sustainable
sanitation
alliance

SuSanA background paper

Opportunities for sustainable sanitation in climate action

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Table of contents


EU response to cyclone Idai,Mozambique © ANOUK DELAFORTRIE / EU

Executive Summary

Sustainable Sanitation is highly relevant for the achievement of three international frameworks: The Paris Agreement, the Sendai Framework and the 2030 Agenda. A sustainable future is impossible without universal access to safe, well-functioning and context-appropriate sanitation services. Until this is achieved, sanitation shortfalls will increase the risks human populations face from climate change and climate-related disasters. Climate change also has a negative impact on water availability and quality as well as on sanitation infrastructure making resilience of sanitation systems a top priority. A combination of technical measures such as resource-efficient systems and flood-proof sanitation with improved planning, capacity building and increased awareness offers best possibilities of adapting to climate-related hazards. Investments in sustainable sanitation can not only minimize these risks but also make substantial cuts in greenhouse gas emissions and provide additional co-benefits through water and energy efficiency measures, replacing synthetic fertilizers as well as avoiding methane emissions. The use of renewable energy from sustainable sanitation systems in form of biogas, hydropower, heat recovery or directly from excreta offers additional mitigation potential. Several tools are available to strengthen climate assessment, adaptation planning and to identify mitigation measures. Despite this, sanitation has been largely overlooked in climate mitigation and adaptation strategies – and in the disbursement of finance for climate action and disaster risk reduction. That is why a joint effort is needed to draw the attention of decision makers to sustainable sanitation and its importance for climate mitigation and adaptation.

1 Introduction

According to the High-Level Panel on Water, which was convened in 2016 by the United Nations and the World Bank, 80% of climate change's impacts are "channelled through water" (HLPW 2016). This is not just in terms of freshwater availability, but also climate-related phenomena such as flooding, drought, storm and extreme precipitation.

This is an alarming message, especially as the global development goals of universal access to safe and sustainable water and sanitation services are already lagging far behind, causing substantial harm to human and environmental health. Climate change will make water, sanitation and hygiene (WASH) targets such as those in Sustainable Development Goal 6 even harder to reach, and also threatens to undo the progress made to date.

However, new, sustainability-oriented investments in sanitation can not only provide more climate- and disaster-resilient services, but also themselves make significant contributions to climate mitigation. There is an urgent need to integrate climate change consideration into plans for the sanitation sector, and sustainable sanitation approaches into climate mitigation and adaptation.

This SuSanA factsheet sets out key interactions between climate change and sanitation. It examines the relevance of sustainable sanitation in light of the Paris Agreement on climate and the Sendai Framework for Disaster Risk Reduction 2015–2030. It also introduces some of the more climate-resilient, low-carbon sanitation solutions available, and practical advice on how to integrate climate and sanitation strategies. This factsheet is also aligned with the Water Action Decade, 2018–2028, as declared by the United Nations General Assembly.[1]

2 Relevant Policy Frameworks

2.1 Paris Agreement

The Paris Agreement, adopted in 2015, calls for reducing greenhouse gas emissions to keep global average temperatures well below 2ºC above pre-industrial levels, and efforts to limit it to a 1.5ºC rise. It has so far been ratified by 180 of its 197 states parties.[2]

Nationally determined contributions (NDCs) are the main instruments for countries to outline climate actions and commitments. Water is the most prioritized adaptation sector in the NDCs, as reported by UN Stats in 2016.[3] However, the way in which NDCs treat WASH-related adaptation and mitigation varies immensely, and sanitation in particular is largely ignored. According to the NDC-SDGs Connections tool, Sustainable Development Goal (SDG) target 6.2 on sanitation access is targeted by fewer specified climate activities than any target under SDG 6, in current NDCs.[4] Only 2% of the SDG 6-related NDCs deal with sanitation access, while wastewater management and water re-use are mentioned in 3%. This suggests that national decision-makers are unaware of how much sanitation could contribute to climate action and sustainable development.

Sewage treatment plant Zagreb © IVAN VRANIĆ HVRANIC / FLICKR

2.2 Sendai Framework

The Sendai Framework for Disaster Risk Reduction 2015-2030 is a 15-year, voluntary non-binding agreement to work towards:

The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.

It recognizes the primary role of the state in disaster risk reduction (DRR) but states that responsibility should be shared with other stakeholders, including civil society and private sector.[5] The Sendai Framework comprises seven global targets and four "priorities for action". All of the targets and priorities are relevant to reducing disaster-related risks linked to sanitation. Most notably, target 4 is to:

Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.

This clearly applies to sanitation infrastructure, and ensuring that they remain safe, effective and operational during and after disasters in order to provide essential life-saving services and reduce the risk of disease outbreaks.

2.3 2030 Agenda

The 2030 Agenda for Sustainable Development was also adopted in 2015 by the UN members states in the General Assembly. It sets out 17 ambitious cross-sectoral goals, each with several targets. SDG 6, "Ensure availability and sustainable management of water and sanitation for all", provides a global framework for water and sanitation development. As well as calling for universal, equitable and sustainable access to clean water and sanitation, it covers integrated water resource management, wastewater treatment and resource recovery.

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[1] http://www.wateractiondecade.org/

[2] https://unfccc.int/process/the-paris-agreement/status-of-ratification

[3] https://unstats.un.org/sdgs/report/2016/goal-13/

[4] https://klimalog.die-gdi.de/ndc-sdg/sdg/6

[5] https://www.unisdr.org/we/coordinate/sendai-framework.

Table 1: Direct or indirect links between sustainable sanitation and climate change.

SDG	Target	Key identified linkages between sustainable sanitation and climate change[7]
SDG 1 ("No poverty")	1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.	The protection of vulnerable populations can be strengthened by improving the resilience of sanitation systems, in the face of extreme weather events (esp. droughts and floods). Waterless and recycling systems can enhance resilience. Strategies such as the construction of elevated structures and capacity development linked to emergency response, may also be crucial.
SDG 2 ("Zero hunger")	2.4 by 2030 ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality.	Treated urine, faecal sludge and wastewater provide quick-acting nitrogen fertilizers, soil conditioners and sources of water and nutrients. Their safe use can significantly increase poor people's access to safe, nutritious and sufficient food, reduce malnutrition for smallholder farmers lacking access to chemical fertilizers and result in more resilient and sustainable agricultural practices in food production systems.
SDG 3 ("Good health and well-being")	3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.	Sustainable sanitation development can mitigate increasing incidences of water-related and/or temperature-influenced diseases due to climate change.
SDG 7 ("Affordable and clean energy")	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.	Recovering the energy from excreta, wastewater and other waste flow streams can provide affordable renewable energy. For example, biogas can be generated as part of sanitation systems to generate electrical or mechanical power, including fuel for vehicles.
SDG 11 ("Sustainable cities and communities")	11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.	Sustainable sanitation systems can reduce the number of people affected and decrease the economic losses of water-related disasters (floods and droughts) and reduce the adverse per capita environmental impact of a city.
SDG 13 ("Climate action")	13.1 Strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries. 13.2 Integrate climate change measures into national policies, strategies, and planning.	Sustainable sanitation is critical to make basic services in cities and human settlements safer and more resilient. Improved waste resource management, treatment and recovery technologies are important sanitation sector contributions to climate change mitigation. These include technologies to generate energy, and to replace chemical fertilisers thereby improving the carbon content of soils.

Target 6.2 deals most directly with sanitation:

> *By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.*

As well as drawing attention to especially vulnerable populations, its call for universal access to adequate sanitation cannot be met without climate-resilient sanitation systems.

Target 6.3 deals with wastewater:

> *By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.*[6]

As discussed below, wastewater treatment and safe reuse of water and other resources found in wastewater and excreta, can help address to reduce climate-related threats such as water shortages and disease outbreaks (especially after floods), as well as providing clean energy, low-emissions plant fertilisers, and soil conditioners that help soils to retain water and nutrients.

The 17 SDGs are closely interrelated, as shown in Table 1, and meeting them requires integrated strategies. Several other SDGs are directly or indirectly linked to SDG 6, including "Affordable and Clean Energy" (SDG 7) and "Climate Action" (SDG 13). The key linkages between sustainable sanitation and climate change described in the table are based on the report on 'Sustainable sanitation and the SDGs: interlinkages and opportunities' (SuSanA 2017).

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[6] https://sustainabledevelopment.un.org/sdg6.

[7] For more detailed overview see SuSanA (2017).

3 Links between climate change and sanitation

3.1 How climate change impacts the sanitation sector

The main water-related impacts of climate change relate to water availability, water quality, and pressures on water supply and sanitation systems (OECD 2013; Howard and Bartram 2010). Each of these is discussed in more detail below. Box 1 gives a summary of climate change impacts relevant to water and sanitation from the International Panel on Climate Change (IPCC).

Box 1. Key climate change impacts relevant to sustainable sanitation

Changing precipitation patterns or melting snow and ice are altering hydrological systems, in many regions around the world, affecting water resources in terms of quantity and quality (medium confidence). Glaciers continue to shrink due to climate change (high confidence), affecting run-off and water resources downstream (medium confidence).

- Impacts from climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of human and natural systems to increasing climate variability (very high confidence). Impacts include: alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for human well-being.
- Burden of human ill-health from climate change is relatively small compared with effects of other stressors and is not well quantified. However, local changes in temperature and rainfall have altered the distribution of some water-borne illnesses and disease vectors (medium confidence).
- Negative impacts on crop yields of climate change have been more common than positive impacts, based on many studies covering a wide range of regions and crops. Reduced availability of water and deteriorating soils are key reasons for decreasing yields. The reduced availability of water and deteriorating soils could have a relevance if we consider recovery of wastewater and excreta.

Source: Based on IPCC (2014)

Impacts on water availability

Rising temperatures coupled with extended droughts will increase evapotranspiration from soil and plants, and deplete other freshwater sources in many regions of the world. Decreasing rainfall coupled with growing water demand – including from agriculture, energy production and industry – will reduce the availability of surface and renewable groundwater. This will impact the availability of water for drinking, hygiene and waterborne sanitation systems. Increasing water efficiency and reusing treated wastewater become a necessity.

In one notable example, in the metropolitan area of La Paz, Bolivia, glaciers that supply about 30% of freshwater shrank by 43% between 1986 and 2014 due to warmer temperatures (Buxton et al. 2013; Radford 2016). They are no longer feeding the city's three reservoirs and in 2016 water shortages and water rationing led to protests, nationwide instability and the sacking of the head of the water company (Rocha 2016).

Impacts on water quality

Decreasing rainfall can reduce the capacity of surface water to dilute, attenuate and remove pollutants (Howard and Bartram 2010). For example, more frequent potentially toxic blue-green algal blooms may result from reduced surface flows and increased concentration of nutrients. Other possible consequences are anaerobic or anoxic water conditions, which can result into methane emissions. Conversely, intensive precipitation can impede water treatment by increasing the levels of suspended solids in surface water, increasing the risk that pathogens from human excreta remain in water used for drinking, food preparation and hygiene. There is also an increased risk for groundwater contamination by surface flooding, which is often a neglected issue (Andrade 2018).

Impacts on sanitation systems

Extreme events intensified by climate change, especially floods and droughts, can have devastating consequences for sanitation infrastructure (see Box 2 for examples). This situation is aggravated by long-term effects such as sea level rise. The damage can often take years to repair, during which time sanitation services will be interrupted. Droughts and water shortages can also affect the functioning of different components of sanitation systems, such as treatment. Waterborne sanitation systems will stop functioning if water supply is interrupted. When toilets and sanitation systems are not flood-proofed, pathogens from excreta and other pollutants in wastewater can easily leak out during floods and contaminate water sources. As a result, waterborne diseases can affect entire neighbourhoods and downstream communities. A systematic literature review showed a significant increase in diarrheal disease following heavy rainfall and flooding event and also correlations between ambient temperature and diarrheal diseases (Levi et al. 2016). Thus, despite the trend of declining diarrheal disease burden globally, climate change has the potential to slow progress in reducing the burden of diarrheal diseases, especially linked to inadequate water and sanitation conditions.

Box 2. Examples of damage to WASH infrastructure in climate-related disasters

Major flooding in Cordoba, Colombia, in 2007 (affecting over 14,000 families from 19 municipalities), damaged the water and sewer systems, which were already in a poor state. Many traditional water sources such as wells and water storage tanks were destroyed, forcing people to take water from unprotected sources like lagoons and rivers. Furthermore, flooding also caused on-site sanitation systems like septic tanks and latrines to break down (Morris-Iveson 2011).

A survey of damage to buried infrastructure following the 2005 storms Katrina and Rita in the United States found, among others:

- Buried pipes damaged by soil subsidence, washing away of soil around pipes, uprooting of trees, and pressure from heavy vehicles used by rescue and clean-up crews.
- Manholes washed away, allowing floodwaters to destroy underground pumping equipment.
- Loss of power to wastewater treatment plants, meaning raw sewage was dumped into rivers.
- Inadequate storage tanks and tunnels for untreated wastewater overwhelmed.

Much of the damage was not discovered until some time later (Chisolm and Matthews 2012).

3.2 Particularly vulnerable populations

The impacts of climate change on WASH are likely to hit some people harder than others. Existing forms of vulnerability will both exacerbate climate-related vulnerability and in turn be exacerbated by it, in a vicious cycle. The particularly vulnerable groups include women, children and the elderly who already have inadequate WASH services, and poor and marginalized communities who are already exposed to disasters.

More than 700 million urban residents globally are estimated to lack access to improved sanitation, including 80 million who practise open defecation (UNICEF and WHO 2015). This number is likely to keep rising, as urban populations grow, especially in low- and middle-income countries (Angel 2011).

A substantial part of this new, vulnerable urban population is likely to comprise rural-urban migrants driven by water stress, floods and other climate-related problems that make rural living untenable. They are most likely to move into urban and peri-urban slum communities with poor infrastructure and services (United Nations 2009) and often located on marginal land more prone to flooding and other climate hazards (ISF-UTS and SNV 2019). Although rural communities often face similar challenges due to poverty, lack of appropriate infrastructure or know-how, and other factors, sanitation deficiencies are particularly critical in urban and peri-urban slums (Rognerud et al. 2016) due not least to the population density. Furthermore, communities in these conditions are less likely to receive information about how to adapt their sanitation facilities to climate hazards (ISF-UTS and SNV 2019).

Lack of safe water supply and sanitation heightens the risk of pathogen exposure and disease; which in turn affects nutrition, health and livelihoods. A community displaced by a flood and living in crowded, unhygienic conditions may be at increased risk of cholera, louse-borne typhus and other infectious diseases as a result. A disaster that damages the water supply for irrigation may result in loss of livelihood in the community, leading to food insecurity.

Another consideration is that any increase in costs of water and sanitation services – for example due to climate change impacts on water availability and quality – may make these basic services unaffordable for the poor in low-income countries (United Nations 2009). Extreme climate events may also put pressure on the achievements of development programmes by diverting resources from development to disaster relief.

3.3 Greenhouse gas emissions from sanitation systems

Greenhouse gas emissions from waste sector accounted for 3% of global GHG emissions in 2010, compared to 2.6% in 1970 (GFC/PBL, 2013). During these 40 years the total emissions from waste almost doubled, primarily in form of CO_2, methane and nitrous oxide. The main sources of these GHG emissions are: solid waste disposal on land (43 %), wastewater handling (54 %), and waste incineration (mainly CO_2), while other sources are of minor importance (JRC/PBL 2013). Notably, it is the wastewater handling that mostly has contributed to the steady increase of GHG emissions during the last decades, see Fig. 1 (IPCC 2014). However, there are major data uncertainties concerning emissions from the waste sector (including sanitation) as well as mitigation potential estimates (Monni et al 2006; Bogner et al. 2008).

During storage, transport and release into water bodies, excreta and wastewater emit GHGs directly, largely due to the breakdown of their organic content. Methane, a 30-times more potent GHG compared to CO_2, is produced when the organic content in excreta and wastewater decomposes anaerobically. The methane emissions are greater in places where there are little or no collection and treatment of wastewater, open sewers, disposal such as latrines, or anaerobic systems without gas management e.g. lagoons. Wastewater contributed about 7% of total global methane emissions in 2010 and is projected to increase by about 28 percent by 2030 compared to 2005 levels (US EPA 2012). Another important GHG is nitrous oxide which is generated during both nitrification and denitrification of the nitrogen present in the wastewater effluent, usually in the form of urea, ammonia, and proteins. It has 265 times the climate-forcing potential of CO_2 over a 100-year time horizon and causes ozone layer depletion (Myhre et al. 2013). N2O from domestic wastewater emissions is expected to increase by 22 percent between 2005 and 2030 (US EPA 2012).

Under business-as-usual conditions, the sanitation sector's GHG emissions are expected to almost double by 2050 (OECD/IEA 2016).The main driver for this predicted increase is population growth, particularly in countries that currently rely on anaerobic treatment and collection systems without biogas

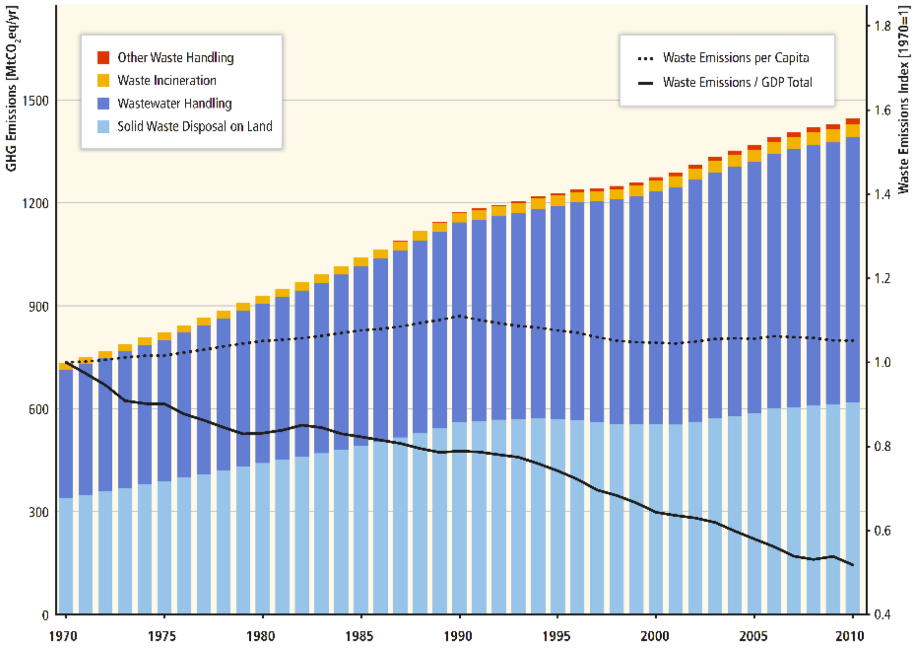

Figure 1: Global waste emissions

$MtCO_2eq$ / year, global waste emissions per GDP and global waste emissions per capita referred to 1970 values. (IPCC 2014).

collection such as latrines, septic tanks, open sewers, and lagoons (Reid et al. 2014). The sanitation sector also produces indirect emissions, for example from generating the power used in wastewater pumping, treatment and other processes; the use of additives; and transportation of additives and sewage sludge. The level of indirect GHG emission vary significantly between different treatment technologies, see Box 3.

Box 3. Indirect emissions from wastewater treatment

Direct and indirect GHG emissions were estimated, using carbon footprint analysis, for two different setups of municipal wastewater treatment plants (WWTPs) in Austria. The two WWTPs were designed with anaerobic digestion (AD) and simultaneus aerobic stabilization (SAS) of sewage sludge. The result shows that the amount of indirect GHG emission can vary greatly depending of selected technologies. The indirect emission from the WWTP with AD was 25% of the size of the direct emissions, while for the WWTP with SAS the indirect emissions were twice as high as the direct. The main reason for this difference is the high input of electricity needed for the SAS (Parravicini et al. 2016).

4 Solutions: Adaptation and DRR

Social, economic and environmental risks from climate change and climate related disasters increase through the frequency or intensity of climate related hazards. In this sense sanitation systems need to be designed more resilient, to be prepared for and recover from effects of a hazard in a timely and efficient manner. This also includes the preservation and restoration of essential basic sanitation structures and functions through risk management. (UNISDR 2017).

To minimise these risks, vulnerability assessments need to be carried out before any sanitation systems are developed in areas likely to be affected by climate-related disasters or climate impacts on the water cycle. Assessments need to identify direct risks to the sanitation system (along the entire sanitation chain), as well, as how changes in water availability, temperature or sea level, for example, might affect sanitation systems, and how climate impacts on sanitation systems could affect water resources. This applies no matter whether sanitation is based on centralised waterborne or on-site “dry” systems. Once the risks have been identified, they should be addressed with integrated solutions.

4.1 Technical measures

Resource-efficient, reuse-oriented systems: Some kinds of sanitation system can create synergies between wastewater management and agriculture, depending on the context. Systems that allow safe reuse of treated water, organic matter and nutrients from the sanitation sector can compensate water scarcity during droughts, or be used to irrigate farmland and urban green spaces or to restock groundwater resources. These systems can also be used to produce safe fertilizers and soil conditioners, boosting agricultural productivity and increasing the soil’s stability to erosion during flooding, heavy rainfall or drought, among other benefits.

Reuse of wastewater can be complemented with installation of water-saving equipment, for example low- or no-flush toilets, and water-saving showers. Adaptations of existing infrastructure should focus on no or low regret solutions (beneficial at present and under a range of possible climate scenarios and not involving heavy trade-offs) making them an improvement fit to all possible climate sceanrios (ISF-UTS and SNV 2019).

While “modern” sanitation is often understood as flush toilets connected to centralized, waterborne sewerage systems, decentralized and on-site wastewater systems should also be considered among the standard options for sanitation development. They are more flexible, sometimes cheaper and they can easily be adapted to new requirements such as resource recovery and reuse.

Flood-proofing sanitation: Sanitation systems need flexibility to operate under a range of different climate conditions and to ensure overall functionality even if one part of the system fails (ISF-UTS and SNV 2019). Centralized sanitation systems should be designed or adapted based on a vulnerability assessment looking at flood-related and other climate risks.

Effect of urine treatement on maize growth © PETER MORGAN / FLICKR

The U.S. Environmental Protection Agency (EPA) developed a guide to help drinking water and wastewater utilities become more resilient to flooding. In the approach, the utility would examine the threat of flooding, determine impacts to utility assets and identify cost-effective mitigation options. This approach was successfully tested during a pilot project at a small drinking water system in Berwick, Maine (US EPA 2014).

Sanitation-related risks need to be taken into account in flood preparedness planning, and emergency measures. Capacity building and educational measures need to be provided to minimize risks during flooding. Box 4 describes an example of low-cost but effective flood-proofing in on-site rural sanitation.

Box 4. Flood-resistant reuse-oriented waterless sanitation in Bihar, India

The village Burmi Tola has problems typical of many communities in rural Bihar state: water shortages for much of the year, but flash-floods during the monsoon when the area can be inundated for up to three months. The residents earlier practiced open defecation, meaning the floodwaters carried faeces and pathogens into homes and farms. During floods the whole village had to use a short section of nearby raised feeder to defecate, on a strictly regimented schedule. A project helped willing villagers to install urine-diverting dry toilets on raised concrete plinths, splitting the costs and tasks. These were not only flood- and drought-resistant, but also gave farmers the option of reusing treated urine and composted faeces as safe, free fertilizers and soil conditioners (Andersson 2014)

Ecosystem-based adaptation (EbA): Societies benefit from a multitude of services provided by ecosystems – from the global climate system down to local freshwater provision, pest control and wild foods. These ecosystem services can – and already do – help to build climate resilience. Protecting ecosystem services and looking for novel, sustainable ways to utilize them offers some cost-effective adaptation and DRR options. At the same time, it offers co-benefits like preserving biodiversity, improving local micro-climates, and creating cleaner, healthier, more liveable spaces.

Ecosystem-based wastewater treatment are processes where flora and fauna in natural ecosystems help to degrade harmful sewage contaminants, including pathogens. Commonly applied systems are planted soil filters, pond systems and greywater irrigation of green spaces. Sustainable drainage systems (SuDS) use features such as permeable paving, ponds, wetlands, gardens and ditches to improve stormwater retention and reduce run-off and pollution from untreated wastewater. Another advantage of ecosystem-based solutions is that they are often cheaper to install, operate and maintain than traditional “grey” infrastructure.

4.2 Non-technical measures

Increasing risk awareness and establishing warning systems: Raising awareness of climate-related risks can help communities to take their own adaptation and risk-mitigation steps. It is a good idea for such awareness-raising to take the form of a dialogue, and even a collaboration, between “experts”, vulnerable populations and other stakeholders. This will help to identify context-specific risks, barriers and solutions. It can also help to ensure that information is translated into action. Early warning alerting the population to impending climate hazards allows preparation measures to be taken (ISF-UTS and SNV 2019). These can also be technical measures.

Building the knowledge base: Further research is needed to understand the interface between climate change and sanitation in specific contexts. Climate change projections or impact and vulnerability assessments help to increase the expertise of decision-makers and practitioners as well as public awareness on the need for adaptation. Once again, science-stakeholder collaboration can help to boost uptake, ensure relevance, and give due weight to local knowledge and experience.

Cross-sectoral planning: Adaptation strategies in the sanitation sector should be harmonized and even co-developed with strategies in other related sectors, such as water, health, energy and agriculture. This can help to identify and resolve competition between sectors, avoid unwanted conflicts and trade-offs between different sectors’ objectives, and maximize synergies – for example through resource reuse.

Nationally determined contributions and national adaptation plans: Ensuring sanitation is well reflected in nationally determined contributions under the Paris Agreement, and in national action plans, can help to formalize and strengthen commitments to action. It can also send a message to other countries that the sanitation sector should not be overlooked in adaptation planning.

Integrated water resource management (IWRM): IWRM aims for allocation of water resources in an equitable, transparent, sustainable manner, based on stakeholder dialogue and conflict management. With increasing climate uncertainties, decision-support tools that aim to help water managers to assess potential climate risks and take appropriate actions are needed in addition to effective IWRM (see section 5 below).

5 Solutions: Mitigation

NDCs under the Paris Agreement set out national targets for reduction of GHG emissions, and outline the strategies to achieve them. NDCs are to be revised and made more ambitious every five years beginning in 2020. With targeted advocacy and scalable solutions to offer, this presents real windows of opportunity to put sanitation on the climate agenda.

This is especially important, since current emission pledges cover no more than a third of the emission reductions needed to achieve the Paris Agreement’s ambition of keeping global warming to well below 2°C above pre-industrial levels by the end of the century. The sanitation sector offers plenty of scope to cut emissions, sequester carbon and generate clean energy. At the same time, appropriate treatment and safe reuse of excreta and wastewater can have innumerable co-benefits for society (Andersson et al. 2016; Ingle et al. 2012).

5.1 Cutting GHG emissions

Methane emissions

Methane emissions from sanitation can be reduced by using aerobic treatment methods. Alternatively, it is possible to capture anaerobically produced methane before it is released in the atmosphere, for reuse as biogas for heat or power generation (see 5.2). The problem of methane emissions from the sanitation sector can thus be reframed as an opportunity to move towards more climate-friendly, reuse-oriented systems.

Energy efficiency

Centralized sanitation systems often have high power consumption – for pumping, transportation and wastewater treatment. Where the local power system is based on fossil fuels, this can generate large amounts of carbon emissions. In energy-poor areas it could also be used to argue against energy intensive sanitation systems. The example in Box 5 demonstrates just how much room there is for energy savings within even advanced treatment systems.

Box 5. New blowers save enough electricity to power 126 homes

In 2013, the Green Bay-Wisconsin Metropolitan Sewerage District in the USA served more than 217,000 residents. The district installed new energy-efficient blowers in the first-stage aeration system of one of its treatment plants. The result was a 50% reduction in electricity consumption, saving about 2,144,000 kWh/year, enough energy to power 126 households and avoiding annual emissions of nearly 1480 metric tons of CO_2e (US EPA 2013).

Heat and energy recovered from excreta and wastewater (see 5.2) are often used within sanitation systems, reducing the need for external energy inputs.

Water efficiency

The treatment and delivery of piped freshwater can also have a large energy footprint – as well as using up potentially scarce water resources (Friedrich et al. 2009). By applying water efficiency measures, less water has to be extracted and pumped and less wastewater has to be treated. In sanitation systems, low-water and no-water solutions can reduce this energy (and emissions) footprint.

In areas with lower population densities, on-site systems are often a more cost-efficient option than centralized, piped sewerage systems. While piped systems rely on water to carry faeces away from the toilet, on-site systems requires often less water or can even be waterless. Excreta can be treated on site or stored (in a latrine pit or septic tank) for collection and treatment off site. In either case, it can be used to produce biogas and other reuse products such as soil conditioner. Greywater can be treated and used instead of piped freshwater to water gardens, irrigate farmland or clean external spaces (see case in Andersson et al. 2016).

Flooding, India © M KANNAN / INDIA WATER PORTAL

Replacing synthetic fertilizers

By far the most common way to boost crop yields globally is by means of synthetic fertilizers. Producing these includes several highly energy-intensive processes along the supply chain, from mining to nitrogen synthesis to transportation (Menter 2016) and becomes increasingly expensive (Hutton and Chase 2016). The main nutrients found in synthetic fertilizers – phosphorus, nitrogen and potassium – as well as valuable micronutrients are plentiful in human excreta. These nutrients also drive eutrophication and related problems in fresh and marine water resources, due to the release of inadequately treated wastewater and run-off from farms.

Box 6. Boosting crop yields with UDDTs

A large scale UDDT project in peri-urban El Alto, Bolivia, initiated in 2008, has covered more than 1,200 families. Urine and faeces are collected separately in each household, for resource recovery and agricultural reuse. Faeces is vermicomposted (with worms), while urine is treated by storage. About 8 tons of solids (faeces and sawdust) and 22,500 litres of urine are collected each month and processed at a treatment centre. During trials with seven hectares of potato fields different type of fertilizer application were carried out to compare impact on yield. A combination of vermicompost and urine was found to produce twice the crop yield compared with the traditional application cow manure, 46 and 23 kg/m2 of potatoes, respectively (Suntura and Sandoval 2012; Andersson et al. 2016).

Safe alternative fertilizers can be produced from excreta at all scales, from on-site systems up to municipal wastewater treatment plants. For example, aerobically composted excreta (potentially mixed with food and other organic waste) and residues from biogas digestion can be reused by farmers to boost crop productivity and improve the condition of soil, including its resistance to erosion and its ability to retain water and nutrients. Toilets that separate urine and faeces, such as urine-diverting dry toilets (UDDTs), can make this even more efficient (see Box 6); urine is nutrient-rich, usually free of dangerous pathogens, and needs only to be stored in the right conditions for a matter of months to be safe for reuse. Faeces require longer and more thorough treatment. Urine separation can be done at building scale or even in small decentralized systems. Excreta (and other organic waste) used to generate biogas can still be processed as fertilizer.

Carbon sequestration: returning organic matter to soil

Returning treated human excreta - and its carbon - to soils in degraded lands can play a significant role in climate change mitigation. It has been estimated that from 2014 to 2100, between 1.9% and 3.9% of average man-made emissions each year could be sequestered in agricultural land (Sommer and Bossio 2014). An effective way of exploiting this potential, is by applying composted faeces (and food waste, crop residues and other organic waste) to agricultural land. It has also proved to be effective to convert dry carbon-rich material into biochar (a soil enhancer) by pyrolysis, while wet nutrient-rich material should better be processed by anaerobic digestion in order to maximize the fertilization value, thus helping to produce more organic matter (Smith et al. 2014; Hansena et al. 2015).

5.2 Renewable energy production

Different approaches are available to put the energy potential in excreta and other organic waste to productive, climate-friendly use. Biogas generation, hydropower, and heat recovery are some of these which have been implemented in sanitation systems. A common indirect option for renewable energy generation is through biomass production, e.g. irrigating energy forest with wastewater or using treated faeces to fertilize energy crops.

Biogas production

Biogas is a mix of gases – primarly methane and CO_2 – produced naturaly during anaerobic digestion of organic matter, including excreta. Biogas can be used to generate power, heat or, after cleaning, as a substitute for natural gas. Examples show that, when coupled with energy-efficiency measures, biogas can meet almost 100% of a wastewater treatment plant's energy needs. The central wastewater treatment plant in Prague, Czech Republic, recently achieved 100% energy self-sufficiency by increasing biogas production from 15 to 23.5 kWh/(PE.yr) (Jenicek et al. 2012; Jenicek et al. 2013). At the household scale, it is estimated that for an average family of five, substituting wood with excreta-derived biogas would avoid emissions of 3.192 t CO_2e per year (Menter 2016).

Hydropower generation

It is possible to install turbines along wastewater systems, including in place of pressure breakers; for example, before or after the treatment plant. This approach has been used in the city of Quito, Ecuador, where the hilly topography ensures strong flows (Armijos et al. 2015).

Heat recovery

Due to its elevated temperature, wastewater has in many locations a substantial thermal energy potential and is therefore an excellent heat source that can be recovered. The recovered heat is often best used on-site within the wastewater treatment plant, for example for sludge drying, but can also be supplied to nearby customers such as business parks or factories.

Excreta as fuel

Because of its high carbon content, faeces itself can be used as a fuel once enough of the water content has been removed. Co-incineration of faecal sludge with other organic waste is possible in power stations and cement plants. Treated faeces and other organic waste can also be made into dry fuel briquettes for safe household use, as an alternative to fossil fuels or wood (Lohri et al. 2017). Different ways of carbonising faecal sludge have been tried, e.g. slow pyrolysis or hydrothermal carbonisation of faecal sludge (Lohri et al. 2018). Non-carbonising processes have also been piloted, where solid fuel was obtained using thickening tanks and drying beds (Gold 2017). Non-carbonised faecal sludge is commonly used as a binder of materials with a higher energy content such as sawdust or carbonised biomass.

6 Making it happen

6.1 Enabling environment

Successfully integrating sanitation development and climate action depends on having the right conditions in place. Box 7 gives some examples of how to create an enabling environment.

6.2 Tools

Climate assessment and planning tools

The application of climate assessment and planning tools should be compulsory in sanitation project and program development. They aim at the integration of climate framework conditions and

Box 7. Sample measures to create favourable conditions for integration of sanitation and climate action

Laws, policies and regulations

- Integrate the water and sanitation sector's objectives on GHG emissions into the national mitigation targets.
- Allow water and sanitation companies to expand their business into other sector like energy generation or materials reuse.
- Ensure competitive tariffs for renewable energy sources, and guarantee prices and long-term stability to help recover investments in sanitation-based energy recovery.

Institutional set-up

- Establish appropriate channels and forums for cross-sectoral dialogue between sanitation and other relevant decision-makers (planning, energy, climate change).

Capacity building:

- Provide climate change readiness training programmes at national, regional and municipal levels that include sanitation issues.
- Ensure sanitation sector practitioners have the capacity to plan, install, operate and maintain more climate-friendly sanitation systems, including for energy recovery and resources reuse.

Finance

- Ensure low-carbon sanitation solutions are favoured in budget allocation and donor funding.
- Promote high-quality sanitation project porposals (incl. MRV-systems) for accessing sources of climate financing.

Infrastructure

- Ensure sanitation infrastructure investments favour climate-friendly sanitation options (e.g. separation of sewage and stormwater and reuse of sewage relted products).
- Risk mitigation measures (DRR) in sanitation infrastructure development.

Socio-cultural and equity aspects

- Gauge and build the readiness of the affected population for proposed sustainable sanitation options – for example handling composted faeces and treated urine, or using excreta-derived products such as biogas, or excreta fertilized crops.
- Involve society, especially end-users, in the projects to build ownership and social acceptance, especially for climate relevant reuse options.
- Ensure sanitation development does not deepen inequalities along the lines of gender, caste, ethnicity or similar.

related uncertainties. Different tools e.g. for simple screeing and for systematic indepth assessements are available. Many of these tools consider climate as well as environmental risk mitigation and opportunities that create added values as e.g. synergies from cross sector approaches. Examples for climate assessment and planning tools are given below:

CRiSTAL (Community-based Risk Screening Tool – Adaptation and Livelihoods) is a project-planning tool to help users to identify and prioritize climate risks and identify livelihood resources most important to climate adaptation. These can be used as a basis for designing adaptation strategies (see https://www.iisd.org/cristaltool/)

CEDRIG (Climate, Environment and Disaster Risk Reduction Integration Guidance) is a practical tool to systematically integrate climate, environment and disaster risk reduction into development cooperation and humanitarian aid in order to enhance the overall resilience of systems and communities (see https://www.cedrig.org).

The EbA (Ecosystem-based Assessment) Tools Navigator has been developed as part of the International Climate Initiative (IKI). It features information on more than 230 EbA tools, methodologies and guidance documents; from planning, assessments, and implementation to monitoring and mainstreaming. The navigator is currently released in pilot form, and practitioners and planners are encouraged to explore and test its usefulness.

A carbon accounting tool for the urban water cycle

The Energy Performance and Carbon Emissions Assessment and Monitoring (ECAM) tool, offers water and wastewater utilities a solution to quantify direct and indirect GHG emissions of the urban water cycle and to identify potential climate mitigation measures. ECAM was developed to be consistent with the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. ECAM helps link monitoring, reporting and verification of mitigation action in the water sector to the national level.

6.3 Climate finance: a new finance source for sanitation investments?

The major sources of finance for sanitation investment are from governments, development banks, multilateral and bilateral organizations, and to a limited extent, private investors. For on-site solutions, the cost of the sanitation systems are also commonly covered by the households or the landlords. Despite the prospects for making sanitation to contribute to both climate mitigation and adaptation, very limited funds for climate actions are currently invested in the sanitation sector.

The Green Climate Fund (GCF) is a financial mechanism under the UNFCCC which helps to fund investment in low-emission, climate-resilient development through mitigation and adaptation projects in developing countries. However, sanitation is generally an undeveloped area, considering the fact that only one out of 21 funded projects in GCF's Portfolio on Water is on sanitation.[8] Apart from grant opportunities for sanitation development, GCF provides loans and equity finance, which also can be used for installing and running sanitation infrastructure.

One of the priority areas in the Sendai framework is "Investing in disaster risk reduction for resilience". These funds are from both public and private investments, in the form of grants or loans, but no good overview is available on how much of the DRR funds is invested to strengthen the resilience of sanitation systems. UNDP and ODI has published guidance on how to "Finance for reducing disaster risk" (Watson et al. 2015), while the Humanitarian Practice Network (HPN) has provided a 'Good Practice Review' (Twigg 2015). A key recommendation from the HPN practice review is to incorporate risk reduction measures into existing funding streams, rather than having stand-alone DRR budgets.

Another source of finance worth further exploration is emissions trading, considering the sanitation sector's potential to reduce GHG emissions and even displace fossil fuel consumption.

Conclusions

Given the persistant global gap in improved sanitation access, and the untapped co-benefits available from sustainable sanitation, the 2030 Agenda, the Sendai Framework and the Paris Agreement offer potential new drivers of action and sources of finance for sanitation investment.

There is already a wealth of evidence to show that sanitation investments can help meet numerous SDG targets, can reduce the GHG emissions that drive climate change, and can greatly reduce the risks to health and ecosystems from natural disasters. Actors from the WASH sector need to continue to build the evidence base, and to formulate and deliver convincing arguments. Then we can help sanitation to receive the attention it deserves in climate action, development and DRR.

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