Societal and Cultural Influences on the Uptake of Water Disinfection Technologies; a Case Study of California, Australia, and South Africa

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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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The Problem of Global Water Insecurity and Usage of Disinfection Technologies

Over 2 billion people around the world do not have access to safely managed drinking water services, a concerning number that continues to grow with the global water crisis (World Health Organization, 2019b). In fact, by 2025, it is estimated that "half of the world's population will be living in water-stressed areas" (World Health Organization, 2019a). Contaminated water can cause a plethora of diseases, including diarrhea, cholera, dysentery, typhoid, and polio. At its worst, polluted water can lead to death; contaminated drinking water causes almost 500,000 diarrheal deaths each year (World Health Organization, 2019a). To combat this overarching issue, many types of disinfection technologies have been developed that are effective in providing safe, clean drinking water.

While there are many powerful water disinfection technologies around the world, some seem to be more liked and used than others within different regions and communities. It is crucial to comprehend how societies can influence their respective communities' acceptances of water disinfection technologies. With this understanding, researchers and innovators will be better able to develop and refine new and existing technologies that will be both scientifically sound and consistently used by consumers. Effective technology alone will not solve the problem of contaminated water; people and communities need to be willing to use these technologies as well for a complete solution.

To better grasp the notion that the success of disinfection technologies is dependent on their acceptance from society, historical case studies of various water technologies and their applications within California in the United States, Toowoomba in Australia, and Thohoyandou in South Africa, are analyzed. The successes or failures of implementation of the "toilet-to-tap" system in California, the Water Futures Initiative reuse water referendum in Toowoomba, and silver-embedded ceramic pots in Thohoyandou were all ruled by the respective communities' degree of comprehension and acceptance of the technology. To understand the political and societal structures in place within the differing regions, these three cases studies are compared to grasp just how influential society and cultures are in determining the level of access to clean drinking water. This is consistent with the STS framework of social construction of technology, which argues that humans and society shape technologies, rather than the other way around (Klein & Kleinman, 2002).

Understanding the Problem Through Historical Case Studies

Research Question: How can society influence the respective community's acceptance of water disinfection technologies?

By exploring this research question, this analysis of the historical case studies considers the qualities and characteristics of a community or society that influence the overarching level of acceptance of a proposed water disinfection technology. To effectively analyze the impacts of societal and cultural expectations on the acceptance or rejection of viable water disinfection technologies, accounts of historical case studies about the Groundwater Replenishment System in Orange County, California, the "Water Futures Initiative" referendum in Toowoomba, Australia, and ceramic water filters in Thohoyandou, South Africa are assessed. Each account is organized to present a clear timeline of the existing societal, cultural, and political structures, the introduction of the respective water system, and the acceptance or pushback of these technologies from the community. This provides a path to gain a clearer understanding of the aspects of each social group that contribute to the degree of success and sustainability of the water disinfection technology. Additionally, the analyses of these case studies place an emphasis on each respective governmental organization and political environment. Understanding the societal structures that govern and guide a community is crucial to determine how they influence each community. This process helps to provide explanations as to why some societies choose to accept and use a water disinfection system, and why others do not. The keywords that guide the research consist of water; disinfection technologies; reuse systems; Orange County, California; Toowoomba, Australia; Thohoyandou, South Africa; point-of-use treatment; water referendum; ceramic pots; toilet-to-tap; and water infrastructure.

The Background of Clean Water Insecurity in California, Australia, and South Africa

As of 2008, Orange County, California has implemented a Groundwater Replenishment System, essentially purifying wastewater from local sewage water to be reused as potable water (Bendix, 2019). Like many places around the world, California faces water scarcity issues that threaten food production and more health crises (From Toilet to Tap: Drinking Recycled Waste Water, 2014). Specifically, California encounters droughts and saltwater intrusion: overpumping the Orange County's underground aquifers in the mid 1900s caused seawater to seep into the freshwater supply, jeopardizing the safety of the residents (Bendix, 2019). To address this problem, the Orange County Water District (OCWD) started recycling sewage water through the Groundwater Replenishment System, what is also known as the "toilet-to-tap" system, making the water drinkable again. This involves a three-step process: the sewage water is first filtered through microfiltration to remove solids, bacteria, and oils, then the water goes through reverse osmosis to filter out pharmaceuticals and viruses, and finally, the water is treated with UV light to remove organic compounds. From this technology, about 100 million gallons of water are recycled each day, enough for about 850,000 people (From Toilet to Tap: Drinking Recycled Waste Water, 2014).

In 2005, a referendum was proposed in Toowoomba, Australia; this referendum, titled the "Water Futures Initiative," addressed the growing concern of the lack of water security in the area by proposing the construction of a new potable water reuse system (Hurlimanna & Dolnicar, 2010). As climate change worsens and regional rainfall has declined, residents of Toowoomba have faced water usage restrictions and limitations. In response, Toowoomba city officials launched the "Water Futures Initiative," containing many solutions, "...most prominently the construction of an advanced water treatment plant to provide potable quality recycled water for the town" (Hurlimanna & Dolnicar, 2010). While this proposal was supported by the local government, residents ultimately voted against the referendum in 2006, subsequently leading to even lowered surface dam levels and stricter water usage limitations (Hurlimanna & Dolnicar, 2010; van Vuuren, 2009).

In Thohoyandou, in the Limpopo Province in South Africa, many residents rely on at-home point-of-use water treatment technologies to disinfect their water. Since 2012, the Limpopo Province has experienced dry conditions that have culminated in droughts, leaving many people with ongoing water shortages (Rakgwale & Oguttu, 2020). In fact, between 2002 and 2019, access to water declined by almost four percentage points in the area (Ledwaba, 2021). As a result, family members, mostly women and children, must travel an average of 6 kilometers, or 3.8 miles, to communal water taps to collect water in containers to bring back to their homes for use (Reid, 2020). This leaves ample opportunity for the water to become contaminated, whether it be from the communal water tap, unclean buckets, or during usage in homes. To combat this problem, researchers assessed the feasibility of implementing a ceramic water filter in Thohoyandou. These filters are embedded with silver nanoparticles to help disinfect the water as it is stored inside the ceramic pot-shaped filter and plastic container (Tyeryar, et al., 2010). Given the low rates of access to at-home running water, a point-of-use treatment option such as the silver embedded ceramic filter was sought for as a solution to disinfect stored, still water.

The Social Construction of Technology

The social construction of technology, or SCOT, is a theory about how "social structures can influence the development of technology" (Klein & Kleinman, 2002). It is the idea that humans and society dictate technological developments, instead of technology shaping society. SCOT was originally introduced by Trevor Pinch and Wiebe Bijker through their article in 1987, titled, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." Pinch and Bijker describe SCOT's framework through four components: interpretive flexibility, relevant social group, closure and stabilization, and wider context. Interpretive flexibility means that "technology design is an open process that can produce different outcomes depending on the social circumstances of development" (Klein & Kleinman, 2002). The relevant social group aspect refers to the idea that "all members of a certain social group share the same set of meanings, attached to a specific artifact" (Pinch & Bijker, 1987). The third component of closure and stabilization means that, "when different interpretations lead to conflicting images of an artifact," conflicts are resolved so that all relevant social groups agree (Klein & Kleinman, 2002). Lastly, the wider context component plays a small role in the original interpretation of SCOT; it refers to the “wider sociocultural and political milieu in which artifact development takes place” (Klein & Kleinman, 2002).

Since the original theory of SCOT has been developed, many people have argued against aspects of this framework. In fact, Pinch has critiqued the initial formulation and components as insufficient (Pinch, 1996). The most common criticism of SCOT is about the implicit assumptions the theory makes about society and social groups; the components of SCOT assume that every social group is accounted for and has equal input in the design process of a technology or artifact (Klein & Kleinman, 2002). Opponents argue that some groups may not participate in the design process, or that there is one voice representing a diverse collection of subgroups (Williams & Edge, 1996; Russel, 1986). To resolve this overarching critique, Bijker later added another concept to SCOT: technological frame. The technological frame aspect “defines a relevant social group and constitutes members’ common interpretation of an artifact” (Klein & Kleinman, 2002). This concept helps to address the unbalanced power dynamics between social groups and provide structure, which was argued to be strongly lacking previously.

Still, the social construction of technology provides a way to understand a technology through the stakeholders and societies that give meaning to it, while accounting for the social groups included in and excluded from defining the technology’s success or failure. SCOT is helpful in explaining why there are varying attitudes towards technological development across different cultures and societies. Because of this, SCOT is used to analyze the implementation and success, or lack thereof, of water disinfection technologies across different geographical and demographical locations. The cultural and societal norms in place throughout Orange County in

California, Toowoomba in Australia, and Thohoyandou in South Africa, seriously affected the respective water systems' successes or failures. Because the communities in each of these areas have already been deeply established prior to the respective technologies being introduced, this paper argues that it was mainly the societies that influenced the technological development and usage. Therefore, this paper advocates that SCOT is the most applicable framework in assessing the "toilet-to-tap" system in Orange County, the Water Futures Initiative reuse water referendum in Toowoomba, and the silver-embedded ceramic pots in Thohoyandou.

The Societal Characteristics That Influence Technological Acceptance

Societal and cultural norms and expectations have great influence over the level of acceptance and usage of introduced technologies. The societies and communities in Orange County in California, Toowoomba in Australia, and Thohoyandou in South Africa have all experienced new, proposed water disinfection technologies aimed at making drinking water safer and more sustainably accessible. In Orange County, the "toilet-to-tap" water refuse system was proposed and later installed; in Toowoomba, a Water Futures Initiative referendum was also proposed, but the public voted against its implementation; in Thohoyandou, ceramic pots were introduced and widely accepted as a point-of-use water treatment. Each of these regions are different, both geographically, demographically, and culturally. After conducting a case study of each of these areas and the respective proposed water technologies, it is evident that some factors of a society hold dominance over the fate of a suggested technology and its usage. The general awareness that the public has about the problems the region is facing with respect to clean water insecurity, the level of knowledge about the water system and its technical workings, the amount of media bias and misinformation spread among the community, and the degree of governmental influence, trust, and involvement in providing accessibility and sustainability for clean water are the major societal contributors to the resulting level of acceptance of an introduced water disinfection technology.

Some of these components are more influential than others, depending on the area in question. In California, knowledge, or lack thereof, about the “toilet-to-tap” system, along with the levels of media presence surrounding the technology, initiated pushback on the disinfection system. However, with a strong governmental focus to inform the public about the water disinfection technology that was necessary to address the threatening water security issues that Orange County was facing, society slowly began to accept the technology, which is still being used today. In the case of Toowoomba, Australia, governmental focus, along with media bias and the spread of misinformation, greatly hurt the effort to pass the Water Futures Initiative referendum. This proposal outlined many objectives to secure safe drinking water, most prominently the construction of a water refuse system. In Thohoyandou, South Africa, the awareness of the contaminated drinking water problem that the community was facing and the level of knowledge about the introduced technology and how to use it paved the way for a successful implementation of ceramic pots point-of-use treatment. The following discussion details the ways in which these societal features were activated to determine how successful each water disinfection technology ultimately was, in terms of being used within the respective society.

California and the “Toilet-to-Tap” System

Orange County, California has experienced water shortages since the early 1900s due to droughts and overpumping of the Orange County Groundwater Basin. These problems became so severe that in 1933, the Orange County Water District (OCWD) was founded to help ensure a sustainable, reliable source of water for the county ("History," n.d.). Overuse of the Basin led to saltwater intrusion, where too much pumping of the groundwater caused coastal saltwater to migrate landward and infiltrate the Basin, effectively contaminating the water ("History," n.d.; "Saltwater Intrusion," 2019). As Orange County's population doubled between 1949-1959, the OCWD was forced to address the growing demand for clean water. Beginning in 1975, the OCWD started recycling and purifying water. By taking treated wastewater from the Orange County Sanitation District (OCSD) and blending it with deep well water, the OCWD was the first in the world to use reverse osmosis to purify wastewater to drinking water standards ("History," n.d.). Today, the OCWD is responsible for protecting the Basin, which provides 77% of the water supply to over 2.5 million people around Orange County ("Drought in California," n.d.).

The Groundwater Replenishment System (GWRS), commonly known as the "toilet-to-tap" system, was first introduced in 2008 by the OCSD and OCWD to combat the drinking water shortages the area was facing (Thornton, 2012). Beginning in January 2008, the $481 million GWRS plant was constructed to purify 70 million gallons of water each day for potable reuse, thereby replenishing the Orange County Groundwater Basin to supplement the supply of drinking water, while preventing saltwater intrusion ("History," n.d.). This is a three-step system: microfiltration is used to remove solids, bacteria, and oils from the water, then reverse osmosis is used to filter out pharmaceuticals and viruses, and lastly, UV light is used to remove organic compounds. After just a few years of operation, the water plant has expanded to recycle about 100 million gallons of water each day, enough for 850,000 people ("From Toilet to Tap: Drinking Recycled Waste Water," 2014).

While the technology itself has proven to be technologically advanced and necessary to ensure enough water for Orange County residents in the long-term, there was some initial pushback from citizens. Expectedly, convincing people to not only use, but drink, water that has been recycled from sewage has proven to be difficult. The “yuck factor” refers to feelings of disgust that people have about the idea of using recycled water, which is a very real, and hard, phenomenon for experts to hurdle to secure communal usage of a water reuse system (Wester et al., 2016). In fact, efforts to encourage the public to use a water reuse plant in San Diego and Los Angeles in the 1990s were shut down; activists who were against the development of this technology called the system “toilet-to-tap,” emphasizing a negative attitude and inciting the “yuck factor” among the residents (Schwartz, 2015).

Overcoming the yuck factor was something that Orange County officials knew they had to do to successfully implement the GWRS and secure a sustainable drinking water supply. Studies have suggested that informing and educating people about water reuse, especially when framed in an affective or cognitive way, can lower their disgust in such a technology (Wester et al., 2016). Building trust between the organizations that recycle the water and the residents was also crucial to gain communal support. The OCWD hosted thousands of tours and community meetings to familiarize the residents with the water system. They have allowed public tours of the facilities and have been committed to transparency and competency; the OCWD’s Board of Directors are elected officials who are experts and professionals in their fields (Harris-Lovett & Sedlak, 2019; “Service Area & Board of Directors,” n.d.). Thus, there was a sense of trust, competency, and clarity between the governmental officials and the residents that has allowed California to successfully implement this technology to address their growing water problems.

Through community engagement, education about the technology, mutual trust, and transparency, Orange County was able to effectively construct and use the Groundwater Replenishment System. Overcoming the “yuck factor” is a major feat, and doing so has secured an otherwise threatened drinking water supply. Just as the social construction of technology (SCOT) asserts, it was Orange County and its respective societal features that ultimately determined the success of the GWRS (Klein & Kleinman, 2002). The residents all shared the same set of attitudes and feelings towards the sustainable drinking water system. While this system was not doubted for its technological viability, societal fears and disgust posed a hazard for the successful implementation of the water disinfection system. In the same capacity, the government and officials were able to connect with the residents to build a sense of trust in the technology, shifting the attitudes of the residents and gaining its successful application into the community.

Australia and the Water Futures Initiative Referendum

Toowoomba, Australia is home to about 100,000 people, most of whom rely on surface water from dams for their water supply. While the city’s population is growing, the water supply has been depleting due to climate change and decreased rainfall over Lake Cooby, Lake Perseverance and Lake Cressbrook, the three major storage areas of Toowoomba. In 2006, the total water demand in the city was estimated to be greater than 17.5 billion liters per year, far exceeding the available supply; at this time, dam levels were at 20% of capacity (Hurlimanna & Dolnicar, 2010). Hence, city officials proposed an indirect potable reuse system to address the growing concern about the dwindling water supply.

In July of 2005, Toowoomba City Council proposed the Water Futures Initiative, aimed at addressing the city's water insecurity. This referendum consisted of an array of water solutions, most notably the construction of a water reuse treatment plant that would provide potable, recycled water to the residents. As part of this proposal, the city council also planned to invest in a three-year engagement program, which would involve community members in learning about the water treatment technologies and building trust and comfort around the idea of reusing wastewater. The council expected for this initiative to be fully funded by later in the year, as they initially got unanimous support from the National Water Commission and respected governmental figures and members of Parliament (Hurlimanna & Dolnicar, 2010).

However, this referendum was quickly met with harsh criticism and pushback from residents. An activist group called Citizens Against Drinking Sewage, or CADS, compiled more than 10,000 signatures on a petition against the referendum and presented it to Ian Macfarlane, the federal representative and Minister for Industry, Tourism, and Resources in Toowoomba. In doing so, they urged him to repeal his support for the program, even though the proposed reuse system was technologically sound and important for the city to start dealing with their diminishing water supply (van Vuuren, 2009).

With the increasing public opposition, the federal governments' Secretary for Water Policy, Malcolm Turnbull, announced that a local referendum would be held to vote on the support of the Water Futures Initiative; if the project passed with a positive majority, Turnbull promised that the National Water Commission and federal government would put $22 million towards helping to build the proposed projects (Hurlimanna & Dolnicar, 2010; van Vuuren, 2009). By some, this was seen as a way to undermine the roles of elected officials and welcome more polarization within the community.

The media presence also played an important role in the divide among community members with respect to the proposal. The mayor of Toowoomba, Diane Thorley, described the media coverage as a “feeding frenzy” and “something to make a mockery out of” (*Late Night Show*, 2007). Additionally, many argued that the media failed to present an unbiased overview of each side of the debate, thereby influencing the outcome of the referendum. Anti-recycling lobbyists used television advertisements to show polluted, raw sewage flowing through channels of water, pushing a negative connotation about reusing water for drinking purposes (van Vuuren, 2009).

As the social construction of technology framework asserts, conflicting interpretations and ideas of a technology lead to a resolution in which all relevant social groups agree upon (Klein & Kleinman, 2002). Citizens, the media, and governmental figures all expressed differing views of the Water Futures Initiative. Consequently, the combination of political polarization, biased news media, and misinformation spreading through anti-reuse activism led to the failure of passing the referendum. As a result, dam levels dropped further and drought worsened, only highlighting the need for urgent response to this issue (van Vuuren, 2009). The competing discourses surrounding the Water Futures Initiative exemplified that it takes more than just scientific evidence for people to support a technology that is necessary to ensure clean water access; it was the social construction of Toowoomba, consisting of conflicting governmental officials and widespread biased information, that ultimately determined the future of the water reuse proposal.

South Africa and Ceramic Filters

Thohoyandou is located in the Limpopo Province in South Africa. This mostly rural area is one of the poorest provinces in the country and struggles to secure safe drinking sources. Because of the arid climate, harsh topography, sandy rivers, and limited potential for increased groundwater abstraction, there remains limited access to water supplies. Of the water available for use, most are polluted to some degree. In fact, 50% of the groundwater sampled in the Limpopo Province was determined to be unsafe for human consumption (Odiyo & Makungo, n.d.). Contaminated water poses a serious threat to those who use it; diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio have all been linked to contaminated water. Around the world, over 485,000 people die each year from contracting diarrhea from dirty drinking water (World Health Organization, 2019a). In Thohoyandou, of 200 households sampled across two communities, only 3.9% met the World Health Organization's drinking water standards (Tyeryar et al., 2010). As water security is continuously decreasing in the area, new technological responses are necessary.

Ceramic filters are used throughout the world as a point-of-use, household level water treatment technology. They have been proven to reduce bacteria and protozoa in water, along with a reduction of diarrheal disease incidences for its users. Additionally, this technology is easy for people to use and is generally accepted, as it does not alter the taste, color, or odor of the water. Ceramic filters are relatively cheap and last long if used correctly (Center for Disease Control and Prevention, 2012).

A study of the acceptance of ceramic water filters in Thohoyandou was conducted in 2010. Participants, who were community members, indicated that ease of use, cost, local availability, state, coloration and odor of treated water, and water quantity were all important traits for a treatment option to be generally accepted and used within the community. Because ceramic water filters that can be locally manufactured with available resources are simple, effective, and easy for community members to understand, use, and maintain, this technology was greatly accepted into the community. Over 96% of the participants indicated that they would be interested in buying a ceramic filter, with over 95% claiming that they would buy one either immediately or within the next six months (Tyeryar et al., 2010). The ease of these ceramic filters has made the technology understandable for people, thereby encouraging them to accept and use this technology to promote water security.

The social construction of technology is evident in the case of Thohoyandou and ceramic water filters. SCOT suggests that the relevant social circumstances guide the development of a technology (Klein & Kleinman, 2002). The established communities and societies within this region had expectations for what they would value from a water disinfection technology, ultimately shaping the technology design. These criteria included ease of use, low cost, and local availability. The ceramic water filters were able to meet these expectations. As such, this technology was accepted by the community and successfully implemented for use.

Limitations

There are some limitations to the concluded results of this paper. While case studies of three varying regions and respective water disinfection technologies were conducted, there are countless examples around the world that can, and should, be studied for comparison. Hence, a major limitation of this paper is the relatively small number of historical cases that were assessed to determine the overarching features of a society that influence the successful implementation of a water disinfection technology. Therefore, it is suggested that for further research on this subject, researchers should conduct case studies of other countries or areas around the world that have had to face a proposed water disinfection technology and the factors of the society that led to the outcome of the level of acceptance and usage of the respective technology.

Conclusion

Through the analyzation of the communities in Orange County in California, Toowoomba in Australia, and Thohoyandou in South Africa during periods of time when a new water disinfection technology was introduced into the respective society, certain aspects of communities are emphasized as the contributing factors to the degree in which the technology was accepted into the community. These components include the level of general awareness that the public has about the water security problems in the region, the degree of knowledge about the water system and its technical workings, the amount of media bias and misinformation spread among the community, and the degree of governmental influence, trust, and involvement. These findings are key for developers and innovators, companies and organizations, and even governments to understand. When creating, selling, or implementing a new technology, especially one that is crucial for the sustainability of clean water access, it is salient to consider how to ensure the acceptance of the technology. Being technologically effective in providing clean water does not suffice as the only criterion that should be met; these technologies and systems must be adopted into the chosen society to successfully provide clean drinking water to the community.

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