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Water, technology, and development: transformations of development technonatures in changing waterscapes

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Abstract. Delivering safe drinking water is often equated with delivering development in much of the Global South. Yet different arrangements of technologies, waters, and social relations constitute uneven waterscapes and produce different water – society relations across sites and scales. Analyzing the contradictory roles of water-producing technologies and differentiated waters in enabling and challenging processes of development thus becomes important to explaining the political ecologies of development. In order to investigate the technonatural relations of power that constitute development, I look at the ways that different types of waters, water technologies, nature (aquifers, groundwater, arsenic), and power relations coproduce water (in)securities and (un)healthy development subjects, with a case study from waterscapes of the Bengal Delta. Contaminated tubewells have resulted in a drinking water crisis and a reconfiguration of hydro – social relations. Groundwater usage for drinking water purposes was introduced via tubewell technology, creating a public health success story as 'safe' groundwater offered alternatives to the consumption of unsafe surface water sources that had caused high morbidity and mortality rates. But a situation of millions of tubewells producing water with unsafe levels of naturally occurring arsenic has resulted in challenging such development narratives of success, where the tubewells that embodied social status and notions of progress (producing 'good water') came to slowly poison people across the delta (with 'bad water'). I detail the ways that hybrid waters (safe/unsafe/untested and good/bad) and the discourses of water poisoning are produced by water technologies, aquifers, and social relations that are enrolled to support notions of development; in addition, I critically analyze the ways that development goes awry when these technonatural assemblages are unexpectedly altered by the agencies and materialities of variously contaminated waters, differentiated aquifers, and the changing status of water-producing technologies. In contributing to political – ecological analyses of water and technology, I raise questions about the troubled relationship between development and so-called appropriate technologies by bringing attention to the articulations and mutual enrollments of technologies, ecologies, discourses, and subjects in the technonatural processes of development.

Keywords: technonature, political ecology, water, technology, development, tubewell, arsenic

Introduction

On a hot afternoon, after having spent several hours under the blazing sun working outside with different groups of people in the southern part of the Bengal Delta, where the mighty Ganges River flows into the Bay of Bengal, I came upon a tubewell outside a public school. I was grateful to be able to refill my water bottle and quench my thirst, under the shade of the banyan tree. Just as I was about to use the tubewell, Mr Amin,[1] the school headmaster, came running up to me and alarmingly said that I shouldn't drink water from that tubewell and earnestly insisted that I get water from a tubewell about 20 yards away. The tubewell in

[1] Pseudonyms are used in the paper to protect the identity of research participants.

front of me apparently used to have red paint on the spout, which had chipped away and was not visible anymore. The other tubewell, which looked exactly like this one, had the spout painted green, but that tubewell was only visible if one closely peered into the far end of the courtyard of the school (and was comfortable in attempting to use a tubewell that may not be public like the one on the roadside). I was told that I would be drinking *kharap pani* (bad water) from the tubewell here and could get *bhalo pani* (good water) over there. He repeated, "Ei kol kharap, oi koler pani bhalo"—the tubewell here was 'unsafe' and 'bad' but the other one was 'good' and produced 'safe' water. I complied and followed Mr Amin, who was shaking his head and lamenting that development in this village had been set back with the 'bad water' and 'bad tubewells'. Arsenic had been discovered in most of the tubewells' water in the village a couple of years earlier, and some tubewells were marked with red or green paint to signify which ones were unsafe or safe. I had made an honest mistake (like many people before me) in trying to obtain drinking water from a public tubewell that was no longer safe; yet, it had no visible paint on its spout to indicate its status. The same tubewell had been deemed safe only a few years ago, grieved Mr Amin, as he cursed the bad luck that had arrived at his school and his village. He repeated again that the water crisis that people were facing all around was because of these *kharap kol* (bad tubewells) and *bishakto pani* (poisoned water).

Mr Amin's thoughts echoed those of hundreds of people I had been working with across the Bengal Delta, where arsenic was found to exist in high concentrations in groundwater that was the primary source of drinking water for the majority of the people. Red-painted tubewells were the ones tested and identified to have high concentrations of arsenic, and green-painted ones were considered safe;[(2)] however, many newly installed tubewells were unmarked, and some of the older tubewells' paint had disappeared. While these tubewells dotted the landscape and had provided bacteria-free water to villages for the last few decades, an emerging crisis around the quality of the water had entered public consciousness and public life since the late 1990s. Tubewells and drinking water had come to figure highly in people's everyday conversations and daily practices revolving around water—quenching thirst, cooking food, bathing, washing, feeding livestock, watering the kitchen garden, irrigating the cropland. The roles of water and water-producing technologies were immense concerns as contaminated water affected life and livelihood in many ways. In thousands of villages tubewells were a blessing and a curse, the water was good and bad, and development had been set back as people started to get ill from what was expected to be safe water. What the water–technology–development nexus meant in the context of a water crisis, and how tubewells and water had come to be imbricated with social progress and public health, was increasingly of concern for development planners.[(3)]

The importance of safe potable water in the processes of development in much of the Global South has been celebrated in academic and policy literatures. Reducing mortality and morbidity from unsafe water, or inadequate water supplies, remains a top priority for many developing nation-states and international development institutions and organizations. In the Millennium Development Goals policy makers identified the importance of adequate safe water as a key factor to global human development. Water resources management is often cast in development discourses, whereby water is seen as an essential component of economic growth and development.[(4)] For instance, delivering water (via drinking water taps, wells, pipes, reservoirs, etc) is often viewed as actualizing and delivering development. Safe water is

[(2)] Safe tubewells are those which produce water with less than 50 micrograms of arsenic per liter.

[(3)] For greater detail on the history of the arsenic crisis, see Ahmed (2003), Ahmed and Ahmed (2002), BGS and DPHE (2001), Hanchett (2004), Smith et al (2000), and Sultana (2006; 2009a; 2009b).

[(4)] For further analyses of critiques of development, see, for example, Escobar (1995), Ferguson (1994), Gupta (1998), Hart (2004), Mitchell (2002), and Sen (2000).

paramount to good health, and clean water provision is scripted as successful development in embodying progress towards better futures. The ability of states to deliver safe water to their citizens is often the hallmark of good governance and contributes to their status in achieving development goals, whereby safe-water provision and safe-water consumption harbinger further development achievements in future. Yet the provision of safe water is wrapped up in not just various notions of development but also with broader expectations of water technologies and ecologies of the hydrological settings that provide the water. The histories of water provision, the ecological basis of water abstraction, and the social relations of water management are bundled up in the water technologies that are preferred in any context. Water technologies and management systems are thus deeply embedded in development practices and policies and participate in the making of healthy development subjects.

I look at the ways that water technologies, development policies, and power play a role in producing various understandings of safe or good water and how development policies and practices are scripted onto water technologies. Drawing from the research on arsenic contamination of drinking water supplies in South Asia, where millions of people are at risk of poisoning from consuming unsafe water, I undertake a political–ecological analysis of water and development. The roles of groundwater, aquifers, arsenic, and tubewell technologies are imbricated with the development crisis where millions of people are slowly falling ill or dying from arsenic poisoning, and unsafe water has come to disrupt development goals of providing safe water to all and producing healthy subjects. Despite enormous amounts of funds and research that have gone into finding mitigation strategies and alternative water technologies, a development crisis continues to unfold in the Bengal Delta where arsenic occurs as a natural, carcinogenic element in the aquifers. The water being abstracted from such subterranean groundwater sources is increasingly poisoning people through direct consumption (of drinking water) and through irrigation (in agricultural crops). In this paper I focus on the ways that the concept of technonature may provide a fruitful lens through which to analyze the evolving crises and transformations of development. Through the analysis I highlight the ways that water technologies enroll development subjects into being and the ways that development discourses come to be challenged vis-à-vis water technologies.

In the growing literature on political ecologies of water, analyses of various types of waterscapes are providing a greater understanding of water crises and struggles. The materialities of water and water technologies are important in any discussion of political ecologies of water in the development process, and studies have been undertaken by a growing number of critical geographers (such as Bakker, 2004; 2010; Birkenholtz, 2009; Ekers and Loftus, 2008; Gandy, 2008; Kaika, 2005; Kaika and Swyngedouw, 2000; Loftus, 2006; Swyngedouw, 1999; 2004). The bulk of this stimulating scholarship has focused on reticulated networks of water, often in urban settings, or on large infrastructure projects, such as dams or irrigation schemes. The forces of urbanization, commercialization, and privatization have been richly debated and analyzed in such bodies of work. Here, my focus is on rural places in the Global South, with no reticulated or grid-like networks of water provision or large-scale organized water delivery mechanisms, in agrarian societies that are facing the enormous challenges of poverty and grappling with the forces of development (rather than corporate privatization or direct market interventions). The workings of stand-alone (nonreticulated) water-abstracting technologies of tubewells, changing ecological conditions, and transformations of what it means to be 'developed' come to dominate socioecological realities in such places. In addition to the scholarship on political ecologies of water, I draw inspiration from literatures on technonatures (White and Wilbert, 2009) and materialities and agencies of things (Appadurai, 1986; Bennett, 2010; Ingold, 2007; Whatmore, 2002), in order to analyze the ways that water, tubewell technologies, and differentiated social power relations interact to produce and disrupt notions of development.

Safe water consumption is thus imbricated with social power relations, materialities of water, and contradictions of technology-led development. Nature, hydraulic technology, and society articulate to further complicate uneven geographies of access/control/use of life-giving safe water versus death-inducing unsafe water.

Political ecologies of water: technology, modernity, development

Political ecology of water has received increasing attention from geographers in recent years, forging exciting new avenues of research and theorizations of water–society relations. In recent expositions theorists, such as Bakker (2010), Loftus (2009), and Swyngedouw (2009), point to fertile ground for engaging various approaches that constitute political–ecological research in better explaining hydrological and hydrosocial cycles. Swyngedouw (2009) states that "political–ecological perspectives on water suggest a close correlation between the transformations of, and in, the hydrological cycle at local, regional and global level on the one hand and relations of social, political, economic, and cultural power on the other" (page 56). In this vein studies have fruitfully engaged the role of power relations, subjectivities, historical geographies, and ecological differences in the ways that water comes to influence political, social, economic, cultural, and environmental transformation across scales. Similarly, attention to water technologies and infrastructures in coproducing spaces and waterscapes has increasingly become important in analytical studies, in both Global North contexts (eg, Gandy, 2002; Giglioli and Swyngedouw, 2008; Kaika, 2005) and Global South contexts (eg, Bakker, 2003; Birkenholtz, 2009; Gandy, 2008; Loftus, 2006; Molle et al, 2009; Mosse, 2003; von Schintzler, 2008).

Situated within such literatures, I investigate the role of smaller water technologies in the processes of development. While there has been much written about hydraulic societies (Wittfogel, 1957) and water infrastructures being 'temples of development',[(5)] critical scholarship has attempted to demonstrate the ways that water technologies, infrastructures, and power are enmeshed and coproduced (Kaika, 2006; Molle et al, 2009; Swyngedouw, 2007). Swyngedouw (2004) has expounded on the embeddedness of water infrastructure in social power and broader political economy: domestication of water through years of engineering and infrastructural endeavors delivers water into homes and industry, whereby an unruly nature is tamed and contained, its impurities taken out and made usable for human usage through standardized testing and monitoring. Allan (2005) argued that such 'hydraulic mission' dominated water thinking for most of the last century (also Bakker, 2010; Swyngedouw, 1999), whereby large-scale infrastructure and grand plans were espoused in water policy making. Swyngedouw (2004) further posited that the hydraulic mission of the state to modernize involved the state becoming the master hydraulic engineer, producing and reproducing nature/water and changing its flow, availability, and value, which produced a new nature, or new waterscape. He argued that this fusing of nature, culture, society, economy, technology, and ideology ends up producing 'hybrid' natures, where natural and social domains are inseparable, and their "material, representational, and symbolic practices are welded together" (page 110). The drive towards modernity explained the large number of dams, flood control, and irrigation schemes that were financed by development organizations through the 1960s to 1980s. Since then more reflexive modernity has emerged in water management planning, with greater emphasis on local knowledge and smaller plans. This is perhaps due to the failures of large plans (McCully, 1996) and resistance in many areas to their

[(5)] This term was made famous by the first Indian Prime Minister, Jawaharlal Nehru, in the last century in reference to large dams providing water, hydro-electric power, and flood control in postcolonial nation-states; these temples of development were also desired by other postcolonial development planners and leaders.

propagation, where hydraulic processes as forms of rule and control have been challenged in the governance of water (eg, Lopez-Gunn and Llamas, 2008; Mosse, 2003).

Water technologies, integral components in the management of water, are saturated with power dynamics and institutional processes that are historical and geographical, particularly in the context of development. This topic is increasingly of interest to scholars. Bakker (2004; 2010) has investigated the role of water infrastructures and governance in broader processes of development and corporatization in the United Kingdom and Indonesia. Scholars such as von Schintzler (2008) have argued that notions of citizenship are bound up in water technologies and modes of governance in South Africa. Specific political subjectivities are produced through the water infrastructure, which link citizens to the state. Similarly, Loftus (2006), also working in the context of South Africa, has pointed to the regulatory role of the water meter in everyday life. Birkenholtz (2009), focusing on irrigation water in India, investigated the role of irrigation tubewell adaptation in changing social institutions. In addition to these studies, insights from literatures on technonatures and science studies of technology enable scholars to flesh out the scripting and subversions of water technologies. The fluidity of water technology in mediating water–society relations has been brilliantly captured in de Laet and Mol's (2000) exposition on the Zimbabwean bush pump. While the functionality and mechanics of a water technology may remain constant over time and space, its ability to provide water in the desired quality and quantity is what often makes it appropriate and useful in any context.

Technological mediation of water use can affect social interactions and relations at a variety of scales and places and influence the sociocultural meanings of places (eg, Gibbs, 2009; Kaika, 2005; Sofoulis, 2005; Swyngedouw, 2004). Large-scale infrastructures, such as urban piped networks, connected meters, dams, and irrigation systems, are often the focus of such critical geographical scholarship investigating various water-management practices. Here, I argue that smaller-scale water infrastructures and stand-alone technologies that are not in a connected or reticulated system, such as individual tubewells, have not received the same level of attention. The vast number of such individual, vertical, groundwater-accessing technologies form a system of water provision, collectively siphoning out groundwater everyday (at various depths, paces, and locations), where each tubewell can be investigated as individual 'things' as well as part of a bigger collective 'thing'(cf Bennett, 2010), as I discuss later in this paper.

Dubash (2002), in his insightful study of tubewell irrigation and agrarian change in India, argued that "in groundwater dependent societies, the struggle for access to, and control over groundwater, shapes the course of agrarian change and development" (page 2). Since tubewells enable the usage of subterranean resources of groundwater, the role of the technology is significant in social change and development endeavors. The hydro–social assemblages of tubewells and groundwater are important in the everyday survival strategies of the rural poor across South Asia, who rely upon tubewells to provide the bulk of their water (for domestic and agricultural purposes). Historically, by situating tubewells and groundwater usage within broader development goals of water provision and local socioecological transformations, it is possible to see the ways that water technologies and development discourses coproduce certain waterscapes.

Groundwater currently provides the bulk of drinking and irrigation water sources for the millions of people living in the Bengal Delta (comprising Bangladesh and the state of West Bengal in India). The deltaic landscape has historically been fertile and densely populated, with agriculture being the mainstay in rural communities. Water is critically important to the lives and livelihoods of people who have historically relied on various sources of water throughout the year (rivers, ponds, lakes, ditches, rainwater during monsoons, groundwater).

While accessing groundwater via shallow dugwells is an older technology, the introduction of powerful tubewells (or boreholes) in recent decades has enabled enormous amounts of water to be abstracted and utilized to provide drinking water to the growing masses and irrigate multiple cycles of cropping throughout the year. The miracle of the tubewell heralded not only an independence from the vagaries of uncertain rainfall, but also allowed poor agrarian households to envision a prosperous future where plentiful water would be available from the invisible but abundant groundwater beneath their feet. With state intervention, and donor and nongovernmental organization (NGO) support, tubewells were subsidized and mass produced through the 1970s and 1980s throughout the region, enabling a proliferation of different types of tubewells (shallow or deep) to be installed to provide drinking water or irrigation. This heralded a public health success story, ushering in an era where morbidity and mortality from waterborne diseases fell, as people slowly reduced consumption of contaminated surface water sources (from ponds, lakes, rivers) that had high amounts of pathogens and pollutants (Briscoe, 1978). In the late 1990s global institutions such as the UN were providing statistics that showed that up to 97% of the population had access to safe water. Development had been delivered via the delivery of tubewell-produced safe water to the rural population, whereby the tubewell was a fluid technology that could be readily available, adapted, and installed (cf de Laet and Mol, 2000) and, thus, produce healthy development subjects.

The history of the hand-pumped tubewell for drinking water is important to contextualize, as it emerges out of discourses of development that sought to provide water-abstracting technology that was relatively affordable to manufacture nationally and distribute widely as a stand-alone, manual technology that could produce adequate quantities of water for individual households. The tubewell, a vertical hand pump that can be drilled into the earth to pull up aquifer water when its handle is manually pumped, is a technology that enables groundwater to be abstracted easily and relatively cheaply for drinking water.[6] Its relative ease of operation and installation meant it could be promoted widely, and it could be subsidized and rolled out as part of the development plans to have more citizens consuming water that they could readily have on demand. Tubewells quickly became the reliable and desirable drinking water system. Children and women were taught how to use the tubewells, and the desire to own a tubewell as a developed subject was entangled with discourses of safe, plentiful groundwater consumption and healthy subjects (ie, those that did not consume bacteriologically contaminated pond or river water that caused diarrhea and dysentery immediately). By the end of the 1990s more than 10 million tubewells were in use throughout the Bengal Delta, becoming the ubiquitous water-providing technology that was the mainstay of the rural water provision system. Tubewells became technologies of development and embodied notions of progress.

Such narratives were shattered with the discovery of naturally occurring arsenic in water from millions of tubewells that was slowly poisoning people.[7] By the early 2000s a full-blown public health crisis started to unfold. More than 30 million people were estimated to be exposed to drinking contaminated water, and the situation was called the "largest mass poisoning of a population in history" (Smith et al, 2000, pag1093). The tubewell was at the center of the public health crisis of arsenic-laced drinking water and went from singularly embodying notions of development (in that it can produce safe water) to one that could also simultaneously produce maldevelopment (where it comes to poison millions of people who drink contaminated water). Thus, the same technology can provide good water (that is

[6] Tubewells are also used to provide irrigation water, although irrigation tubewells generally have motors attached for pumping up greater volumes of water and are technically slightly different from the simpler drinking water tubewells that are hand-pumped.

[7] Arsenicosis, which is chronic arsenic poisoning from intake of small amounts of arsenic over prolonged periods, generally takes anywhere from 5 – 15 years to manifest as serious health concerns, such as cancer, liver/kidney disease, or heart failure.

healthful and part of the narratives of modernity and success) as well as bad water (that is contaminated, undesirable, an embodiment of danger). As hallmarks of safe water and progress, the tubewells that had been enrolled into the development narrative and mobilized to deliver development were suddenly problematic, unruly, and no longer universal markers of advancement. While official statistics indicated that only 25% of the tubewells were contaminated with arsenic, the concentration of these contaminated tubewells in the central and southern parts of the delta were significantly higher, since arsenic was more prevalent in the aquifers there, albeit in different amounts in different parts of the aquifers. The majority of the contaminated tubewells were the shallow tubewells (which drew groundwater from the shallow aquifers that had higher amounts of arsenic-bearing sediments), since these tubewells were cheaper and promoted through development projects; the deep tubewells that could be drilled further down to access the deep (ancient) aquifers (where there was less or no arsenic-bearing sediments) were generally beyond the reach of most households, as they are considerably more expensive to purchase and to install.[8] The variability of arsenic deposits in the aquifers means some tubewells provide safe water, whereas other identical tubewells only a short distance away can produce poisonous water. The location of the tubewell relative to arsenic-loaded groundwater is thus significant. As a result of this uncertainty, identification and testing of contaminated tubewells became a large development program in the early 2000s (BGS and DPHE, 2001). Entire villages were identified to have only red/unsafe tubewells or to have only a handful of green/safe tubewells. The spatial heterogeneity of arsenic in the groundwater and the differential depths at which tubewells accessed water resulted in landscapes dotted with green and red tubewells, a leviathan that had to be negotiated along gender, class, and geographical lines as people attempted to obtain safe water (Sultana, 2009a).

Both fear and happiness were wrapped up in the tubewell, as those that continued to provide safe water were valorized and signified continued success but those that produced arsenic-laced water were quickly a problem at multiple levels—for safe water access, the contribution towards a healthy population, and the very notions of development success. Paying attention to the ways that tubewells and differentiated waters are entangled in the processes of development and public health narratives demonstrates the nonneutrality of water technologies, their active roles in producing contaminated bodies, and their troubled relationship with development discourses and technocratic faiths in the technology-led development paradigms, topics to which I now turn.

Waterscapes of success and failure: technonatures of the ubiquitous tubewells

Technologies and the social formations they are embedded in reflect the political rationality and development trajectories of the state. No water technology is neutral; it is saturated with historical, geographical, political, and social imaginaries (cf Law, 1991; Oudshoorn and Pinch, 2003). Water technologies are developed, rolled out, fought over, reformed, dismantled, and redesigned in various ways through the social histories of place, networks of power, and discourses of development. How certain technonatural assemblages come into being at specific sites and times is linked to broader networks of power, whereby specific water technologies can be reified as singularly optimal at certain moments. Technonatures are often enrolled in development success stories, but can display agential capacities in disrupting development processes. Technonatures are assemblages that are discursively and materially produced by humans, nonhumans, and technologies (Barad, 2003; Bennett, 2004; 2010; Hinchliffe, 2007; 2008; Luke, 2009; Swyngedouw, 2004; Sze, 2009; White, 2006; White and Wilbert 2009). As White and Wilbert (2009) posit,

[8] The estimated cost of a deep hand pump tubewell (that can go down to about 275 meters depth) is over 50 000 Bangladeshi Taka (approximately US$750) compared with shallow tubewells that cost about a tenth of that price. The costs of drilling and installing the tubewells are also much higher for deep tubewells, since more labor, time, and drilling equipment is required to go into the deeper aquifers.

> "the term 'technonatures' seeks to highlight a reworking range of voices ruminating over the claim not only that we are inhabiting diverse social natures but also that knowledges of our worlds are, within such social natures, ever more technologically mediated, produced, enacted, and contested, and furthermore, that diverse peoples find themselves, or perceive themselves, as ever more *entangled* with things—that is, with technological, ecological, cultural, urban, and ecological networks and diverse hybrid materialities and non-human agencies" (page 6, emphasis in original).[9]

Such a focus has the potential to open up spaces of conversation to look at the real, material, and discursive aspects of the world (cf Haraway, 1991; Latour, 1993; 2004; Law and Mol, 2001). White and Wilbert (2009) further state that "technonatural conversations are marked by a distinct preference for processual, dynamic, relational materialisms that can hold the 'real' and 'the symbolic' in tension and that acknowledge the 'recalcitrance' of ecologies as well as the obduracy of objects" (page 11). In engaging with technological and ecological networks, this emerging but contested set of conversations seeks to draw attention to the ways taken-for-granted categories such as 'social', 'natural', or 'technological' are "historically and geographically contingent and the differential boundaries between such fluid categories are contestable and power laden … they leak and they change over, and across, differing time-spaces" (pages 20–21). At the same time the authors warn against technonatural epochal narratives in undertaking analysis of increasingly complex technonatural societies and politics.[10] Given such a caveat when excavating the ways that technologies, societies, natures, and politics come to imbricate socionatural relations, I draw attention to the ways that water–arsenic–tubewell technonatures come to disrupt, reconfigure, and reposition processes and notions of development in the Bengal Delta.

Tubewells can be seen as technonatural assemblages since the technology exists only for its function to abstract water from aquifers, where its own intimate relationship with groundwater brings it into the social relations of water politics. The groundwater would not be readily available to humans (or nonhumans, such as livestock, and agricultural fields) were it not for the water-abstracting technologies like tubewells. The groundwater that flows from the spouts of the tubewells is part of a technonature that was viewed as a significant development accomplishment. Tubewells, groundwater, and arsenic perform certain labor in re/producing development and unraveling development at the same time. This consolidation and disruption of development is made possible by hybrid technonatural assemblages that enroll people, technology, water, and development institutions into the production of a development crisis.[11]

Historically, tubewells had come to be valorized for delivering safe water for society's consumption needs. These technonatural assemblages came to be reified as being natural when millions of people came to accept the groundwater as the best and safest source of drinking water. The tubewell's value was in producing safe water of sufficient quantities with relative ease. Yet, when it was no longer producing safe water, it was painted, vilified, dismantled, or removed. The tubewell with a red-painted spout became the symbol of development gone awry, of a public health crisis, of bad relations with groundwater. It became a symbol of shame and distress for its owners and was socially marked as undesirable. While some people used the water for bathing or washing purposes, most people avoided it for drinking purposes. Red-

[9] By drawing inspiration from the works of Haraway, Latour, Barad, Castree, Braun, Hinchliffe, Whatmore, and others, White and Wilbert (2009) argue that when bringing technonatural conversations into the discourses of social nature, socionatural hybridity, and actor-network theory, the key thrust lies in paying attention to the ontologies of nature and technologies in social processes.

[10] For similar arguments, see also Blomley (2007), Braun (2008), Castree (2002; 2003; 2005), Gareau (2005), Law (1991), Lorimer (2005), and Whatmore (2002).

[11] For an analysis of the role of nature in specific development discourses of community and participation in water resources management, see Sultana (2009b).

painted tubewells began to occupy spaces of abjection; but they continued to be embroiled in a troubled relationship with fewer, selective users. In contrast to this, tubewells with a green-painted spout came to be desired, valued, and fought over, as they had been identified as producing safe water. These tubewells thus came to be sources of joy, pride, relief for their owners and became status symbols. The green tubewell enrolled society into spatially concentrating in the space where it exists, embedding itself in the discourses and practices of safe water management. But should it come to produce unsafe water (by whatever parameters are identified and practiced by policy makers and implemented locally), it too will suffer the fate of becoming the undesired technology, the discarded or dismantled water source, and easily replaced with a deeper tubewell that can access safer aquifers or be modified with other technology apparatuses to produce safe water (eg, the tubewell water being filtered through a gravel/sand tank or arsenic-removing filtration systems being attached to the tubewell). As de Laet and Mol (2000) argue, the tubewell is a fluid actor, one that "brings a lot about, but its boundaries and constitution vary and its success and failure, instead of being clear-cut, are a matter of degree" (page 248).

The hydrosocial transformations through the technonatures of tubewells, groundwater, and arsenic have come to play central roles in the narratives of development, with differential understandings of good-and-bad citizens and good-and-bad water. Green-painted tubewells embody the notion of development and of its users as being developed subjects who use good water and are responding to international and national water discourses that decry the usage of bad water that is highly concentrated with arsenic. Yet the households and individuals who continue to use red-painted tubewells, usually out of necessity and a lack of viable alternative options, are deemed to be unruly development subjects, not heeding official edicts of using only good tubewells, and thus are seen to be confounding development objectives of keeping people safe (by not drinking arsenic-laced water). What forces people to continue to use unsafe water is often not sufficiently explored by planners and policy makers, and safety warnings hardly help those without the financial, social, or political resources to access a safe water source (see also Sofoulis, 2005; Sultana, 2009a; 2011).

The transformed realities, owing to the changing water quality that emerges from water-producing technologies, are important elements in the broader political ecologies of development. Tubewells and arsenic become actors in the development process, thereby complicating and disrupting narratives of success of increased groundwater usage. Unconnected and unnetworked individual tubewells thus enable/disable certain water–society relations (vis-à-vis water quantity, quality, depth of abstraction, tubewell paint color status, etc) as they are all part of a discursive system of tubewell-led water provision and rural development paradigms. When one tubewell is no longer deemed safe, then another that may still be safe and usable—but there is an increased dependence on it by a larger number of people. This situation is compounded by the fact that switching to green-painted or safer deep tubewells is the official recommendation (van Geen et al, 2002). Alternatively, even when one tubewell is painted red, it may still be used but valued differently, in that the water is not consumed but used for washing, bathing, cleaning. Still another way the red tubewells may continue to be used is as they were used before their status changed; but this is often under duress by those who have no other source of safe water for drinking purposes. People's relationships to red tubewells thus shift from ones of social status, joy, or ease to ones of panic, worry, and shame in having to use a tubewell that no longer has a salubrious relationship to safe groundwater sources. However, installing another deeper tubewell that accesses safer aquifers can reestablish the good relationship with tubewells and with groundwater. Thus, the tubewell has an ambiguous status that is mediated by its ability to tap into arsenic-free water sources, and its physical/technical status that allows this to be realized more readily (ie, more expensive

deep tubewells can be drilled deeper, but the more commonly available and affordable shallow tubewell cannot go that deep). While deep tubewells are the technologies of choice amongst wealthier households, there is no guarantee that drilling into deeper parts of the aquifers will necessarily result in having safe water, since the presence of arsenic at different depths varies geologically considerably across the delta. Therefore, while the tubewell remains a mainstay in most villages across the Bengal Delta, it does recast the existing relationships of power and mediate nature–society relationships differently.

Troubling tubewells and recasting development

Dixon and Whitehead (2008) argue for the importance of geographers studying different roles of technology to engage in

> "revealing not only the material relationships that connect technologies with questions of landscape and environment, but also the constitutive role of technologically supported discourses, and discourses of technology, in changing socio-environmental relations. What is more, there is an appreciation of how not only the form and function of the technologies themselves, but also their place within the social imaginary, are transformed through this process" (page 604).

Technologies mediate the relationships between nature and society in dialectical ways, but "relatively little attention (at least when compared to allied work in Science and Technology Studies) has been given the role of technology within the constitutive dynamics of this dialectic" [page 604; see also Furlong (2011) for an excellent summary]. Tubewells can be viewed as constitutive of the water–society dialectic, whereby they mediate the material and discursive access to groundwater. While arsenic does exist in the local geology, its presence in the human world is facilitated by tubewells. Contaminated water is thus a socionatural hybrid, yet it is often reified as purely natural. Arsenic would not intervene in lives and livelihoods to the same extent had tubewell technologies not made it easy for groundwater to be abstracted so readily. The materiality of arsenic comes to manifest itself more forcefully in society as a product of technology, development plans, and local geology/ecology. Over the time that tubewells became the mainstay of the water management system, social power relations that had become somewhat stable vis-à-vis water access regimes were now being challenged through uncertainties in water quality, where tubewells, arsenic, and water coproduced emergent hybrid development realities. Tubewells became things with different powers in the lives of people and development policies.

Bennett (2010) defines 'thing-power' as

> "the strange ability of ordinary, man-made items to exceed their status as objects and to manifest traces of independence or aliveness, constituting the outside of our own experience … [such that] the concept of thing-power offers an alternative to the object as a way of encountering the nonhuman world" (pages xvi–xvii).

As things produce effects, their role in everyday life and development practices becomes important to investigate. The thing-power of tubewells becomes apparent in several ways. Un/contaminated tubewells are embroiled in social power relations and participate in the production of waterscapes of power and health, or marginalization and poisoning, where changes in the status of tubewells, their abilities in pumping up safe water, and their relative spatial locations can enroll water, technology, and society in uneven ways. These produce technonatural landscapes that challenge the very essence of development embodied in tubewell promotion as the mainstay in rural water provision: tubewells were meant to provide safe and healthful water, but these very tubewells are now slowly poisoning people (who knowingly or unknowingly are consuming poisoned water).

Furthermore, the vitality of tubewells enrolls people into different configurations of water–society relationships. Bennett (2010) defines vitality as the

> "capacity of things … not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities, or tendencies of their own … [which] is not a vitalism in the traditional sense … [but one where we can] equate affect with materiality, rather than posit a separate force that can enter and animate a physical body" (page viii).

Drawing upon Latour's notion of actants, Bennett argues that things and thing-power of everyday items can provide insight into the ways that society functions and how we make sense of the world we live in. Given the growing attention to matter and materiality in geography (eg, Anderson and Wylie, 2009; Bakker and Bridge, 2006; Boyd et al, 2001; Dixon and Whitehead, 2008; Gregson and Crang, 2010), vital materiality has to be sought out and understood. Bennett posits that it is important "to articulate a vibrant materiality that runs alongside and inside humans to see how analyses of political events might change if we gave the force of things more due" (2010, page viii).[12] Such an analytic can be brought to bear on the ways that tubewells and arsenic-laced water come to disrupt everyday relations to drinking water, the production of healthy citizens, and the development practices of tubewell-led water planning. However, the contradictory role of tubewells and their changing status in being able to provide safe water has challenged development planning in the drinking-water sector. Thus, tubewells have thing-power and can affect the daily rhythms of life and water–society relations (cf Loftus, 2006; von Schintzler, 2008). However, this is not to engage in commodity fetishism and give life and meaning to objects that thereby reifies them (see Kirsch and Mitchell, 2004). The agency of the tubewell lies in its capacity to enroll or produce an effect in both development discourses and lived realities. Giving tubewells a social life and actor status enables us to view them not just as things but also as objects that embody social relations. Things have political and social lives (Appadurai, 1986), and the aim of this attention to tubewells as actors is not to anthropomorphize or reify these water-producing technologies and infrastructures, or engage in technological determinism, but to bring to attention the ways that nature and technologies are part and parcel of development processes and the production of waterscapes.

Good water, bad water: technonatures of/in development

Materialities of water, arsenic, and tubewells come to vex development paradigms, where a technonatural crisis from the arsenic contamination of tubewells is resulting in paradigmatic shifts in water provision policies. The troubling role of technology in the process of water management raises the specter of other problems down the road. More emphasis is currently being placed on both alternative technologies and alternative water sources—for example, capturing rainwater through rainwater harvesting technologies, reusing pond/surface water sources via sand or gravel filter systems. Thus, the hegemony of tubewells and groundwater is challenged by the introduction of arsenic into the equation, simultaneously leading to a shift to different technonatures and also an increase in the hegemony of deep tubewells. Destabilizing the prevalence of the shallow tubewells as the preeminent providers of drinking water has resulted in a competition of the same technology (ie, more powerful and expensive

[12] Additional comments from Bennett (2010) are insightful: "I believe that this pluriverse is traversed by heterogeneities that are continually doing things. I believe it is wrong to deny vitality to nonhuman bodies, forces, and forms, and that a careful course of anthropomorphization can help reveal that vitality, even though it resists full translation and exceeds my comprehensive grasp. I believe that encounters with lively matter can chasten my fantasies of human mastery, highlight the common materiality of all that is, expose a wider distribution of agency, and reshape the self and its interests" (page 122).

tubewells) and of new technologies (ie, nontubewell technologies to produce different kinds of drinking water, from rainwater and surface water). Yet the technological thrust remains in water planning, and the faith in appropriate technologies delivering development remains hegemonic, rather than these being reflexive assessment and questioning of the inequitable power relations embodied in any of the technologies being promoted or the problematic implementation of water projects in different places.[13]

The water gushing from the spouts of tubewells may be good or bad; it would have to be tested and its quality determined vis-à-vis concentration of arsenic. The water looks, tastes, and smells the same when it has more arsenic in it, but the water's role in development changes, as does that of the tubewell producing the water. Depending on what else is present at the molecular level, or dissolved in it, or carried with it, water comes to signify very different things. With this, the tubewell producing the water comes to hold different values and significance. Thus, tubewells are not just actors but also intermediaries, mediating groundwater access for societal use. The fate of the water and the tubewell are cemented through the presence of arsenic, producing assemblages of good or bad water. Good and bad water are thus constitutive of historical water policies, development imaginaries, tubewell technologies, and aquifer geology.

Alternatively, bad water can be made into good water through further technological mediation. The same bucket of water may be filtered and arsenic adsorbed out, thereby making the water more desirable, healthful, and useful. The intermediaries in the water–society relations, whether tubewells or other technologies of arsenic filtration, come to play important roles in the narratives of development success. Usage of alternative technologies (eg, rainwater harvesting as an alternative to groundwater dependency) depends on the financial resources available to a household, what technological devices are accessible by the household (given that there are only a handful that have been trialed and certified by authorities), and whether such devices are available in their area. Households often revert back to using the familiar tubewell when the new technologies become inoperative or too expensive to maintain (ie, repair, replace, or update). Given the overall costs (social and financial) in working with alternative water technologies, many households resort to using tubewell water directly and treating it with rudimentary methods (such as storing it overnight to let any particulates settle to the bottom of the container, filtering it using gravel or brick chips, etc); while boiling can treat pathogen-contaminated water, it does not get rid of arsenic. As a result, any additional costs to treat water have to be considered in the context of the household's resources, and constraints of poverty often dictate that households continue to consume untreated water from tubewells.

However, the continued technocratic faith in the ability of differently designed water technologies to deliver development remains dominant. Such technologies become part of the development narratives of safe water provision that are integral to development and relegitimizing the actors of development (ie, the state, international development organizations, local NGOs), where development comes to be inscribed onto the new water technologies (albeit not in the same way as the tubewells once were). Although tubewells occupied the lofty position of safe water provide for several decades, and were once unrivalled pillars of success, they are now seen as things that need to be monitored, regulated, painted, socially marked, or dismantled. Whereas the recent history of tubewell technonatures and the arsenic crisis should give cause for concern, this does not appear to be the case on the ground, where new water projects with alternative technologies are often uncritically reproducing technonatural relations of power. While the assessment and verification of various arsenic

[13] For details on different technologies being trialed, see Ahmed (2001) and Howard et al (2006); for details on the national policy on arsenic mitigation, see Bangladesh Government (2004).

removal technologies were vetted for a number of years by the authorities, the rolling out of water technology in villages in the majority of the instances ends up being introduced as savior technologies, with incredible powers to reenroll people in mediating water–society relations and reproducing hierarchies of power in water management systems. Despite such efforts, millions of people continue to consume arsenic-contaminated water and negotiate their relationships with variously marked and variously situated tubewells in their area. Tubewells remain the dominant water technology to this day. While short-term mitigation strategies are important, long-term drinking water solutions remain contentious. What is perhaps needed in the emergent water management and development policies is what Jasanoff (2003) calls 'technologies of humility' (to complement the widespread presence of 'technologies of hubris') in order "to make apparent the possibility of unforeseen consequences; to make explicit the normative that lurks within the technical; and to acknowledge from the start the need for plural viewpoints and collective learning" (page 240). Unfortunately, transitions away from quick-fix, short-sighted, and technology-led development policy making remain atypical.

As hundreds of research participants made evident in their concerns and comments, tubewells were still occupying dominant but liminal positions in the development process and in their lives. Some tubewells were good, others were bad, but tubewells were still needed for everyday water usage. Some people had aspired to own deep tubewells, while others had become convinced of the value of other water technologies (eg, dugwells, rainwater harvesters). However, no household was fully free of tubewells, as they still used them for multiple water-related purposes. Greater knowledge and awareness of arsenic had enabled people to think through which technologies they wanted in their lives, but not everyone had the luxury of choice to consider other technologies for safer water. For the majority of households that depended on tubewells, whether contaminated or not, negotiating the access and use of safe water was embroiled in other aspects of life (Sultana, 2011). Thus, tubewells enrolled people into different behaviors regarding water consumption and influenced the everyday practices of water management and understandings of development.

Conclusion

In this paper I have attempted to highlight the materialities and hybridities of nature/water, technology, and social relations in uneven waterscapes that constitute technonatures in the development process. Easily available and affordable tubewells were seen to usher in a public health success story and deliver development in the Bengal Delta. Tubewells were symbolic and material representations of development, and they were meant to produce good/safe groundwater, not arsenic-laced poisoned water. Thus, red tubewells are deviant actants in the water–development–health narratives, reminders of fluid technonatures gone awry, become unruly, or deemed ungovernable. Red and green tubewells signify un/safe waters in technonatural networks that involve power relations in development and water management, linking water policies, development subjectivities, and proliferation of tubewell technologies. Tubewells come to signify both good and bad development, as they mediate social access to subterranean water containing unpredictable quantities of arsenic as well as become infrastructures that embody everyday water politics and socioecological relations. Tubewells intervene in broader debates about the role of water in development in contradictory ways. Arsenic-water, or bad water, is introduced into social relations via tubewell technology, reminders of recalcitrant things in the development process. But the same tubewell technology has the capacity to provide arsenic-free water and, thus, embody development success. Analyzing the political ecologies of development with attention to the liminalities of water technologies and vagaries of heterogeneous nature/water, brings to the fore the contested and contradictory processes of development itself.

Hybrid waters (safe/unsafe/untested) and the discourses of water poisoning are products of the ways that historical water technologies, aquifers, and social relations are enrolled to support notions of development, but can simultaneously symbolize development that has gone awry when these technonatural assemblages unexpectedly perform differently, recasted by the agency and materialities of arsenic and tubewell technologies combining to disrupt desired development ends. The ubiquitous tubewell comes to embody different notions of development. As Mr Amin articulated on behalf of his school and village, tubewells were a blessing and a curse, and the modern, developed subject is one who responds to the present realities by consuming good water and avoiding bad water. The developed subject is one who relates to technonatures appropriately and understands the importance of safe water and water-producing technologies in the development process. Safe water consumption and usage of different water technologies is, thus, imbricated with social power relations, materialities of water, and contradictions of modernist technology-led development, which combine to produce uneven geographies of life-giving safe water versus death-inducing unsafe water. Through these processes, technonatures of development are transformed in paradoxical ways in changing waterscapes.

By contributing to emerging analyses of technology in geography, I have underscored the importance of paying close attention to environmental, social, and material contexts as well as the contingency and dynamism of any technology. I raise questions about the troubled relationship between development and so-called appropriate technologies by bringing attention to the articulations and mutual enrollments of technologies, discourses, and subjects. Such political–ecological investigations of technonatural processes of development warrant further investigation by scholars in geography.

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References

Ahmed M, 2001, "An overview of arsenic removal technologies in Bangladesh and India", in *Proceedings of BUET-UNU International Workshop on Technologies for Arsenic Removal from Drinking Water* Dhaka, 5–7 May 2001, Bangladesh University of Engineering and Technology and United Nations University, Bangladesh, pp 251–269

Ahmed, M, 2003 *Arsenic Contamination: Bangladesh Perspective* (ITN-Bangladesh, Dhaka)

Ahmed M, Ahmed C, 2002," Arsenic mitigation in Bangladesh", an outcome of the international workshop on arsenic mitigation in Bangladesh, 14–16 January, Local Government Division, Ministry of LGRD and Cooperatives, Government of Bangladesh

Allan J, 2005, "Water in the environment/socio-economic development discourse: sustainability, changing management paradigms and policy responses in a global system" *Government and Opposition* **40** 181–199

Anderson B, Wylie J, 2009, "On geography and materiality" *Environment and Planning A* **41** 318–335

Appadurai A, 1986 *The Social Life of Things: Commodities in Cultural Perspective* (Cambridge University Press, New York)

Bakker K, 2003, "From archipelago to network: urbanization and water privatization in the South" *The Geographical Journal* **169** 328–341

Bakker K, 2004 *An Uncooperative Commodity: Privatizing Water In England And Wales* (Oxford University Press, Oxford)

Bakker K, 2010 *Privatizing Water: Governance Failure and the World's Urban Water Crisis* (Cornell University Press, Ithaca, NY)

Bakker K, Bridge G, 2006, "Material worlds? Resource geographies and the 'matter of nature'" *Progress in Human Geography* **30** 5–27

Bangladesh Government, 2004, "National policy for arsenic mitigation", Local Government Division, Ministry of Local Government, Rural Development, and Cooperatives, Government of Bangladesh

Barad K, 2003, "Posthumanist performativity: toward an understanding of how matter comes to matter" *Signs: Journal of Women in Culture and Society* **28** 801–831
Bennett J, 2004, "The force of things: steps to an ecology of matter" *Political Theory* **32** 347–372
Bennett J, 2010 *Vibrant Matter: A Political Ecology of Things* (Duke University Press, Durham, NC)
BGS, DPHE, 2001, "Arsenic contamination of groundwater in Bangladesh", British Geological Survey Technical Report, WC/00/19 (British Geological Survey, Keyworth, Notts)
Birkenholz T, 2009, "Groundwater governmentality: hegemony and technologies of resistance in Rajasthan's (India) groundwater governance" *The Geographical Journal* **175** 208–220
Blomley N, 2007, "Making private property: enclosure, common right and the work of hedges" *Rural History* **18** 1–21
Boyd W, Prudham S, Schurman R, 2001, "Industrial dynamics and the problem of nature" *Society and Natural Resources* **14** 555–570
Braun B, 2008, "Environmental issues: inventive life" *Progress in Human Geography* **32** 667–679
Briscoe J, 1978, "Role of water supply in improving health in poor countries (with special references to Bangladesh)" *American Journal Of Clinical Nutrition* **31** 2100–2113
Castree N, 2002, "False antitheses? Marxism, nature and actor-networks" *Antipode* **34** 111–146
Castree N, 2003, "Environmental issues: relational ontologies and hybrid politics" *Progress in Human Geography* **27** 203–211
Castree N, 2005 *Nature* (Routledge, London)
de Laet M, Mol A, 2000, "The Zimbabwe bush pump: mechanics of a fluid technology" *Social Studies of Science* **30** 225–263
Dixon D, Whitehead M, 2008, "Technological trajectories: old and new dialogues in geography and technology studies" *Social and Cultural Geography* **9** 601–611
Dubash N, 2002 *Tubewell Capitalism: Groundwater Development and Agrarian Change in Gujarat* (Oxford University Press, New Delhi)
Ekers M, Loftus A, 2008, "The power of water: developing dialogues between Foucault and Gramsci" *Environment and Planning D: Society and Space* **26** 698–718
Escobar A, 1995 *Encountering Development: The Making and Unmaking of the Third World* (Princeton University Press, Princeton, NJ)
Ferguson J, 1994 *The Anti-Politics Machine: 'Development', Depoliticization, and Bureaucratic Power in Lesotho* (University of Minnesota Press, Minneapolis, MN)
Furlong K, 2011, "Small technologies, big change: rethinking infrastructure through STS and geography" *Progress in Human Geography* **35** 460–482
Gandy M, 2002 *Concrete and Clay: Reworking Nature in New York City* (MIT Press, Cambridge, MA)
Gandy M, 2008, "Landscapes of disaster: water, modernity and urban fragmentation in Mumbai" *Environment and Planning A* **40** 108–130
Gareau B, 2005, "We have never been human: agential nature, ANT, and Marxist political ecology" *Capitalism Nature Socialism* **16**(4) 127–140
Gibbs L, 2009, "Water places: cultural, social and more-than-human geographies of nature" *Scottish Geographical Journal* **125** 361–369
Giglioli I, Swyngedouw E, 2008, "Let's drink to the great thirst! Water and the politics of fractured techno-natures in Sicily" *International Journal of Urban and Regional Research* **32** 392–414
Gregson N, Crang M, 2010, "Materiality and waste: inorganic vitality in a networked world" *Environment and Planning A* **42** 1026–1032
Gupta A, 1998 *Postcolonial Developments: Agriculture in the Making of Modern India* (Duke University Press, Durham, NC)
Hanchett S, 2004, "Social aspects of the arsenic contamination of drinking water: a review of knowledge and practice in Bangladesh and West Bengal", report presented to the Arsenic Policy Support Unit, Ministry of Local Government, Rural Development, and Cooperatives, Government of Bangladesh
Haraway D, 1991 *Simians, Cyborgs and Women: The Reinvention of Nature* (Routledge, NewYork)
Hart G, 2004, "Development and geography: critical ethnography" *Progress in Human Geography* **28** 91–100

Hinchliffe S, 2007 *Geographies of Nature* (Sage, London)
Hinchliffe S, 2008, "Reconstituting nature conservation: towards a careful political ecology" *Geoforum* **39** 88 – 97
Howard G, Ahmed M, Shamsuddin A, Mahmud A, Deere D, 2006, "Risk assessment of arsenic mitigation options in Bangladesh," *Journal of Health, Population, and Nutrition* **24** 346 – 355
Ingold T, 2007, "Materials against materiality" *Archaeological Dialogues* **14** 1 – 16
Jasanoff S, 2003, "Technologies of humility: citizen participation in governing science" *Minerva* **41** 223 – 244
Kaika M, 2005 *City of Flows: Modernity, Nature and the City* (London, Routledge)
Kaika M, 2006, "Dams as symbols of modernization: the urbanization of nature between geographical imagination and materiality" *Annals of the Association of American Geographers* **96** 276 – 301
Kaika M, Swyngedouw E, 2000, "Fetishizing the modern city: the phantasmagoria of urban technological networks" *International Journal of Urban and Regional Research* **24** 120 – 138
Kirsch S, Mitchell D, 2004, "The nature of things, dead labour, nonhuman actors and the persistence of Marxism" *Antipode* **36** 687 – 706
Latour B, 1993 *We Have Never Been Modern* (Harvard University Press, Cambridge, MA)
Latour B, 2004 *Politics of Nature: How to Bring Sciences into Democracy* (Harvard University Press, Cambridge, MA)
Law J, 1991 *A Sociology of Monsters: Essays on Power, Technology and Domination* (Routledge, London)
Law J, Mol A, 2001, "Situating technoscience: an inquiry into spatialities" *Environment and Planning D: Society and Space* **19** 609 – 621
Loftus A, 2006, "Reification and the dictatorship of the water meter" *Antipode* **38** 1023 – 1045
Loftus A, 2009, "Rethinking political ecologies of water" *Third World Quarterly* **30** 953 – 968
Lopez-Gunn E, Llamas M, 2008, "Re-thinking water scarcity: can science and technology solve the global water crisis?" *Natural Resources Forum* **32** 228 – 238
Lorimer H, 2005, "Cultural geography: the busyness of being 'more-than-representational'" *Progress in Human Geography* **29** 83 – 94
Luke T, 2009, "The property boundaries/boundary properties in technonatures studies: 'Inventing the Future'", in T*echnonatures: Environments, Technologies, Spaces and Places in the Twenty-first Century* Eds D White, C Wilbert (Wilfrid Laurier University Press, Waterloo, ON) pp 193 – 214
McCully P, 1996 *Silenced Rivers: The Ecology and Politics of Large Dams* (Zed Books, London)
Mitchell T, 2002 *Rule of Experts: Egypt, Techno-politics, Modernity* (University of California Press, Berkeley, CA)
Molle F, Mollinga P, Wester P, 2009, "Hydraulic bureaucracies and the hydraulic mission: flows of water, flows of power" *Water Alternatives* **2** 328 – 349
Mosse D, 2003 *The Rule of Water: Statecraft, Ecology, and Collective Action in South India* (Oxford University Press, Oxford)
Oudshoorn N, Pinch T, 2003 *How Users Matter: The Co-construction of Users and Technologies* (MIT Press, Cambridge, MA)
Sen A, 2000 *Development as Freedom* (Anchor Books, New York)
Smith A, Lingas E, Rahman M, 2000, "Contamination of drinking-water by arsenic in Bangladesh: a public health emergency" *Bulletin of the World Health Organization* **78** 1093 – 1103
Sofoulis Z, 2005, "Big water, everyday water: a sociotechnical perspective" *Continuum: Journal of Media and Cultural Studies* **19** 445 – 463
Sultana F, 2006, "Gendered waters, poisoned wells: political ecology of the arsenic crisis in Bangladesh", in *Fluid Bonds: Views on Gender and Water* Ed K Lahiri-Dutt (Stree Publishers, Kolkata) pp 362 – 386
Sultana F, 2009a, "Fluid lives: gender, subjectivity and water management" Gender, Place, and Culture **16** 427 – 444
Sultana F, 2009b, "Community and participation in water resources management: gendering and naturing development debates from Bangladesh" *Transactions of the Institute of British Geographers, New Series* **34** 346 – 363
Sultana F, 2011, "Suffering for water, suffering from water: emotional geographies of resource access, control and conflict" *Geoforum* **42** 163 – 172

Swyngedouw E, 1999, "Modernity and hybridity: nature, regeneracionismo, and the production of the Spanish waterscape, 1890–1930" *Annals of the American Association of Geographers* **89** 443–465

Swyngedouw E, 2004 *Social Power and the Urbanization of Water: Flows of Power* (Oxford University Press, Oxford)

Swyngedouw E, 2007, "Technonatural revolutions: the scalar politics of Franco's hydro-social dream for Spain, 1939–1975" *Transactions of the Institute of British Geographers, New Series* **32** 9–28

Swyngedouw E, 2009, "The political economy and political ecology of the hydro-social cycle" *Journal of Contemporary Water Research and Education* **142** 56–60

Sze J, 2009, "Boundaries and border wars: DES, technology, and environment justice", in *Technonatures: Environments, Technologies, Spaces and Places in the Twenty-First Century* Eds D White, C Wilbert (Wilfrid Laurier University Press, Waterloo, ON) pp 125–148

van Geen A, Ahsan H, Horneman A, Dhar R, Zheng Y, Hussain I et al, 2002, "Promotion of well-switching to mitigate the current arsenic crisis in Bangladesh" *Bulletin of the World Health Organization* **80** 732–737

von Schintzler A, 2008, "Citizenship prepaid: water, calculability, and techno-politics in South Africa" *Journal of Southern African Studies* **34** 899–917

Whatmore S, 2002 Hybrid Geographies (Sage, London)

White D, 2006, "A political sociology of socionatures: revisionist manoeuvres in environmental sociology" *Environmental Politics* **15** 59–77

White D, Wilbert C, 2009 *Technonatures: Environments, Technologies, Spaces and Places in the Twenty-First Century* (Wilfrid Laurier University Press, Waterloo, ON)

Wittfogel K, 1957 *Oriental Despotism: A Comparative Study of Total Power* (Yale University Press, New Haven, CT)