## Sanitation and climate change adaptation

Louiza Duncker (CSIR BE)

### Introduction

Climate change is a natural process; however, human activities are contributing to its relentless acceleration. With likely long-term changes in rainfall patterns, rising temperatures and shifting climate zones (IPCC, 2013), climate change is expected to increase the frequency of climate-related shocks, which in turn will put pressure on food, energy and water supply. Water is a key resource for sustaining life and society. No community and no economy can survive without water of sufficient quality and quantity for the purposes needed. Water is becoming more and more polluted by human activities due to wash-off in areas with inadequate sanitation and open defecation practices, and due to a number of wastewater treatment plants that are unable to cope with the increased volumes of wastewater from rapidly growing urban areas (DBSA, 2013).

Whilst nature-based, infrastructure-based and technology-based adaptation are important, it is the human factor that rocks and sinks the boat. Technology-based adaptation interventions can only be partially effective if they do not also address factors that are the underlying contextual drivers of vulnerability to climate change (USAID, 2015). For example, the implementation and effectiveness of non-conventional toilets is limited by their acceptance in a community, which in turn depends on their needs, aspirations, and cultural preferences (Duncker, 2017; Duncker, 2014; Duncker & Matsebe, 2008), as well as its costs, ease of use and maintenance, and access to spare parts and service support.

Even though technology can increase the effectiveness of adaptation, it will not solve all the uncertainties associated with climate change and sanitation. It needs to be combined with other enabling mechanisms to be effective in reducing vulnerabilities and building resilience. Given the many relationships between the impacts of climate change, the water and sanitation sector, as well as the social and economic systems, adaptation cannot be implemented efficiently by itself or as a strictly technical or environmental issue (Howard *et al*., 2010). Long-term, sustainable adaptation to climate change requires Integrated Water Resources Management (IWRM) that promotes the coordinated development and management of water, land and related resources, in order to maximise economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems (Slootweg, 2009; DWA, 2013, Kohlitz, Chong & Willets, 2017). The National Climate Change Adaptation Strategy supports this by recommending that adaptation should go beyond the biophysical and economic variables and should respond to the triggers and processes that define and influence changes in decision-making and action (DEA, 2017).

The purpose of this chapter is to raise awareness about the effects of climate change on the sanitation value chain, and the importance of community-based climate change adaptation regarding sanitation. Sanitation infrastructure is important, but what people do and their attitudes and behaviour regarding sanitation in the changing climate is crucial. An environmental scan has been conducted to obtain a delineation of the issues regarding sanitation and adaptation to climate change. The environmental scan involves using various sources of information, such as academic and grey (popular) literature, press releases, newsletters and journal articles; key word internet searches; proceedings of conferences or seminars; and tracking blogs. Analysis and synthesis of the information follow the scanning. The loop stays in play, directing further scans (Gordon & Glenn, 2009).

### Background

Water and climate change are inextricably linked, as the effects of climate change are first felt through droughts, floods and storms. These disasters can destroy water supplies and toilets, or can leave behind contaminated water, endangering the lives of millions of people (UNICEF, 2016; Hutton & Chase, 2016; SAHRC, 2014; Braks & de Roda Husman, 2013; Howard *et al.* 2010; OHCHR, n.d.). In September 2015, the United Nations endorsed the Sustainable Development Goal 6 *(Ensure availability and sustainable management of water and sanitation for all*). This goal cannot be met without explicitly recognising climate change as a key component (UN, 2015).

Rapid urbanisation and population growth is putting extraordinary demands on water, accompanied by the disposal of equally large volumes of wastewater into rivers, dams and the groundwater (WWF-SA, 2016; UN-Habitat, 2018; Miller & Hutchins, 2017). Faecal waste and raw sewage are present in the environment often due to a lack of adequate toilets, or poor quality toilets, broken sewers and inadequate or overburdened wastewater treatment systems (DBSA, 2013). This contributes to contamination of surface and groundwater, thus impacting on the wellbeing of humans and wildlife.

Even though greenhouse gas emissions from septic tanks, pit toilets, and open-air defecation are largely unquantified, emissions from wastewater are expected to rise by almost 50% by 2020 (Bates *et al*., 2008; Bogner *et al*., 2007; Fischedick *et al*., 2014), with developing countries being the primary contributors due to the larger number of septic tanks and other on-site sanitation facilities and practices. Good wastewater management does reduce greenhouse gas emissions and therefore it can be assumed that these levels of emissions may decrease as sanitation coverage increases (El-Fadel & Massoud, 2001; Prendez & Lara-Gonzalez, 2008). However, sanitation and wastewater management poses a number of operational challenges. Studies showed that 80% to 90% of all wastewater generated in developing countries is discharged without proper treatment into surface water bodies (UNESCO, 2017). With increasing population growth, urbanisation and industrialisation, the collection, treatment, and disposal of increasing quantities of wastewater remains a major challenge for municipalities and utilities in both developed and developing countries.

Climate change not only affect lives and livelihood but also make social and socio-economic system of the country vulnerable. As a result, social discrimination, deprivation, dissatisfaction, unacceptability and migration are increasing significantly (WaterAid, 2012).

The National Climate Change Response Plan White Paper of South Africa (DEA, 2017) defines government's vision for effective climate change response and transitioning to a climate-resilient, low-carbon economy. The National Climate Change and Health Adaptation Plan of the National Department of Health adopted community participation as one of the guiding principles for implementing the Plan, especially as behavioural change is likely to be important for adaptation and coping strategies (Garland, 2014).

## Climate change and sanitation infrastructure

Climate change is already a major pressure on wastewater infrastructure. Excess rain (too much water) or drought (too little water) can lead to threats for sanitation ranging from increased concentrations of pollutants (with negative health consequences), a lack of adequate water flow for sewage, and flood-related damage to physical assets (Sinisi & Aertgeerts, 2011; Midgley *et al*., 2005). The consequences of the increases in average and extreme temperatures that are projected by climate models are the changes in the incidence of several critical excreta-related diseases; an increase in water consumption (this is also impacted by the availability and quality of water supply which in turn is influenced by the climate); and the extent and rate of algal growth in nutrient-enriched surface waters (Arouja, *et al*., 2016).

While there is an abundance of toolkits and guidelines internationally on climate change adaptation in general, there is remarkably little on specifically sanitation (Fankhauser & Burton, 2011). The little on sanitation that exists focus mostly on system vulnerability and technical change as adaptation measures. At the National Sanitation Indaba on 18 May 2015, the then Minister of Water and Sanitation also focussed on technical adaptation by saying that: *"We must introduce new technologies that appreciate that water is a scarce resource and as such provide solutions to dispose of effluent via alternative methods. It's not all about flushing and that is the Sanitation Revolution we are here to instigate,"…."We must begin by challenging the property development sector through regulation and licensing requirements to invest itself in developing properties less reliant on water for sanitation in order to ensure we introduce the alternative solutions to low, middle and high income areas*" (https://www.gov.za/speeches/national-sanitation-indaba-18-may-2015-0000). The National Sanitation Policy (DWS, 2016) supports this approach in saying that the long-term effects and impacts of climate change on the sanitation services sector need to be understood and means to avoid, minimise and mitigate these effects need to be incorporated into policy and legislation with special attention to enhancing the capabilities of communities to adopt climate resilient sanitation technological options.

Generally sanitation technology refers to everything from toilets to sewerage to domestic wastewater treatment plants. These technologies are part of the sanitation value chain, which forms the basis for sanitation services delivery. The sanitation value chain comprises broadly of collection/storage; transport/conveyance; treatment; distribution; wastewater treatment; and discharge/disposal or recycle/re-use. Each link of the chain is highly vulnerable to the effects of climate change – some examples of infrastructural vulnerability are given below.

- Collection/storage/emptying

  In settlements not served by sewerage systems, sanitation may be based on on-site systems, such as pit toilets, bucket toilets or flush toilets connected to septic tanks, which are highly susceptible to adverse weather conditions and climate change as they can become flooded, overflow and pollute the environment (USAID, 2015), causing contamination at the local level; and wash out and destruction of sewers and treatment plants (Fewster & Smith, 2012). Flooding may also result in the areas with on-site sanitation becoming isolated, leading to them not being be emptied, as well as an increase in transport costs for trucking excreta due to flooded roads and access points. Where changes in climate result in increased waterlogging, it is likely to cause pits, tanks and sewers to be inundated with groundwater, which will impact on treatment processes as well as the groundwater (Franceys, Pickford & Reed, 1992). Flooding from sea level rises can lead to inundation of pit toilets, and/or sewage treatment facilities, which increases the risk of contamination of the environment (Howard & Bartram, 2010).

- Transport/conveyance

In urban areas, sewage is typically conveyed through a system of pipes, pumps, and other associated infrastructure to a centralised storage and/or treatment system. These sewer systems may be damaged by adverse weather conditions and cause uncontrolled discharge of domestic wastewater, including sewage and greywater, into aquatic systems (DEFRA, 2012), which can lead to microbial and chemical contamination of the receiving water, oxygen depletion, increased turbidity, and eutrophication (Howard *et al*., 2016). As the sewer infrastructure ages, it becomes vulnerable to infiltration of groundwater, contamination of groundwater and pollution of the environment (UNFCC, 2017). Wastewater discharge onto streets or open ground can contribute to spread of disease, odours, contamination of wells, deterioration of streets, etc. (DWS, 2016; EPA, 2004). Prolonged periods without any rainfall cause the degradation of sewers and the resulting accumulation of solid waste sediments and encrustation in sewers that can clog them and attract an increasing population of rodents; a decrease in wastewater flow and unpleasant odour from water rotting in the system; and a growing risk of disease dissemination (Sinisi & Aertgeerts, 2011).

- Treatment

Sewage treatment plants are often positioned on low-lying ground, as sewerage systems rely on gravity, but this puts them at risk when water levels rise due to flooding or sea-level rise. Declining annual rainfall and/or drought leads to insufficient water resources being available to flush sewage systems adequately, and accompanying higher temperatures can have an impact on how sewage systems operate. Every extreme in hydrology (flooding or drought) causes fluctuations in pollutant concentrations in wastewater inflow to the wastewater treatment works and adversely affects the efficiency of the treatment processes (Howard *et al*., 2016). The differences in biochemical load cause problems in different technological sections and related treatment processes. Lower oxygen solubility in water can lower the efficiency of active sludge compartment (Sinisi & Aertgeerts, 2011). Sea level rise threaten coastal zones due to saline intrusion and damage to wastewater treatment works from inundation during coastal storms (Oates, *et al.*, 2014).

- Discharge/disposal

Flooding and drought affect the receiving body as the quality of the effluent vary depending on the volume of water in the receiving body (Miller & Hutchins, 2017). Drought reduces the capacity of surface water to dilute, attenuate and remove pollution (DWA, 2013).

## Climate change adaptation options for sanitation

The Intergovernmental Panel on Climate Change (IPCC) released a report stating that future climate-related risks could be reduced by the upscaling and accelerating multi-level and cross-sectoral climate mitigation, as well as both incremental and transformational adaptation (IPCC, 2018). Adaptation is a broad concept covering actions and interventions by individuals, communities, private companies and governments. Adaptation actions can range from nature-based to infrastructure-based solutions (UNFCC, 2017). Nature-based solutions include plant cover expansion, coastal resource management, and mangrove and natural reef ecosystem protection. Infrastructure-based solutions comprise climate-proofing infrastructure, including storm drainage systems, water supply and treatment plants, as well as the protection or relocation of energy or solid waste management facilities (UNFCC, 2017).

The most common and most mentioned adaptation options for sanitation identified in the environmental scan are the following:

- *Appropriate and effective technology*

Appropriate and effective sanitation technology can minimise the dependency of settlements on rainfall or their vulnerability to extreme weather events. For example, on-site and decentralised sanitation solutions could be more systematically investigated, even in large cities. Sewerage systems are not always the ultimate sanitation solution as they are generally too expensive for locally available funds (Gabert, 2016). A focus can be placed on modular, decentralised, energy-efficient wastewater treatment technologies (Howard & Bartram, 2010; Massoud, Tarhini & Nasr, 2009) and no-water sanitation facilities, where appropriate, to conserve water and to reduce public safety risks in the event of failure due to climate shock. Decentralisation means that the service is not dependent on a centralised hub or main area to function, thus if the main hub is destroyed or damaged due to adverse climate conditions, the decentralised service provider responsible for daily and vital services to communities is still able and operating (USAID, 2015). Sanitation facilities should not be located in or near flood plains, rivers and wetlands, to prevent flooding. On-site sanitation solutions, especially ecological sanitation, are more resilient to climate change (Nadkarni, 2004) owing to decentralisation and ownership of operation and maintenance. Encouraging low-income residents to empty their pit toilets before the rainy season starts reduces the amount of faecal waste flowing into streets and spreading through communities during periods of flooding (WSUP, 2018b). Wastewater treatment plants could improve the energy efficiency of their operations to reduce demands on fossil fuel energy sources. They could also produce renewable energy using biogas, solar, and wind, to reduce their greenhouse gas emissions (WRC, 2017).

- *Building robustness, i.e. hardening infrastructure*

More robust sanitation infrastructure is more likely to ensure resilience to climate change (Venema & Temmer, 2017; Ministry of Interior, Hungary, 2011). For example, design and siting of sanitation facilities in coastal areas should take into account projected sea level rises and storm surges. Storms, heavy rainfall events and a higher frequency of flood events require protection of drainage systems, sewer systems and wastewater treatment works against inundation; high peaks of hydraulic load; and damage (Sinisi & Aertgeerts, 2011), such as constructing barriers and retaining walls, ensuring emergency back-up generation, and keeping key electrical equipment elevated.

- *Optimal resource use and re-use*

In many cities, around 50% of water can be lost before it even reaches customers (WSUP, 2018a). Non-revenue water has a crippling effect on the availability of water, as well as water for flushing toilets and washing hands. As droughts become longer and more frequent, leakages must be reduced and available water needs to be used optimally. Creative re-use of wastewater and sludge minimise reliance on conventional sanitation services and centralised sewer networks that are vulnerable to climate change. Greywater re-use and composting of human waste for fertiliser apply water, energy and nutrient recycling principles that are crucial for resilience to climate change (WRC, 2017). Energy recovery, such as biogas, can generate thermal and electrical energy for the internal usage of biogas plants, thus reducing operational demand (Jordaan, 2018; GIZ & SALGA, 2015; DWA, 2013). Resource extraction from sludge (e.g. fertiliser) is already being done at a number of wastewater treatment works. Water reclamation, particularly in acid mine drainage and desalination can be done (GreenCape, 2016). In 2013, the National Strategy for Water Re-use was developed to better inform decision-making for the implementation of water reclamation projects (DWA, 2013).

- *Policy and economic instruments*

National and local role players and the international community should be made aware of the need for realistic and adapted sanitation planning and solutions. Sanitation policies and strategies, climate adaptation plans, and carbon emissions reduction strategies will be more effective and equitable if all role players are fully involved throughout the adaptation processes, i.e. an integrated and holistic approach, which can result in better climate agendas (WSUP, 2018a). Climate financing can be an incentive to drive the joint development and climate actions that are needed to achieve universal access and build climate resilience (WaterAid, 2016).

- *Monitoring and evaluation*

Monitoring and evaluation (M&E) is essential because of the complexity and inter-related nature of climate change adaptation measures, and the number of stakeholders involved with its execution. The Global Water Partnership (GWP) and UNICEF (2017) state that M&E is vital to know which interventions worked and why, and what needs to be adjusted. Strong monitoring and information management systems will enable constant adaptation and the upgrading of plans and activities to effectively track progress, advocate for improved sanitation resilience, and make informed choices on policy and resource allocation (GWP/ UNICEF, 2017). It is important that the data collected and analysed through the M&E system is reliable and credible to ensure that decisions are based on accurate, current and complete information (DEA, 2017). Monitoring systems can put pressure on community members to maintain adequate sanitation standards, as well as pressure on the authorities to provide the necessary supporting inputs (WSUP, 2018a).

## Community based adaptation to climate change

Not only must society limit greenhouse gas emissions and fossil fuel use, but it must adapt to rising sea levels, increased droughts and floods, extreme storm events, all of which affect their vulnerability and adaptability (UNFCC, 2017). Marginalised and vulnerable populations, such as low-income people, indigenous communities, and other disadvantaged groups, generally have decreased resources to adapt to climate change (Levy & Patz, 2015). These populations generally have very little or no input into the decisions that affect their lives, particularly related to sanitation. People in general will put in major effort to make themselves safer, especially if they are provided with the necessary information and resources, but there are limits to what a community or household can do (DEA, 2014). Households can make plans to prevent or prepare for flooding, but they are usually not able to build the stormwater infrastructure that would most effectively mitigate the effects of a flood on their homes and sanitation facilities.

Awareness of the impacts of climate change and adapting to it is wholly dependent on adaptive capacity, especially for the vulnerable systems and groups (Noble *et al*., 2014; Abdul-Razak & Kruse, 2017). 'Adaptation' describes a large set of behaviours and strategies by a variety of actors (Gorddard *et al*., 2016, Rozenzweig *et al,* 2015). Adaptation needs vary with the particular climate vulnerability experienced by an area or settlement, including the economic, institutional and socio-economic context (Ancha, Ikyaagba & Tondo, 2017; Smit & Wandel, 2006). Effective adaptation capacity requires that people have assets, flexibility, learning, and social organization, but also the power and freedom of choice to activate adaptation responses (Sorre, Kurgat & Musebe, 2017; Cinner *et al.*, 2018). Good policy, planning and implementation can result in, at best, partial adaptation; there also needs to be intrinsic adaptation where the people affected by climate change alter their own behaviour and environments to adapt (DEA, 2014; Gorddard *et al*., 2016; IPCC, 2018).

Community-based adaptation is essential as a complement to planned adaptation by government. It goes beyond the development of technological solutions to climate change, it endeavours to empower people, build adaptive capacities and reduce vulnerabilities. Community-based adaptation recognises that environmental knowledge and resilience to climate impacts lie within societies and cultures. It recognises the different situations of children, women and other vulnerable groups in society and builds on their specific needs and assets (Ayers & Huq, 2009). This involves incorporating both the function of the sanitation system as well as the vulnerability of users (e.g., women, children, elderly, ill or disabled) into the design.

The focus of community-based adaption is on empowering communities and individuals within communities to take action on vulnerability to climate change, based on their own decision-making processes (Mitchell & Tanner, 2006). "Community-based adaptation can reach the poor by targeting the communities most vulnerable to climate change and developing appropriate adaptation options with them, building on information about community capacity, knowledge and practices used to cope with climate hazards" (Huq, 2008). It operates at the local level in communities that are vulnerable to the impacts of climate change. It identifies, assists, and implements community-based development activities that strengthen the capacity of local people to adapt to living in a riskier and less predictable climate. It generates adaptation strategies through participatory processes, involving local stakeholders and development and disaster risk-reduction practitioners. It builds on existing cultural norms and addresses local development concerns that make people vulnerable to the impacts of climate change in the first place (Ayers & Forsythe, 2009).

The advantages of community-based adaptation are better tailored interventions that consider the needs of different social groups within communities. Constraints are the high cost of local level initiatives - many successful projects have remained islands of success, struggling to be scaled up to a regional or national level. Often there is no link between these initiatives and higher level policy formulation, which limits the potential for mainstreaming (Butterworth & Guendel, 2011). To reduce the vulnerability of people to climate change, community-based adaptation initiatives should (Mitchell & Tanner, 2006; CARE, 2014):

- begin with a thorough understanding of local factors and context – climate change adaptation is sustainable when it is tailored to reflect local realities, including cultural norms and practices regarding sanitation and the timing of livelihood and domestic activities and local planning cycles;
- help communities develop an understanding of the main climate risks and how they impact on sanitation and health (through a learning-by-doing approach);
- promote inclusive and informed participation and decision-making - empowering local stakeholders, including members of particularly vulnerable groups, to participate in and contribute to adaptation processes is more likely to result in local ownership and sustained outcomes;
- emphasise active participation of community members in all stages of an adaptation intervention (design, implementation, monitoring) and use existing social institutions to implement activities;

- encourage the strong participation of women, recognising their role as community resource managers, while also acknowledging their specific roles and vulnerability to climate risks;
- combine different knowledge types – integrating local and scientific knowledge along with information and knowledge from other sources will ensure that decisions about adaptation strategies and plans are robust, locally relevant and responsive to climate change impacts;
- promote social learning in co-generation of new insights and knowledge among multiple stakeholders;
- be flexible in community plans and actions to enable people to anticipate and respond to changes in climate conditions and trends, as well as other changes and opportunities; and
- invest in long-term resilience-building efforts, which also meet immediate development needs for sanitation.

## Conclusion

Sanitation, and its requirement for water, is affected *by* climate change and have an impact *on* climate change. All future sanitation development and technology needs to be sustainable and resilient to climate change. All climate change activity and adaptation interventions for sanitation should take into account the impact on water resources and the water security of individuals and communities.

Climate change affects people both locally and regionally, and participatory approaches need to take a regional as well as local perspective, and provide for better coordination between communities and the government. Whilst local people are aware of changes in their environment due to the weather, they often have little knowledge of the global causes and effects of climate change. Due to the 'top-down' nature of climate change knowledge, people will distrust any initiative that does not address their local priorities. It is thus essential that locally perceived climate problems and priorities are well understood before decision making and action planning takes place. Knowledge, capabilities and adaptive, participative governance make communities and societies more resilient and better able to cope with the uncertainties of future weather events and the impacts of climate change on sanitation (Oates *et al*., 2014). Adaptation approaches that are rooted in local knowledge and coping strategies, and in which communities are empowered to take their own decisions, are likely to be far more successful than top-down initiatives. In addition, communities have the right to participate in decisions that affect them (Warrick, 2009). Sanitation is a very sensitive matter and impacts on every individual. To be left out of the decision making process for something so close will spark protests and non-adoption, resulting in not adapting to climate change.

Community based adaptation can be cost effective economically, socially and environmentally under almost all potential climate scenarios, including when the climate is favourable. Community-based adaptation programmes provide communities the opportunity to participate in identifying priorities, both local and regional, and in planning, implementing, monitoring, and reviewing adaptation, and to link up with the relevant decision-making institutions. The capacity of local organisations and local governments to enable effective participation in decision-making processes need to be strengthened. Flexibility is needed from government to integrate non-governmental and community initiatives in its planning and to allow these initiatives to become common practices. The most effective conditions for adaptation to climate change are a combination of strong, effective government and representative community organisations working together.

No more 'about us without us'.

## References

Abdul-Razak, M. & Kruse, S. 2017. 'The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana'. In: *Climate Risk Management* 17 (2017) 104–122. Published by Elsevier B.V.

Ancha, P.U., Ikyaagba, E.T. & Tondo, M.M. 2017. 'Assessment of Adaptive Capacity of Communities to Climate Change in Mbakaange Council Ward, Vandeikya Local Government Area of Benue State, Nigeria'. In: *Journal of Research in Forestry, Wildlife & Environment* Vol. 9(4) December, 2017.

Araujo, J., Marsham, J., Rowell, D., Zinyengere, N., Ainslie, A., Clenaghan, A., Cornforth, R., De Giusti, G., Evans, B., Finney, D., Lapworth, D., Macdonald, D., Petty, C., Seaman, J., Semazzi, F. and Way, C. 2016. 'East Africa's Climate: Planning for an Uncertain Future'. In: *Future Climate for Africa / Africa's climate: Helping decision-makers make sense of climate information.* Future Climate for Africa. Cape Town.

Ayers, J. & Forsyth, T. 2009. *Community based adaptation to climate change*. Environment: Science and Policy for Sustainable Development, 51 (4). pp. 22-31.

Ayers, J. & Huq, S. 2009. *Community-based adaptation to climate change: an update*. IIED briefing, June 2009.

Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (eds). 2008. *Climate change and water*. Tech. Pap. VI, IPCC, Geneva, Switzerland.

Bogner, J., Abdelrafie Ahmed, M., Diaz, C., Faaij, A., Gao, Q., Hashimoto, S., Mareckova, K., Pipatti, R. & Zhang, T. 2007. 'Waste Management'. In: *Climate Change 2007: Mitigation*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Braks, M.A.H. & de Roda Husman, A.M. 2013. 'Dimensions of Effects of Climate Change on Water-Transmitted Infectious Diseases'. In: *Air and Water borne Diseases* (2013) 2:109.

Butterworth, J. & Guendel, S. 2011. *WASH & climate change adaptation training module: factsheets.* A training module prepared by the IRC International Water and Sanitation Centre for UNICEF and the National Water Resources Institute. Kaduna, Nigeria.

CARE. 2014. *Climate Change: Adaptation planning with communities*. Adaptation Learning Programme, CARE International. Nairobi, Kenya.

Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S., Hicks, C.C, Hughes, T.P., Lau, J., Marshall, N.A. & Morrison, T.H. 2018. 'Building adaptive capacity to climate change in tropical coastal communities'. In: *Nature Climate Change* | Vol 8 | February 2018 | 117–123. Macmillan Publishers Limited, part of Springer Nature.

DBSA. 2013. *Infrastructure Barometer 2012.* Development Bank of Southern Africa Limited. Halfway House, Midrand.

DEA. 2017. *National climate change adaptation strategy Republic of South Africa*. Department of Environmental Affairs, Pretoria.

DEA. 2014. *Climate Change Adaptation: Perspectives on Urban, Rural and Coastal Human Settlements in South Africa*. Report No. 4 for the Long Term Adaptation Scenarios Flagship Research Program (LTAS). Department of Environmental Affairs. Pretoria.

DEFRA (Department of Environment, Food and Rural Affairs). 2012. *National Policy Statement for Waste Water: A framework document for planning decisions on nationally significant waste water infrastructure*. Presented to United Kingdom Parliament in March 2012. London: The Stationery Office.

Duncker, Louiza. 2017. 'The Effect of Consumer Expectations and Perceptions Regarding Sanitation on Access to Clean Water'. In: *The Journal of Ethical Urban Living, August, 2017. Volume 1, Issue 1.* pp 19–36. Center for Cognition and Neuroethics. Flint, Michigan.

Duncker, L. 2014. 'Sanitation: User perceptions and acceptance'. Chapter in: *The Green Building Handbook, Vol 6*. Page 193 - 206. Alive2Green, South Africa.

Duncker, L. & Matsebe, G.N. 2008. 'Prejudices and attitudes towards reuse of nutrients from urine diversion toilets in South Africa'. In: *Conference proceedings for 33rd WEDC Conference*, April 2008, Accra, Ghana

DWA. 2013. The *Second National Water Resources Strategy.* Department of Water Affairs, Pretoria.

DWS. 2016. *National Sanitation Policy*. Department of Water and Sanitation, Pretoria.

DWS. 2015. *Media statement at the National Sanitation Indaba*. https://www.gov.za/speeches/ national-sanitation-indaba-18-may-2015-0000

El-Fadel, M. & Massoud, M. 2001. 'Methane emissions from wastewater management'. In: *Environ. Pollut.* 114:177–85.

EPA. 2004. *Primer for Municipal Wastewater Treatment Systems*. UNEPA, Office of Wastewater Management. Washington DC.

Fankhauser, S and Burton, I. 2011. *Spending adaptation money wisely.* Grantham Research Institute on Climate Change and the Environment Working Paper No. 37. Centre for Climate Change Economics and Policy, University of Leeds, UK.

Fewster, E. & Smith, M. 2012. *Resilient WASH systems in flood-prone areas*. CARE Nederland. The Hague, The Netherlands.

Fischedick, M., Roy, J., Abdel-Aziz, A., Acquaye, A., Allwood, J.M., Ceron, J.P., Geng,Y., Kheshgi, H., Lanza, A., Perczyk, D., Price, L., Santalla, E., Sheinbaum, C. & Tanaka, K. 2014: 'Industry'. In: *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Franceys, R., Pickford, J. & Reed, R. 1992. *A Guide to the Development of on-Site Sanitation*. World Health Organisation (WHO). Geneva, Switzerland.

Gabert, J. 2016. *How to make urban and sanitation planning work? Lessons learnt from West Africa, South East Asia, Madagascar, and Haiti*. Paper prepared for and presented at the 2015 BORDA Symposium. GRET, Nogent-Sur-Marne, France.

Garland, R.M. 2014. 'National policy response to climate change in South Africa'. In: *Afr Med J* 2014;104(8):584. DOI:10.7196/SAMJ.8605.

GIZ & SALGA. 2015. *Biogas potential in selected waste water treatment plants: Results from scoping studies in nine municipalities*. South African-German Energy Programme (GIZ-SAGEN). Deutsche Geselschaft für Internationale Zusammenarbeit (GIZ) & South African Local Government Association (SALGA), Pretoria.

Gorddard, R., Colloff, M.J., Wise, R.M., Ware, D. & Dunlop, M. 2016. 'Values, rules and knowledge: Adaptation as change in the decision context'. In: *Environmental Science & Policy* 57 (2016) 60–69.

Gordon, T.J. & Glenn, J.C. 2009. 'Environmental scanning'. In: Glenn, J.C. & Gordon, T.J., eds. *Futures research methodology - Version 3.0.* The Millennium Project, Washington, DC.

GreenCape. 2016. *Water: Market Intelligence Report 2016*. GreenCape Water Sector Desk, Cape Town.

GWP/UNICEF. 2017. *Monitoring and evaluation for climate resilient WASH.* WASH Climate Resilient Development Technical Brief. UNICEF and Global Water Partnership. https://www.gwp.org/ globalassets/global/about-gwp/publications/unicef-gwp/gwp_unicef_monitoring-and-evaluation-brief.pdf

Howard, G., Calow, R., Macdonald, A. & Bartram, J. 2016. 'Climate Change and Water and Sanitation: Likely impacts and emerging trends for action'. In: *Annu. Rev. Environ. Resour. 2016.* 41:253–76.

Howard, G. and Bartram, J. 2010. *Vision 2030 The resilience of water supply and sanitation in the face of climate change*. Technical report to the World Health Organisation. WHO Document Production Services, Geneva, Switzerland.

Howard, G., Charles, K., Pond, K., Brookshaw, A., Hossain, R. & Bartram, J. 2010. 'Securing 2020 vision for 2030: climate change and ensuring resilience in water and sanitation services'. In: *Journal of Water and Climate Change* (2010) 01.1, 02-16.

Huq, S. 2008. 'Community-based adaptation'. In: *Tiempo*, Issue 68, July 2008 (Special issue on community-based adaptation).

Hutton, G. & Chase, C. 2016. 'The knowledge base for achieving the Sustainable Development Goal Targets on water supply, sanitation and hygiene (WASH)'. In: *International Journal of Environmental Research and Public Health* 2016, 13, 536.

IPCC. 2018. *Summary for policy makers*. First Joint Session of Working Groups I, II and III of the IPCC. 48th Session of the IPCC, 06 October 2018. Incheon, Republic of Korea.

IPCC. 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Jordaan, G.P. 2018. *Evaluating the sustainable potential of biogas generation in South Africa*. Thesis for the degree of Master of Science in Sustainable Agriculture, University of Stellenbosch.

Kohlitz, J.P., Chong, J & Willets, J. 2017. 'Climate change vulnerability and resilience of water, sanitation, and hygiene services: a theoretical perspective'. In: *IWA Journal of Water, Sanitation and Hygiene for Development* (2017) 7 (2): 181-195.

Levy, B.S. & Patz, J.A. 2015. 'Climate Change, Human Rights, and Social Justice'. In: *Annals of Global Health* (2015) 81 (3): 310-322. Published by Elsevier Inc. on behalf of Icahn School of Medicine, Mount Sinai.

Massoud, M. A., Tarhini, A., & Nasr, J. A. 2009. 'Decentralized approaches to wastewater treatment and management: applicability in developing countries'. In*: Journal of Environmental Management*, 90(1), 652-659.

Midgley, G.F., Chapman, R.A., Hewitson, B., Johnston, P., de Wit, M., Ziervogel, G., Mukheibir, P., van Niekerk, L., Tadross, M., van Wilgen, B.W., Kgope, B., Morant, P.D., Theron, A., Scholes, R.J. & Forsyth, G.G. 2005. *A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-economic Effects of Climate Change in the Western Cape.* CSIR Report No. ENV-S-C 2005-073, Stellenbosch.

Miller, J.D. & Hutchins, M. 2017. 'The impacts of urbanisation and climate change on urban flooding and urban water quality: A review of the evidence concerning the United Kingdom'. In: *Journal of Hydrology: Regional Studies* 12 (2017) 345–362.

Ministry of Interior, Hungary. 2011. *Climate-friendly Cities – a Handbook on the Tasks and Possibilities of European Cities in Relation to Climate Change.* For Regional Development and Town Planning. VATI Hungarian Non-profit Ltd. Budapest.

Mitchell, T. & Tanner, T. 2006. *Adapting to climate change: Challenges and opportunities for the development community.* Institute of Development Studies. URL: www.tearfund.org/webdocs/website/Campaigning/policy%20and%20research/Adapting%20to%20climate%20change%20discussion%20paper.pdf

Nadkarni, M. 2004. *The Meaning of Sanitation: An Ecosystem Approach*. Boursiers de la Ville de Paris Programme. Paris, France.

Oates, N., Ross, I., Calow, R., Carter, R. and Doczi, J. 2014. *Adaptation to Climate Change in Water, Sanitation and Hygiene: Assessing risks, appraising options in Africa*. UKAID. Overseas Development Institute, London, UK.

OHCHR. n.d. *Climate Change and the Human Rights to Water and Sanitation.* Position Paper. Office of the High Commissioner, United Nations. Geneva, Switzerland.

PAHO. 2006. *The challenge in disaster reduction for the water and sanitation sector: improving quality of life by reducing vulnerabilities*. Pan American Health Organization (PAHO/WHO), United Nations Children's Fund (UNICEF), International Strategy for Disaster Reduction (ISDR), International Federation of Red Cross and Red Crescent Societies (IFRC). Washington, D.C.

Prendez, M. & Lara-Gonzalez, S. 2008. 'Application of strategies for sanitation management in wastewater treatment plants in order to control/reduce greenhouse gas emissions'. In: *J. Environ. Manag.* 88:658–64.

Rosenzweig C., W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, T. Bowman, and S. Ali Ibrahim. 2015. *ARC3.2 Summary for City Leaders*. Urban Climate Change Research Network. Columbia University. New York.

SAHRC. 2014. *Water and Sanitation, Life and Dignity: Accountability to People who are Poor.* South African Human Rights Commission, Pretoria.

Sinisi, L. & Aertgeerts, R. (ed). 2011. *Guidance on Water Supply and Sanitation in Extreme Weather Events*. World Health Organization (WHO) Regional Office for Europe. Copenhagen, Denmark.

Slootweg, R. 2009. 'Integrated Water Resources Management and Strategic Environmental Assessment – Joining forces for Climate Proofing'. In: P*erspectives on water and climate change adaptation - Introduction, summaries and key messages*. Netherlands Commission for Environmental Assessment, 5th World Water Forum, Istanbul.

Smit, B. & Wandel, J. 2006. 'Adaptation, adaptive capacity and vulnerability'. In: *Global Environ. Change* 16 (3), 282–292.

Sorre, A.M., Kurgat, A. & Musebe, R. 2017. 'Adaptive Capacity to Climate Change among Smallholder Farmers' in Busia County, Kenya'. In: *IOSR Journal of Agriculture and Veterinary Science.* Volume 10, Issue 11 Ver. I (November 2017), PP 40-48.

UN-Habitat. 2018. *Climate change*. https://unhabitat.org/urban-themes/climate-change/. Accessed on 19 October 2018.

UNESCO. 2017. *Wastewater, the untapped resource*. The United Nations World Water Development Report 2017. United Nations World Water Assessment Programme (WWAP), Perugia, Italy.

UNFCCC. 2017. *Initiatives in the area of human settlements and adaptation*. Subsidiary Body for Scientific and Technological Advice, Forty-sixth session, Bonn, 8–18 May 2017. United Nations Framework for Climate Change (UNFCC).

UNICEF. 2016. *Climate Change.* Updated 04 April 2016. UNICEF/HQ07-0896/Georgina Cranston. URL: https://www.unicef.org/wash/3942_4472.html

USAID. 2015. *Incorporating climate change adaptation in infrastructure planning and design: Sanitation*. Global Climate Change, Adaptation, and Infrastructure Issues Knowledge Management Support Project, United States Agency for International Development. Washington DC.

Venema, H. & Temmer, J. 2017. *Building a Climate-Resilient City: Water supply and sanitation systems.* The International Institute for Sustainable Development and the University of Winnipeg. Canada.

Warrick, O. 2011. 'Ethics and methods in research for community-based adaptation: reflections from rural Vanuatu'. In: *Participatory Learning and Action* 60. The International Institute for Environment and Development (IIED). Russell Press, Nottingham, UK.

Water Aid. 2012. *Handbook: Climate Change and Disaster Resilient Water, Sanitation and Hygiene Practices*. Nirapad and WaterAid in Bangladesh.

WHO & DFID (Department for International Development). 2009. *Vision 2030 – The Resilience of Water Supply and Sanitation in the Face of Climate Change*. World Health Organization, Geneva.

WSUP. 2018a. *An integrated approach to peri-urban sanitation and hygiene in Maputo. Working with city authorities to improve services and practices*. Topic Brief, February 2018. Water and Sanitation for the Urban Poor (WSUP) and World Bank.

WSUP. 2018b. *Mapping sanitation in peri-urban Lusaka: a toilet database.* Practice Note, June 2018. Water and Sanitation for the Urban Poor (WSUP) and World Bank.

WRC. 2017. *Greywater: an under-utilised resource?* Drought Series Report No. 4. May 2017. SP 105/17. Water Research Commission, Pretoria.

WWF-SA. 2016. *Water: Facts & Futures*. WWF-SA, Cape Town, South Africa.