pS-Eau programme Solidarité-Eau

WASH services and climate change in developing countries

Working Document

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Acronyms and Abbreviations

COP	Conference of the Parties
FWP	French Water Partnership (or: Partenariat Français pour l'Eau, PFE)
IWRM	Integrated Water Resources Management
IPCC	Intergovernmental Panel on Climate Change
SDG	Sustainable Development Goals
pS-Eau	Programme Solidarité Eau

Introduction

pS-Eau facilitates a network that is open to all organizations working within the water, sanitation and solidarity sectors and which fosters the sharing of experience and information. Member organizations have requested that the network examine climate change risks and explore the impact these may have on the sustainable improvement and development of water and sanitation services in the global South.

The importance of this issue was highlighted during the United Nations Climate Change Conference (COP 21/CMP11) held in Paris between 30th November and 11th December 2015, which underlined the need to take urgent measures to prevent and protect people from the effects of climate change.

A number of organizations have been working to draw attention to the climate change issues affecting the large water cycle, notably as part of the campaign being run by the French Water Partnership (FWP) *#Climate is Water*.

In order to examine this topic in more depth and more clearly define climate change risks and potential solutions for the small water cycle, specifically local water and sanitation services within developing countries, pS-Eau has set up a working group (which has produced this document) to:

- provide water, sanitation and hygiene sector stakeholders with information to help them more effectively factor climate risk into their water supply and sanitation service development strategies;
- contribute to the definition of water and sanitation-related mitigation and adaptation measures in developing countries.

The aim of this paper is to stimulate debate. Intended for widespread distribution, the authors invite comments and feedback on its content.

This document complements the valuable work being carried out by Partenariat Français pour l'Eau on "water and climate change", which looks at the issue from a more holistic perspective (examining the large water cycle).

This document is divided into three chapters:

1. **Background and climate change issues** affecting the water and sanitation sector in developing countries.
2. Why take action?
   - Water and sanitation service-related climate change risks and impacts
   - The water and sanitation sector: an emitter of greenhouse gases
3. How to take action
   - Strategic reference frameworks for factoring climate change into water and sanitation service development strategies
   - Operational solutions for both adaptation and mitigation

Background and climate change issues affecting the water and sanitation sector

Global warming has an impact on water cycles

The international scientific community, under the umbrella of the Intergovernmental Panel on Climate Change (IPCC), is in agreement that greenhouse gases from human activities are increasing the temperature of the planet.

The water-related aspects of the fifth and most recent IPCC report published in 2014[1] have been analyzed in detail by FWP (FWP, 2014). The report highlights the impact of global warming on the water cycle and details the natural phenomena associated with this. Although many uncertainties remain, evidence suggests that the rise in air and sea temperatures is intensifying extreme weather events. Countries in the inter-tropical convergence zone can expect to experience more severe heatwaves, longer dry seasons and short wet seasons with sudden and intense rainfall events.

Thus, there will either be too much water or not enough and it is the poorest people who are the most vulnerable, due not only to their geographic exposure but also to the fragility of their current service provision and to their lack of resources for anticipating and adapting to the effects of climate change. Therefore, many countries vulnerable to climate change, including countries in Africa, want the global temperature increase to be limited to 1.5°C above pre-industrial levels rather than to the 2°C adopted by the international community at the Copenhagen Summit. The Paris Agreement has partially met this requirement by aiming to work towards "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C".

The climate: an issue linked to other global changes

The impact of climate change on water and sanitation services cannot be considered in isolation. Other concurrent global changes must also be taken into account, such as demographic trends (population growth, urbanization, "coastalization"), rising living standards, dietary trends, land use changes and economic development-related needs (farming, industry, etc.); all of these demand greater quantities of water that inevitably leads to higher volumes of wastewater being discharged into the environment causing river basins to deteriorate.

Developing sustainable water and sanitation services therefore involves simultaneously meeting the growing needs of users, protecting the resource and the environment and addressing the risks posed by climate change, which are exacerbating existing tensions.

[1] The fifth GIEC / IPCC Assessment Report is made up of three parts: 1. The Physical Science Basis; 2. Impacts, Adaptation and Vulnerability; and 3. Mitigation of Climate Change. These reports are available in both French (GIEC) and English (IPCC) from: http://www.ipcc.ch

The climate: a global issue requiring local and urgent responses

Climate change is monitored and measured at the global level and, to varying degrees, is a shared responsibility. Carbon dioxide and other greenhouses gases released in one part of the world affect the whole planet and have extremely long-lasting repercussions. This is thus a worldwide issue on which decisions need to be taken collectively and without delay.

In contrast, the impacts of climate change are felt at the local level; its effects vary from one region to the next and thus require an adapted response. While a smaller monitoring area can create more uncertainty and less predictability, there is greater local knowledge of the situation on the ground and the responses required are locally implemented.

In addition to this local area aspect, consideration also needs to be given to timeframes. In order to effectively address climate change risk when developing a local water supply and sanitation project, forecasts need to be produced for various timescales. Although the impacts of climate change are already being felt, medium and long-term scenarios still have to be defined. Along with the forecasts produced for other global changes that influence strategic decisions and facility design, such as population figures, urban development and consumption trends, this will help to streamline the investment being made today. However, producing climate-related forecasts involves higher levels of uncertainty, hence why it can prove difficult to integrate this nonetheless crucial factor into planning scenarios.

Mitigation, adaptation and resilience

The goals of the Conference of Parties to the United Nations Framework Convention on Climate Change are dictated by the need to reduce greenhouse gas emissions in order to keep the global temperature increase below the critical threshold of 2°C.

This therefore involves **mitigating** the impact of human activities on global warming. The water and sanitation sector is not a large producer of greenhouse gases, especially in developing countries. That being said, the sector nonetheless needs to implement effective mitigation efforts. Short-term action should be taken to reduce the energy required to operate water supply facilities and to utilize sanitation by-products.

During COP19 in Warsaw in 2013 and at COP20 in Lima in 2014, developing countries, which, paradoxically, are low greenhouse gas emitters but highly vulnerable to its effects, lobbied for parties to develop and support **adaptation** measures that focused on water-related issues. The water sector has been identified as one of the sectors most affected by climate change. It is mentioned in 92% of the adaptation components of the proposals submitted by countries for COP21 as they seek to prevent and protect areas from the growing threat of flooding and drought.

The water sector's **resilience** is its capacity to identify, understand and address these heightened risks, which are difficult to predict. It is therefore important to build knowledge and define the adaptation measures that can be taken and financed by sector stakeholders.

Definitions

Mitigation: refers to efforts to reduce emission of greenhouses gases produced by human activities.

Adaptation: involves anticipating the impact of climate change and reducing the vulnerability of natural and human systems.

Resilience: this is a complementary, and more dynamic, concept that incorporates the notions of both sustainability and flexibility in relation to climate-related uncertainties. The IPCC defines it as "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation."

The Sustainable Development Goals include an ambitious goal for developing a global approach to water and sanitation issues

The General Assembly of the United Nations' adoption of the 2030 Sustainable Development Goals (SDGs) on the 27th September 2015 is a step forward for the water and sanitation sector. Firstly, because they apply to all countries around the world; and secondly, because they address the water and sanitation sector in all its forms using an integrated and sustainable development approach that incorporates climate change risk.

Goal 6 of the 17 SDGs relates directly to water and sanitation. Targets 6.1 and 6.2 carry on from where the Millennium Development Goals left off (MDG7.c) by focusing on universal access to water, sanitation and hygiene. However, new targets have also been developed to further enhance the notion of services. For instance, a new concept of "safely managed" services has been introduced into the water and sanitation service level indicators.

For target 6.1, this means that the water supply service has to provide water to the households' point of consumption, ensure it is available when needed and that it complies with quality standards.

For target 6.2 that covers sanitation (and which is related to target 6.3 that deals with reducing pollution and, thus, wastewater treatment), the main change is that this target now covers more than just access to sanitation facilities. It now addresses the entire sanitation chain and underlines the importance of sludge management and treatment. Target 6.4 makes explicit reference to the risk of water scarcity that may arise from climate change.

The SDGs and goal 6, in particular, thus provide an opportunity to establish long-term strategies in which climate change is legitimately included in approaches for achieving the SDGs.

Goal 6. Ensure availability and sustainable management of water and sanitation for all

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all

6.2 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

6.3 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

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.7 By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

6.8 Support and strengthen the participation of local communities in improving water and sanitation management

Source: UN, 2015

Why take action?

Climate change risks and impacts on water and sanitation services

The various documents consulted agree with the IPCC's conclusion that global warming of the atmosphere affects rainfall patterns and exacerbates extreme weather events. Droughts, heatwaves, evaporation, sudden heavy rain and storms have an impact on the quality and quantity of raw water available for water and sanitation services. The intensity and frequency of these extreme weather events pose a threat to existing facilities. Those parts of the world already affected by water scarcity or flooding are thus seeing their situation deteriorate due to global climate change.

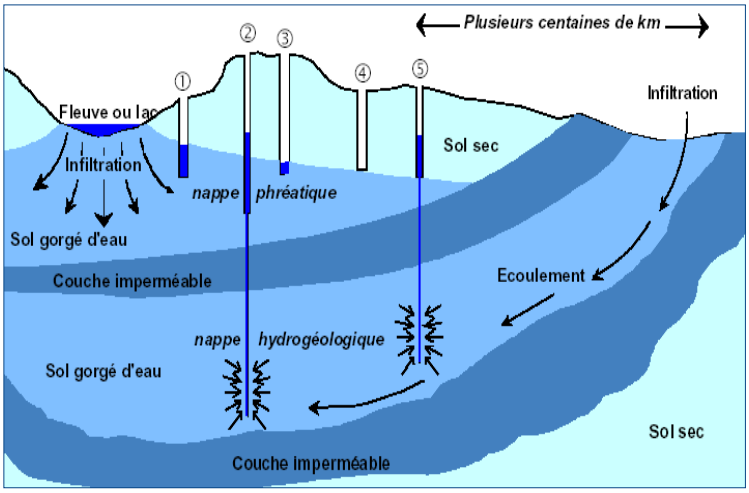
In inter-tropical areas, particularly in the Sahel region of Africa, sector managers and experts point out that these weather events are nothing new. Over the course of recent decades, the Sahel has experienced a significant drop in both rainfall and the mean average flow rate of its watercourses. The turning point is considered to be the start of the 1970s, as both average rainfall and mean average flow rates started to fall during this period, with flow rates for the Senegal River and Niger River dropping by 30% and 60% respectively (OECD, 2015).

Building an understanding of climate change's impact on water and sanitation services will help minimize the risks threatening the sustainability of the investment made to improve access to water and sanitation.

It is important to differentiate between the risks that impact on water resources, which are biophysical systems, and the risks that affect water and sanitation services, which are socio-technical systems.

The impact on water resources

Figure 1. Water infiltration into the soil



Source : pS-Eau, 2013

The climate sensitivity of water tables can be seen in the seasonal movements caused by groundwater recharge and discharge.

Table 1. Climate change risks and impacts on water resources

Climate Hazards	Risks	Impacts on Water Resources
Variability of seasonal rainfall patterns	Average annual rainfall may remain stable but there can be a much longer gap between 2 rainy seasons.	**Low levels or a lack of surface water and groundwater at the 'end' of the dry season** available to the water service.
Drop in rainfall, a rise in temperatures	 Droughts, water scarcity  Heatwaves  Evaporation	**A reduction in the quantity and quality of surface water and groundwater, both seasonally** (where the hydrostatic potential is affected by large-scale sinusoidal fluctuations) **and inter-annually** (the basic piezometric level continually falls indicating stocks will be depleted during periods of rainfall shortages). → A fall in the flow of the water level of rivers and reduced dilution, particularly in low-water periods. → Higher concentrations of various (chemical and organic) pollutants in the water due to poor dilution. → Decreased groundwater recharge. → Algae blooms. → Increased salinity: river water becomes more saline due to reduced water flows / saltwater intrusion into coastal groundwater caused by decreased groundwater recharge.
Increased rainfall and storms	 Sudden and intense rain events, flooding  Storms	**Pollution – contamination of surface water and groundwater** → Pollutants leach into the soil, pit latrines are flooded and higher volumes of wastewater are discharged untreated (as wastewater treatment plants are overloaded) thereby contaminating all surface water and then groundwater as the contaminated water infiltrates water tables through wells and boreholes. **Poor infiltration** → The rain falls so quickly and suddenly that the ground cannot soak it up and the water runs off.

The impact on services

Water supply services

A sustainable water supply service involves the extraction/pumping, treatment, storage and distribution to users of good quality, affordable water in sufficient quantities to sustainably satisfy their needs while respecting the environment. Service levels and the types of infrastructure and facilities used can be adapted to local needs and each specific setting and aligned to the technical and financial resources available. Water extraction systems used to harness the resource vary in accordance with the type, location and quantity of the water available: shallow or deep groundwater, surface water, springs, etc.

When developing a new water supply system, the probability and type of climate change-related risks need to be considered during the design phase to make sure the facilities selected are properly sized and adapted to the environment and ensure the system's sustainable operation. Seasonal variations in rainfall, increases in extreme weather events (floods, typhoons) and worsening droughts exacerbate the fragility of water services.

The impact of the different types of weather events on service sustainability can be assessed using the following indicators (pS-Eau *et al.*, 2013):

1. Specific consumption, which equates to the average water volumes consumed per user per day and influences water withdrawals and the lifespan of electro-mechanical equipment.
2. Service quality, which encompasses quality of the water distributed, service continuity and the pressure available to the end-user.
3. The condition of infrastructure and facilities and network efficiency.
4. Service investment and operating costs.

Climate-induced service interruptions or drops in quality have extremely significant social, health and environmental impacts.

The following table is intended to help identify and understand the links between weather events and water supply services and the technical, social, health and environmental effects these can have.

It is to be noted that, for a water service to be properly sustainable, effective organizational, management and financial procedures also need to be put in place and monitored. Climate change risks can affect and, more generally, jeopardize these organizational and financial arrangements. For instance, the additional cost of addressing both the episodic and long-term impacts of climate change can mean changes are required to current budgets, which has a knock-on effect on pricing schedules.

Table 2. Links between climate change and water supply services

<table>
<tr><th>Climate Hazards</th><th>Impact on Specific Consumption</th><th>Impact on Service Quality</th><th>Impact on Infrastructure and Facilities</th><th>Social & Health Impacts</th></tr>
<tr><td>Variability of seasonal rainfall patterns</td><td></td><td>Interrupted or temporarily reduced services due to lack of available water resources</td><td></td><td></td></tr>
<tr><td>  Droughts, water scarcity</td><td rowspan="2">○ Increase in water needs and in volumes withdrawn for all uses (domestic, agricultural, industrial, etc.)</td><td>○ Service interruptions caused by lack of available water resources
○ Drop in the quality of water distributed as the raw water, which has high concentrations of pathogens, physico-chemical pollutants, salt, etc. or high turbidity, is insufficiently treated</td><td>○ Weakened facilities:
- facilities are over-used during droughts to meet high demand
- dry pumping can damage pumps
- concrete cracks during heatwaves</td><td rowspan="3">○ Chore of drawing water becomes more difficult:
- need to travel greater distances
- water table is deeper and less productive
○ Increase in diarrheal diseases:
- drop in water quality
- during service interruptions, people use water points where quality is not controlled and potentially poor
○ Increase in conflicts of use during periods of water scarcity
○ Greater migration or people leaving as they have no water</td></tr>
<tr><td>  Heatwaves</td></tr>
<tr><td>  Sudden and intense rain events, flooding</td><td></td><td>○ Contamination of water resources by uncontrolled stormwater runoff and flooded pits containing pollutants
○ Service interruptions due to damaged facilities
○ Water points are inaccessible (landslides – floods)
○ Storage facilities are weakened by saturation</td><td>○ Facilities are weakened, less efficient and damaged: flooded wells, silting, flooded electrical equipment, erosion of facilities, burst pipes, network leakages, etc.</td></tr>
<tr><td>Storms
(including sand and dust storms)</td><td></td></tr>
</table>

Sanitation services

There are various types of wastewater:

- domestic wastewater, which includes both blackwater and excreta and greywater;
- industrial wastewater;
- agricultural wastewater.

Population growth, higher standards of living and economic development have a tendency to increase the volumes of wastewater produced.

Domestic wastewater essentially generates organic pollution. Industrial wastewater can also create organic pollution, but most of the pollution it generates is physico-chemical. Lastly, agricultural wastewater also causes organic and physico-chemical pollution, particularly when phytosanitary products are used.

During droughts, when water levels in watercourses and bodies of water fall, the concentration of pollutants produced by this wastewater can have a seriously adverse effect on the quality of water resources.

During sudden rain events, on-site sanitation facilities (pits) can overflow and wastewater pipes (loading) and treatment plants can be flooded, releasing untreated wastewater into the environment (by-pass).

These impacts have been outlined above, both in terms of deterioration of the resource and in relation to the level of water treatment required prior to distribution.

Weather events also have a direct impact on sanitation service operations, affecting not only wastewater treatment but also sanitation facilities and sewer systems.

The following table lists the links between these weather events and the technical, social, health and environmental effects these can have on sanitation services.

As with water supply services, organizational, management and financial procedures need to be implemented and monitored to ensure the sustainability of sanitation services. Climate change risks will also have an impact on these service arrangements.

Table 3. Links between climate change and sanitation services

Climate Hazards	Impact on Service Operations and Infrastructure	Impact on the Environment and Water Resources	Social & Health Impacts
 Droughts, water scarcity		• **Drop in water resource quality** due to lower dilution of pollutants	
 Heatwaves	• **Biological treatment processes fail to function** (certain bacteria die) • **Condition of infrastructure and facilities deteriorate** due to the heat • **Concrete structures deteriorate due to the increased production of hydrogen sulfide**[2] (H_2S)	• **The quality of the water resource falls as the wastewater discharged is not properly treated**	• **Hydrogen sulfide (H_2S) poisoning through inhalation** as H_2S production is exacerbated by the heat (staff health & safety risk, particularly for sewer workers) • **Olfactory pollution** due to increased nitrous oxide emissions (N_2O)
 **Sudden and intense rain events, flooding**	• **Flooding leads to breakdowns** on lift pumps and other electrical systems within wastewater treatment plants taking them out of service • **Collapse of latrines** not built to recognized standards (this can have a significant impact on access rates) • **Pit emptying services are disrupted** (some areas become inaccessible, pits needs emptying more frequently, etc.)	• **Increase in untreated wastewater discharged into the environment** as stormwater runs into the sewers causing these to overflow; lift pumps become flooded and wastewater treatment plants are by-passed • **Treatment processes fail to function** (hydraulic overload) • **A mixture of wastewater and stormwater overflows onto public roads** as toilet and latrine pits are flooded causing severe health risks	• **People no longer have working sanitation facilities available** • **Increase in waterborne diseases** as there is a higher risk of people coming into contact with polluted water
 Storms			

[2] Hydrogen sulfide, H_2S, is a toxic gas that results from the breakdown of organic matter and, being heavier than air, it collects in unventilated, low-lying areas.

Impacts of intense rainfall on stormwater management

Over half of the world's population lives in urban areas, with urban population figures being particularly high in developing countries (UN-Habitat, 2008). This unprecedented urbanization has led to the construction of informal housing in areas lacking the most basic services.

The spontaneous settlements built by these new urban residents are often in high-risk areas (low-lying areas, flood zones, swampland, shorelines, etc.) where lack of stormwater management can have serious health, environmental, economic and safety implications. Climate change exacerbates these risks as extreme weather events become more frequent and intense. In these circumstances, as well as addressing the lack of access to basic services, stormwater management is a crucial for developing the urban areas of developing countries.

Table 4. Links between climate change and stormwater management

Climate Hazards	Impact on Stormwater Management Services and, indirectly, on Water and Sanitation Services	Impact on Housing, Urban Public Facilities, Industrial, Economic and Commercial Facilities	Social & Health Impacts
 Sudden and intense rain events, flooding	• **Stormwater management facilities do not work properly due to excess water and flooding and, for water and sanitation services:** equipment is flooded and sewers overflow, etc. (cf. Tables 2 and 3).	• **Housing is damaged** (or destroyed) • **Communication routes are cut off and there are interruptions on many of the networked services** (electricity, telephone, etc.) • **Economic activities are disrupted / forced to close**	• **Population displacement** as dwellings are no longer habitable • **Public and private property is frequently damaged** • **Accidents, injuries and drowning** due to people being swept away by the current, landslides and earthfalls and traffic accidents • **Diseases are spread** by: - people using contaminated water for domestic use - an increase in carriers of disease, such as mosquitoes and rats, etc.
 Storms			

The water and sanitation sector, an emitter of greenhouse gases

The water and sanitation sector is not one of the highest emitting sectors, being more a victim than a cause of global warming. Nevertheless, it is important to highlight the various sources of greenhouse gas production that could potentially increase in situations of water scarcity and falls in water quality.

Water

The impacts of climate change on water quality and scarcity mean that more energy is required to gain access to the resource, transport it and ensure the quality of the water is such that it is safe enough to drink.

The propensity is to install water extraction facilities at greater depths, to transport water over greater distances, introduce additional treatment processes to compensate for the drop in quality or use desalination technologies.

This requires more energy, which, when fossil fuels are used, further exacerbates climate change.

Sanitation

Sanitation services also use energy, both for transporting wastewater (via lift pumps and by vacuum truck) and for treatment. Furthermore, should it be necessary to enhance treatment processes to avoid damaging the receiving environment, these energy needs may well increase.

In addition, both domestic and industrial wastewater contain high levels of organic material that (particularly during their treatment) can give off methane (CH_4) and nitrous oxide (N_2O), both of which are more potent greenhouse gases than carbon.

Table 5. Comparative Global Warming Potential (GWP) of CO_2, CH_4 and N_2O over 100 years (based on mass)

	GWP (over 100 years)
CO_2	1
CH_4	25
N_20	298

Source: IPCC, 2007

Wastewater gives off high volumes of methane, with emissions estimated to be between 26 and 40 million tons a year for industrial wastewater and around 2 million tons a year for domestic and commercial wastewater. Together, they account for 8 to 11 percent of global methane emissions (IPCC, 1996).

In contrast, the IPCC report (2006) revealed that, although harmful, the level of nitrous oxide emitted by domestic wastewater is very low.

> "The principal factor that determines methane generation potential of wastewater is the amount of organic material in the wastewater stream. For domestic and commercial wastewater and sludge, this is indicated by the Biochemical Oxygen Demand (BOD); for industrial wastewater, the Chemical Oxygen Demand (COD) is used. The BOD indicates the amount of carbon that is aerobically biodegradable, whereas the COD indicates the total amount of carbon, biodegradable and non-biodegradable, that is available for oxidation. This is a change from the previous methodology (IPCC, 1995), which used BOD as the organic material parameter in both domestic/commercial and industrial wastewater streams.
>
> An important addition to the previous methodology (IPCC, 1995) is the incorporation of emissions from sludge. Sludge is produced as a by-product of certain wastewater handling systems, and can produce methane under anaerobic conditions."
>
> *Extract from the 'Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Workbook (Volume 2)'*

Table 6. CH4 and N2O emission potentials for wastewater and sludge treatment and discharge systems (source: IPCC, 2006)

☐ No emissions ▨ Risk of emissions ■ Emissions

Types of treatment and disposal					CH4 and N2O emission potentials		
						CH_4	N_2O
Collected wastewater	Untreated	River discharge			Stagnant, oxygen-deficient rivers and lakes may allow for anaerobic decomposition to produce CH_4. Rivers, lakes and estuaries are likely sources of N_2O.	▨	▨
		Sewers (closed and underground)			Not a source of CH_4/N_2O.		
		Sewers (open)			Stagnant, overloaded open collection sewers or ditches/canals are likely significant sources of CH_4.	▨	
	Treated	Aerobic treatment	Centralized aerobic wastewater treatment plants	Well-designed and well-managed	May produce limited CH_4 from anaerobic pockets. Advanced plants with nutrient removal (nitrification and denitrification) are small but distinct sources of N_2O.	▨	▨
				Poorly designed and poorly managed	Produce CH_4	■	▨
			Sludge anaerobic treatment in centralized aerobic wastewater treatment plant	Where CH_4 is recovered and flared	The CH_4 emitted from sludge is recovered and flared		
				Where CH_4 is not recovered and flared	Sludge may be a significant source of CH_4 if emitted CH_4 is not recovered and flared.	■	
			Aerobic shallow ponds	Well-designed and well-managed	Unlikely source of CH_4/N_2O		
				Poorly designed and poorly managed	Produce CH_4	■	
		Anaerobic treatment	Anaerobic lagoons		Likely source of CH_4. Not a source of N_2O.	▨	
			Anaerobic reactors	Where CH_4 is recovered and flared	The CH_4 emitted by the anaerobic reactors is recovered and flared		
				Where CH_4 is not recovered and flared	May be a significant source of CH_4 if emitted CH_4 is not recovered and flared	■	
Uncollected wastewater	Septic tanks			With frequent solids removal	Frequent solids removal reduces CH_4 production.	▨	
				Without frequent solids removal	Produce CH_4	■	
	Open pits / Latrines				Pits/latrines are likely to produce CH_4 when temperature and retention times are favorable.	▨	
	River discharge				See above.	▨	▨

How to take action?

Strategic intervention frameworks

Taking action involves reviewing existing reference frameworks and developing these to define and implement strategies to address the climate change risks affecting the water and sanitation sector in developing countries.

Water and the climate, sectors that remain compartmentalized

The climate is intrinsically linked to all aspects of our societies' development. Climate change has diverse impacts on bio-physical systems and related socio-economic activities. Each natural system and activity sector will be affected differently, depending on its type, location and stakeholder capacity to prevent and protect the system/sector from the impacts of climate change.

Developing countries have had national action plans for adaptation to climate change (NAPA) in place since 2005 – 2006. These plans include a detailed review of the main expected effects of climate change and provide general guidelines on the priority climate change adaptation actions to be implemented at the national level. Water is included as one of the key priorities. However, sector strategies have either ignored or poorly incorporated these guidelines, which remain somewhat separate to water and sanitation program planning and implementation processes. Overall, water and sanitation stakeholders appear not to have taken proper ownership of the issue. However, this situation is not confined to the water and sanitation sector as a similar lack of ownership is also found in other sectors. While several capital cities have implemented climate plans and started to include these climate scenarios in their sector planning documents, the same cannot be said for the vast majority of smaller municipalities.

The analysis of national contributions (INDC) conducted by the French Water Partnership (FWP) during COP21 once again confirms the importance of water-related adaptation measures to developing countries. The FWP determined that, for nearly 90% of countries, water is the number one priority when it comes to adaptation measures (FWP, 2015). Developing countries emphasized the need to preserve water resource quality and quantity, secure access to the resource to supply water for domestic use and agriculture and to develop appropriate facilities.

Risk management and the complementarity between levels of intervention

The impacts of climate change on water and sanitation services can be addressed from a risk management and resource protection perspective. For public authorities and service managers, this involves continuing to supply sufficient quantities of good quality water while minimizing flood and drought-related risks and bearing in mind that these weather events are likely to become more intense and frequent in the future.

This risk management approach should also underline the importance of integrated water resources management (IWRM) as promoted by the IPCC and the international community. IWRM makes it possible to determine what is feasible over time given the quality and quantity of the water resources available, set the relevant limits and identify the measures and organizational arrangements required to ensure these limits are respected. Furthermore, the scope of IWRM

extends beyond water and sanitation services as it covers different and larger surface areas (river basins) and involves a wider range of stakeholders and areas of activity (agriculture, energy, biodiversity, etc.). In light of the climate change risks and compelling need to preserve the environment, it now appears all the more important to create/strengthen linkages between water and sanitation service development and IWRM.

Strengthening the knowledge base, developing tools

Knowledge on the regionally different impacts of climate change on water and sanitation services needs to be enhanced and made widely available to sector policy-makers and stakeholders. These decision-makers need to be kept better informed and made more aware of climate change issues so that they can appropriate these and include them in development strategies. Following the example of their counterparts in the global North, local authorities and river basin organizations in the global South need to produce and assimilate more accurate local climate forecasts.

Successfully factoring climate change mitigation and adaptation measures into water and sanitation service development projects (new systems, system extensions or infrastructure replacement) involves reviewing current organizational arrangements, planning tools and various strategy levels to produce a critical analysis of the extent to which climate-related issues have been included. This analysis can then be used to form the basis of optimal strategies that take climate hazards, the environment and meeting the water needs of end-users into account.

As it is difficult to predict climate hazards, particularly when the area under consideration is small, and determine their multiple and wide-ranging impacts on water supply and demand, a participatory and multi-disciplinary approach is required. This approach should involve all the various stakeholders: devolved government technical agencies (water, sanitation, the environment, etc.), local authorities, specialist consultants, scientists and water service managers and end-users, etc. It also appears important to ensure that all training and activities undertaken to enhance the professionalism of the sector include modules on environmental and climate risks.

The various strategic levels and intervention frameworks

Table 7. The various strategic levels and intervention frameworks

Level	Reference Frameworks	Lead Stakeholder
International	• The resolution on the human right to water and sanitation adopted by the UN General Assembly on 18 December 2013	• UN
	• The Sustainable Development Goals adopted by the UN General Assembly on 27 September 2015	• UN
	• The Paris climate agreement of 12 December 2015	• UN
Sub-Regional	• Transboundary river management plans	• River basin organizations
	• Regional water resource management action plans	• Regional economic commissions • Governments
	• Regional declarations on water and sanitation (e.g. the Ngor and eThekwini declarations on water and sanitation in Africa)	• Governments and water and sanitation ministries
National	• Development and poverty reduction strategies • Water and sanitation sector policies and national action plans • Water, sanitation and environment acts • National climate change adaptation plans	• Ministries of water, sanitation, the environment and other related sectors (health, urban planning, finance, decentralization, infrastructure, etc.)
Local	• Local development plan • Water and sanitation master plan / sector plans • Water management plan • Climate plan • Risk prevention plan	• Local authorities • Devolved government agencies: water, sanitation, the environment, health, etc. • Service managers • Consultancy firms • Companies • NGOs • Users

Courses of action

From the analysis of the links between the climate and water and sanitation services and the review of the various intervention frameworks, a number of courses of action emerge. These relate both to governance around and within water and sanitation services and to more technical and specific solutions.

Adaptation measures

Service governance-related adaptation measures

Policy

➔ **Include climate and environmental issues in water and sanitation service improvement strategies**: for instance, in guiding principles, legislation, vocational training and sector stakeholder communication.

Planning

➔ **Collaboratively conduct local water and sanitation diagnostics that take climate risks and water resource data into account.** The following particularly need to be considered:

- optimizing the various resources: surface water, rainwater (runoff, rainwater harvesting), groundwater and treated water;
- demand assessment of the different uses;
- resource protection and renewal: stormwater management (emergency preparedness and groundwater recharge) and the management of wastewater and excreta (to minimize the risk of contamination);
- water saving: cost of using the resource, demand management, wastewater reuse;
- measuring and modeling climate hazards and their local impacts.

The knowledge and data available on water resources and climate risks is currently insufficient. It is not solely up to the water and sanitation sector to collect this information and there needs to be a collective, inter-sector effort made to improve data collection and knowledge-sharing.

➔ **Rank water access priorities and define the activities to be undertaken in conjunction with sector and other relevant stakeholders to meet policy goals, ensuring climate risk is included.**

Planning needs to take into account demand and needs, the water resources available, risk analysis findings (flooding, droughts, pollution, water source depletion, etc.), forecast climate data (modeling) and environmental protection factors (IWRM, clean energy, sanitation, etc.).

➔ **Develop and implement a risk assessment plan that is regularly updated and define emergency procedures** for water and sanitation service managers, operators and end-users.

➔ **Organize supporting measures:** training stakeholders on factoring climate risk into their strategies, delivering awareness-raising campaigns to end-users on sanitation promotion and water saving measures.

Preliminary studies, construction work, service monitoring

➔ **Conduct preliminary studies for new water and sanitation infrastructure that is adapted to the climate conditions:** in-depth demand assessments, tailored technical studies, suitable management methods, adjusted forecast operating accounts, appropriate pricing schedules, supporting measures (awareness-raising and training), etc. should all take climate factors into account.

➔ **Introduce incentive measures for sector professionals** to further encourage companies that successfully incorporate climate change risks into their business models.

➔ **Improve work site monitoring mechanisms by introducing quality control measures that address climate change risk** to ensure facilities are able to withstand extreme weather events.

➔ **If necessary, supplement technical and financial monitoring systems by adding specific climate vulnerability indicators:** groundwater levels, service interruptions due to weather events, etc.

Water service performance adaptation measures

Table 8. 'Water' adaptation measures linked to specific consumption

Climate Hazards	Impact on Specific Consumption	Adaptation Measures
Variability of seasonal rainfall patterns Droughts, water scarcity Heatwaves	• **Increase in water needs and in volumes withdrawn** for all uses (domestic, agricultural, industrial, etc.)	• **'Enhanced' demand assessment** taking the variability of seasonal rainfall patterns into account. The aim is to anticipate the demand for water during periods of water scarcity in order to adapt the water facilities in line with the different possible scenarios • **Demand management**: this involves saving water by controlling the demand for various uses, introducing specific prices for different types of consumption, raising end-user awareness and monitoring large consumers

Table 9. 'Water' adaptation measures linked to service quality

Climate Hazards	Impact on Service Quality	Adaptation Measures
Variability of seasonal rainfall patterns	• **Interrupted or temporarily reduced services** due to lack of available resources	• **Increase the storage capacity to stockpile water between two rainy seasons to ensure continuous drinking water is available** • **Prioritize allocating water resources** to domestic uses in a fair and equitable manner
 Droughts, water scarcity	• **Services interruptions** caused by lack of water resources	• Introduce real-time groundwater level **monitoring tools** • **Improve the resource knowledge** of water-supply stakeholders (decision-makers and managers) • **Improve the performance of domestic and industrial water supply networks / reduce losses** • **Diversify and rationally utilize water withdrawal points** from different locations • **Link water supply networks together** to manage and share the resource on a larger scale • **Respect the balance** between groundwater withdrawal and recharge rates • **Build dams** to encourage infiltration and groundwater recharge • **Desalinate seawater** • **Import raw water** when sufficient quantities of good quality water are unavailable locally • **Reuse treated wastewater** to ease the pressure on other groundwater resources during droughts
 Heatwaves	• **Drop in quality of the water distributed** due to high concentrations of pathogens in the raw water or salinity	• **Monitor water quality** to adapt treatment processes accordingly • **Lower the concentration of pollutants in the water** used by reducing wastewater production (particularly for industrial wastewater by improving production processes) and by implementing or improving domestic and industrial wastewater treatment systems (cf. § *Sanitation service adaptation measures*

Climate Hazards	Impact on Service Quality	Adaptation Measures
 Sudden and intense rain events, flooding  Storms	• **Contamination of water resources** by uncontrolled stormwater runoff • **Service interruptions** due to damaged facilities • **Water points are inaccessible** (landslides – floods) • **Storage facilities are weakened** by saturation	• **Monitor water quality and adapt treatment accordingly** • **Prepare for extreme weather events** • **Systematize risk assessment plans** that include climate risks, identify vulnerable users (hospitals, etc.) and **communicate emergency procedures** to service managers, operators and end-users (cf. § *Stormwater management adaptation and prevention measures to minimize the impact of intense rainfall*)

Table 10. 'Water' adaptation measures linked to the quality of infrastructure and facilities

Climate Hazards	Impact on the Condition of Facilities	Adaptation measures
 Droughts, water scarcity  Heatwaves	• **Weakened facilities:** - facilities are over-used during droughts - concrete cracks during heatwaves - dry pumping can damage pumps	• **Ensure infrastructure and facilities are suitably robust** • **Improve the technical specifications** for studies, the construction company selection process, water and sanitation facility monitoring and inspections to include water scarcity and heatwave-related risks • **Diversify water withdrawal points and link networks together**
 Sudden and intense rainfall, flooding  Storms	• **Facilities are weakened, less efficient and damaged:** flooded wells and pumps, erosion of facilities, silting, burst pipes, network leakages, etc.	• **Improve the technical specifications** for water professionals • **Construct water retention basins** to protect facilities and create special infiltration areas • **Adapt the design and size** of water reservoir spillways to the newly defined risks

Sanitation service adaptation measures

Table 11. 'Sanitation' adaptation measures linked to service operation and infrastructure

Climate Hazards	Impacts	Adaptation Measures
Heatwaves	• **Biological treatment processes fail to function** (certain bacteria die) • **Condition of infrastructure and facilities deteriorate due to the heat** • **Concrete structures deteriorate due to the increased production of hydrogen sulfide** (H_2S)	• **Regularly monitor these treatment processes and adapt them** to any changes in climate conditions • **Monitor and eliminate hydrogen sulfide**
Sudden and intense rainfall, flooding	• **Flooding leads to breakdowns** on lift pumps and other electrical systems within wastewater treatment plants taking them out of service • **Collapse of latrines** not built to recognized standards (this can have a significant impact on access rates)	**Install (i) a stand-alone power production system** (generator and fuel stored in a secure location that can be used in the event of flooding) and **(ii) electro-mechanical equipment** (motors, control panels) **above the potential flood level** • **Build latrine foundations in erosion-resistant materials**
Storms		

Table 12. 'Sanitation' adaptation measures to protect the environment and water resources

Climate Hazards	Impacts	Adaptation Measures
Droughts, water scarcity	• **Drop in water resource quality** due to lower dilution of pollutants	• **Improve wastewater treatment capacity prior to discharging wastewater into the environment**
Sudden and intense rainfall, flooding	• **Increase in untreated wastewater discharged into the environment** as stormwater runs into the sewers causing these to overflow; lift pumps become flooded and wastewater treatment plants are by-passed • **A mixture of wastewater and stormwater overflows onto public roads** as toilet and latrine pits are flooded causing severe health risks	• **Install separate sewer systems** for wastewater and stormwater • **Minimize stormwater intrusion into the sewers** • **Create buffer ponds** • **Increase treatment capacity** • **Dig pits on higher ground** or • **Install pits with airtight seals**
Storms		

Table 13. 'Sanitation' adaptation measures linked to social and health impacts

Climate Hazards	Impacts	Adaptation Measures
Heatwaves	• **Hydrogen sulfide (H_2S) poisoning through inhalation** as H_2S production is exacerbated by the heat (staff health & safety risk, particularly for sewer workers) • **Olfactory pollution** due to increased nitrous oxide emissions (N_2O)	• **Monitor and eliminate hydrogen sulfide** (H_2S)
Sudden and intense rainfall, flooding Storms	• **People no longer have working sanitation facilities available** • **Increase in waterborne diseases** as there is a higher risk of people coming into contact with polluted water	• **Immediately install temporary toilets** to be used until facilities are rebuilt • **Ensure safe water and domestic water treatment systems are available in emergency situations**

Stormwater management adaptation and prevention measures to minimize the impact of intense rainfall

Table 14. Stormwater management adaptation and prevention measures to minimize the impact of intense rainfall

Climate Hazards	Impacts	Prevention and Adaptation Measures
Excess water	Flooding	• **Actions to reduce the extent of floods** - Manage surface runoff upstream of the town - Ensure stormwater infiltration and reuse at individual plot level - Minimize soil sealing - Lay porous road surfaces - Build and properly maintain drainage networks • **Actions to halt the urban development of areas at permanent risk** • **Actions to minimize the risk to people and property during rain events** - Introduce weather forecasting tools able to identify the magnitude of rain events - Install public warning and evacuation systems in high-risk areas - Develop measures to temporarily protect safety equipment

And also mitigation measures…

It is worth reiterating that the water and sanitation sector is not considered to be a major emitter of greenhouse gases. For example, in France, the sector produces less than 1% of all greenhouse gas emissions, whereas the transport sector, for instance, generates 27% (ADEME and ASTEE, 2013). Nevertheless, water shortages and pollution, combined with other global changes (such as growing populations and higher standards of living) that lead to an increased demand for water and higher service level requirements, result in more energy being required to operate the facilities.

Efforts made to adapt and provide water and sanitation services to meet needs and satisfy demand must not overlook the fact that low greenhouse gas emitting technical solutions need to be found.

For water services

It is necessary to:

- identify what other types of energy (solar, wind, etc.) can be used to replace fossil fuel ("thermal power");
- streamline the entire chain (extraction, transport, treatment, distribution) and, in particular, improve treatment processes so that they require less energy.

➔ Install dams that enable water to be released without pumping

➔ Use solar power for water extraction

Sector stakeholders affirm that, due to water shortages, they already have to draw water from increasingly deeper aquifers in order to obtain sufficient quantities of good quality groundwater and to ensure the water sources used will not dry up during the dry season.

The onerous task of manually drawing water from deep aquifers, coupled with people's desire for an improved level of service, namely a tap not far from or in the home, means that more and more energy is required for pumping and storing water.

Where there is no electricity grid nearby, "thermal" energy sources – or generators – are currently most commonly used. However, the long lifespan and continuing fall in the cost of solar panels means that solar-powered pumping is fast becoming a highly competitive alternative to systems powered by increasingly expensive fossil fuels.

Solar power is an option worthy of further consideration as its low operating costs could help reduce water prices. There is also now a growing local pool of experience to draw upon to manage this increasingly efficient clean energy source.

Other courses of action for greenhouse gas mitigation and improving the performance of water and sanitation services highlighted by sector stakeholders include:

➔ Improving the energy efficiency of service-related equipment (pumps, generators, etc.) and optimizing the use of any unconsumed energy produced.

➔ Reducing network leakages as fewer water losses mean less pumping – and thus less energy - is required.

➔ Developing local chlorine production for use in water treatment to minimize the impact of transport-related greenhouse gas emissions.

The main extraction systems used in developing countries

- Manual water extraction: using a rope and bucket (and sometimes an animal-drawn system)
- Handpumps: rope pump, Volanta flywheel pump, India Mark II pump, foot pump, etc.
- Motorized pumps:
  - *thermal-powered pumps*, i.e. using a diesel-powered generator
  - *solar or wind-powered pumps*
  - *pumps connected to the electricity grid*
- Gravitational systems: developed springs

For sanitation services

Mitigation measures for sanitation need to focus on three different aspects:

- Reducing the greenhouse gas emissions (methane, nitrous oxide) released by wastewater and excreta and thus selecting the most appropriate sanitation technologies and treatment processes;
- Developing methane energy recovery;
- Introducing energy-efficient sanitation chains (transport and treatment).

Key points to remember…

Global warming, a phenomenon confirmed by IPCC studies, is taking place on a worldwide scale and exacerbating extreme weather events, the impacts of which are being felt in varying degrees in each region of the world. Thus, in inter-tropical countries, there are likely to be more intense heatwaves, longer dry seasons and shorter rainy seasons with sudden and heavy rainfall.

These climate upheavals, which need to be considered in conjunction with other global changes, such as population trends, will have an impact on both the water cycle and water and sanitation services.

Water and sanitation services are low greenhouse gas emitters and, compared to other sectors, they have little influence on global warming. In contrast, **changes in the climate and to the water cycle are likely to have a severely adverse effect on the operation, quality and sustainability of water and sanitation services**.

For water and sanitation services, therefore, the stakes are high, particularly in light of the targets set out in the 6th Sustainable Development Goal (SDG6).

Why take action?

Understanding the impact of climate change on water and sanitation services can help to minimize the risk posed to the sustainability of the investments made to improve access to water and sanitation.

<table>
<tr><th>Climate Hazards</th><th>Impact on Water Resources</th><th>Impact on Water Services</th><th>Impact on Sanitation Services</th><th>Social & Health Impacts</th></tr>
<tr><td>Variability of seasonal rainfall patterns</td><td rowspan="2">Low levels or a lack of surface water and groundwater at the ‘end’ of the dry season available to the water service</td><td rowspan="2">Interrupted or temporarily reduced services due to lack of available water resources
Drop in the quality of water distributed
Increase in water needs and in volumes withdrawn</td><td rowspan="2">The quality of the water resource falls as the wastewater discharged is not properly treated (as biological treatment processes fail to function or facilities deteriorate)</td><td rowspan="3">Chore of drawing water becomes more difficult
Increase in diarrheal diseases
Increase in conflicts of use
Greater migration</td></tr>
<tr><td>Droughts, water scarcity</td></tr>
<tr><td>Heatwaves</td><td rowspan="2">A reduction in the quantity and quality of surface water and groundwater</td><td rowspan="3">Service interruptions
Water points are inaccessible
Facilities are weakened, less efficient and damaged</td><td rowspan="3">Infrastructure is damaged and facilities break down
Pit emptying services are disrupted
Treatment processes fail to function
Increase in untreated wastewater discharged into the environment</td></tr>
<tr><td>Sudden and intense rainfall, flooding</td><td rowspan="2">Pollution – contamination of surface water and groundwater
Poor infiltration</td><td rowspan="2">People no longer have working sanitation facilities available
Increase in waterborne diseases</td></tr>
<tr><td>Storms</td></tr>
</table>

How to take action

Useful vocabulary

Mitigation refers to efforts to reduce emission of greenhouses gases produced by human activities.

Adaptation involves anticipating the impact of climate change and reducing the vulnerability of natural and human systems.

Resilience is defined by the IPCC as being "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation."

There is a general lack of ownership of climate change issues among water and sanitation stakeholders and planning tools reveal that the water and climate sectors remain compartmentalized. Efforts therefore need to be made to **integrate climate and environmental issues into the various intervention frameworks**, whether international, sub-regional, national or local.

The impacts of climate change on water and sanitation services can be addressed from a risk management and resource protection perspective and through **integrated water resource management** (IWRM) in particular. IWRM makes it possible to determine what is feasible over time given the quality and quantity of the water resources available, set the relevant limits and identify the measures and organizational arrangements required to ensure these limits are respected.

Mitigation measures: The water and sanitation sector is not considered to be a major emitter of greenhouse gases. Thus, mitigation measures predominantly involve **using cleaner sources of energy and reducing consumption**. For water services, this means finding alternative energy sources (wind, solar), especially for water extraction, and reducing network leakages. For sanitation, mitigation involves reducing methane emissions (using suitable treatment processes), introducing energy efficient sanitation chains and developing methane energy recovery (biogas).

Adaptation measures: As outlined above, the water and sanitation sector is heavily impacted by climate change. Adaptation measures for water services should focus on **service governance (improving the inclusion of climate issues), water resource protection and service performance** (demand assessment and management, resource knowledge and protection, quality monitoring, adapting infrastructure to withstand extreme weather events, risk management). For sanitation services, **adaptation measures should include improving service monitoring and wastewater treatment, adapting sanitation infrastructure** (expansion or flood protection) and introducing emergency procedures.

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