politicians, academic institutions, development organizations such as the United States Agency for International Development (USAID) and GIZ, as well as individuals such as farmers who are active in their communities. The combination of these actors working together to increase awareness of the water crisis in Jordan and provide education of possible technological solutions involving greywater and wastewater reuse could cause significant change in public perspective. From the case studies reviewed, such a change in public perspective would have a positive impact on the further development of new water technology, and this change is likely necessary before any technological solution is accomplished.

Limitations and Future Research

As there are so many actors involved in influencing the water technology industry of Jordan, there are many limitations for a full analysis of how public perception has impacted change in water technology adoption in Jordan. The system involving water technology in Jordan is very complex, and many of the case studies were analyzed with a focus on the social aspects, ignoring other actors that were likely involved which create additional challenges to the implementation of new technology. Additionally, even if new technological solutions were to become culturally accepted, they are unlikely to provide any short-term relief to the ongoing water crisis as their implementation will likely require several rounds of approval by various

government bodies as well as then being developed and integrated into existing infrastructure, both very time-consuming processes.

In order to provide more fleshed out solutions to the ongoing water crisis in the region, and to better understand the public perception of water technology in Jordan, further research is recommended. A full historical account of the water treatment technology in Jordan would provide a more complete understanding of how the technology developed. Furthermore, comparing this account to that of a neighboring country with comparable access to water and climate would show how the Jordanian public has influenced their technological development. In addition to a broader historical context, personal interviews with locals including farmers, students, refugees, and the average citizen would provide a deeper understanding of perspectives of Jordanians on water technology in the context of the current water crisis.

Conclusion

It is important to understand how technology and society connect as the better we can understand this relationship, the easier technological advancement and integration will be in the future. The water crisis in Jordan is a current example of how significant of an impact a society, and its various social groups, can have on a technology which does not align with the cultural values of said society. Through an analysis of historical and current case studies, it can be concluded that a change in the public perception of a water technology, such as wastewater treatment, would support its implementation into Jordan's current water infrastructure. Although social views are not likely to change as much as allowing for the drinking of treated wastewater, they might allow for a higher percentage of wastewater and greywater reuse for irrigation and agriculture to supplement the groundwater and surface water supplies that are being exploited.

This analysis of Jordan's unique cultural and physical climate shows that whatever the technological solution to Jordan's ongoing water crisis may be, local values must be incorporated and respected in order to be successful.

Appendix A - Interview Questions

1. What are the accepted ‘rules’ in Jordan set by society regarding water? Who sets the rules? Who enforces them? For example, what decides whether the water is pure enough for drinking or not? Can treated wastewater be used for drinking, as long as it is not for a religious ceremony?
2. What have been the biggest impacts of religion on water technology?
3. How is using wastewater for agriculture different from treating it for drinking water?
4. Is the source of water highly talked about and acknowledged?
5. How does the public perception of wastewater vary nationally?
6. Historically what have been the main sources of water for Jordan, and how has this technology had to change?
7. What are the main technologies used today to provide water?
8. What are some unique solutions that have been implemented to comply to jordanian culture?
9. Are there solutions being researched/implemented in Jordan that are culturally conscious and more economic than desalination?

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