Analysing and evaluating local and global responses to water scarcity

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Abstract

To identify the global scope and causes of water scarcity, this essay will explore the factors affecting access to water around the world. By assessing the scale of the factors that affect water security, the case will be made for the existence of a global water scarcity crisis. The contrasting factors affecting the specific case studies of Singapore and Mexico will be compared, to identify the local impacts currently leading to water scarcity events across the world. The specific geographical contexts of the case studies will be compared, and the relationship between the physical and human factors will be assessed. The aim of this essay is to suggest a strategy for mitigation that meets the most relevant needs of the communities affected.

1. Water scarcity: the global context

The United Nations definition of 'water scarcity' will be adopted throughout this essay. This definition refers to 'scarcity in availability due to physical shortage, or scarcity in access due to the failure of institutions to ensure a regular supply or due to a lack of adequate infrastructure' (UN-Water 2021). 'Water' itself will also be used to refer to freshwater unless otherwise stated.

The latest IPCC report on the issue of water scarcity reinforces a sense of urgency and global crisis, which this essay seeks to make a case for, where there is rampant inequality surrounding consistent access to clean water (IPCC 2022). Water scarcity is a profound and rapidly growing crisis, such that it has become paramount to its prevention to analyse and compare the efficacy of local and global responses to identify appropriate and effective solutions. Efforts should be made to combat specific local issues, and the more general global situation. The case studies of Singapore and Mexico will not only indicate contrasting local causes of water scarcity but also will be individually analysed to assess respective management strategies. Finally, by comparing them, this essay will be accounting for a variety of social, economic, and situational differences when devising a solution strategy.

2. Common and global causes of water scarcity: a summary

According to the NOAA the 10 warmest years on record all occurred after 2005 (Lindsey and Dahlman 2021; Royal Society 2020). Higher average temperatures are causing higher levels of evaporation, combined with the recently evidenced Hadley Cell expansion which involves clouds being moved towards the poles as a result of rising global temperatures (Schleifer, 2017). This phenomenon occurs when the difference in temperature between the equator and the poles reduces, causing the Hadley air circulation cell next to the equator to expand. This has meant that there is a more uneven distribution of precipitation, leading to 15 countries accounting for 80% of population exposed to river flood risk globally because of the precipitation increase, and regions at mid-latitude (such as those in Central America and Central Africa) facing higher rates of drought due to a lack of vital rainfall (Winsemius and Ward 2013).

Despite the profound changes due to these physical factors, most common triggers for water deficit and scarcity events worldwide could be considered to be human factors. For example, poor levels of water infrastructure continue to reduce the clean water available from pipes and taps around the world, in North America 20-50% of water is estimated to have been lost to leaks (Torrent Tucker 2020) and in England and Wales under 3 billion litres of water are lost for the same reason each day (Baraniuk 2020).

Positive feedback systems have contributed to a growing water scarcity crisis across the globe. For example, in the Amazon rainforest, rising global temperatures and deforestation have triggered more intense droughts and wildfires, destroying vegetation and causing greater levels of surface runoff and transport of precipitation out of the forest via channel flow. This in turn reduces vegetation cover and causes more water from the system to be lost, impacting water sources that many local communities rely on. The vulnerability of countries, communities and individuals also exacerbates the effects of water insecurity and scarcity around the world. How vulnerable a population is to water scarcity is dependent on a myriad of factors from political and economic to physical. However, it could be argued that water insecurities are mostly a man-made problem, a point which many experts have argued in the case of other 'natural' hazards (Kelman 2020).

These physical and human causes, along with positive feedback loops and the creation of vulnerability through social, economic and political factors, have combined to create a global water scarcity crisis (see figure 1). This essay will now explore this crisis in specific local contexts to compare the significance of such factors regarding potential mitigation strategies.

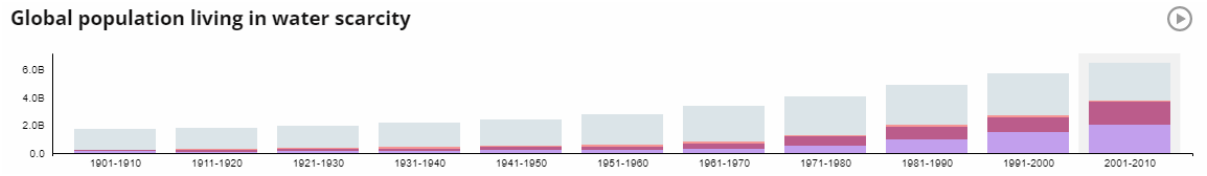

Figure 1. A graph showing the global population of people living in water scarcity from 1901-2010. Source: The Global Water Scarcity Atlas, n.d.

3. The Challenges of Water Scarcity: locally Specific Examples

3.1 Singapore's water scarcity

Singapore is a high-income economy (World Bank 2019). Its separation from the Malaysian mainland means that it has a large supply of saline ocean water and very few freshwater sources across the country. The island is very densely populated, with 7919 people per square km in 2020 (The World Bank, 2021). Consequently, demand for freshwater is high whilst the land available for water-based infrastructure, such as reservoirs and pipelines is limited. For this reason, Singapore currently relies on four different sources of freshwater (known as the four national taps by Singapore's national water agency) to meet demand: catchment water, imported water, desalination and NEWater.

Catchment water is relied upon because of both its physical circumstances and its development pattern. There is an abundance of precipitation (around 2300mm of average rainfall each year (Follows-Smith 2018: 12-16)) because of the country's tropical climate (resulting from its proximity to the equator, which means it falls into an area of low pressure) and no natural lakes. Furthermore, its growing population in recent years has resulted in most of the land being built on, meaning capturing, storing and distributing rainwater is difficult. Despite this, the PUB (Singapore's national water agency) has stated that 'Water from local catchment is a pillar of our sustainable water supply' (PUB 2022, no page).

Due to these challenges preventing Singapore from accessing freshwater independently, a significant amount of its supply is imported water, Malaysia being its largest supplier due to a series of bilateral agreements in 1961 and 1962 (PUB 2022). The latter agreement with the Johor State Government allowed Singapore to draw a maximum of 250mgd (or million gallons per day) from the Johor River until 2061 and is the agreement still maintained today (PUB 2022). In return, Singapore must provide at least 2% of this imported water for Johor. Due to Singapore's large reliance on imported water, any breach of the agreement would 'Undermine Singapore's very existence' (PUB 2022). This example highlights the political significance of national water scarcity, as international power geometries are often shaped by factors involving resource availability, which can cause further political vulnerability of a nation by relying on international imports and temporary agreements.

Since 2005, when it opened its first desalination plant in Tuas, Singapore has been gradually expanding its use of the process to meet national water demand. Singapore currently has four desalination plants, with a fifth (Jurong Island Desalination Plant) in development. This relatively new practice has a variety of pros and cons- not the least of which is the fact that it is energy- intensive, with 3.5kWh/m3 of energy currently needed to convert the saline water surrounding the island into potable water (PUB 2022). Furthermore, desalination only currently provides around 30% of the nation's water supply (Tang 2018) as the construction, maintenance, energy and research costs are still high (not to mention that the necessary technology still requires development. On the other hand, desalination technology reduces Singapore's dependency on imported water (and therefore political vulnerability), and is especially suited to Singapore, an island surrounded by saline water. In fact, desalinated water (combined with NEWater) is estimated to meet up to 80% of the nation's water demand by 2060 (Development Asia 2018).

NEWater is the brand name of a professional water treatment system manufacturer in China, which began in 2004 as a reverse osmosis company (NEWater, 2021). They provide a method of water supply where used water is treated through ultraviolet disinfection and purification so that it can be re- used. Singapore currently has 5 NEWater plants operating as well as a used water 'Superhighway' made of a 48 km long underground sewage tunnel to transport used water for treatment. Due to strong political and public support, this technology has become highly significant and successful across the country and now supplies water to 40% of the population (PUB 2022). NEWater is a cheaper and more energy-efficient method than desalination, however, construction of the plants is still expensive (for example the most recent BEWG-UESH NEWater Plant cost $170 million to build) (The Straits Times 2017). Overall, it appears to be one of the most favourable methods of meeting the increasing demand in the long term.

In conclusion, Singapore is widely regarded as an example of a successful and resilient nation in the face of water scarcity- both from a political perspective, through its effective government management schemes, and a scientific one through its use of emerging technologies (such as water recycling or desalination). It is also worth considering the significant positive impact of public support and cooperation on the government's strategies. For example,

the annual Water Conservation Awareness programme in 2016 by the PUB to 'Save Water' by encouraging the public to cut back on their domestic use relied on the cooperation of the community. This campaign was so successful that Singapore's daily water consumption per person was reduced from 154 litres in 2010, to 143 litres in 2017 (see figure 2).

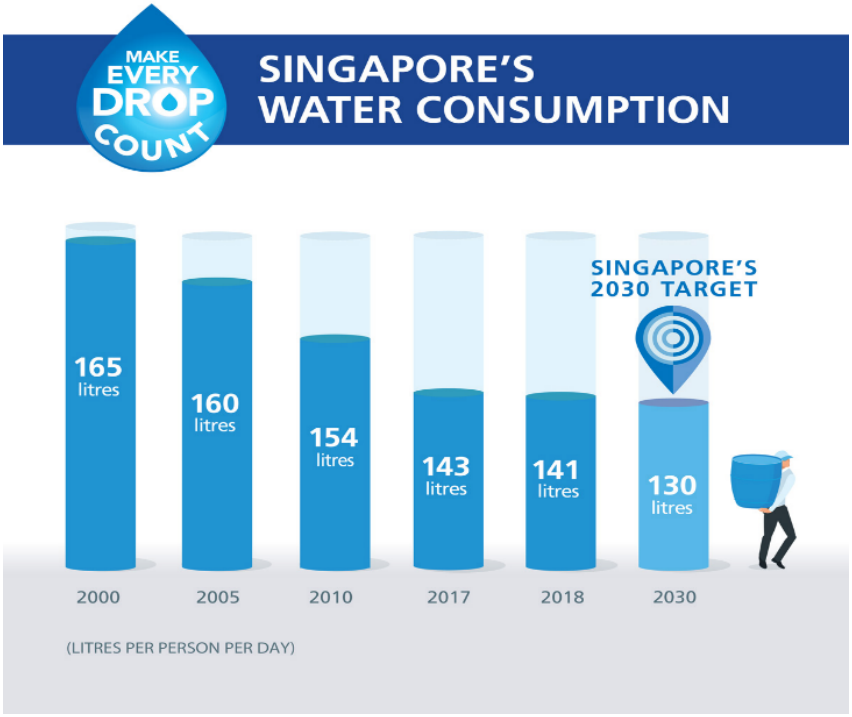

Figure 2. A PUB graph showing Singapore's water consumption. Source: PUB (2022)

3.2 Mexico's water scarcity

Mexico is a lower-income country than Singapore, with a GNI (Gross National Income) per capita of USD$8033 in 2020 (Knoema 2022). As a result, Mexico experiences great economic disadvantages and scarcity surrounding its water supply. For example, 20% of the inhabitants of Mexico City get only a few hours of water from their taps each week (BBC 2018). Unlike Singapore, however, this issue is not mostly due to physical factors. Mexico's infrastructure is prone to contamination and leaks, and the challenge of providing water is exacerbated by a political divide on how to solve the problem; as well as an inability to invest in infrastructure at an adequate rate for keeping up with rapid population growth. Mexico City has long struggled to accommodate all its citizens, with a population of 27 million in 2018 (BBC Future 2018).

Infrastructure failure routinely causes systems overflow, substantial volumes of water loss and contamination. As a result of this incapability to supply much of the population with consistent and clean water, Mexico's policies regarding control of and access to international water sources- for example, the Colorado river- are vital to the country's industrial and agricultural stability. The Colorado river supplies water to approximately 30 million people between Mexico and the United States (BBC 2012) and is therefore of political significance to both countries. It has also been under increasing pressure in recent years due to an increase in droughts in the Southeast of the US and Northern Mexico. This rising tension appeared to peak in September of 2020 when violent protests developed in Mexico, with farmers opposing the National Guard after attempting to divert

water from the US at La Boquilla dam in Chihuahua. Even though Mexican farmers were demonstrating for access to more water, Mexico had previously taken 9% more water than the previous treaty allowed (BBC 2020). This example demonstrates both the extent of the current water scarcity crisis in Mexico; as well as the inefficiency of Mexico's infrastructure to adequately supply water to all groups that require it.

Mexico and the US have also collaborated to improve their shared insecurity, including via the construction and management of the International Wastewater Treatment Plant in the Tijuana River Valley on the American side of the border (Water Technologies n.d). This was built in 1994 in response to the contamination of the Tijuana River, which was polluting beaches in San Diego County and Tijuana, where raw wastewater was being discharged into the river instead of being treated and recycled for further use. The project was successful in preventing pollution through the discharge of wastewater, as 95,000m3 of effluent is discharged from it each day (Water Technologies n.d) and further upgrades were completed on Tijuana's sewage system in 2000 as part of it. These included constructing a new pump station, which would have been highly beneficial to the local area as the treatment process would not only have become more efficient but reduced its reliance on other treatment plants such as the South Bay Water Reclamation Plant (which belongs to San Diego). The project also resulted in 85% of houses on and around the Mexican border receiving sewer connections six years later (Water Technologies n.d). On the other hand, the plant's construction cost the US government $239.4 million, as well as $16.8 million initially and $2 million a year for running costs provided by the Mexican government (IBWC n.d). 1200 litres of wastewater per second were also discharged into the ocean over a period when the treatment plant was non-operational. These dangerous levels of contamination continued, as, in 2021, 78% of samples tested in the region failed Mexican safety standards (Waterkeeper Alliance 2022).

In conclusion, the project is no longer considered to be successful, with the main disadvantage being the fact that the plant was not correctly utilised or maintained, resulting in it no longer functioning, and grave levels of pollution ensuing. On the other hand, the financial contribution was small in comparison to that of the US, and therefore advantageous to Mexico. Moreover, the wider prospects enabled by this project include the fact that cleaner water was now available for a higher proportion of residents of the area. This can often have a 'butterfly effect'- involving more residents able to pursue work and/or education due to fewer illnesses and less time taken sourcing water.

Therefore, the International Wastewater Treatment Plant in Tijuana had multiple immediate and wider advantages for the region and its economy during the first 18 years of its operation. It is a lesson for the future of Mexico's water pollution and contamination management.

4. Comparison of local examples

4.1 Causes and inciting factors

Regarding Singapore, the reasons for water scarcity and insecurity are almost solely physical and relate to the uneven distribution of natural saline water sources to freshwater sources due to the nation being located on an island.This contrasts with Mexico which, despite being flanked by the North Pacific Ocean and the Gulf of Mexico, has historically been covered (especially during the time of the Aztecs) in abundant freshwater sources, which were utilised as 'Chinampas' or 'floating gardens' around the 14th to 16th centuries in areas such as the Valley of Mexico. However, the increase of settlers to the land (which included most notably the Spanish Conquistadores) during the 16th century and onwards, caused rapid draining of the lakes. More recently, in the 20th and 21st centuries, the lakes in rapidly urbanising areas such as Mexico City have been built over and drained completely in favour of infrastructure and housing; in a struggle to accommodate growing urban populations. Therefore, it is safe to summarise the major cause of Mexico's water scarcity crisis as human- a mixture of past colonial intervention and the modern struggles associated with uncontrolled, rapid urbanisation.

4.2 Efficacy of respective management strategies

Resulting from the physical nature of its water insecurity, the strategies employed by Singapore have relied more heavily on accessing water from foreign nations through bilateral agreements than other means. This being said, Singapore's PUB is adamant that it is moving towards a more independent future through new technologies such as desalination. Moreover, although it is the larger supplier of water to the island nation, bilateral agreements are only one of the four 'taps' that it utilizes. Other methods (such as Catchment water and NEWater) reinforce the independence of Singapore's water supply.

Similarly, although Mexico's water crisis is mostly influenced by human factors, Mexico's government has also relied heavily on foreign water sources, and its relationship with the United States. In contrast to Singapore, however, this method (combined with the fact that Mexico is a lower income country and much more rapidly urbanising than Singapore) has proven less effective, as 20% of the inhabitants of Mexico City in 2018 got around a few hours of water from their taps each week (BBC 2018).

To conclude, Singapore's version of a semi-independent strategy has and continues to appear much more sustainable long term; and effective in alleviating the impacts of its physical disadvantages. Conversely, Mexico's strategy, whilst similar in parts to Singapore's, has been much more unsustainable, despite some projects (for example the International Wastewater Treatment Plant in Tijuana) yielding short-term improvement for local areas.

5. Concluding thoughts: Strategy for mitigation

Firstly, as demonstrated by Singapore's experience with water scarcity, a public information campaign can be a cost-effective method of reducing the impacts of water scarcity, whilst simultaneously informing the public and building trust between them and the government (represented here by the PUB). In 2016 their 'Save Water' campaign was so successful that Singapore's daily water consumption per person was reduced from 154 litres in 2010, to 143 litres in 2017 (see fig. 2). This method was both successful and required fewer funds than the continued research or implementation of technologies like desalination. However, as populations grow there is a limit to the level of water consumption that can be reduced without negative consequences.

Secondly, Mexico exemplifies the validity of international agreements as a response to mitigate water scarcity in a country. However, it also shows how they can be unreliable and unsustainable, as they are difficult to maintain indefinitely and rely on stable relationships between (usually neighbouring) nations. They are also shaped, perhaps unfairly, by international power geometries.

In conclusion, both case studies demonstrate that both the causes and mitigation strategies for water scarcity are variable and locally specific, despite underlying global systems which are causing water availability to be increasingly threatened across the globe. Therefore, a consideration of local needs and processes is essential to an effective water scarcity mitigation strategy, as well as a knowledge of global factors.

6. Summary

Goodhart (2017) does acknowledge that some anywheres 'retain some connection with their roots' and that somewheres' local place attachment might be diluted by going 'on holiday with EasyJet or talk[ing] on Skype to a relative in Australia' (Goodhart, 2017, p. 4). However, he concludes that anywheres are 'less connected to particular places' (Goodhart 2017, p. 36) and implies that it is only somewheres, rooted in the places where they grew up, who feel intense place attachment (Goodhart, 2017). This premise has been questioned by Chan and Kawalerowicz (2022) whose analysis of different survey data shows anywheres are more likely to demonstrate place attachment to their locality by participating in local civic organisations and engaging in social activities in their adopted local communities than somewheres who have lived there all their lives (Chan and Kawalerowicz, 2022). My experience confirms Goodhart's thesis as my parents' education has been powerful in creating my anywhere sense of place attachment. Nevertheless, my experience demonstrates, just as children's literature often creates narratives with a strong sense of the materiality of a place, my family

folklore and personal memories are often connected to the material landscape. This has created a personal world of stories that root me intensely in multiple and diverse places. This suggests that the stories we tell ourselves about who we are and where we belong could have the potential to disrupt the divisive 'politics of culture and identity' which characterises anywheres as unrooted and lacking in place attachment (Goodhart, 2017 p.1).

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References

Baraniuk, C. (2020). Tracking down three billion litres of lost water. *BBC News*. [online] 17 Aug. Available at: https://www.bbc.co.uk/news/business-53274914#:~:text=Across%20England%20and%20Wales%2C%20just [Accessed 20 Jan. 2022].

BBC (2012). Colorado River: Mexico and US sign water-sharing deal. *BBC News*. [online] 21 Nov. Available at: https://www.bbc.co.uk/news/world- latin-america-20422899 [Accessed 1 Mar. 2022].

BBC (2018). The 11 cities most likely to run out of drinking water – like Cape Town. *BBC News*. [online] 11 Feb. Available at: https://www.bbc.co.uk/news/world-42982959.

BBC (2020). Mexico reaches water deal with US despite violent protests. *BBC News*. [online] 22 Oct. Available at: https://www.bbc.co.uk/news/world-latin-america-54652706.

Development Asia (2018). *Strengthening Water Resilience through Diversified Sources and Conservation*. [online] Development Asia. Available at: https://development.asia/case-study/strengthening-water-resilience- through-diversified-sources-and-conservation [Accessed 28 Feb. 2022].

Follows-Smith, Y. (2018). Achieving water security, a case study in Singapore. *Geography Review*, pp.12–16.

Hogenboom, M. (2018). *How a city that floods is running out of water*. [online] http://www.bbc.com. Available at: https://www.bbc.com/future/article/20180510-how-a-city-that-floods-is-running-out-of-water.

International Boundary & Water Commission (n.d.). *South Bay IWTP*. [online] http://www.ibwc.gov. Available at: https://www.ibwc.gov/Mission_Operations/sbiwtp.html [Accessed 21 Mar. 2022].

Iturralde, R. (2022). *Tijuana Waterkeeper Works to Improve Some of the Most Contaminated Beaches in the World But They Need Your Help*. [online] Waterkeeper. Available at: https://waterkeeper.org/news/tijuana- waterkeeper-works-to-improve-some-of-the-most-contaminated-beaches-in- the-world-but-they-need-your-help/ [Accessed 23 Mar. 2022].

Knoema (n.d.). *Mexico GNI per capita, 1970-2021 – knoema.com*. [online] Knoema. Available at: https://knoema.com/atlas/Mexico/topics/Economy/National-Accounts- Gross-National-Income/GNI-per-capita [Accessed 1 Mar. 2022].

Lindsey, R. and Dahlman, L. (2022). *Climate Change: Global Temperature*. [online] Climate.gov. Available at: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature [Accessed 14 Jan. 2022].

Mekonnen, M.M. and Hoekstra, A.Y. (2016). Four billion people facing severe water scarcity. *Science Advances*, [online] 2(2), p.e1500323. doi:10.1126/sciadv.1500323.

NEWater (2021). *About NEWater*. [online] Newater. Available at: https://www.newater.com/about-us/ [Accessed 1 Jan. 2023].

PUB (2022). *PUB, Singapore's National Water Agency*. [online] PUB, Singapore's National Water Agency. Available at: https://www.pub.gov.sg/watersupply/singaporewaterstory/ [Accessed 16th January-28th February 2022].

Schleifer, L. (2017). 7 Reasons We're Facing a Global Water Crisis. *http://www.wri.org*. [online] Available at: https://www.wri.org/insights/7-reasons-were-facing-global-water- crisis [Accessed 17 Jan. 2022].

Seymour, F. (2021). 2021 Must Be a Turning Point for Forests. 2020 Data Shows Us Why. *http://www.wri.org*. [online] Available at: https://www.wri.org/insights/2021-must-be-turning-point-forests-2020- data-shows-us-why [Accessed 20 Jan. 2022].

Sidhu, B.S. (2022). *IPCC report: Half the world is facing water scarcity, floods and dirty water — large investments are needed for effective solutions*. [online] The Conversation. Available at: https://theconversation.com/ipcc-report-half- the-

world-is-facing-water-scarcity-floods-and-dirty-water-large-investments- are-needed-for-effective-solutions-175578 [Accessed 28 Mar. 2022].

Tang, L. (2018). *PUB aims to double water supply by 2060 without using more energy or producing more waste*. [online] TODAYonline. Available at: https://www.todayonline.com/singapore/pub-aims-double-water-supply-2060-without-using-more-energy-producing-more-waste [Accessed 28 Feb. 2022].

The Global Water Scarcity Atlas (n.d.). *Home*. [online] Water Scarcity Atlas. Available at: https://waterscarcityatlas.org/ [Accessed 1 Jan. 2023].

The Royal Society (2020). *1. Is the climate warming? | Royal Society*. [online] royalsociety.org. Available at: https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/question-1/ [Accessed 20 Sep. 2022].

The Straits Times (2017). *$170m fifth Newater plant launched*. [online] The Straits Times. Available at: https://www.straitstimes.com/singapore/environment/170m-fifth- newater-plant-launched [Accessed 28 Feb. 2022].

The World Bank (2019). *The World Bank in Singapore*. [online] World Bank. Available at: https://www.worldbank.org/en/country/singapore/overview#1[Accesse d 28 Mar. 2022].

The World Bank (2021). *Population density (people per sq. km of land area) – Singapore | Data*. [online] data.worldbank.org. Available at: https://data.worldbank.org/indicator/EN.POP.DNST?end=2020&locations=SG&start=1961&view=chart [Accessed 1 Jan. 2023].

Torrent Tucker, D. (2020). *A better way to detect underground water leaks*. [online] Stanford News. Available at: https://news.stanford.edu/2020/02/27/better-way-detect-underground-water-leaks/ [Accessed 17 Jan. 2022].

United Nations (2011). *Scarcity | UN-Water*. [online] UN-Water. Available at: https://www.unwater.org/water-facts/scarcity/ [Accessed 3 Jan. 2022].

Water Technology (n.d.). *International Wastewater Treatment Plant, Tijuana, Mexico*. [online] Water Technology. Available at: https://www.water-technology.net/projects/tijuana/ [Accessed 14 Mar. 2022].

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