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Tasting Numbers: The Numerical Politics of Total Dissolved Solids and the Privatisation of Drinking Water Quality in Bhuj City, India

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ABSTRACT: Critical water scholarship has acquired a sustained interest in the quantification of water flows to further agendas of control and commodification. However, these numerical politics receive greater attention in the areas of agricultural water and wastewater than that of drinking water quality. This paper explores the numerical politics of the water quality parameter of Total Dissolved Solids (TDS) and how it shapes the privatisation of drinking water quality in the small town of Bhuj in the western Indian state of Gujarat. TDS, which measures the total organic and inorganic substances dissolved in a specific volume of water, produces a numerically simplified engagement with the complex materiality of drinking water quality in Bhuj, supplanting a more embodied, experiential, and gustatory understanding of the same expressed through a rich lexicon of local terms. As TDS emerges as the sole legitimised indicator of water quality, the TDS meter functions like a clinical thermometer, digitally displaying the health of the drinking water in numbers. This numerical homogenisation of a diverse sensorial understanding of taste and quality serves to stabilise market demand for membrane-based reverse osmosis (RO) water purifiers – the only technology that promises to address the 'problem' of 'excess' TDS in drinking water. As TDS numbers become an indicator of contamination, it nudges the middle classes of Bhuj to seek mediation of public water supply through RO water purifiers, which are exclusively provided through private markets. As I go on to show, interrogating the numerical politics of drinking water quality is critical to understanding the diffused commodification of water in the majority world.

KEYWORDS: Water quality, materiality, total dissolved solids, membranes, reverse osmosis, purifiers, privatisation, India

INTRODUCTION

Scholarship in the subfield of political ecology of water (and critical water scholarship in general) has displayed a noticeably uneven engagement with water quality concerns. The sustained focus on power choreographies that unevenly direct and distribute the flow of water has led to a heightened engagement with the quantitative (i.e. volumetric) aspects of water, where questions related to commodification have been interrogated in the context of normative concerns of justice, equity, and access (Bakker, 2000, 2005, 2014; Loftus and McDonald, 2001; Swyngedouw, 2003, 2005, 2013; Bond, 2004; Budds, 2004; Loftus and Lumsden, 2008; Birkenholtz, 2009, 2016; Loftus, 2009; Ranganathan et al., 2009; Loftus et al., 2016; Williams, 2018; Lankford, 2022).

In recent years, however, the material properties of water have drawn scrutiny, critique, and contribution, and scholars have explored questions of water quality through the lens of safe water, environmental conflicts, and racial and multispecies justice (Sultana, 2013; Acharya, 2015; Ranganathan, 2016; Rusca et al., 2017; Arce-Nazario 2018; Hurst et al., 2022; MacAfee, 2022, 2023). Acharya (2015), for example, has shown how conflict around the conservation of Chilika Lake in eastern India coalesces around differing interpretations of salinity between state agencies and fishing communities. While bureaucrats and scientists desire increased salinity to restore ecosystem functions, fisherfolk argue that increasing salinisation reduced fish diversity (Acharya, 2015). Similarly, Menon et al. (2023) have problematised the discourse of salinity and how it is used to normalise the promotion of brackish water aquaculture in coastal South India, which in turn contributes to increasing salinisation of local environments (Menon et al., 2023). Sultana (2013) has drawn attention to the arsenic contamination of groundwater in Bangladesh, illustrating how the urge to produce potable water through a technonatural assemblage of handpumps and aquifers encounters the "agency and materialities of arsenic and tubewell technologies", which not only upend such agendas but also highlight the "contested and contradictory processes of development itself" (Sultana, 2013: 349).

Critical water scholarship recognises that numerical politics, in various forms, animates the flow, fluxes, and materiality of water. I broadly categorise this literature on the numerical politics of volumetric flow as 'accounting', i.e. the measurement of flow related to concerns of productivity and efficiency. Such calculations are aimed at answering the question of 'how much?' and apply to all major sectors, such as agriculture, industry, drinking water supply, and wastewater. In agriculture, such quantification is deemed necessary to 'improve' crop water efficiency, which involves reducing 'wastage' and improving 'productivity' in irrigation through approaches such as water accounting. These are guided by the utilitarian desire to produce 'more crop per drop' (Luquet et al., 2005; Ali and Talukder, 2008; Thenkabail, 2009; Molden et al., 2010; Cai et al., 2011; Giordano et al., 2021). Such quantification involves significant levels of sensor-based measurements to calibrate the supply of water to the specific needs of a particular crop and to assess plant health. In industry, the application of virtual water, or a water footprint, involves measuring the quantity of water embedded in the production of goods and services and is expressed in volumetric terms, such as cubic metres (m^3) or acre-feet (A-F) (Allan, 2011; Hoekstra, 2020).

The study of water quality, on the contrary, tends to converge around 'counting', where the operating question is 'how many?' The focus shifts to the presence and absence of specific substances in water. In discussions on biological contamination, two specific strains of bacteria are frequently mentioned – *Escherichia coli* (i.e. *E. coli*) and *Vibrio cholerae* – as they cause gastrointestinal diseases and their presence in water is deemed undesirable (Rusca et al., 2017; Arce-Nazario, 2018; Hurst et al., 2022).

The allowable presence of chemicals and metals in drinking water is mediated through 'water quality indices' (WQIs) that elaborate to what extent the presence of certain 'chemicals' and 'metals' is allowable (Whelton et al., 2007; Spackman and Burlingame, 2018; Spackman, 2020; MacAfee, 2022; MacAfee, 2023). While the presence of pathogens is measured through units like 'colony-forming units' (CFUs) and 'most probable number' (MPN), chemicals, metals, and 'volatile organic compounds' (VOCs) are counted through colourimetry, potentiometry, and mass spectrometry, to name the most widely used techniques. Here, a diverse range of units are mobilised to 'explain' the health of water and its potability based on its colour, the quantity and type of suspended and dissolved solids, and permissible contents of metals and chemicals. A few such units, for reference, include nephelometric turbidity units (NTUs; to measure turbidity), parts per million (ppm; to measure TDS), and pH (to measure if the water is acidic or alkaline).

Both 'accounting' and 'counting' are entangled with the political desire to know and discipline water and, with that, the lives of people who consume and use it. This desire manifests in production of scientific knowledge systems dedicated to establishing what I call a 'numerical reality', in which abstracted numbers communicate the nature of the problem and shapes the trajectory of the solution. Concerns around such abstractions, disconnected from the social relations and knowledge practices of farmers, have already been expressed and explained by Lankford (2022) in his critique of water accounting in irrigation as 'accounting – abstraction – absolutism (AAA)', a form of disembodied and abstracted assessment that produces knowledge and expertise at a distance, based purely on a volumetric understanding of irrigation water (Lankford, 2022: 1155).

Similarly, Arce-Nazario's (2018) research on drinking water supply systems in Puerto Rico illustrates that, since federal guidelines state that the presence of *E. coli* in water makes it unsafe for drinking, it leads to the perception of community-managed water supplies as unreliable compared to those of central authorities. However, "since non-pathogenic *E. coli* is not itself a risk, but rather an indicator of risk" (Arce-Nazario, 2018: 473), such generalised standards do not account for Puerto Rico's ecological realities. Not only do such indicators simplify the nonhuman world, but Arce-Nazario's (2018) work substantiates the statement that "problems may also arise when those committed to the standards for one world attempt to argue that their standards should be applied to *all* worlds" (Busch, 2011: 261; emphasis original). I add to this Lave's (2012) argument that neoliberal science translates complex ecosystems into easily measurable and comparable units to produce "market-enabling metrics" (Lave, 2012: 30).

I must add that 'accounting' and 'counting' are not discrete determinations but are often entangled. A water accounting exercise involves the collection of water quality data along with that of other qualitative parameters like soil health. Reduction in water quantity can cause water quality concerns; for example, the over-extraction of groundwater can lead to increasing concentrations of metals and minerals in an aquifer, as is the case with salinity in many parts of India (Lorenzen et al., 2012; Saha et al., 2018). Therefore, I view 'accounting' and 'counting' as dominant processes used for determination and assessment.

Research shows that concepts and practices related to 'accounting' and 'counting' gravitate towards the calculus of commodification. The most notable example is how numbers showing the presence of 'necessary' minerals and the absence of unwanted pathogens have crafted a desire for bottled water (Jaffee and Newman, 2013; Bhaduri and Sharma, 2014; Sharma and Bhaduri, 2014; Sharma, 2018; Spackman and Burlingame, 2018; Jaffee, 2023). Furthermore, Espeland and Stevens, in their discussion on how water quality is considered during the decision-making process of dam-building, argue that the metric of water quality involves an explicit act of commensuration:

> Water quality has many dimensions (e.g. temperature, the amount and nature of dissolved solids, turbidity, pH), and even though these dimensions are already quantified, they are measured with different scales. Aggregating these attributes according to some broader metric creates "water quality" (1998: 317)

Commensuration, according to Espeland, is a quantified mediation between different entities and their properties through a homogenised metric which "reduces large amounts of information into a single number" (1998: 25). The production of such homogeneity emerges from the desire to not only discipline the entity being studied but also to produce new markets (Espeland, 1998; Espeland and Stevens, 1998).

While Espeland and Stevens (1998) consider water quality itself as a commensurate category, produced through the numerical politics of quantification and standards, in my research, I engage with the politics of counting in a specific water quality parameter: Total Dissolved Solids, popularly referred to as TDS, a hydrochemical term that collectively accounts for all inorganic and organic substances present in water. I first discuss how TDS became a shorthand for understanding poor water quality in India and through that emerged as a "market-enabling metric" (Lave, 2012: 30) for reverse osmosis (RO) membrane-based water purifiers. I proceed to empirically illustrate how the rising demand for RO membrane-based water purifiers in the small town of Bhuj is linked to the numerical rendering of TDS as a contaminant. As I will demonstrate, such numerical politics works towards flattening Bhuj's diverse water lexicon, produced out of an intimate understanding of the city's groundwater, into a singular numerical expression – TDS. By doing so, it establishes TDS as an exclusive standard for water quality. This commensurated water quality parameter proceeds to supplant the intimate and place-based understanding of water quality in Bhuj. I probe the reciprocal relationship between the RO membrane-based purifiers and TDS to argue that the latter being defined as a 'problem' in water quality allows for the shaping of a market for the former, as RO membranes are seemingly the only technology capable of dealing with the removal of TDS. To establish the superiority of and market demand for a specific drinking water technology, a numerical politics of water quality is mobilised. This allows for a discursive control of the sensorial script of water.

COUNTING MATTER IN WATER

The genealogy of the discourse of TDS in water quality in India can be traced back to the Green Revolution, a statist programme introduced in 1967 aimed at improving agricultural productivity for national food security. It introduced a range of agricultural technologies, of which the most critical component was tubewells (Shankar et al., 2011). The use of groundwater using tubewells generated an agricultural productivity boom in India, but it also led to the depletion of aquifers (Shah, 2008). Concerns about groundwater salinity began to emerge from rainfed regions of India, where mineral and salt concentrations increased in aquifers as the quantity of water started to decrease (Lorenzen et al., 2012; Saha et al., 2018). Since 85% of India's rural water supply comes from groundwater, increasing groundwater salinity was viewed as a public health risk (Kulkarni and Shankar, 2014).

Salinity is defined as specific concentrations of salt in a given sample of water, while Total Dissolved Solids (TDS) is defined as a parameter that comprises "inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water" (WHO, 2003). As the problem of groundwater over-extraction spread across India, the metric of salinity, suited to describe the condition of groundwater in coastal districts and excessively irrigated areas involving increased concentration of salts in aquifers, was replaced with TDS, which gradually became a substitute indicator for salinity (Mehta et al., 2014; Wright and Winter, 2014; Subramani and Jacangelo, 2015; Li et al., 2018; Singh et al., 2019). The Bureau of Indian Standards specifies that TDS in drinking water is acceptable up to 500 parts per million (ppm) and permissible up to 2000 parts per million (BIS, 2012). Similarly, WHO guidelines specify a range of 600-1000 ppm (WHO, 2003). These desired ranges imply that TDS and salinity are not interchangeable parameters, and that high TDS, based on what kind of minerals are present in the water, alters its palatability and potability but doesn't make it necessarily saline (and hence undrinkable) (McCleskey et al., 2023). Just to put things in perspective, a bottle of San Pellegrino mineral water has a TDS of 850 ppm. The TDS map shared below (Figure 1) is derived by researchers from data provided by the Central Groundwater Board (CGWB) in India, but is defined as a "map of salinity levels in Indian groundwater" (Wright and Winter, 2014: 85), though the two parameters measure quite different things (Wright and Winter, 2014; Li et al., 2018).

From a hydrochemical perspective, it is not the quantity of dissolved solids in water that is harmful to human health; it's the type that matters. However, the interchangeable use of salinity and TDS in India implies that the latter is an indicator of poor water quality, and the ability to remove TDS has emerged as a benchmark for water purification (Aumeier et al., 2017; Saha et al., 2018; Karunanidhi et al., 2021; Singh et al., 2022; Saqib et al., 2023; Singh et al., 2023).

The discursive transformation of TDS into an impurity was used to generate concern around tap water in the 1990s in India when water purifier sellers arrived at the doorsteps of unsuspecting customers with an electrolyser. The device would pass an electric charge through the water in a glass tumbler, precipitating the salts into a brownish sludge. The other practice involved pouring a few drops of a flocculating agent into a glass of water and waiting for the sediments to form a clump and settle at the bottom. These forms of door-to-door marketing of water purifiers have almost disappeared from urban India today, though they still exist in other parts of the majority world.[1] However, the arrival of the TDS meter – a small pocket-sized device with a digital display – changed the way dissolved solids in water were visualised. Now the dissolved solids are made visible through numbers displayed on the screen (See Figure 2).

[1] https://www.kimberley.org.za/the-water-test-scam/

Figure 1. TDS Map of India developed from Central Groundwater Board Data (Wright and Winter 2014).

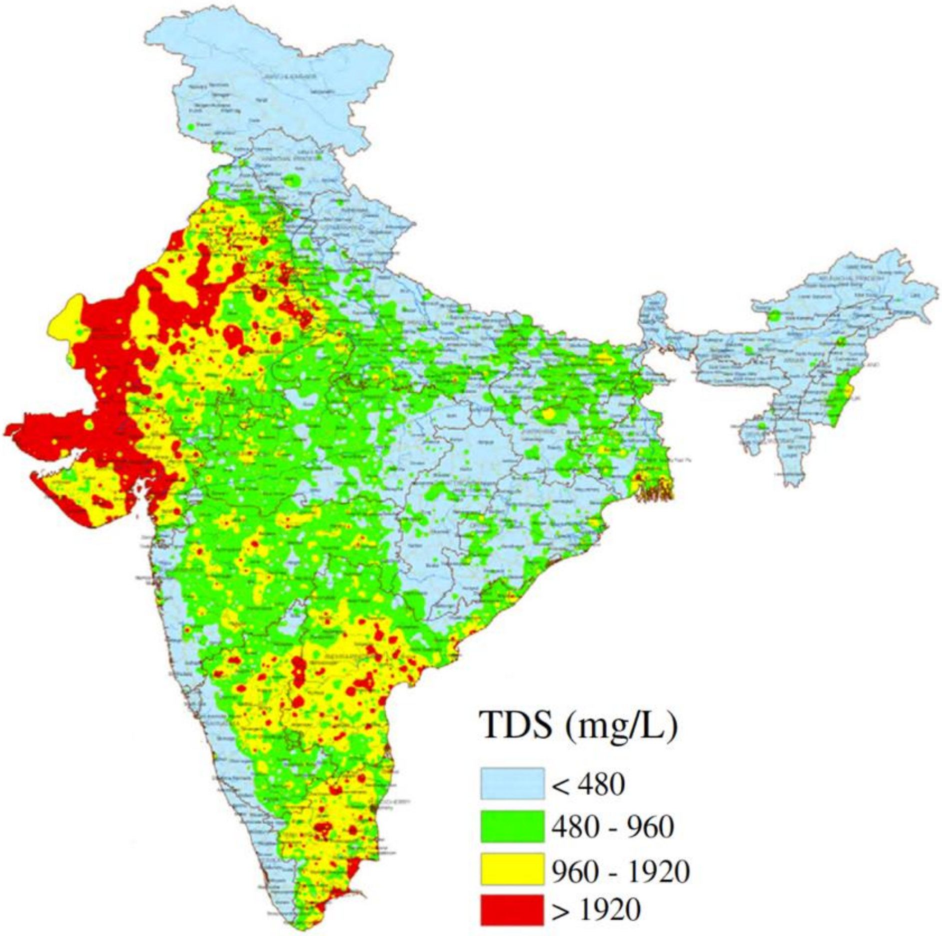


Figure 2. A TDS meter is used to show the quality of output from an RO water purifier.

Photo Credit: Karmveer Jadeja

As Espeland and Stevens argue, "Commensuration can be understood as a system for discarding information and organizing what remains into new forms" (1998: 317). The TDS meter emerges as the end product of such a process; it allows for the conversion of quality into quantity by counting and displaying the total number of salts present in a given volume of water. However, it discards the information on what kind of salts and substances are present in water. Neither does it show if the water is hard or saline. The TDS values are interpreted simplistically: Higher values are communicated as contamination. Just like a thermometer, which generates concern when the digital display shows body temperature to be higher than 98.6 degrees Fahrenheit, the number on the screen of the TDS meter in ppm generates a similar reaction. This clinical and reductive engagement with the materiality of water follows in the wake of previous commensurations, in which TDS was discursively transformed into an 'impurity'.

As research on water purification technologies in Ahmedabad, Gujarat, shows, though municipalities monitor a range of water quality parameters in water treatment plants, TDS becomes the easiest and "the one and only measurable parameter" for citizens to monitor the quality of their supplied water (Annala et al., 2018: 5). As I argue, the numerical visualisation and interpretation of the materiality of water works towards producing an enabling condition for water 'purification' technologies that promise to reduce TDS. This brings me to reverse osmosis membrane-based water purifiers, considered to be the only technology available which promises to eliminate TDS from drinking water.

REVERSING WATER'S NATURE

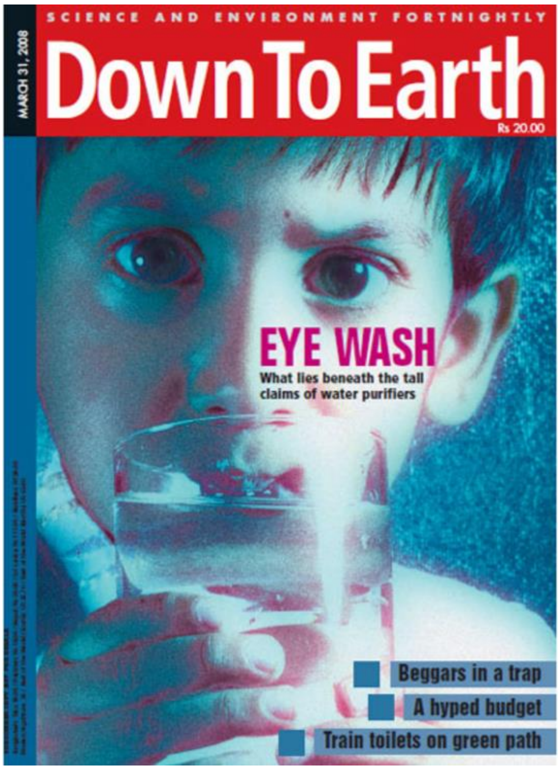
Reverse osmosis (RO) is a desalination technology in which water is subjected to high external pressure to move it through a membrane from a state of higher concentration (e.g. saline) to that of a lower concentration. In this process, water leaves behind almost all dissolved particles of size greater than 10 nanometres (nm). In other words, the water that emerges out of an RO system has been forced to relinquish its constituent solutes. But it is the very nature of water to accrete the substances it comes into contact with. Reverse osmosis, as the name suggests, reverses water's nature, making it expel the matter it carries.

Figure 3. A reverse osmosis (RO) water purifier.

Photo Credit: Amitangshu Acharya

Over the last two decades, the RO membrane-based water purifier has been gaining popularity in urban middle-class homes across India. In 2008, the noted Indian environmental magazine *Down to Earth* was the first to investigate this phenomenon with a cover story (see Figure 4 below). The Managing Director of Kent RO, one of the largest RO membrane-based water purifier manufacturers in India, was quoted to have said that his "company's profits grew 40 times [in] 2002-2003 and 2007-2008, from Rs 2.5 crore[2] to Rs 100 crore" (Babu, 2008).

Figure 4. Cover Story on Water Purifiers in *Down to Earth* magazine, March 31, 2008.



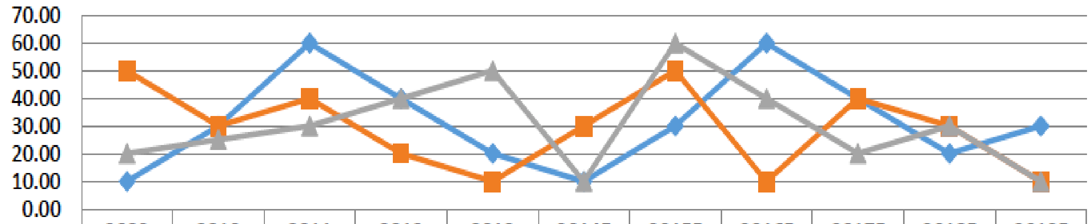
The water purifier market in India has expanded rapidly since then, witnessing sales to the tune of nearly 2.48 million units between 2016 and 2018 (*Business Standard*, 2016), and the market was pegged at US$1.1 billion in 2015, projected to grow to US$4.1 billion in 2024 (*Business Standard*, 2017). Kent RO would go on to increase its profit margin from INR 100 crore in 2008 to INR 1000 crore in 2016, a stunning jump of 90%. It is estimated that in 2020, RO membrane-based water purifiers occupied almost 30% of the total sales of water purifiers in India. Between 2009 and 2019, on average, US$30 million worth of RO membrane-based water purifiers were sold every year in India (*TechSci Research*, 2019).

One key actor to whom the popularity of domestic RO water purifiers in post-liberalisation India is often accredited is Mahesh Gupta, the founder of Kent RO Systems. Currently, the company commands the second-highest market share in the RO water purifier business in India.[3] Gupta was an engineering graduate from the Indian Institute of Technology, Kanpur – an educational institution set up in post-independent India by the central government to further the pursuit of science and technology. Gupta started Kent RO based on personal experience. To quote from a *Forbes India* story about him:

[2] The term 'crore' refers to 10 million in the Indian numbering system.

[3] https://timesofindia.indiatimes.com/business/india-business/Kent-RO-aims-to-be-a-Rs-1000-crore-firm-by-2016-17/articleshow/45326623.cms

Figure 5. India's water purifier market size (by technology and volume), FY 2009-2019.



	2009	2010	2011	2012	2013	2014E	2015F	2016F	2017F	2018F	2019F
RO	10.00	30.00	60.00	40.00	20.00	10.00	30.00	60.00	40.00	20.00	30.00
UV	50.00	30.00	40.00	20.00	10.00	30.00	50.00	10.00	40.00	30.00	10.00
Offline	20.00	25.00	30.00	40.00	50.00	10.00	60.00	40.00	20.00	30.00	10.00

Source*: TechSci Research* (2019).

> …in 1998, his children Surbhi and Varun contracted jaundice, a water-borne disease that claims many lives even today. "It forced me to think of installing a water purifier at my south Delhi home", he says. But Gupta couldn't find a good purifier in the market. "The only purifiers back then were the UV ones, which didn't remove dissolved impurities. I had heard about the reverse osmosis technology, which removed soluble matter, so I imported parts from Taiwan and made a purifier for my home". The home-made purifier worked well. "It struck me that there must be a market for it", says Gupta, who started manufacturing purifiers at his oil meter factory, with a seed capital of Rs 5 lakh[4] (Hussain, 2014).

This personal story, narrated by Gupta, attempts to showcase the critical need for water purifiers for health reasons, but what remains unexplained is that dissolved impurities in drinking water do not cause jaundice. It can be caused by strains of the Hepatitis A or E viruses, and though outbreaks of jaundice from public water supply contaminated with these viruses through the influx of sewage is not uncommon in India (Tandon et al., 1985; Mohanty et al., 2017; Tripathy et al., 2019)[5], it is believed that the affected water can be treated through boiling, UV radiation, and chlorination (Battigelli et al., 1993; Raj Subba, 2015). Thus, it becomes obvious that Gupta was not exclusively looking for a filter that removes disease-causing viruses, because those processes and technologies already existed. What he had identified was a market for a purifier that removed soluble matter from water.

That the increasing TDS in India's drinking water supplies was a market opportunity was made more explicit in a report published by a European research institute in 2015, which states:

> In India's membrane market, RO membranes are one of the key growth drivers. The demand in various Indian regions for RO membranes is increasing due to the high total dissolved solids (TDS) level. Consequently, in the upcoming years, the domination of the RO membranes segment will likely continue to grow in India's membranes market (Hamingerova et al., 2015: 18).

The purifier – a technoscience shaped into a consumer product – was sold to the middle classes as a form of autonomy from the public water supply. What the purifier as a technology promised was not just freedom from polluted water but, borrowing from Nandy's discussions on postcolonial technology, "an escape from the dirtiness of politics" (Nandy 1998: 8). In other words, an escape from the messy

[4] GBP 50,000 (in 1998)

[5] In 2016, a jaundice outbreak took place in Shimla, in the Indian state of Himachal Pradesh, because of sewage leaking into a water source. The outbreak left 10 people dead and at least 1600 affected, a number that was pegged at closer to 10,000 by unofficial sources. (https://www.hindustantimes.com/india/shimla-battles-worst-jaundice-outbreak-since-1947/story-l3LhFdiCO0TjuYGaYXs8sK.html)

democratic politics of public services in India. Today, the RO water purifier market has taken over a third of the overall purifier market in India and, though more expensive than other types of purifiers, it commands the higher share of the value (*TechSci*, 2019). Recent scholarship has pointed out that RO water purifiers do not seem to be superior in disease prevention capability than other water purifiers, and they require electricity to function. Despite this, they are becoming a "panacea to all water quality problems" (Talat and Bhaduri, 2017).

In my research, located away from the metropolis in the small town of Bhuj in Gujarat, I wanted to understand what reasons were prompting people to specifically choose the RO membrane-based water purifiers. This is where I encountered the entanglement of the numerical politics of TDS with the cultural politics of taste.

THE RESEARCH PROCESS

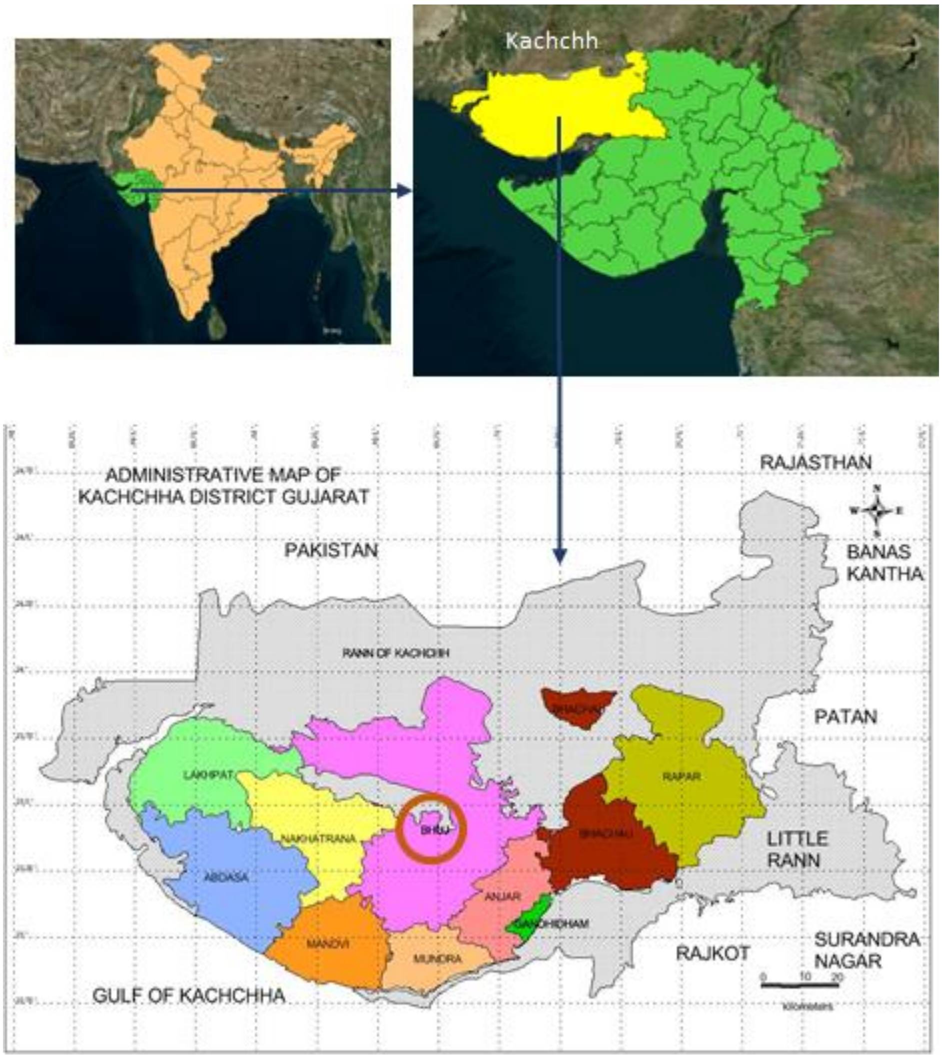
Gujarat, located in western India (see Figure 6) with a population of approximately 60 million people (MoSPI, 2011), has been a testing ground for RO membrane-based water purification since the 1970s (Prabhakar et al., 1987). This is partly driven by a need for safe water, as Gujarat's groundwater aquifers have been witnessing a steady decline for decades (Matzger and Moench, 1994). Gujarat is mostly dependent on rainfall to replenish its water supply, and 27% of its total land area is in drought-prone areas receiving low rainfall. This makes large parts of Gujarat dependent on its groundwater aquifers. In this context, the arrival of tubewell technology ushered in a paradox – it fuelled Gujarat's rapid economic growth but also exhausted its groundwater reserves (Mukherji, 2006; Shah, 2008).

The Green Revolution of the 1960s – a state-planned, sponsored, and subsidised programme aimed at increasing agricultural productivity in India – ushered in a host of policies that proved detrimental to Gujarat's groundwater reserves. Tubewell technology and the provision of subsidised fossil fuels and electricity led to a pervasive decline in the water table across the state, with an overall rate of decline of 0.11 m/year in the pre-monsoon season between 1995 and 2005 (Panda et al., 2012). In post-liberalised India, faced with dwindling groundwater reserves, the agrarian capitalists found their aspirations entwined with their support for the Narmada project – one of India's largest hydro-development projects. This project encompassed 30 large dams, including the largest, the Sardar Sarovar Dam (SSD), along with 135 medium-sized dams and 3,000 small dams. The upper-middle classes and industries also threw their weight behind this project, staking their claim to its waters in the process (Mukta, 1990; Mehta, 2010).

Gujarat has hosted several RO membrane-based water purification experiments since the 1950s (Sadhukhan et al., 1994; Indu, 2002; Rangarajan et al., 2011). Located at the intersection of groundwater depletion, rapid urbanisation, and economic growth, it was an ideal state to explore the politics of drinking water quality. The small town of Bhuj in the district of Kachchh was selected as a primary fieldwork site. A recipient of the Narmada pipeline water, Bhuj – a post-earthquake city – is located at the intersection of Gujarat's growth story, its historical trajectory of drinking water supply and technologies, and an evolving calculus of urban water politics.

By placing my research in Bhuj, I addressed the 'metrocentricity bias' in urban research (Bunnell and Maringanti, 2010) and shifted attention to a small town instead of a big city. Rapidly developing small towns in India are largely outside the ambit of urban political ecology analysis, and the majority of the research takes place in large metropolitan cities like Mumbai, Delhi, Chennai, and Bangalore. This mirrors the pattern in global urban political ecology research, which has been steadfast in its investigation of urban water politics in large cities – Accra, Buenos Aires, Dhaka, Dar es Salaam, Guayaquil, Jakarta, London, Lilongwe, Los Angeles, Mexico City, Paris, Sao Paulo, and Singapore, to name a few (Swyngedouw, 1997; Loftus and McDonald, 2001; Kaika, 2003; Gandy, 2004; Dill and Crow, 2014; Cousins and Newell, 2015; Furlong and Kooy, 2017; Morinville, 2017; Millington, 2018; Tiwale, 2019; Watson, 2019). This study thus contributes to the emerging scholarship on small towns that seeks to decentralise and decentre urban research (Bunnell and Maringanti, 2010; Bunnell et al., 2018; Mukhopadhyay et al., 2020; Zimmer et al., 2020).

Figure 6. Map showing Bhuj in India.



Data courtesy of the National Remote Sensing Centre, India, and Central Ground Water Board, India.

According to the 2011 Census, the Bhuj urban agglomeration (which includes peri-urban areas like Haripar, Madhapar, and Mirzapar) has a population of 187,279 (*Census*, 2011). The Bhuj municipality, which excludes these peri-urban areas from its administration, has a population of 143,286. The research presented in this thesis is based on 12 months of qualitative data collection, primarily in Bhuj. My research data collection was centred around key informant interviews, focus group discussions (FGDs), and descriptive field notes. I also accessed the archives of Kachchh Mitra, one of the oldest daily newspapers in Bhuj, and those of the Bhuj Municipal Corporation (BMC).

Because of the focus of my research, my fieldwork was mostly limited to middle-class housing societies. The selection of these societies was purposeful and based on the proportions of Bhuj's population that belong to different social groups. I conducted two focus groups in each society, one with men and the other with women. The discussions were recorded with prior informed consent using a digital recorder, and a set of questions and themes were prepared in advance to guide the discussion.

The main focus of the discussion was to understand why the residents were buying RO water purifiers, their experience of using them, and their perception of municipal water quality. Additionally, I conducted 15 key informant interviews, which were guided by an interview schedule.

THE WATER LEXICON OF DRINKING WATER IN BHUJ

The numerical politics of TDS and its relation to the rising popularity of RO membrane-based water purifiers in Bhuj cannot be understood without a discussion of the cultural and material perceptions of the taste of drinking water. I have previously discussed the numerical transformation of a multitude of soluble solids into a single enumerated parameter, i.e. TDS, and how it evolves in common perception into a 'contaminant' or an 'impurity'. Before I empirically establish how such quantified understanding gets enrolled into the technopolitics of purification by RO membrane-based technologies, it is important to understand that enrolment requires supplanting other place-based understandings of water quality. Espeland and Stevens have argued that "commensuration transforms qualities into quantities." (1998: 316). TDS, as I have discussed, is produced out of a process involving quantification, homogenisation, and numeration, but once stabilised in the public domain, as I will show here, it works towards discursively homogenising a place-based understanding of water. It is here where we witness its afterlife as a "market-enabling metric" (Lave, 2012: 30).

Technologies serve as the grammar that structures the language of water. The process by which each technology harvests water not only alters water’s materiality but, based on embodied and sensory experiences, it also generates its vocabulary – i.e. a sensorial script. Control of the sensorial script is essential to stabilise and legitimise TDS as a benchmark for water quality and develop a market for a technology that promises to deal with it.

This is where Bhuj, as the headquarters of a former princely state, emerges as an appropriate site to investigate the entanglement of the numerical politics of water quality with the sensorial script. The memory of water from diverse types of technologies – open wells, taps (i.e. pipelines), and RO membrane-based purifiers – is still accessible and alive in Bhuj, as, unlike the larger cities in India, a piped water supply reached Bhuj in the 1950s and was universalised only two decades later.

Until the 1960s, drinking water was mostly obtained from 30-odd community-managed drinking water wells. These community wells yielded the best quality of drinking water in the city. Wealthy upper-caste families had private wells inside their premises, though respondents remember the taste of water from these individual wells to be *tura* – neither sweet nor bitter (Vachranjani, pers comm, 2018), while others remember it to be *bhanvra* – without *swad*, i.e. 'taste', and hence unfit for drinking or cooking (Jethi, pers comm, 2018). "There were two types of wells in the city. One was that of *meetha jal* ('sweet water') which were mostly the large community wells and the other *khaara jal* ('salty water')" which were smaller wells located inside people’s homes (Vachranjani, pers comm, 2018).

In 1969, Bhuj Municipality developed the city’s first tubewell-based water supply system at a village called Bhujodi, seven kilometres away from the city (ACT, 2017). In 1975, this was formalised into the Kukma water supply scheme, and initially, nine tubewells were drilled to meet new government guidelines on the universalisation of the water supply (ACT, 2017). For the first time, the city started to access water from outside its boundaries and from a different and deeper aquifer. This meant that the taste of water from the local wells that the people of Bhuj were familiar with also changed, and new idioms emerged in the lexicon of water quality. While *khaara/khaado* and *meetha/meetho* were used extensively to discuss water supply in pre-pipeline days, the words *peela* ('yellow'), *kadwa* ('bitter'), *feeka* ('flat'), *kayo* ('reddish'), and *saar* ('dissolved salts') recur in discussions on piped water supply in focus groups and interviews. These words highlight changes in the quality of drinking water based on transformations in its colour, taste, and appearance. Such changes to supplied water were emerging across Kachchh in general and Bhuj in particular (Bharwada and Mahajan, 2002; Mehta, 2005), and were produced by the entanglement of the materiality of water with new water-producing technology – the deep tubewell. The local words used to describe water quality conceal within them the evolving relationship between people and nature, now changing into something techno-mediated.

Bhuj and its adjoining areas are placed upon cretaceous sandstone aquifers, which are divided into two parts – the lower and upper Bhuj formations. A layer of ferruginous (i.e. iron-containing) laterite with a thickness of 0.5 to 1.5 metres separates the Upper and Lower Bhuj formations (ACT, 2017; CGWB, 2019). This means that the more one tries to access groundwater from the deeper layers of sandstone aquifers, the more the water can dissolve higher amounts of solids (ACT, 2017), making the quality of groundwater in Bhuj an excellent proxy for symptoms of over-extraction. In short, the taste of water can reveal the health of an aquifer.

The proliferation of RO membrane-based water purification in Bhuj was seeded by the city's declining water quality and, subsequently, by a tragic earthquake in 2001 that completely altered the city's geohydrological regime and temporarily impaired piped water supply. This was when the water tankers[6] made their presence felt in Bhuj for the first time (Ashwin, pers comm, 2018; Vachranjani, pers comm, 2018; Virmani, pers comm, 2018). This period also witnessed a sharp rise in demand for bottled drinking water as a temporary solution. The popularity of RO membrane-based water purification technology (on which the bottled water industry was based) was birthed amidst this hydrosocial uncertainty.

It is not that people in Bhuj were unaware of reverse osmosis membrane-based water purifiers before the earthquake. While water processed by an RO-based water plant through bottled water was making some inroads, respondents in focus groups agreed that owning a domestic RO membrane-based water purifier before the earthquake of 2001 was quite uncommon. The sellers of domestic water purifiers in Bhuj concur that, before the earthquake of 2001, the technology witnessed limited demand. After 2003, Bhuj acquired a new layout, where it expanded from a radius of 12-15 kilometres to that of 54 kilometres. This expansion ushered in increased water demand, deepening dependence on fragile aquifers. In some housing societies, which were located on the outer limits of the city and dependent on their own borewells, the aquifers produced water with higher concentrations of iron and other dissolved solids. As a result, the demand for RO-based water purifiers witnessed a steady rise in specific areas of the post-earthquake city.

Prices dropped with the arrival of cheaper Chinese imports of membranes and other components. An RO-based water purifier, which used to cost an average of INR 12,000-15,000 (US$255-320) between 2005 and 2012, was now available for INR 3000-4000 (US$45-57). The fragmented nature of the market and the absence of any written records[7] make it difficult to ascertain exactly how many individual units have been sold in Bhuj since the earthquake. Sellers interviewed agree that in 2018, almost all middle-class housing societies were accessing water purified by RO-based membrane technologies (Ashwin, pers comm, 2018; Sahoo, pers comm, 2018; Sodha, pers comm, 2018). What is important to note here is that, irrespective of whether one owns a personal water purifier or buys 20-litre bottles, they are drinking water processed through RO membranes. To quote one seller, "Almost 90% of people in the city are drinking RO water, in some form or the other" (Sahoo, pers comm, 2018).

The deterioration of groundwater quality could not have been the main driver for increased sale of RO water purifiers, had not Bhuj become a recipient of water supplied by the Narmada project in 2004. The Narmada Drinking Water Project, also known as the Sardar Sarovar Project (SSP), is a large-scale water supply project that emerged from the damming of the Narmada River in Central India, especially

[6] The tankers are also a form of water supply technology, and they play a substantive role in supplying water to Bhuj even today during periods of water scarcity; however, they are not everyday technologies, compared to open wells, piped water, or RO water. Also, water tankers often supply municipal water to users, and in middle class homes, water supplied from pipelines or tankers both pass through RO purifiers before consumption. Hence, I have kept water tankers as a water supply technology out of the remits of this discussion.

[7] I was told that most of the sales were cash transactions. Even if the sales data is being maintained, it was not shared.

the Sardar Sarovar Dam, which is one of the largest concrete gravity dams in the world (Baviskar, 2004; Nilsen, 2008; Luxion, 2017). The dam displaced 42,000 families, most of whom were of Adivasi ethnicity, and was a site of one of India's largest environmental protest movements. As Bhuj became a recipient of drinking water from this contentious project, it increased "the distance between Bhuj and its water source seventy-fold, from 11 km to over 700 km" (van der Meulen et al., 2023: 11). The city now receives 77% of its water supply from the Narmada pipeline, which is mixed with the local groundwater supplies (van der Meulen et al., 2023).

In this context, I wanted to investigate the continued popularity of RO-based water purifiers in Bhuj. It became apparent that it was substantively linked to the establishment of a numerical politics of TDS, where the numbers 'explaining' this parameter were regarded as a reliable homogenised standard of Bhuj's drinking water quality.

FLATTENING THE WATER LEXICON

As focus group discussions revealed, RO water purifiers have emerged as a panacea to Bhuj's water quality problems amongst the middle classes. TDS – a three-lettered acronym – recurred in discussions in almost every interview and focus group. That Bhuj's water supply contains high levels of TDS was stated repeatedly. However, only a few knew what the acronym stood for. As this excerpt from one focus group with men in an upper-caste housing society in Bhuj shows, there was a substantial difference of opinion about how people know, understand, and interpret TDS.

> A.A.: What made you buy an RO water purifier?
>
> FGD Respondent: Because of high TDS in our water.
>
> A.A.: What is TDS? Can you explain it?
>
> FGD Respondent: In our first bore [tubewell], the water was of 20,000 TDS.

[Disagreement ensues in the group; someone says it couldn't have been that much. The respondent defends his claim of 20,000. Another person says it was 13,000, then corrects himself and says it was 1300. But the water used to be too khaara, says the person who began the discussion. Another person contradicts him, claiming that seawater has a TDS of 8000, so water from the borewell couldn't have been 20,000. Meanwhile, a few people continue to insist it was 1300. Then the original respondent turns towards me.]

> FGD Respondent: Do you have a TDS metre with you? (aggressive tone)
>
> A.A.: I haven't brought it with me. (apologetic tone)
>
> FGD Respondent: You should be carrying one, no? (admonishing tone)

In this conversation, as a person researching water quality, I was expected to carry a TDS meter with me. This specific interaction was not an outlier. When I asked questions on quality, taste, and perceptions during my focus groups, I was frequently asked by individual respondents to come to their homes after the focus group and evaluate the quality of their drinking water using a TDS meter.

Just like a fever in the human body is understood by taking the reading on a thermometer, a TDS meter, which displays a number when its sensors are dipped into water, has become indicative of the health of the water. It was used by all RO water purifier sellers in Bhuj to evaluate the quality of water before installing an RO water purifier, and then again after the water was filtered through it. If the TDS was significantly lower than that of the municipal tap water, it indicated not only that the system was working, but those numbers then became a benchmark for good quality water. Some households had purchased a TDS meter to intermittently check their water. If the TDS value was perceived to be 'high' (and how the word 'high' was understood varied across homes), then it would lead to a request for maintenance or the system's replacement. When respondents were asked about what they felt was the problem with their drinking water quality, the response was high TDS as visible on the meter, rather than any embodied experience of physical discomfort, except that of a perceptible change in the water's taste. The purifier industry in the city had finetuned the purifier units they sold and maintained to operate within a range of 50 ppm to 100 ppm. Even the annual maintenance contract (AMC) for the purifiers varied with the locality. A housing society deemed to have high TDS in its water supply was charged a higher amount for maintenance, as membranes required more frequent replacement. Even public water supply engineers would refer to areas of Bhuj with irregular piped water supply as "high TDS water" zones (Municipal Officer, pers comm, 2018).

The diverse lexicon that once emerged around Bhuj's drinking water quality – *kaayo, saar, khaado/khaara,* or *namkeen* – seems to have collapsed into a singular overarching narrative of TDS.

But how did people in Bhuj get familiar with the term TDS? All responses to this question pointed to RO water purifiers. Every respondent in the focus groups had come across the term TDS either in the process of buying or hearing about RO water purifiers. This phenomenon was aptly summarised in one focus group discussion with men:

> Till this RO system arrived, nobody knew what these terms, 'TDS' and 'pH', were, in the real sense. These advertisements kept telling us about TDS, and then they supplied us with these machines [i.e. RO water purifiers] and told us that the water has so much TDS and it will impact your health. It is because of this marketing that we became familiar with the term TDS. We knew about impurities in our water, but we knew how to deal with it using basic tools [i.e. alum and candle filters]. (focus group, men, Bhuj, 2018)

> *Waise toh TDS ka pata bi nahin tha, jabse RO aaya hain, tabse TDS ka pata chala hain.* [We had no clue what TDS was before, but ever since these RO filters arrived then we started hearing about it]. (focus group, women, Bhuj, 2018)

TDS had produced a simplified and numerical understanding of the complex materiality of drinking water in Bhuj in place of a more embodied, experiential, and gustatory understanding.

Saar in piped water was rendered visible through everyday forms of use. It floated up to the surface of the water when kept in containers, it caused the scaling of taps and pipes, and it left little white specks on metallic utensils after they had been washed and left to dry. *Kaayo*, on the contrary, was a visible indicator, identified through a reddish-yellow tinge to the water. Depending on what kind of water which neighbourhood was accessing, words to define the water quality varied. *Kaayo* was usually an indicator of higher levels of iron in the water, while *saar* could indicate a variety of dissolved minerals. *Namkeen* meant the water was salty, which indicated that the water was tapping into saline aquifers. TDS erased these distinctions and supplanted them collectively into numbers. Commensuration, as Espeland and Stevens explain, "changes terms of what can be talked about, how we value [it], and how we treat what [we] value" (1998: 318). In the case of TDS, higher numbers indicated poor water quality, while a lower count meant the water was potable and sweet. The valuation of 'potable' accordingly undertook a numerical turn.

However, there was no clear understanding of what exactly was 'high', as the BIS range of 500 ppm-2000 ppm was rarely referred to. What emerged from the focus groups was that respondents believed that the smaller the number of TDS, the better the quality of water. In discussions with women respondents, I documented significant pride in husbands/other male family members owning a TDS meter and calling for a technician to replace the membrane cartridges if the value surpassed 100 ppm. The understanding of drinking water quality had coalesced around the TDS meter and the numbers it produced by a reductive translation of the materiality of water. It was a self-fulfilling relationship, as those numbers also worked to legitimise the diagnostic device.

However, as the conversation around water quality coalesced around the numbers displayed on the TDS meter, it also generated controversy. Concerns around low TDS and its adverse impact on human health had been circulating in Bhuj (as well as in India more generally), and there was increasing interest in retaining 'some' TDS in the water. The water purifier market had accommodated that concern through innovations such as the TDS control valve, which mixes input water with the membrane-processed water to increase the concentration of minerals in the water, and through TDS cartridges, which release a proprietary formulation of minerals into the treated water. The number on the TDS meter produced both anxiety when it was high and relief when it was low. The ability of the RO water purifier to reduce TDS was verified through the meter, which reified reliance on the RO water purifier as a middle-class tool for disciplining an 'unruly' public water supply.

The stabilisation of TDS into everyday discussions on water has simultaneously legitimised and entrenched the inevitable use of RO membrane-based purification. Even concern around 'low' TDS hasn’t been able to wean people away from RO membrane-based purifiers, as the solution was being offered by the same device that generated the problem in the first place. If TDS has been established as *the* 'problem', then RO membrane-based purifiers have been universalised as an exclusive solution.

As the understanding of water quality was homogenised through a 3-lettered acronym, it supplanted a place-based, embodied, sensorial, and diverse experience of water. A homogenised understanding of a problem legitimises a specific technology that promises to address the same. When water quality issues are framed within a TDS-RO binary, the problem points to a specific solution. Presently there is no other water purification technology on the market that can remove TDS as effectively as an RO water purifier. The popularity of RO water purification in Bhuj is partly explained by this phenomenon of a specific measurable water quality parameter, flattening the city’s water lexicon. This makes it evident that control of the sensorial script of water is necessary to establish the superiority of a specific drinking water technology and stabilise market demand for the same.

CONCLUSION

As I have shown, the politics of quantifying water quality through TDS has two distinct movements. The first involves the inadequate commensuration of dissolved minerals and salts (and organic matter) into the water quality parameter of TDS. Once TDS gets stabilised in water quality discussions, it begins to get interchangeably used with other such parameters such as salinity. This interchangeable use plays a role in discursive construction of TDS as a contaminant.

The second movement, as I have explored in this paper, relates to the shaping of perceptions of numericised TDS values and how they produce an exclusive, middle-class market for private corporations and entrepreneurs. In Anglo-European contexts, the appeal of bottled mineral water is embedded in the valorisation of TDS and of the sources of the water, which are mountain springs located in remote regions untouched by pollution (Parag and Roberts, 2009; Biro, 2017; Spackman and Burlingame, 2018). Their popularity is built on the promise of allowing users access to unmediated nature, and dissolved solids and particles attest to the same. However, in Bhuj, the appeal of RO membrane-based water purifiers is built on the vilification of TDS, which is seen as needing to be eliminated as much as possible. In both cases, *counting* soluble substances in water produces a market, whether it involves addition or erasure, valorisation or vilification.

The numericised translation of water quality has political consequences, as the counting of TDS through a digital meter produces a "market-enabling metric" (Lave, 2012: 30). The RO water purifier market that emerges out of this works to frame water quality concerns exclusively around TDS and, in the process, it supplants all other ways of knowing and remembering water.

The TDS metre also numerically compares and illustrates the success of private markets over municipal water supply, allowing, to borrow from Espeland and Stevens (1998), for the creation of a market where it previously didn’t exist. Therefore, when a technician uses a TDS meter to evaluate the quality of tap water in Bhuj (which, based on locality, can range anywhere between 400 ppm and 3500 ppm), and then uses the same TDS meter to evaluate filtered water (which consistently ranges between 50 ppm and 250 ppm), it builds a simplistic quantified narrative of the 'efficiency' and 'reliability' of markets as compared to 'inefficient' public services. Irrespective of how much any municipality tries, it cannot produce water at the tap with the TDS value of an RO purifier unless it overhauls its entire infrastructure, an expensive endeavour upon which any municipality is unlikely to embark. This is exactly why RO business operators in Bhuj are not worried about improved public water supply from the Narmada project, which has been claimed to improve the quality of piped water in Bhuj significantly over the last few years.

I am not denying that Bhuj's drinking water supply does not have a potability problem, but those concerns are place-based and vary across localities. Drinking water with higher levels of dissolved solids is not unique to people in Bhuj (nor in Kachchh). RO water purifiers do work to purify water and make it safer to drink. However, as this research shows, the numerical politics of water quality in Bhuj involves fashioning a quantitatively homogenised understanding of water in the city, divorcing it from its qualitative and place-based sensorial script. Even in the absence of any epidemiological study establishing that higher levels of TDS (within the permissible limits of 2000 ppm) produce health problems, in public discourse any presence of TDS above 100-150 ppm gets identified as a contaminant.

As knowledge of drinking water quality undergoes a numerical turn, it nudges the middle classes towards private markets for accessing 'safe' water free of TDS. The RO water purifier is unique because the kind of water it produces, by altering its materiality, cannot be replicated by any other technology and hence makes it inevitable in middle-class homes.

This produces two distinct governance effects. One effect, borrowing from the literature on 'responsibilisation', uses the counting of water quality to shift safe drinking water concerns and responsibilities onto citizens. This transfer from the state to the citizen happens through the affectation of 'consumer awareness' (Merry, 2016; Pyysiäinen et al., 2017; Mustalahti and Agrawal, 2020). The other is one in which the middle classes, a powerful and vocal constituent of urban water services, absolve the water utilities of their responsibility to supply safe water by disconnecting themselves from safe water provisioning debates. As this shifts the burden of addressing unsafe water supply onto the urban poor, it deepens the pathologies of uneven urbanisation.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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