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Going with the Flow? Directions of Innovation in the Water and Sanitation Domain

Synne Movik and Lyla Mehta

Water

STEPS centre

About this paper

Water and sanitation issues are looming large on the international agenda, not least due to the impetus created by the Millennium Development Goals (MDGs) to halve, by 2015, the proportion of the world's population who do not have access to clean water and adequate sanitation. Water resources for productive uses have also received increased focus given the recent food crisis, and is further accentuated by the impacts of climate change (altering precipitation patterns, the frequency of floods and droughts, etc). Increasing incertitude and complexity are the norm, rather than the exception, and finding ways to secure people's access to water resources for consumptive and productive use, as well as adequate sanitation, needs to draw on innovative ideas in terms of technological solutions and institutional frameworks. This paper sets out to explore some of the present narratives dominating the field of water and sanitation, highlighting current challenges and teasing out how three key concepts – directionality, diversity and distribution – can act as guiding principles for further innovations and future developments.

About the authors

Lyla Mehta is convenor of the STEPS water and sanitation domain. Lyla is a sociologist whose work has focused on issues concerning knowledge, power, rights and access in natural resource management. Research areas include global and local responses to water scarcity and, more recently, community-led total sanitation.

Synne Movik is an independent consultant, working on STEPS water and sanitation projects. Synne completed her PhD at the Institute of Development Studies in October 2008 with a thesis exploring the politics of water allocation reform in South Africa.

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For further information please contact: STEPS Centre, University of Sussex, Brighton BN1 9RE
Tel: +44 (0) 1273915673
Email: steps-centre@ids.ac.uk
Web: www.steps-centre.org

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INTRODUCTION

Water and sanitation issues are looming large on the international agenda, not least due to the impetus created by the Millennium Development Goals (MDGs) to halve, by 2015, the proportion of the world's population who do not have access to clean water and adequate sanitation. Water resources for productive uses have also received increased focus given the recent food crisis, and their availability is even more uncertain due to the impacts of climate change (altering precipitation patterns, the frequency of floods and droughts, etc). Increasing incertitude and complexity are the norm rather than the exception. In order to find ways to secure people's access to water resources for consumptive and productive use as well as adequate sanitation, it is necessary to draw on innovative ideas both in terms of technological solutions and institutional frameworks. This domain note sets out to explore some of the present narratives dominating the field of water and sanitation, to highlight current challenges and tease out how three key concepts – *directionality*, *diversity* and *distribution* – can act as guiding principles for further innovations and future developments.

Traditionally, water and sanitation – popularly known as 'watsan' – has tended to focus on water issues and neglected the sanitation aspects. It was far easier to shore up political support for investments in drinking water infrastructure; politicians relished having their names associated with projects that provided pure, life-giving water to the poor. Sanitation, on the other hand, conjured up images of shit and dirt, images with which most people would be loath to be associated. When not totally ignored, sanitation tended to be dominated by top-down approaches and ready-made, standardised technologies.

Moreover, water and sanitation have historically been rather strictly separated from water resources management, i.e. water for productive uses such as agriculture, industry and energy. Managing water for productive uses has often been framed as being mainly a question of infrastructure – of building dams and reservoirs and distribution systems that would store and make water available for productive purposes when needed. The term 'hydraulic mission' (Swyngedouw 1999; Reisner 1984) captures the essence of many governments' long-lasting infatuation with grand infrastructure projects where governments set out to control the fickle nature of water resources. The controversies surrounding large dams are a good case in point (Mehta 2005; World Commission on Dams 2000). From Karl Wittfogel and others (e.g. Wittfogel 1957), we also know that the desire to control water has been a hallmark of many civilizations. More recently sanitation has moved from being 'the last taboo' (Black and Fawcett 2008) to gaining more attention from policy makers and politicians. 2008 was the international year of sanitation, and in 2007 the British Medical Journal voted for sanitation as the greatest medical advance in the last 166 years (BBC, 18th January). However, many problematic narratives persist despite growing global and national importance of both water and sanitation. We now go on to explore them and highlight the challenges that remain.

CURRENT NARRATIVES AND CHALLENGES IN WATER AND SANITATION

MEETING THE MDG GOALS

With the turn of the millennium, the formulation of the Millennium Development Goals framed much of the discussions around access to drinking water and sanitation. Presently, more than one billion people still lack access to safe water (Ban Ki-moon 2008). The emphasis has been on ensuring access to 'safe' water, while the Joint Monitoring Programme of the World Health Organisation refers to 'improved' water sources. However, consensus has yet to be reached on what an improved water source actually is – a borehole? A protected spring? (WaterAid 2003, in Mehta et al 2007: 6). Such definitions are often products of Westernised ideas about 'improvement'. By contrast, research in India has revealed that local people may have different preferences and priorities. For example, in

Merka in Kutch, India, villagers prefer the taste and quality of water from 'local' sources such as holes in the riverbed and tanks whilst finding the government-supplied water suspect (Mehta 2005). Government sources may qualify as 'improved', but whether they are suitable to local needs and interests is questionable.

Sanitation, on the other hand, is still struggling from historical neglect, and only managed to fight its way into the MDGs in 2002. Sanitation is considered to be one of the most difficult to achieve of the MDGs, with about 2.4 billion people worldwide lacking access (Ban Ki-moon 2008). But sanitation is now receiving increasing policy attention and the amount of resources being channelled into sanitation projects is on the rise. Still, key challenges include tackling cultural and social issues of so-called behaviour change in order to ensure that toilets are not just built, but also used and rebuilt once they collapse. Thus, there is an urgent need to go beyond top-down notions of toilet construction and toilet coverage.

Since 1999, the novel approach of Community-Led Total Sanitation (CLTS) is offering an alternative pathway in terms of addressing sanitation issues. Taking communities as the point of departure, CLTS relies on collective action to deal with sanitation issues – the desire for action is ignited when communities are made aware of the linkages between open defecation and unsafe handling of faeces and the frequency of diarrhoea and their overall health and well-being (Kar and Pasteur 2005; Kar and Chambers 2008). Unlike former projects, the CLTS approach does not offer any subsidies – rather, community members are encouraged to draw on their own knowledge and local resources to construct sanitary facilities to meet their needs. So far, CLTS has spread to more than 20 countries, and recent research has documented many successes but also revealed challenges concerning social, institutional and technological sustainability (see Movik and Mehta, forthcoming).

PRIVATISATION DEBATES

Since the turn of the century privatisation controversies have charged water debates worldwide. Ely's (2009) notion of 'borderless capitalism' resonates with water domain issues, as powerful multinationals such as Suez and Vivendi have taken over the responsibility of water provision in an increasing number of localities around the world. Often this is due to persistent narratives concerning the 'inefficiency' of the public sector and the need to inject new capital into the sector (see Mehta 2004). Whilst the engagement of such corporations is far from unproblematic, and the issue of whether water supply services should be a public or a private responsibility is still hotly debated, discussions are often muddled by misconceptions in terms of what is actually at stake. In particular, there has been a protracted and rather polarised debate around whether water should be perceived as a human right or an economic good (see e.g. McNeill 1998; Briscoe 1997; Perry et al 1997), rather than seeing ways to reconcile these views through regulatory action, and concentrating on how to secure poor people's access through technological innovations and regulatory measures. In contrast to the 'water privatisation debates', sanitation is more of a public health issue. Still, many finance ministries around the world have not realised the profound linkages between sanitation, health, human well-being and overall productivity. While 'public' vs. 'private' debates are not so charged in the sanitation domain, one controversial area remains regarding whether or not to use hardware subsidies for toilet construction (Kar and Pasteur 2005; Bongartz and Movik 2009). CLTS, for example, has traditionally eschewed hardware subsidies on the grounds that this removes a sense of ownership over the toilets and does not guarantee their use. Instead, it draws on 'private' initiative in terms of enlisting NGOs and spurring community collective action, which in turn opens up questions about the role of the state versus other actors in realising the human right to sanitation.

SCARCITY AND THE IWRM NARRATIVE

In water debates, scarcity is usually taken to be natural and a given and solutions are usually focus on augmenting or increasing water supply (see Jairath, forthcoming). As a corollary of the increased perceptions of water scarcity, the notion of Integrated Water Resources Management (IWRM) (see e.g. Jonker 2007; Gyawali et al 2006; Global Water Partnership 2000) has attained a hegemonic status in the realm of water management. The idea of integrated management is not new; it has a rich history spanning the multi-purpose use of rivers in the ancient world to the emergence of river basin organisations in Europe and other contexts in the 19th century that focused on facilitating integrated management (Delli Priscoli 1998). Currently, however, IWRM has 'become *the* discursive framework of international water policy – the reference point to which all other arguments end up appealing.... IWRM combines intuitive reasonableness, an appeal to technical authority, and an all-encompassing character of such great flexibility that it approaches vagueness' (Conca 2006: 126-127, emphasis in original). IWRM and the associated concept of Integrated River Basin Management (IRBM) are central themes of many policies and water legislations, and 'feature as the guiding philosophies of the international donor community's approach to water' (Lankford and Hepworth 2007: 4). The IWRM approach often tends to be rather technocratic, focusing on the implementation of particular requirements and thresholds that are to guide water allocation and management in river basins. The contrast tends to be quite great between European river basin management in temperate climes, and the vast basins in developing regions that are often prone to high variability and unpredictability. The hierarchical structures of basin management, with an apex body that oversees and regulates formal water rights tend towards rigidity and technocratisation that seldom work well, due to a dearth of capacity, lengthy, costly and complex litigation processes, patchy legal frameworks, etc. The idea of such apex bodies – river basin authorities, catchment management agencies, etc – being the most 'natural' institutional framework for water resources management in river basins has become received wisdom, but is being increasingly challenged (Warner et al 2008) Emerging research in developing countries highlights that the uncritical adoption of IWRM only becomes another arena for the State and other authorities to assert territorial control over water resources despite claims of consultation and participation (Sitorus 2009).

IRRIGATION

Due to the pressing problem of food security much has been made of the need to expand irrigation, and increase irrigation efficiency in order to get 'more crop per drop' (IWMI 2004). This is especially the case in Africa, where agriculture accounts for some 85 per cent of all water use on the continent (though there are huge regional variations) (UNEP and AMCEN 2002). Africa also boasts some of the largest watercourses and natural storage reservoirs in the world, but many areas still suffer from acute water stress. In 2005, the Commission for Africa, concerned about the lagging performance of agriculture, pointed out the need to ensure more sustained agricultural production to increase food security and foster development. The report focused on the challenges of increasing spending on physical irrigation infrastructure and extending the area under irrigation to twice the current coverage (Commission for Africa 2005: 73), noting that just 7 per cent of Africa's arable area is under irrigation compared to 33 per cent for Asia. Does Africa need a 'blue revolution'? (Movik et al 2005) The emphasis of the Commission's report was largely on creating new infrastructure as opposed to looking at the social and institutional aspects of water management, or indeed on enhancing the potential of dryland agriculture. Often, extending irrigation infrastructure tends to mean building large dams with associated massive canal networks, a topic to which we now turn.

REVISITING DAMS AND DEVELOPMENT

Dams, once considered temples of modernity (to paraphrase Jawaharlal Nehru) emerged as technological triumphs in the 1950s, but by the end of the 1980s scepticism began to mount against

dams as their negative social and environmental impacts came into focus. Campaigns were organised to argue the case for resettled peoples, such as the Narmada Bachao Andolan in the case of India's Narmada dam, which received much media publicity (see Mehta 2005). In response to the increasing criticisms against dams, the World Commission on Dams was formed in 1998, and the final report published in 2000 (World Commission on Dams 2002). The report, in a pragmatic but critical tone, discussed the various ramifications around dams and largely succeeded in raising questions regarding the notion of the large dam as the panacea to address water scarcity. The conclusions of the WCD, however, were openly rejected by dam-building nations such as China, India, and Turkey and also to some extent by the World Bank, which had played a key role in the entire two-year process of the Commission's work. The criticism of dams has often been seen by local stakeholders as attempts to subvert development – particularly by elites in many countries in the global South, who often hold that 'anti-dam' NGOs are more concerned about ecosystems and environmental impacts than development to meet growing water and energy needs (Alhassan 2009). Of course, the proposition of dams as development is itself contested. Some argue that dam projects that displace millions, are unequal in their spread of pains and gains, and have several unintended consequences such as disease spread and long term environmental impacts, cannot therefore be considered development projects (see Mehta 2009). However, while Western countries now balk at the prospects of investing in risky dam projects, China willingly makes available low-interest loans and concessions to construct large dams and other infrastructure in Africa and countries in the global South (Wild and Mepham 2006; Kaplinsky et al 2007, in Alhassan 2009: 148). After more than a decade of investment dry-up, Chinese funding is making dam construction possible again, sparking Western fears of a new neo-colonialism, a fear some say is fanned by the narrative that 'the future is Asian' (Ely and Scoones 2009). Thus, the controversy around large dams to a certain extent captures the dilemmas faced by every society, and goes to the core of what is meant by development, and the 'very meaning, purpose, and pathways for achieving development' (Alhassan 2009: 151).

SHAPING THE FUTURE – THE THREE D'S: DIRECTIONALITY, DIVERSITY AND DISTRIBUTION

Having considered some of the major issues and controversies framing water and sanitation issues at present, it is prudent to reflect on the shape of the future; what innovations and pathways open up people's access to water and sanitation? As Stirling notes (2009: 1), 'Rather than restricting policy considerations to questions over the pace, efficiency and consequences of proceeding in any particular direction (often taken as a given), there is a need to give commensurate attention to the nature of the direction itself (...)'. Questions also need to be asked in terms of the directionality of particular approaches – who is shaping the way things move, how, and for what reasons? Moreover, encouraging diversity is key; experience amply demonstrates that 'one-size-fits-all' solutions tend to flounder as they fail to acknowledge contextual diversity. With respect to distribution, it is vital to consider how opportunities for survival and economic, environmental and social well-being are distributed in a particular society, and against which any large-scale prospects for change should be assessed.

For example, the focus of the MDGs has very much been on the pace and scale of reaching the goals, and while relatively less attention has been paid to *how* these are to be reached, i.e. the directionality of the efforts to achieve the goals. Though meeting the MDGs is a praiseworthy effort, it has come under criticism for becoming too focussed on the indicators and not enough on the process and direction of development (Tearfund 2004). This has led to hasty, often top-down projects that ultimately fail because they do not pay attention to people's actual needs. The CLTS approach is promising in that it offers a new and decidedly bottom-up approach to sanitation. Even though CLTS has had a big impact so far, there are still challenges aplenty. One of the major challenges revealed by research is the fact that although many villages become open defecation-free after having gone through the motions of CLTS, they are not able to remain so. Often, villagers state that they revert to

open defecation because their latrine constructions broke down due to torrential rains or other environmental factors, or simply that the pits filled up. Though the emphasis in CLTS is to draw on local resources, a 'second phase' or 'wave' of CLTS should focus on technological innovations that are adapted to particular climatic conditions. Sharing is key, as finding ways to create institutional frameworks that can help foster and share technological innovations and knowledge about sanitation more generally are also vital (Mehta and Movik forthcoming). Informal 'centres of excellence' (Leach and Waldman 2009) could be a way forward here, offering the potential to bring together diverse approaches and technologies, such as CLTS and eco-sanitation, to create innovative ways of dealing with sanitation. Moreover, it is necessary to interrogate the 'purist' stance of some advocates (Musyoki 2007) so that the evolution and diversification of CLTS is not blocked. Also, CLTS tends to focus on rural areas; but peri-urban slums pose a major challenge given the accelerating trends of urbanisation. Rather than pursuing a unitary approach, it should be a goal to encourage diversity and innovation.

With respect to the privatisation debates, the polarised positions arguing for and against privatisation *per se* tend to detract away from the real issue at hand; what works best in which context? How can the focus on harmonisation and standardisation be opened up to a more diversified array of options to ensure people's access to water? The notion of public-private partnerships have gone some way in bridging the staunch divide between pro- and anti-privatisation advocates, but as Budds and McGranahan (2003) ask, are these debates really missing the point? Of course, distributional concerns are valid in terms of the widely-held view that private suppliers are only interested in profit maximisation, and therefore will marginalise poor people further (in some cases even shutting off their water supplies). Such issues can in principle be solved through regulation. Still, research on water privatisation in the West highlights that truly independent regulatory frameworks are often few and far between - in Britain, a proper system of regulation of water took several decades to achieve (Mehta 2004). Also the focus on privatisation ignores the crucial and often problematic role played by informal providers who abound in rural and peri-urban areas. Their services are very expensive and the quality is questionable, but there are often no alternatives because it is notoriously difficult to provide infrastructure and services in rural areas, with scattered populations (ibid.). Peri-urban settings also pose particular problems, due to ad-hoc settlements not connected to the pipeline system. The problem is not so much who is the provider, but the nature of and scope of provision itself. Peri-urban areas are often seen by policy makers as 'temporary spaces' and thus fall between the cracks of administrative and institutional jurisdictions. Thus there is a lack of responsibility for water and sanitation provision in these areas, and more attention is required to address the specific needs of populations living in such areas. Finding innovative ways of serving needs should be the key focus. Multi-purpose designs accommodating both domestic and productive needs (see e.g. Van Koppen et al 2006; Moriarty et al 2004) may offer opportunities that should be explored more thoroughly. More focus should also be given to how providers conceptualise technology; how factors influence which technologies are chosen and to what extent consumers are able to influence technological designs and their fit with the local environment and needs. The focus on 'optimality' (Stirling 2009: 2) may be blocking innovative ways of addressing water services issues, such as communities developing their own technological solutions to address the supply problem (see e. g. Malzbender et al 2005).

Water scarcity continues to be a defining factor of water debates and reform efforts, and the narrative of IWRM has become *the* paradigm within which water resources management is framed. This in turn has led to a preoccupation with attaining technological control over water resources, in terms of facilitating and supporting the institutionalisation of formal regulatory systems, including administrative water use rights (see e. g. Movik 2008). However, within this focus, technologies of access have often been overlooked. The question is, to paraphrase Lankford, whether the sights for regulatory water management are set too high, and whether the way IWRM and IRBM are being externally framed actually restrict creativity and action amongst developing country water resource practitioners? (Lankford and Hepworth 2007). The reality is that water reform has not in practice opened up access of water to new stakeholders. If the water reforms are to lead to significant

agricultural development among small-scale and communal farmers, the reforms have to confront and take cognisance of the historical legacies that define much of Southern Africa, particularly in Zimbabwe, South Africa and Namibia, where the legal and administrative frameworks governing ownership, access, control and use of water favoured the elite – often racially defined – interests (Van Koppen 2007; Mtisi and Nicol 2003). With such skewed access typifying past arrangements, recent water reforms hold little promise for African agriculture, particularly if the reforms are implemented in a context of structural inequities of ownership and access to land.

Regarding irrigation, whilst the renewed focus on increasing agricultural productivity is to be welcomed, care should be taken in terms of regarding irrigation expansion as the new 'silver bullet' (Brooks et al 2009). Though irrigation is an important component of increasing agricultural productivity, it is not the only answer. Concentrating narrowly on the physical aspects of supply infrastructures may detract away from other important aspects, such as the timing, reliability and efficiency of supply. Furthermore, there is a wide range of technological options that could be pursued in the interests of increasing productivity, including the supplementing of rain-fed agriculture with simple technologies such as treadle pumps, the 'bucket and drop kit', collector well technologies and sprinkler irrigation (Lovell et al 1996). Other options include enhancing cropping techniques, such as that developed for the system for rice intensification (SRI), which may hold much potential (Prasad and Basu 2005), and effectively utilising Africa's floodplains and better agronomic practice; e.g. mulching and zero tilling, spacing and plant management systems, as well as increasing the drought resistance toward more tolerant of saline/low-quality water (IWMI 2004). In US President Obama's words:

> There is no reason why Africa cannot be self-sufficient when it comes to food. It has sufficient arable land. What's lacking is the right seeds, the right irrigation, but also the kinds of institutional mechanisms that ensure that a farmer is going to be able to grow crops, get them to market, get a fair price.

(US President Barack Obama, 10 July 2009, G8, Italy, quoted in Lankford (2009: 1))

But as Lankford points out in a reflective piece (Ibid.), finding the 'right irrigation', although it sounds straightforward enough, is anything but. For the last 20 years, funding for irrigation has been reduced to a trickle, due to disappointing results and poor returns on huge investments, and the term 'irrigation' has almost disappeared from development debates. Consequently, there has been scant attention to irrigation in research and education. There are few international NGOs working on irrigation, though there has been a smattering of formal policy interventions and farmer initiatives. A much-favoured category of technologies is the so-called 'micro' technologies aimed at smallholders, such as treadle pumps (most suited for growing vegetables) and bucket storage. However, the energy required to operate a treadle pump is equivalent to having to climb 1000 metres each day to irrigate half a hectare. In Lankford's opinion, treadle pumps 'are best left to entrepreneurs to sell and for smallholders to judge.' (Ibid.: 1). Another option attractive to policy-makers is 'irrigation improvement', where donors rehabilitate existing traditional systems into more 'modern' ones – which may in fact have detrimental effects, as it weakens the existing social structures of maintenance and governance. Indeed, specialists may be able to pick up a thing or two from observing local artisans at work. Other popular technological options are sprinkler and drip irrigation systems, but these quite high-tech options often are associated with high electricity and maintenance costs. There is a need to steer away from the preoccupation with the technological solution *per se*, and to look at the contextual factors that determine its appropriateness, to ensure that it is the end users – the farmers, peasants and smallholders - who ultimately decide the direction of appropriate options among a diversity of technological innovations.

With respect to *distribution*, the dams and development debates are perhaps the starkest examples of distributional issues. Much of the controversy around dams has focussed on how unevenly the benefits and costs – social, economic, environmental, health – have been distributed. As observed

earlier, water management debates are re-engaging with large infrastructure projects, a main argument being that water storage is a critical issue in helping achieve macro-economic stability, particularly in the many sub-Saharan African countries subject to highly variable rainfall regimes. The World Bank's lending for hydropower projects decreased by 90 per cent over the last decade largely due to the fact that such projects were viewed as high-risk ventures, especially concerning social and environmental impacts (World Bank 2003). However, the Bank's renewed promotion of large dams as a solution to scarcity and variability is controversial, even stirring *The Economist* (2004) to decry the 'ominous revival' of large-scale infrastructure projects in development. A renewed emphasis on large-scale infrastructure projects in the absence of effective institutions for cooperation may increase political disputes between governments. Such political disputes, however, may often play out covertly, as it is often the case in transboundary settings that the power balance between countries sharing a watercourse is highly unequal, with the weakest party often resorting to alternative solutions to address water shortages, such as virtual water trading, to avoid open conflict. Revealing such power asymmetries thus becomes of even greater import in terms of mapping issues of distribution (Zeitoun and Allan 2008).With respect to the issue of large-scale infrastructure itself, asking questions around directionality help us to ask who is pushing large dams and why? Are there other more equitable and environmentally friendly options to enhance access to water rather than merely augmenting supply through infrastructure development? What is the role of science and technology in mitigating harmful effects from the past? What lessons can be learnt from the Asian experience of large-scale dam and irrigation development?

RECENT INNOVATIONS

RAINWATER HARVESTING AND SMALL-SCALE WATERSHED DEVELOPMENT

One alternative to large-scale infrastructure development is catching and harnessing water locally. Examples abound of rainwater harvesting helping rivers to revive in Rajasthan, India, and helping to supplement small-scale agriculture in the central regions of South Africa (Botha et al 2007) . Small-scale watershed development has a great potential to harness water locally whilst avoiding all the social and environmental problems of large-scale dam and irrigation development. It entails local technological innovation in creating new and locally suitable form of micro hydro-development projects. However, small may not always be beautiful, and clearly those who benefit most from small hydro-schemes are not necessarily the poor and the marginalised. Research from India reveals that here, too, it is the landed and well endowed who benefit (Mehta 2005). Challenges also remain regarding the role of local entrepreneurs, institutions and knowledge sharing.

DESALINISATION

Considering the fact that most of Earth's surface is water, some engineers dream of being able to convert that salty expanse into freshwater suitable for human consumption or for irrigating crops. However, the dream is a highly energy-intensive and expensive one, and it is far more costly to remove salt from seawater than to use water from rivers or underground aquifers. Some countries in the Middle East that suffer acute water scarcity and that also possess the necessary resources have funded the construction of desalinisation plants of some magnitude. But, while seawater desalinisation has long been the 'holy grail' of water supply, the prohibitively expensive costs, the often ineffectual implementation of desalinisation plants and the lack of clear judgement and guidance have made it an elusive goal in terms of providing viable solutions for supplying water in arid areas, particularly in the developing world. It would appear more fruitful to pursue alternative approaches, such as finding cost-efficient ways of treating low-quality local water sources, and focussing on ways to conserve, recycle and use water more efficiently, as well as considering more optimal land-use practices (Cooley et al 2006).

CERAMIC AND UV FILTERS AND REVERSE OSMOSIS

More low-key technologies that have recently emerged include ceramic filters and ultraviolet (UV) filters. The ceramic filter technique was pioneered by Dr. Fernando Mazariegos at the Central American Industrial Research Institute (ICAITI) in Guatemala in 1981, an initiative that helped to spawn the formation of the organisation Potters for Peace. The technology is very simple, relying on low-cost and readily available materials, and can be fabricated by communities with only limited resources (see Potters for Peace). UV filters are more elaborate. The principle underpinning the technology is that proper exposure to ultraviolet radiation can kill off disease-causing bacteria in water sources. Currently, the filters are produced by several companies, and are distributed to a number of developing countries where communities or franchisees purchase the product for further distribution. Training and the appropriate use of technology are important components as the end users need to be able to operate the filters, again raising the question of how to create effective institutional frameworks for knowledge-sharing and training (Committee on Creation of Science-Based Industries in Developing Countries 2007). Local entrepreneurs in peri urban areas of Delhi are also using reverse osmosis technology to ostensibly improve water quality (Sharan et al 2009). However, the charges for this water are often exorbitant and largely only serve the rich who reject state supplied water in favour of water coming from privately operated water plants. It is also unclear whether the quality of this water is any better than state supplied water (ibid).

INNOVATIVE TOILET DESIGNS

While ecosanitation technologies mainly emerged in the North and were later introduced into developing countries, there are several striking examples of local innovators who design their own toilet structures. Such 'barefoot engineers' (Kar and Pasteur 2005) in rural Bangladesh have developed hundreds of creative and low cost toilet models that have helped make thousands of villages 'open defecation free'. These barefoot engineers have also emerged as trainers and helped diffuse CLTS from region to region and country to country. More learning, exchanges, training and sharing amongst these local engineers would help enhance the technological sustainability of these constructions, which continue to remain a challenge.

FUTURE CHALLENGES

An emerging challenge in the water and sanitation domain is coalescing around the notion of the impact of climate change on hydrology. The unpredictability and variability of water resources are likely to be further accentuated through the effects of climate change. Climate change has been high on the agenda for a long time, but the links between climate and hydrology have been rather neglected until recently. Koutsoyiannis et al (2009) argue that climatologists have something to learn from hydrologists in terms of modelling philosophy; where climatologists focus on predicting the nature and scale of change, hydrologists – long used to coping with variability and complexity – focus on estimating *the degree of uncertainty*, which is what the current technological know-how allows us to do. Further, they argue that climate change research, though justifiable, risks drawing attention away from equally crucial issues in water, such as pollution, unequal distribution, etc. Water is inherently a dynamic resource, and though climate change is likely to accentuate such dynamics and incertitude, it might be better to focus on how people are already adapting to unpredictable circumstances. There is a significant body of ethnographic research on how local people adapt to uncertain and variable water supplies (For example, see Mehta 2005 for details of the case of climate variability in Kutch, India) and these local perspectives need to inform more macro debates concerning climate change. Some argue that groundwater offers a buffer to stave off the impacts of climate change, but viable technologies for utilising such fossil resources in a sustainable manner still need to be developed.

There is, then, plenty of scope for thinking outside the conventional box and encouraging innovative ways of dealing with current problems in water and sanitation. Rather than the historical preoccupations with technologies of control (water resources), or top-down standardised systems of service supply (drinking water, sanitation facilities), the focus needs to shift towards dealing with the diversity of contexts and the variability and incertitude in terms of ensuring access to water and sanitation. There are no 'silver bullets' (Brooks et al 2009) in the water and sanitation realm, but a wide range of potential options that must be attenuated to the particular challenge and its context. A cross-cutting theme that is emerging through this brief analysis is the notion of *technologies of access*, and how the often narrow focus of particular narratives and associated policies have tended to neglect this issue which should be a key concern for future innovation and research. Also, the history of formal interventions needs to be reassessed, and new forms of generating, spreading and sharing knowledge investigated. This should be done by bringing on board the entrepreneurs and the users of technologies themselves – which calls for innovative thinking in terms of institutional frameworks. Questions that should be explored further include: What is the potential of deliberative processes in terms of assessing technological and institutional options? How can research engage more fruitfully with technological entrepreneurialism? How can innovative technologies be made to 'go with the flow' rather than be pushed, to stimulate and nurture more diversity and innovative ways of generating, gaining and sharing knowledge on particular problems and ways to solve them? It is not only about meeting the MDGs, but also bringing about fundamental changes in the way water and sanitation challenges are approached that can help foster more sustainable, long-term solutions.

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