SANITATION SAFETY PLANNING

Step-by-step risk management for safely managed sanitation systems

World Health Organization

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CONTENTS

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The sanitation safety planning approach follows the Stockholm framework for preventive risk assessment and management and uses the methods and procedures of hazard analysis and critical control point (HACCP). The manual incorporates experiences of using sanitation safety planning in more than 25 countries across different regions and was developed under the guidance of a strategic advisory group and with review by experts and practitioners.

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ABBREVIATIONS

DALY	disability-adjusted life year
DRR	Disaster risk reduction
F	Farmers exposure group
HACCP	Hazard analysis and critical control point
IPCC	Intergovernmental Panel on Climate Change
LC	Local community exposure group
LRV	$\log_{10}$ reduction value
NGO	Non-governmental organization
QMRA	Quantitative microbial risk assessment
SFD	Excreta Flow Diagrams
S	System Flows
SOP	Standard operating procedure
SS	Suspended solids
SSP	Sanitation safety planning
TDS	Total dissolved solids
TSS	Total suspended solids
U	Users exposure group
W	Workers exposure group
WC	Wider community exposure group
WHO	World Health Organization
WSP	Water safety plans
WWTP	Wastewater treatment plant

GLOSSARY

Term	Definition
Aquaculture	Raising plants or animals in water (water farming).
Climate change	A change of climate that is attributed directly or indirectly to human activity and alters the composition of the global atmosphere; this is in addition to natural climate variability observed over comparable time periods (UN, 1992).
Climate Resilient Sanitation Safety Plan	A step-by-step risk-based approach to assist in local-level risk assessment and management for the sanitation service chain (toilet, containment–storage/treatment, conveyance, treatment, and end use or disposal), considering the implications of climate variability and climate change. This methodology identifies opportunities to enhance the sanitation safety planning process and outcomes by considering the provision of safe sanitation under changed future conditions and extreme weather events, such as prolonged droughts and heavy rains, which may become more frequent and severe as the climate changes.
Climate variability	Variations in the mean state and other statistics (e.g. standard deviations, occurrence of extremes) of the climate on all spatial and temporal scales beyond that of individual weather events.
Containment–storage/treatment	Relevant to non-sewered sanitation systems, refers to the container, usually located below ground level, to which the toilet is connected. Several technologies are associated with this step, including septic tanks, dry- and wet-pit latrines, composting toilets, dehydration vaults and urine storage tanks, as well as containment and storage technologies without treatment, such as fully lined tanks and container-based sanitation.
Control measure	Any action and activity (or barrier) that can be used to prevent or eliminate a sanitation-related hazard or reduce it to an acceptable level.
Conveyance	Transport of products from either the toilet or containment step to the treatment step of the sanitation service chain – for example, where sewer-based technologies transport wastewater from toilets to wastewater treatment plants. Technologies include conventional gravity sewers, small-bore sewers and simplified sewers, and human-powered and motorized emptying and transport.
Disability-adjusted life year (DALY)	Population metric of life years lost to disease, as a result of both morbidity and mortality.
Disease vector	A living agent (e.g., mosquito, rat) that carries disease from one animal or human to another.
End use/disposal	Methods by which products are ultimately returned to the environment as reduced-risk materials or used in resource recovery. Includes application of compost for soil improvement; use of water for irrigation and aquaculture; energy generation through incineration; and production of solid fuel (pellets, briquettes, powder burned for fuel), building material and animal fodder. Also includes disposal technologies such as soak pits, leach fields, and surface water and groundwater recharge.
Escherichia coli (E. coli)	A bacterium found in the gut. It is used as an indicator of faecal contamination of water.
Excreta	Faeces and urine. *See also* faecal sludge, septage and nightsoil).
Exposure	Contact of a chemical, physical or biological agent with the outer boundary of an organism (e.g. through inhalation, ingestion or dermal [skin] contact).
Exposure route	The pathway or route by which a person is exposed to a hazard.
Faecal sludge	Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Septage, the faecal sludge collected from septic tanks, is included in this term. See also excreta, nightsoil.

Term	Definition
Greywater	Water from the kitchen, bath or laundry, which, generally, does not contain significant concentrations of excreta.
Hazard	A biological, chemical or physical constituent that can cause harm to human health.
Hazardous event	An event in which people are exposed to a hazard in the sanitation system. It may be an incident or situation that: • introduces or releases a hazard to the environment in which humans are living or working; • amplifies the concentration of a hazard; or • fails to remove a hazard from the human environment.
Health-based target	A defined level of health protection for a given exposure. This can be based on a measure of disease, or the absence of a specific disease related to that exposure. In the WHO 2006 *Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture*, the health-based target recommended is 10^{-6} DALYs per person per year.
Helminth	A broad range of organisms that include intestinal parasitic worms: trematodes (flatworms, also commonly known as flukes; e.g. *Schistosoma*), nematodes (roundworms; e.g. *Ascaris, Trichuris,* human hookworms) and cestodes (tapeworms; e.g. *Taenia solium*, the "pork tapeworm").
High-growing crops	Crops that grow above the ground and do not normally touch the ground (e.g. most fruit crops).
Highly mechanized farming	Farming practices in which farm workers typically plough, sow and harvest using tractors and associated equipment, and could be expected to wear gloves when working in irrigated fields. This is representative of exposure conditions in industrialized countries.
Infection	The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea). Infection can be measured by detecting infectious agents in excreta or colonized areas, or through measurement of a host immune response (i.e. the presence of antibodies against the infective agent).
Intermediate host	The host occupied by juvenile stages of a parasite before the definitive host and in which asexual reproduction often occurs. For example, specific species of snails are the intermediate host for *Schistosoma*, a parasitic flatworm causing schistosomiasis.
Labour-intensive farming	Farming practices, typical in developing countries, in which the practice puts people in close contact with soil, water and produce.
Lead organization	The organization or agency that takes the lead in a sanitation safety planning process.
Leaf crops	Crops in which the leaf portions are harvested and either eaten raw or cooked (e.g. lettuce, celery, spinach, salad greens).
Localized irrigation	Irrigation application technologies that apply water directly to the crop, through either drip irrigation or bubbler irrigation. Generally, localized irrigation systems use less water, resulting in reduced crop contamination and a reduction in human contact with the irrigation water.
Log reduction	Organism reduction efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.
Low-growing crops	Crops that grow below, or just above but in partial contact with, the soil (e.g. carrots, lettuce, tomatoes or peppers, depending on growing conditions).
Nightsoil	Untreated excreta transported without water (e.g. via containers or buckets).
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard breakthrough.
Pathogens	Disease-causing organisms (e.g. bacteria, helminths, protozoa, viruses).
Quantitative microbial risk assessment (QMRA)	Method for assessing risk from specific hazards through different exposure pathways. QMRA has four components: hazard identification, exposure assessment, dose–response assessment and risk characterization.

Term	Definition
Restricted irrigation	Use of wastewater to grow crops that are not eaten raw by humans, but are cooked before eating (e.g. potatoes).
Risk	The likelihood and consequences that something with a negative impact will occur.
Root crops	Crops in which the root portion of the crop is edible (e.g. carrots, potatoes, onions, beetroot).
Safe sanitation system	A system designed and used to separate human excreta from human contact at all steps of the sanitation service chain, from toilet capture and containment through emptying, transport, treatment (in situ or off-site) and final disposal or end use. Safe sanitation systems must meet these requirements in a manner consistent with human rights, while also addressing co-disposal of greywater, associated hygiene practices and essential services required for the functioning of technologies.
Sanitary inspection	An on-site inspection by qualified individuals of sanitation system, normally toilet and containment steps, of system faults and hazards that pose of health risks to user and local community. A sanitary inspection includes identification of remedial measures to be undertaken by households of service providers.
Sanitary surveillance	A surveillance programme, often incorporating sanitary inspection, that gives a continuous and vigilant public health assessment of the safety and acceptability of the sanitation system(s).
Sanitation	Access to, and use of, facilities and services for the safe disposal of human urine and faeces.
Sanitation service chain	All components and processes comprising a sanitation system, from toilet capture and containment through emptying, transport, treatment (in situ or off-site), and final disposal or end use.
Sanitation service providers	Service providers may be private enterprises, publicly or privately owned utilities, local government departments, or (in most cases) a combination of these. Sanitation service providers range from small businesses offering hardware supplies, toilet construction or removal of faecal sludge to operators of sewerage or faecal sludge treatment plants, and engineering companies that design and construct treatment works (e.g. to ensure that the products and services offered do not pose any health risk).
Sanitation step	Elements or building blocks of the sanitation safety planning system to help analyse the sanitation system. Typically, elements may consist of toilet, containment–storage/treatment, conveyance, treatment, and end use/disposal.
Sanitation system	The combined sanitation service chain from waste generation to final use and disposal.
Septage	See faecal sludge
Severity	The degree of impact on health if a hazardous event occurred.
Sanitation safety planning (SSP) area	Area in which SSP is conducted.
Sanitation safety planning (SSP) system assessment	Assessment of the hazards and risks in the SSP system.
Toilet	The user interface with the sanitation system, where excreta is captured. Can incorporate any type of toilet seat or latrine slab, pedestal, pan or urinal. There are several types of toilets – for example, pour- and cistern-flush toilets, dry toilets, and urine-diverting toilets.
Tolerable health risk	Defined level of health risk from a specific exposure or disease that is tolerated by society. It is used to set health-based targets.
Treatment	Processes that change the physical, chemical and biological characteristics or composition of faecal sludge or wastewater so that it is converted into a product that is safe for end use or disposal. Includes technologies for containment–storage/treatment of wastewater and faecal sludge on-site, technologies for treatment of wastewater (containing one or more of blackwater, brown water, greywater or effluent) off-site and technologies for treatment of sludge off-site.
Unrestricted irrigation	Use of treated wastewater to grow crops that are normally eaten raw.
Validation	Proving that the system and its individual components are capable of meeting specified targets (i.e. microbial reduction targets). Validation should be part of the documentation when a new system is developed, new processes are added or new information (e.g. climate projections) is obtained that may affect control measure performance.

Term	Definition
Vector-borne disease	Disease (e.g. malaria, leishmaniasis) that can be transmitted from human to human via insect vectors (e.g. mosquitoes, flies).
Verification	Application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and whether the system meets specified requirements (e.g. microbial water quality testing for E. coli or helminth eggs, microbial or chemical analysis of irrigated crops).
Waste stabilization ponds	Shallow basins that use natural factors such as sunlight, temperature, sedimentation and biodegradation to treat wastewater or faecal sludges. Waste stabilization pond treatment systems usually consist of anaerobic, facultative and maturation ponds linked in series.

INTRODUCING SANITATION SAFETY PLANNING

Why is sanitation safety planning needed?

Sanitation safety planning (SSP) supports the implementation of the World Health Organization (WHO) *Guidelines on sanitation and health* (WHO, 2018) at the local authority level. SSP is the approach recommended by WHO for incremental improvement leading to safely managed sanitation services for all.

The underlying purpose of sanitation systems is to protect public health. However, sanitation interventions do not always sustainably improve health to the extent anticipated. This is primarily because the combination of technologies, behaviour change and management approaches used in these interventions does not systematically interrupt transmission of locally relevant diseases. The burden of these diseases often falls on the poorest in society and areas most affected by a changing climate. Too often, there is insufficient analysis of local risks and ongoing management of the system needed to sustain safe services.

Large, but ultimately cost-effective, investments are needed to achieve safely managed sanitation services. Other health targets – such as for cholera and other diarrhoeal diseases, neglected tropical diseases, and antimicrobial resistance – depend on such services. Similarly, targets on decent work and the circular economy rely on management of hazards from sanitation systems for workers and the environment.

It can be challenging, especially in urban areas, to achieve safely managed services using a single intervention. Therefore, investment is needed in incremental improvements where they can have the greatest impact for the most people, along with sound management of existing services to reduce risk and prevent backsliding.

What is sanitation safety planning?

SSP is a risk-based management tool for sanitation systems that:

- helps with systematically identifying and prioritizing health risks along the sanitation chain – that is, toilet, containment–storage/treatment, conveyance, treatment, and end use or disposal;
- guides management and investments in sanitation systems according to risk;
- identifies operational monitoring priorities and regulatory oversight mechanisms that target the highest risks; and
- provides assurance to authorities and the public on the safety of sanitation-related products and services.

Key updates in this edition of *Sanitation safety planning* include:

- simplification of the SSP process;
- reorientation to support recommendations on local-level risk assessment and management in the WHO *Guidelines on sanitation and health*, covering all steps of the sanitation chain, with or without safe end use; and
- inclusion of climate risks.

This edition provides more in-depth information to strengthen climate resilience, including identification of climate-related risks (such as those caused by water scarcity, sea level rise and extreme weather events), and associated management and monitoring options (Kohlitz, 2019). Proactive management is central to SSP. Considering climate impacts improves the preparedness of local authorities for an uncertain future. These principles also apply to other future shocks and emergencies, such as disasters, epidemics and pandemics.

SSP provides a coordinating structure to bring together actors along the sanitation service chain to identify risks, and agree on improvements and regular monitoring. The approach ensures that controls and investments target the greatest health risks and emphasizes incremental improvement over time. SSP is applicable in both high- and low-resource settings. It can be used at the planning stage for new schemes, and to improve the performance of existing systems. The methodology and tools in this SSP manual can be applied to all sanitation systems (e.g. sewered, non-sewered, decentralized systems). Ideally, SSP covers all service types within an administrative area.

SSP underscores the role of the health sector in sanitation and helps bring a human health perspective to sanitation, supporting the roles of the local government, housing, sanitary engineering and agriculture sectors.

SSP complements the water safety planning (WSP) approach. Both SSP and WSP are based on the Stockholm Framework for preventive risk assessment and management of water-related diseases. Both methodologies use the methods and procedures of hazard analysis and critical control points (HACCP).

BOX 1. Linkages between sanitation safety planning and water safety planning

Poor sanitation management can have a profound impact on drinking-water quality, particularly with regards to source protection in drinking-water catchments. Water safety planning (WSP) is a risk-based management tool for water supply systems that helps water supply managers to assess sources of contamination and prioritize public health risks from catchment to consumer.

SSP complements the water safety planning approach, and can be applied in parallel to WSP implementation. SSP can support the management of sanitation-related risks throughout the entire drinking-water supply chain, including at the:

- catchment-level (e.g. leaking septic tanks contaminating ground water sources)
- treatment level (e.g. disinfection systems compromised due to high pathogen loading in raw water)
- distribution-level (e.g. open sewers overflowing into network air valves during flood events)
- user-level (e.g. open defecation resulting in faecal material in the vicinity of public tap stands which contaminates collection vessels).

WSP, like SSP, provides a robust framework to manage current and future threats from climate variability and change, and can build resilience to unforeseen events and future uncertainty.

Where both approaches are being applied in a given setting, the WSP Team and SSP Team should be considered important stakeholders in the respective processes. In certain contexts, consideration may be given to implementing water and sanitation safety planning in an integrated manner.

For further information, see https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/water-safety-and-quality/water-safety-planning

Navigating this manual

This manual presents the SSP process in six modules (Fig. 1) supported by guidance notes, examples and tools and a complete worked example.

Step by step guidance

Module 1 answers the questions *Where should SSP be done? Who should be involved and what are their roles?* The SSP area and SSP priorities of the sanitation system are defined, together with the membership of the SSP team.

Module 2 answers the questions *How does the sanitation service chain work? Who is at risk?* It results in a complete description of the sanitation system.

Module 3 answers the questions *What could go wrong? What existing control measures are in place and how effective are they? How significant are the risks?* Within this module, SSP teams identify hazards and hazardous events, including climate-related hazards. They then perform a health risk assessment that prioritizes the highest risks.

Module 4 answers the question *What needs to be improved and how?* Improvement measures that address the highest risks are selected and organized in an incremental improvement plan.

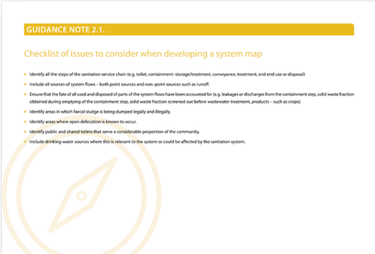
Module 5 answers the questions *Is the sanitation system operating as intended? Is it effective?* As a result, an operational monitoring plan and a verification plan are prepared.

Module 6 answers the questions *How should SSP be supported? How can we adapt to changes?* SSP teams identify key supporting programmes, and plan SSP review and updates.

Fig. 1. Modules of sanitation safety planning

Guidance notes and examples

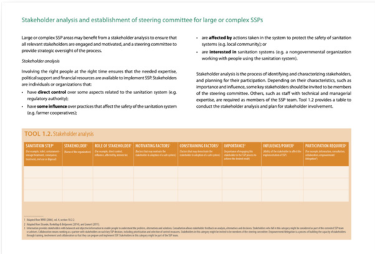
Get further information on key concepts and their application in examples and real-world cases for each module


GUIDANCE NOTE 2.1.

Checklist of issues to consider when developing a system map

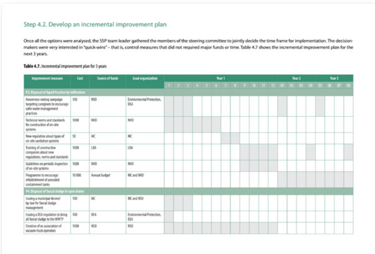
Tools

Get a quick start for a first SSP by using the templates provided, adapting them to your local context.


Stakeholder analysis and establishment of steering committee for large or complex SSPs

Worked example

Follow a full worked example from the start to finish of the SSP process using tools and with decision points along the way explained.


Step 4.2. Develop an incremental improvement plan

Who are the target audiences?

This SSP manual is primarily targeted to:

- local authorities, as a tool to coordinate, plan improvements to, and monitor, services in an administrative area;
- sanitation service providers, as a tool to manage service quality, and provide assurances to local authorities and regulators; and
- public health regulators, as an oversight tool to identify and verify effectiveness of risk-based regulatory measures applied to local authorities and service providers.

How does sanitation safety planning contribute to the implementation of WHO guidelines?

This SSP manual provides step-by-step guidance for the implementation of the 2018 WHO Guidelines on sanitation and health (WHO, 2018) and the 2006 WHO *Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture* (WHO, 2006). It offers practical advice on implementing the following recommendations in the *Guidelines on sanitation and health*:

- **Recommendation 1** – Ensure universal access and use of toilets that safely contain excreta. Users of this manual can plan and promote improvements based on an incremental progress approach to achieving universal access.
- **Recommendation 2** – Ensure universal access to safe systems along the entire sanitation service chain. This manual offers a local-level risk assessment and management methodology to ensure that progressive improvements in sanitation systems and services are context-specific, responding to local physical and institutional conditions. It proposes adequate health and safety measures to protect sanitation workers from occupational exposure.

- **Recommendation 3** – Sanitation should be addressed as part of locally delivered services and broader development programmes and policies. This manual invites the user, while selecting improvement measures, to consider a multibarrier approach to address all pathways of faecal pathogen transmission, including safe water supply, hygiene promotion and vector control programmes, as well as other related local services.
- **Recommendation 4** – The health sector should fulfil core functions to ensure safe sanitation to protect human health. This manual points out key functions to be performed by local health authorities, including target setting according to public health considerations, coordination, setting of standards and norms, sanitation promotion and monitoring within health surveillance systems.

Why should climate-related risks be addressed in sanitation safety planning?

This SSP manual integrates considerations of climate variability and climate change because there is increasing evidence that climatic events influence the health risks associated with sanitation systems (see Box 2).

BOX 2. Climate, sanitation and health

Global heating driven primarily by anthropogenic greenhouse gas emissions is leading to significant changes in climate throughout the world. It is very likely that heatwaves will occur more often and last longer, extreme precipitation events will become more intense and frequent in many regions, and global mean sea level will continue to rise (IPCC, 2014a). In many regions, changing precipitation is already affecting quantity and quality of water resources (IPCC, 2014b). Although there is a level of uncertainty about how climates, particularly at local levels, will change, it is clear that these changes pose significant risks to the sustainability of sanitation systems.

Changes in climate variability, extreme weather events and seasonality of weather events can directly and indirectly affect sanitation systems in numerous ways along the entire service chain. Floods that cause containment units to overflow, corrosion and inundation of wastewater treatment infrastructure from sea level rise, and rising temperatures that allow pathogens in waterways to proliferate are only a few of many examples of how climate can affect sanitation. Although climate-related hazardous events have always existed, climate change has the potential to increase their severity and the likelihood of public health risks. Disadvantaged groups are likely to disproportionately bear the burden of these increased risks.

The SSP process provides a framework to identify, prioritize and manage climate-related risks, and to integrate these considerations into local management, policies and programming. Climate change is considered within the SSP risk assessment, planning and management processes based on current knowledge of the potential impacts identified in the scientific literature, particularly the most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2021).

What is needed for sanitation safety planning?

Countries need institutional and regulatory functions and capacities for both sewered and non-sewered sanitation systems. SSP can help identify and clarify institutional roles and coordination, and identify priority actions for regulation and capacity development. Ultimately, these institutions and regulatory functions sustain implementation of local-level risk assessment and management. SSP frameworks should provide for four separate functions related to SSP.

- **Policy-making** – health-based risk assessment and management approaches to sanitation should be addressed in national policies, legislation, regulations and standards.
- **Local planning** – local-level health-based risk assessment along the entire sanitation service chain should be compulsory, with the aim of prioritizing improvements, and therefore investments, in sanitation systems.
- **Operation of sanitation systems** – sanitation service providers should implement measures to mitigate health risks, and follow performance criteria and standards to protect public health.
- **Monitoring** – SSP surveillance should be overseen by an independent authority.

Sanitation systems often have several service providers along the sanitation service chain, especially for non-sewered services. This may require prolonged policy discussion to achieve sector-wide endorsement and intersectoral cooperation. Integrating climate change considerations may require that authorities responsible for meteorology and climate adaptation are incorporated into the process.

Chapter 4 ("Enabling safe sanitation service delivery") of the 2018 WHO *Guidelines on sanitation and health* (WHO, 2018) presents a framework for sanitation interventions, describing the components of national and local governance functions, and agency responsibilities.

Given the complex nature of regulatory and policy change, SSP may be undertaken to inform the policy dialogue by providing practical guidance on risk assessment and management at the local level. SSP assessments such as routine surveillance or audits should ensure the sustained high-quality management of sanitation systems and provide feedback on performance.

MODULE 1

PREPARE FOR SANITATION SAFETY PLANNING

MODULE 1

PREPARE FOR SANITATION SAFETY PLANNING

Where should SSP be done?
Who should be involved and what are their roles?

STEPS

1.1 Define the SSP area and lead organization
1.2 Assemble the SSP team
1.3 Establish SSP priorities

TOOLS

Tool 1.1. Suggested SSP team membership recording form
Tool 1.2. Stakeholder analysis

OUTPUTS

- **Agreed SSP area, leadership and priorities**
- **A multidisciplinary team representing the sanitation chain for development and implementation of SSP**

Overview

SSP requires clarity on the area where SSP will be applied and on the coordinating organization that will lead the SSP process. SSP can be implemented by a local authority or within the operations of a sanitation service provider such as a utility, faecal sludge management service or entity treating and using treated faecal waste. Implementation in the entire administrative area by local authorities is the goal. However, when initiating SSP, specific subareas, and specific challenges for public health and the sanitation service chain may be prioritized. In all cases, a team needs to be identified that represents the various steps of the sanitation chain.

Step 1.1 Define the SSP area and lead organization – helps to drive and sustain the SSP process, and ensures that the scope is manageable and understood by all stakeholders.

Step 1.2 Assemble the SSP team – ensures broad stakeholder commitment to design and implementation for the entire SSP process. This is particularly important in sanitation systems, because responsibility along the sanitation chain is seldom held by a single organization.

Step 1.3 Establish SSP priorities – establishes the priority sanitation challenges for SSP.

Although presented sequentially, in practice, steps 1.1–1.3 might be carried out as an iterative process. The SSP team leader may revisit and update the area, priorities and SSP team membership as more information becomes available, new stakeholders are identified and decisions are taken by the steering committee (see section 1.2).

1.1 Define the SSP area and lead organization

SSP is carried out within an administrative area, or the service area of a sanitation utility or service provider.

- When SSP is initiated in a municipality, district or other administrative unit (e.g. ward), the SSP area is determined by the area administered by the local authority (see example 1.1). In this case, all the existing sanitation systems (e.g. sewered, on-site, decentralized systems) and all sanitation steps within the sanitation service chain (i.e. toilet, containment–storage/treatment, conveyance, treatment, and end use or disposal) should be included. The lead organization should be the local authority with the mandate for oversight of sanitation service provision, because SSP is used as a tool to coordinate sanitation, service providers, programmes and investments. A team leader should be appointed to drive the SSP process – that is, identify, engage and coordinate key service provider representatives (e.g. toilet masons, sanitation utilities, vacuum service providers) and other stakeholders, such as other local government departments and agencies.

EXAMPLE 1.1. Peri-urban town in Karnataka, India: SSP area and lead organization

Location: Peri-urban town in Karnataka, India, population approximately 25 000.

SSP area: The SSP area was defined as the town administrative area. The sanitation systems in the area included an on-site sanitation system (toilets, septic tanks, sludge collection, and formal and informal disposal) and an off-site sanitation system (toilets, combined sewer system – open drains/stormwater sewer and sewer system – and formal and informal use of the combined drainage/sewer water for agricultural production).

Lead organization: Town municipal council health department.

- SSP may be also implemented by sanitation service providers (e.g. utilities, faecal sludge management service providers, sanitation enterprises) to ensure that the sanitation systems under their responsibility are safely operated and their products (e.g. treated wastewater, dried sludge, fertilizers) do not pose health risks during disposal or use (see examples 1.2, 1.3 and 1.4). The area is determined by the service provider's operations, and the team leader is identified within its organization structure.

EXAMPLE 1.2. Intermunicipal water and sanitation service provider in Portugal: SSP area and lead organization

Location: Seven municipalities in Portugal with a total population of 160 000 and an area of 3300 km2. SSP was developed for the wastewater system of an intermunicipal company responsible for the water supply and sanitation system.

SSP area: The area of the system consisted of the entire wastewater infrastructure managed by the intermunicipal service provider, including the household connections to the sewer system, the combined sewer system (stormwater and wastewater), pumping stations, the wastewater treatment plant (WWTP), treatment of WWTP sludge, disposal of treated wastewater in the water body and indirect reuse in agriculture, and disposal of treated WWTP sludge. Because some houses are served with on-site systems (e.g. septic tanks), the faecal sludge management system, operated by the same service provider, was also included.

Lead organization: Water and sanitation utility.

EXAMPLE 1.3. Container-based sanitation (CBS) system in a densely populated area in Cap Haitian in Haiti: area and lead organization (SOIL 2019)

Location: 1000 households in a densely populated area in Cap Haitian in Haiti.

SSP area: The area of the SSP system included all activities within the CBS business's household sanitation service chain, and subsequent treatment and transformation of waste collected by the household sanitation service. These include construction of toilets, provision of the service to households in the area, transport and treatment of waste at the composting site collected through the household service, and reuse of compost.

Lead organization: CBS company; a programme officer was appointed as team leader.

EXAMPLE 1.4. Company producing and commercializing compost produced with faecal sludge and organic solid waste

SSP area: In this case, only the treatment and reuse steps of the sanitation service chain were included as part of the SSP system. SSP was conducted by this business to ensure that the compost produced with faecal sludge and organic solid waste was safe for reuse in agricultural fields. Because the company receives the faecal sludge and the organic waste from markets from other service providers, the SSP area starts with reception of the raw material (faecal sludge and organic waste) at the company premises. Besides the treatment, the SSP also covered the point of sale of the resulting compost and application of the compost in the field.

Lead organization: Private company producing compost; the SSP team leader was the quality assurance manager.

In some cases, part of the sanitation activities might fall outside the administrative area, or the mandate of a service provider – for example, a wastewater treatment plant in an urban area, coupled with effluent reuse on agricultural lands located in a different administrative area and overseen by a different authority. In this case, a coordination team composed of the most relevant authorities should be formed to lead the SSP process. Example 1.5 shows the SSP area and the lead organizations in a complex system.

EXAMPLE 1.5. Urban wastewater system and farm application, Kampala, Uganda: area and lead organizations

Location: Kampala, Uganda.

SSP area: The sewer network, treatment plants and the Nakivubo wetland channel, where farming takes place using treatment plant effluent before discharging to Lake Victoria (which acts as the drinking-water supply for Kampala city).

Lead organizations (coordination team): National Water and Sewerage Corporation (a water utility responsible for provision of water and sewerage services in Uganda), in collaboration with the Kampala Capital City Authority.

1.2 Assemble the SSP team

Appoint an SSP team leader

SSP requires clear and active leadership to succeed. A team leader should be identified and appointed at the outset who will play a critical role in communicating the objectives of SSP; mobilizing stakeholders; and leading development, implementation and updates of the SSP. The team leader should have the authority, the organizational and interpersonal skills, and sufficient time and management resources to ensure that the process can be implemented effectively. Their time should be planned as part of the official workload rather than being an additional parallel assignment.

If the required skills are not available locally, the lead organization may explore opportunities for external support from national or international partner organizations and consultants. This can help ensure that SSP is well defined and build internal capacity.

Form the SSP team

To make SSP successful, the SSP team leader will need the support of people who represent the whole system and who have skills to identify hazards, understand how the risks can be controlled and drive improvements in their respective area (see example 1.6). These people may include:

- managers within the relevant organizations to allocate staff time and resources;
- a team representing a range of technical, managerial and social/behavioural skills along the sanitation chain (e.g. faecal sludge management, treatment processes, agriculture) – all sanitation steps outside the responsibilities of the lead institution should be represented;
- people with public health expertise; and
- representatives of key exposure groups (e.g. sanitation workers), where appropriate.

EXAMPLE 1.6. Suggested SSP team membership in Polokwane, Limpopo, South Africa

With the aim of initiating an SSP process in Polokwane, South Africa, stakeholders along the service chain of non-sewered sanitation were mapped according to the activities they performed. Examples of activities included passing regulations for the construction of septic tanks, constructing toilets, providing licences, and undertaking surveillance of vacuum trucks. The following stakeholders were proposed as members of the SSP team.

SANITATION STEP	SUGGESTED SSP TEAM MEMBERS AND REPRESENTATION
Toilet and containment–storage/treatment	Senior engineers of the municipality water and sanitation department Municipal environmental health practitioners Local building association Nongovernmental organization working with sanitation for vulnerable populations Homeowners association
Conveyance (emptying and transport of faecal sludge)	Private and public truck operators association Sanitation workers associations, including representatives of informal and/or manual emptying service providers City service authority for traffic law enforcement and licences
Treatment and disposal	Senior engineers of the municipality water and sanitation department Department of Environmental Protection Faculty of Engineering of a local university
Reuse	Department for Agriculture and Rural Development Faculty of Agriculture of a local university Farmers association
Entire sanitation service chain	Official of the municipality water and sanitation department (SSP leader) Public health official or expert Climate change adaptation official or expert Representative of the local council

GUIDANCE NOTE 1.1.

Checklist of issues to consider when identifying the SSP team

- Are organizations (or stakeholders) for all steps of the sanitation chain represented?
- Are day-to-day technical operational skills included?
- Do one or more members understand management systems and emergency procedures?
- Do one or more members understand climate-related hazardous events and how climate change may influence them?
- Do members have the authority to implement recommendations stemming from SSP?
- How will the work be organized? Will the activities be regular or periodic?
- Can the team activities be done as part of regular activities?
- How will specific stakeholders not represented on the team be engaged?
- How will documentation be organized?
- What external technical support can be brought in to support the team?

It is important to include environmental health and public health authorities in the SSP team to ensure that proposed investments respond to health challenges and result in improved public health. The team should also include (or engage on an ad hoc basis) people with specific knowledge of climate, hydrology, and disaster or emergency management, who can understand climate projections and how they may affect the sanitation system (see Box 3). Where it is difficult to involve climate experts (e.g. small communities or rural areas), people with experience in environmental resources management or disaster risk reduction can help. The team should include a balance of technical skills and stakeholder perspectives, including gender balance and representation from vulnerable groups (see example 1.7).

BOX 3. Climate expertise to consider when including climate change considerations in the SSP

- Climatologists specializing in localized impacts from climate projections
- Hydrologists or hydrometeorologists to advise on possible impacts on water resources for the region of interest
- Emergency planning or civil protection experts to advise on disaster or emergency plans and responses
- Adaptation planners with experience in a region where the current climate is similar to that likely to be faced in future in the region of interest

Source: WHO (2017a)

Inclusion in the SSP team of some types of important stakeholders may not be warranted, because of lack of availability or skill level. As well, the number of people in the team needs to be manageable. In such cases, external assistance and specialists can complement the team's expertise. External experts can be engaged for selected issues on an ad hoc, short-term basis.

It may be appropriate to include independent members (e.g. from universities and research institutes). Independent experts can also be involved in periodic health surveillance by health authorities and external assessment.

EXAMPLE 1.7. Team formation experience, Portugal

A three-person **project coordination team** was formed to keep the project on track and to ensure that all the key issues were addressed within the time constraints.

The SSP team comprised representatives from all the departments of the water company that had a direct impact on the management and operation of the wastewater drainage and treatment subsystem: board of administration, quality department, production and treatment department, network management department, commercial (customers) and information technology/geographic information system department, and financial and human resources department. The SSP team leader was the water company quality manager, who had existing links with all the stakeholders and was also team leader of the company's WSP project.

The multi-stakeholder team comprised stakeholders who could provide input or support for successful completion of the project. These stakeholders were chosen because they could affect, or be affected by, the activities carried out in relation to the sanitation system, or because they could be involved in implementation of risk reduction measures. They represented specialties in policy management, technical know-how and practical experience.

This team included representatives from environmental authorities, agriculture authorities, regulators, the catchment authority, the general directorate of health, the local health authority, the municipality, civil protection and emergency response services, nongovernmental organizations, local organizational structures, research partners, farmers associations and the water sector association.

A **consultant** assumed the role of the SSP facilitator and technical expertise provider. This involved planning and facilitating meetings, liaising with members of the SSP team and the multi-stakeholder team, identifying information gaps, compiling and validating the information collected, and providing technical expertise in identification of hazards and hazardous events, and risk assessment.

For project background, refer to example 1.2.

Define and record roles of the individuals on the team

Responsibilities should be divided among the team members at the start of the process, and roles clearly defined and recorded. For large teams, a table can be used to outline SSP activities and responsibilities (tool 1.1).

TOOL 1.1. Suggested SSP team membership recording form

NAME/JOB TITLE	REPRESENTING	ROLE IN SSP TEAM	CONTACT INFORMATION

Example 1.8 shows the allocation of roles to members according to their knowledge and skills, for SSP for an irrigation water catchment area. The total area was adjacent to one bank of the river, which was contaminated with wastewater and excreta from nearby communities, and the SSP area concentrated on specific sites with more than 300 landholdings.

EXAMPLE 1.8. SSP team, Peru: indirect agricultural use of wastewater

SSP MEMBER	KEY KNOWLEDGE, SKILLS AND ROLES IN SSP TEAM
River Users' Board	**Knowledge/skills:** Management of the irrigation system in the agricultural areas adjacent to the river **Role:** • Team leader • Provide information on uses, practices and other information to the team
Academic institution within SSP area	**Knowledge/skills:** User of the water, technical process information **Role:** • Provide technical process information • Sample water and wastewater
Representatives of farmers in the area	**Knowledge/skills:** Owners of farmland and on-plot reservoirs **Role:** • Provide information on practices and other information to the team • Permit sampling of water, soil, vegetables and fish • Implement on-farm control measures (e.g. crop selection, withholding periods)
Ministry of Health, and National Environmental Health Agency	**Knowledge/skills:** Monitoring and reporting on health of uses and consumers **Role:** • Provide information and sampling on health-related issues • Implement training and surveillance for food safety of produce in markets
International public health United Nations agency (sponsor of the SSP)	**Knowledge/skills:** Technical cooperation and partnership mobilization in health sector **Role:** • Provide technical support to the team

Stakeholder analysis and establishment of steering committee for large or complex SSPs

Large or complex SSP areas may benefit from a stakeholder analysis to ensure that all relevant stakeholders are engaged and motivated, and a steering committee to provide strategic oversight of the process.

Stakeholder analysis

Involving the right people at the right time ensures that the needed expertise, political support and financial resources are available to implement SSP. Stakeholders are individuals or organizations that:

- have **direct control** over some aspects related to the sanitation system (e.g. regulatory authority);
- have **some influence** over practices that affect the safety of the sanitation system (e.g. farmer cooperatives);
- are **affected by** actions taken in the system to protect the safety of sanitation systems (e.g. local community); or
- are **interested in** sanitation systems (e.g. a nongovernmental organization working with people using the sanitation system).

Stakeholder analysis is the process of identifying and characterizing stakeholders, and planning for their participation. Depending on their characteristics, such as importance and influence, some key stakeholders should be invited to be members of the steering committee. Others, such as staff with technical and managerial expertise, are required as members of the SSP team. Tool 1.2 provides a table to conduct the stakeholder analysis and plan for stakeholder involvement.

TOOL 1.2. Stakeholder analysis

SANITATION STEP[a] (For example, toilet, containment–storage/treatment, conveyance, treatment, end use or disposal)	STAKEHOLDER[a] (Name of the organization)	ROLE OF STAKEHOLDER[a] (For example, direct control, influence, affected by, interest in)	MOTIVATING FACTORS[a] (Factors that may motivate the stakeholder in adoption of a safe system)	CONSTRAINING FACTORS[a] (Factors that may demotivate the stakeholder in adoption of a safe system)	IMPORTANCE[b] (Importance of engaging this stakeholder in the SSP process to achieve the desired result)	INFLUENCE/POWER[b] (Ability of the stakeholder to affect the implementation of SSP)	PARTICIPATION REQUIRED[b] (For example, information, consultation, collaboration, empowerment/delegation[c])

[a] Adapted from WHO (2006), vol. 4, section 10.2.2.
[b] Adapted from Strande, Ronteltap & Brdjanovic (2014), and Lienert (2011).
[c] **Information** provides stakeholders with balanced and objective information to enable people to understand the problem, alternatives and solutions. Consultation allows stakeholder feedback on analysis, alternatives and decisions. Stakeholders who fall in this category might be considered as part of the extended SSP team or advisers. Collaboration means working as a partner with stakeholders on each key SSP decision, including prioritization and selection of control measures. Stakeholders in this category might be invited to be members of the steering committee. Empowerment/delegation is a process of building the capacity of stakeholders through training, involvement and collaboration so that they can prepare and implement SSP. Stakeholders in this category might be part of the SSP team.

SSP steering committee

Following stakeholder analysis, an SSP steering committee should be established (see example 1.9). This should be a representative body with combined oversight of each step of the sanitation service chain, from toilet, including on-site containment, to conveyance through sewers or vacuum trucks, to treatment and disposal or reuse. The steering committee should include senior representation from relevant local authorities (e.g. municipality; local council and planning; housing, environmental, health and agriculture departments), as well as implementation partners (e.g. sanitation service providers, construction boards, farmers association). Its outputs will include:

- leadership and oversight of the entire process;
- agreed priorities for SSP;
- engagement with, and commitment of, senior management of the lead organization, and secured financial and resource commitment; and
- policy dialogue and amendment as needed to create an enabling environment for safe sanitation service delivery.

EXAMPLE 1.9. Establishment of the SSP steering committee, Peru: direct use of treated wastewater for irrigating green spaces of a large public park

The first criterion for choosing the members of the steering committee was to include all sectors involved in the use of domestic wastewater. Therefore, representatives from departments responsible for wastewater collection and treatment, health, the environment, agriculture and green spaces, and the sanitation regulatory body were included on the steering committee, led by the National Water Authority. In Lima, where priority is given to the use of treated wastewater for irrigating municipal parks, the Municipality of Lima was included as the representative of district councils, which are the water users. Academia was also included as a strategic partner, to monitor the scientific quality of the studies, and to include procedures for drafting and managing SSP in their academic programmes.

The steering committee chose the priority areas to implement SSP, and served as a platform to discuss the interoperability of laws and regulations for reuse in the context of city planning priorities.

Management and financial considerations

The SSP effort will require an in-kind commitment of time and some direct costs during the preparation phase (e.g. sampling and testing, data collection, field investigations). During Module 1, provisional estimates can be made by considering the likely data requirements of Module 2 and likely additional testing required from the application of Module 5. Management support will be needed for the SSP process to allocate staff time and any start-up funding needed.

1.3 Establish SSP priorities

Teams in charge of multiple sanitation systems (e.g. sewered systems with treatment and reuse, on-site systems with septic tanks, on-site systems with pit latrines) within an administrative area or teams with constrained funding and capacities may need to establish priorities so that the SSP process is manageable.

Risk-based tools can be used to analyse the situation, to identify and reach agreement on SSP priorities. The following diagnostic tools may have already be used in the area.

- **Excreta flow diagrams (SFDs)** help to establish priorities by graphically showing proportions of excreta in a city or town that are not safely managed at each step of the sanitation chain (SFD Alliance, 2018). Red or green arrows signal where the greatest risks lie and help city stakeholders identify the highest risks for management using SSP (see guidance note 1.2).
- **The SaniPath Exposure Assessment Tool** helps to establish priorities by identifying the primary pathways (e.g. open drain, produce, drinking-water) of exposure and the magnitude of contamination in a locality (Emory University, 2020) (see guidance note 1.3).

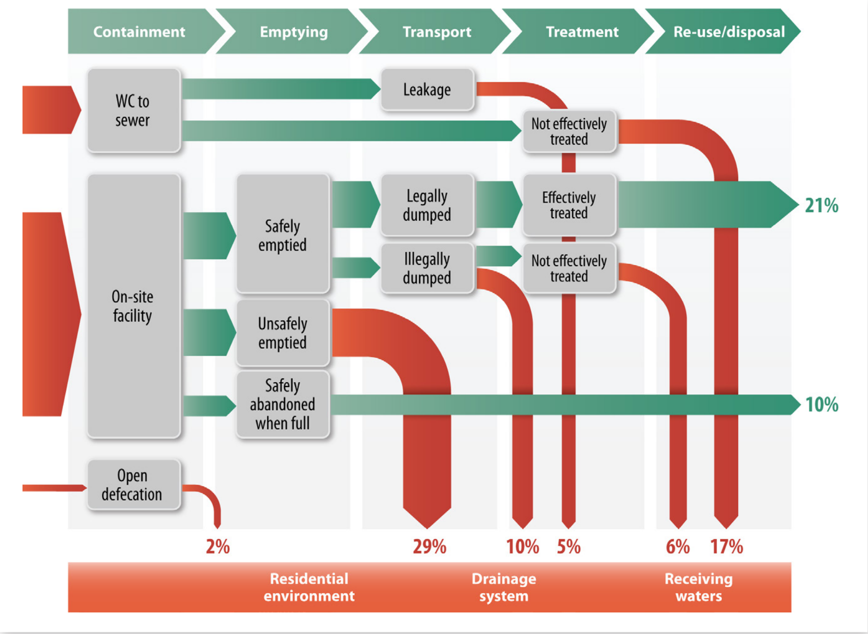
The steering committee, with the support of the SSP team, might also prioritize the highest risk to health considering the following factors, keeping in mind that, in all cases, the full sanitation service chain should be covered:

- Districts and neighbourhoods with high reported or suspected sanitation-related disease (e.g. cholera and other recurrent diarrheal disease outbreaks, soil-transmitted helminths, schistosomiasis);
- communities where toilets are poorly constructed and unsafe, containment systems do not safely contain excreta (e.g. are unsealed, or have direct discharge of effluent from on-site systems into open drains), or drainage systems are inadequate;
- nonregulated sanitation service chains (e.g. faecal sludge management), and waste streams that receive inadequate or unknown treatment;
- sanitation systems that historically, or can be envisaged to, have a high susceptibility to climate-related events (e.g. sewer overflows near recreation areas or water supplies, overflowing of pit latrines);
- water supply catchments and intakes affected by wastewater, excreta or greywater; and
- areas with high formal or informal wastewater use activities (e.g. agriculture, aquaculture).

GUIDANCE NOTE 1.2.

How to use excreta flow diagrams to identify SSP priorities

Excreta flow diagrams (SFDs) are a simple and effective way of visualizing the service types in a city and the fate of different excreta streams. Green arrows represent the proportions of excreta that are "safely managed" along the sanitation chain. Red arrows show where the excreta flows are not safely managed. The example SFD shows the thickest red arrow (29%) representing illegal emptiers discharging sludge in fields, the drainage system and open waters, followed by effective treatment at the wastewater treatment plant. By identifying the thickest red arrows, the SSP steering committee can quickly agree on risk-based priorities.



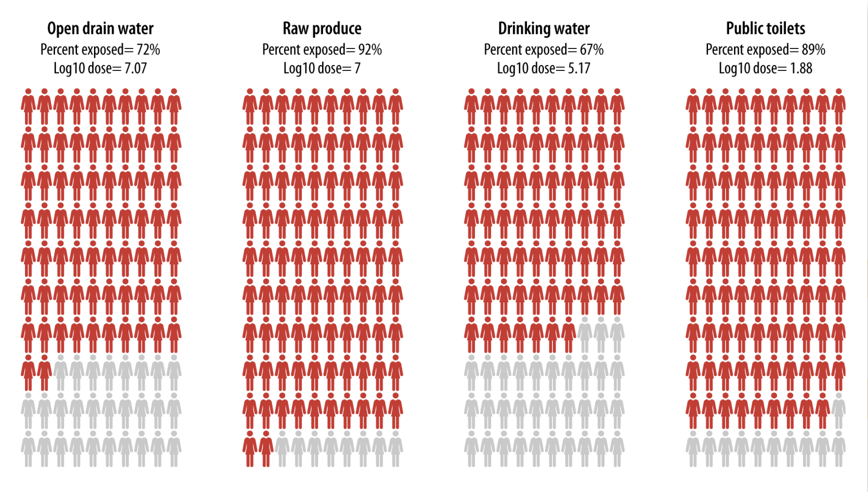
For more information, visit the SFD Alliance Portal (https://sfd.susana.org).
Source: Blackett, Hawkins & Heymans (2014) (example of an SFD in Dakar, Senegal).

GUIDANCE NOTE 1.3.

How to use SaniPath to identify SSP priorities

The SaniPath Exposure Assessment Tool was developed to identify and compare risk of exposure to faecal contamination across the following 10 exposure pathways associated with inadequate sanitation in the public domain: surface waters, produce, municipal water, public latrines, floodwaters, open drains, bathing waters, soil, street food and ocean water. SaniPath provides guidance for standardized primary data collection. The data are then used to automatically produce an exposure assessment analysis, including the people plots shown below.

People plots allows easy visual comparison of exposure across different pathways, neighbourhoods or populations. Each red figure represents 1% of the population that is exposed to faecal contamination through a specific pathway. The darkness of the red colour represents the magnitude of the average dose of E. coli ingested per month (Raj et al., 2020). Using SaniPath results, members of the SSP steering committee can prioritize specific neighbourhoods or a particular exposure pathway. In the example above, decision-makers would tend to prioritize the contamination of raw produce and hazards in open drain water.



For more information, visit the Sanipath Portal (https://www.sanipath.org) hosted by the Center for Global Safe WASH at Emory University.

MODULE 2

DESCRIBE THE SANITATION SYSTEM

MODULE 2

DESCRIBE THE SANITATION SYSTEM

How does the sanitation service chain work? Who is at risk?

STEPS

2.1 Map the system
2.2 Characterize system flows
2.3 Identify exposure groups
2.4 Gather supporting information
2.5 Confirm the system description

TOOLS

Tool 2.1. Template to characterize system flows
Tool 2.2. Template to characterize exposure groups

OUTPUTS

- **A map and description of the sanitation system**
- **An understanding of the constituents (excreta and mixed waste) in flows at all steps of the system**
- **Identification and characterization of exposure groups**
- **An understanding of the factors affecting the performance and vulnerability of the system**
- **A compilation of relevant technical, legal and regulatory information**

Overview

Module 2 generates a complete description of the sanitation system. A thorough understanding of all parts of the sanitation system and its performance requirements supports the subsequent risk assessment process.

The outputs of Module 2 should provide sufficient information to allow the SSP team to identify where the system is vulnerable to hazardous events, and to validate the effectiveness of any existing control measures (to be identified in Module 3).

Much of the information needed may have already been gathered if the system has undergone investigations such as an SFD or SaniPath exposure assessment.

Step 2.1 Map the system – helps with understanding the source and path of flows through the system.

Step 2.2 Characterize system flows – involves collecting key quantitative information, and examining the microbiological, physical and chemical constituents of flows along the sanitation system.

Step 2.3 Identify exposure groups – identifies and characterizes exposed groups in terms of who they are, how many there are, where are they in the system and how exposure occurs.

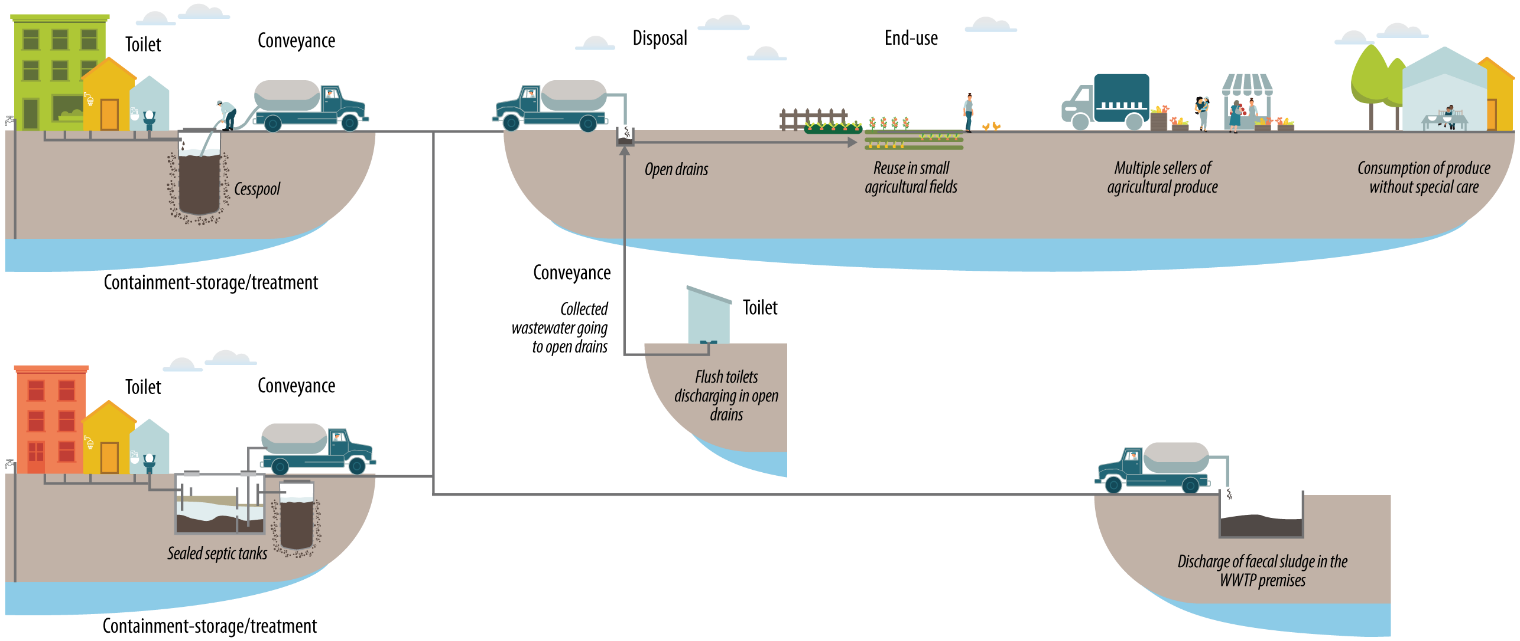
Step 2.4 Gather supporting information – involves collecting and documenting system context, such as legal and regulatory requirements; historical monitoring and compliance data; and information on climate, land use, cultural practice, demographics, the likely concentrations of pollutants and pathogens, and the efficiency of the system and system components. Any gaps or discrepancies between existing requirements and potential health hazards should be prioritized for policy dialogue.

Step 2.5 Confirm the system description – ensures that the system description is complete and accurate. Data requirements and potential institutional gaps can be identified.

2.1 Map the system

A safe sanitation system is defined as a system that separates human excreta from human contact at all steps of the sanitation service chain from toilet capture and containment through emptying, transport, treatment (in situ or off-site), and final disposal or end use, for both liquid and solid fractions (WHO, 2018). Fig. 2.1 shows the elements of the sanitation service chain.

Fig. 2.1 Sanitation service chain



Note: Depending on the system design, liquid and solid fractions may follow separate paths in the system map at all steps, particularly for conveyance, treatment and end use/disposal. Refer to glossary for definitions of each step.
Source: WHO (2018).

A combination of technologies at each step of the chain can be used; when linked and properly managed, these can form a safe chain. The type of technology needed is highly context-specific, depending on local technical, economic and social factors (WHO, 2018).

Each sanitation system is unique, and its description and maps should therefore be specific. The method chosen for mapping will depend on the scale and complexity of the system. Detailed asset lists and detailed asset condition statements are not necessarily needed. Usually, simplified drawings or free-flowing sketches that illustrate the various sanitation processes are sufficient (see example 2.1).

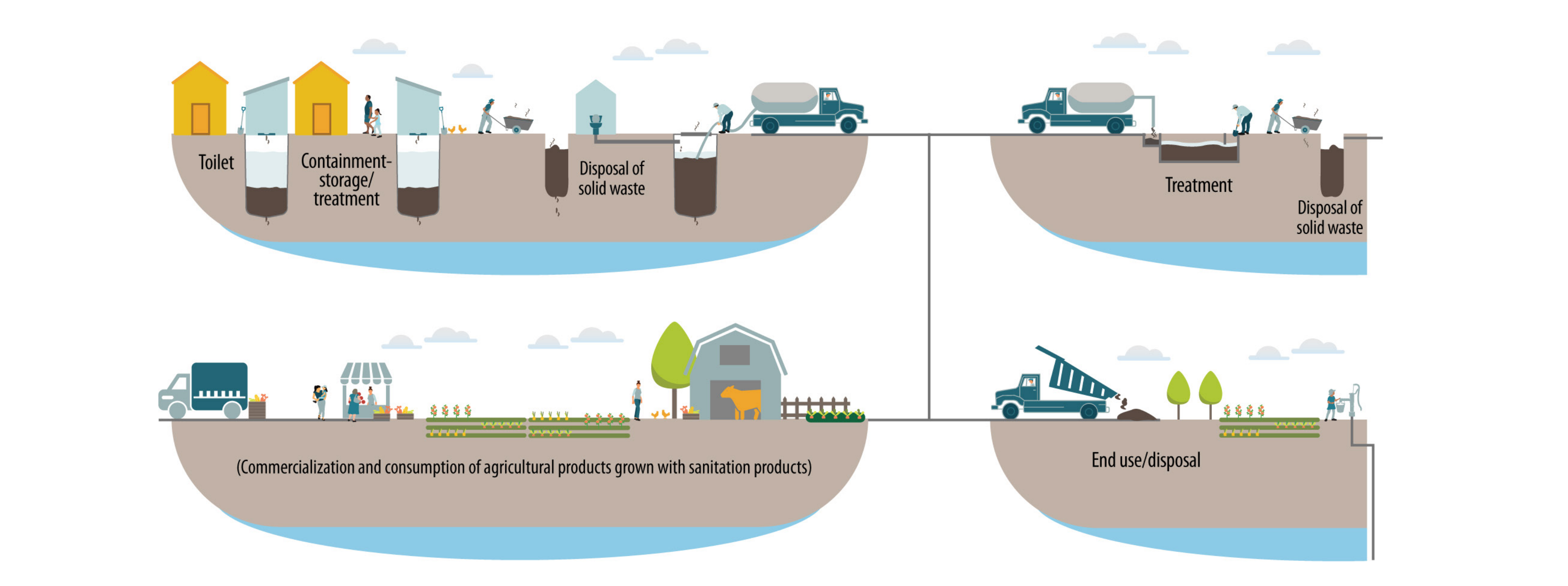
Follow the checklist in guidance note 2.1 when developing a system map.

GUIDANCE NOTE 2.1.

Checklist of issues to consider when developing a system map

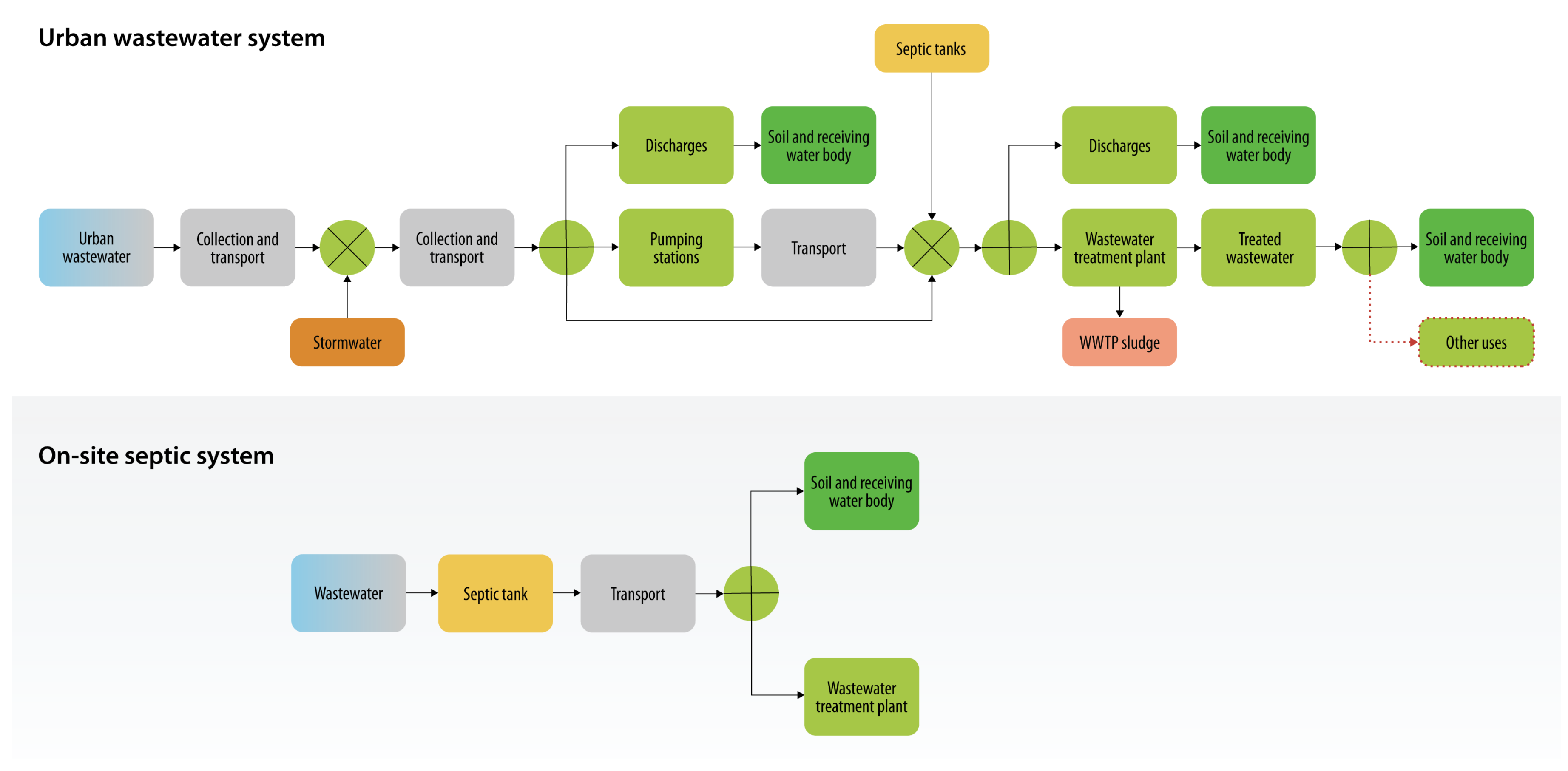
- Identify all the steps of the sanitation service chain (e.g. toilet, containment–storage/treatment, conveyance, treatment, and end use or disposal)
- Include all sources of system flows – both point sources and non–point sources such as runoff.
- Ensure that the fate of all used and disposed of parts of the system flows have been accounted for (e.g. leakages or discharges from the containment step, solid waste fraction obtained during emptying of the containment step, solid waste fraction screened out before wastewater treatment, products – such as crops).
- Identify areas in which faecal sludge is being dumped legally and illegally.
- Identify areas where open defecation is known to occur.
- Identify public and shared toilets that serve a considerable proportion of the community.
- Include drinking-water sources where this is relevant to the system or could be affected by the sanitation system.

EXAMPLE 2.1. Map of system consisting of a dry or flush toilet with pit, liquid effluent infiltration and off-site treatment of faecal sludge for reuse



SSP teams might choose to map the system with system process diagrams, using standard process flow symbols. They could also use a simplified schematic, referencing more detailed process flow information held in other drawings for larger systems, as shown in example 2.2. A detailed geographic map may be more helpful for smaller-scale SSP.

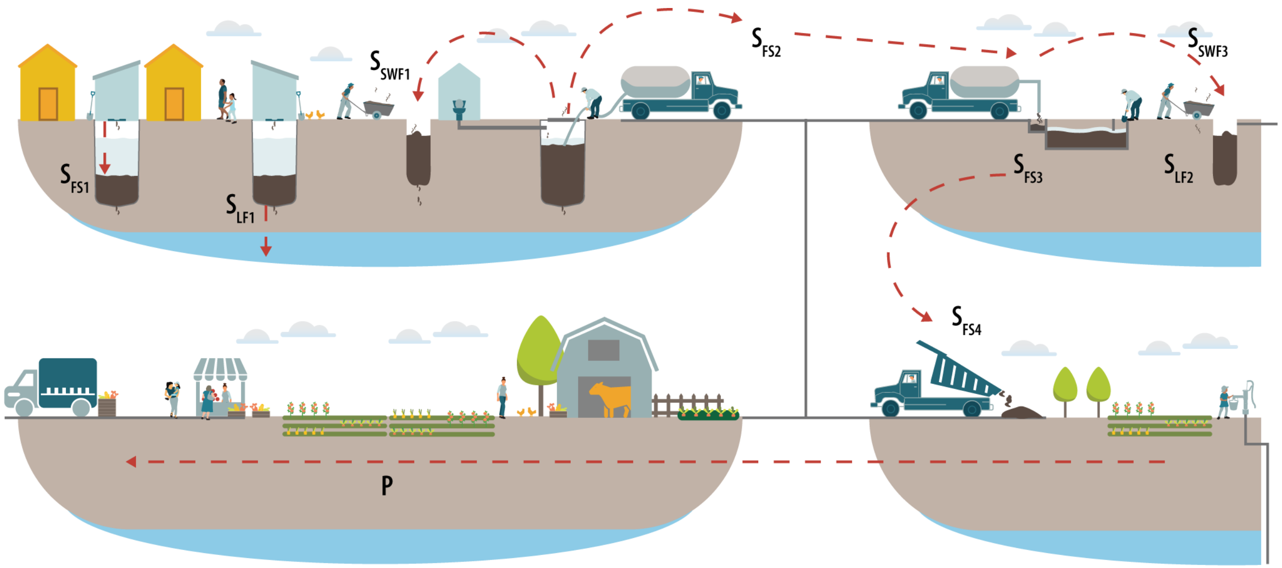
EXAMPLE 2.2. Map of system consisting of flush toilets with sewerage and off-site wastewater treatment, which also receives septic tank sludge



Note: Based on the Portugal experience.

Once the system map is ready, the SSP team should indicate the path of different flows through the sanitation system, from the point of generation (i.e. toilets in various settings) to use or disposal (i.e. use in agriculture or aquaculture; or disposal to rivers, ocean and landfill). The team should map excreta-related flows, such as collected urine and faeces, leakages from the pits, faecal sludge transported, wastewater in sewers and treated effluents. Other waste fractions, such as industrial effluents, pesticide runoff or specific wastes that might have an impact on the sanitation system, could also be mapped. Example 2.3 shows a simplified drawing for mapping the system flows (S).

EXAMPLE 2.3. Illustration of system flows indicated in a sanitation map



S_{FS1} = Faecal sludge collected in pit latrines

S_{LF1} = Liquid fraction that percolates from the pits

S_{SWF1} = Solid waste fraction obtained during emptying of pits

S_{FS2} = Faecal sludge emptied in vacuum trucks and transported to the treatment plant

S_{SWF3} = Solid waste fraction screened out before treatment

S_{FS3} = Faecal sludge treated

S_{LF2} = Liquid fraction infiltrated from the treatment plant

S_{FS4} = Dried faecal sludge trasported to agricultural land

P = Produce reaching the market

The team should consider seasonal and climatic effects on the pathways (e.g. potential increase in wastewater reuse during drought, potential for flooding) or other potential changes, such as changes in population growth or land use. Multiple maps may be needed to demonstrate how drier or wetter conditions (given uncertainty in climate predictions) change system flow pathways.

It is important to ensure that mapping is accurate and not simply a desk-based exercise. For this reason, site visits should be conducted to validate maps and to collect information for step 2.4.

Maps should be accompanied by a written description of the condition of the sanitation system. Each step should be described, with key facts such as current practices, malfunctions and failures, to help the health risk analysis in Module 3.

2.2 Characterize system flows

In this step, the SSP team collects and adds to the map available quantitative information about the sanitation system (e.g. flow rates, flow composition, design capacity of treatment elements; see guidance note 2.2). The team should also record variability in load quantity and concentration, including variations during heavy rain or flooding.

GUIDANCE NOTE 2.2.

Factors to consider when characterizing system flows

When characterizing system flows, the team should focus on excreta-related inflows and effluents from each step of the sanitation system – that is, what comes in and what goes out. Typical system inflows and effluents are the so-called sanitation products: faeces, urine, blackwater, compost, dried faeces, dry cleansing materials, effluents, excreta, greywater, pit humus, pre-treatment products (fat, grease, oil and solids), sludge and stored urine (Tilley et al., 2014). Information should be collected about:

- the sanitation system in which flows are generated or pass through;
- flow rates, where known, including for different seasons, or different levels of rainfall, in the context of potential climate change impacts; and
- capacity or design loading of components, where known (e.g. treatment plant flow or loading limits, transfer system capacities).

Because of the potential for mixing with other waste fractions, it is important to keep in mind:

- the potential for accidentally mixed components of the waste that may pose a risk (e.g. faecal contamination of agricultural waste, razor blades and batteries in faecal sludge);
- the potential biological, chemical or physical hazards present in the flow (see guidance notes 2.5, 2.6 and 2.7); and
- how changes in seasons or weather influence the system flows. ■

The SSP team should also identify the microbiological, physical and chemical constituents of the system flows to enable identification of potential hazards in step 3.1 and factors that will affect system performance. The terms "wastewater" and "sludge" are broad; they describe a mixture of flush water, greywater, faeces, urine, and anal cleansing and menstrual hygiene materials. They can also include other discarded solid waste, stormwater and industrial wastewater.

Tool 2.1 offers a simple template to characterize system flows.

2

TOOL 2.1. Template to characterize system flows

SANITATION STEP	DESCRIPTION OF THE SYSTEM FLOW (Focus on excreta-related flows, such as wastewater or sludge. Also list other waste streams when relevant to the sanitation system)	KEY INFORMATION OF THE SYSTEM FLOW (Volume, flow, concentration, etc.)	EXPECTED VARIATIONS (Seasonal variations or unusual events, such as accidentally mixed components or climate events)	TYPE OF POTENTIAL HAZARD (Biological, chemical or physical)

2.3 Identify exposure groups

Identification of exposure groups categorizes groups of people who may be exposed to particular hazards using broad classifications, shown in guidance note 2.3.

Exposure groups can be identified on the system map developed in step 2.1, using the symbols U, L, W, and so on, as shown in example 2.4.

2

GUIDANCE NOTE 2.3.

Exposure group categories

According to the 2018 WHO Guidelines on sanitation and health (WHO, 2018), the people most likely to be exposed to hazards during hazardous events at different steps of the sanitation service chain are as follows.

U Sanitation system users: all people who use a toilet.

L Local community: people who live and/or work nearby (who are not necessarily users of the sanitation system) and may be exposed.

W Sanitation workers: all people – formally employed or informally engaged – responsible for maintaining, cleaning or operating (e.g. emptying) a toilet or equipment (e.g. pumps, vehicles) at any step of the sanitation service chain.

WC Wider community: the wider population (e.g. farmers, communities in lower-lying areas) who are exposed to sanitation end-use products (e.g. through recreation or flooding), use sanitation end-use products, or consume products (e.g. fish, crops) that are produced using sanitation end-use products, intentionally or unintentionally. Sanitation end-use products include compost, faecal sludge and wastewater.

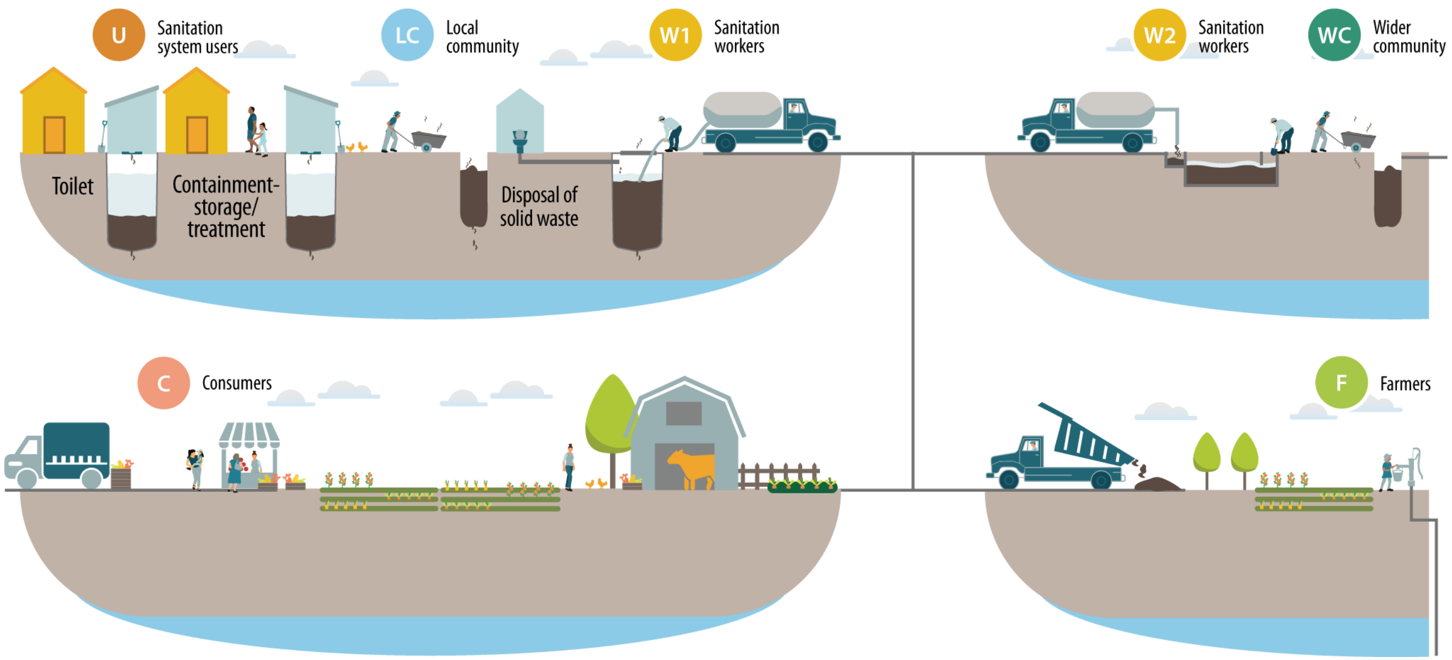
Depending on the sanitation service chain to which SSP applies, it might be necessary to treat the following exposure groups separately because they are exposed to very specific hazardous events during the end-use step (e.g. reuse in agriculture or aquaculture, consumption of products).

F Farmers: people who use sanitation end-use products (e.g. untreated, partially treated or fully treated wastewater, biosolids, faecal sludge).

C Consumers: anyone who consumes or uses products (e.g. crops, fish, compost) that are produced using sanitation products.

The letters U, L, W, WC, F and C are used as symbols to identify the exposure groups in maps and tables, facilitating the health risk assessment in the subsequent modules. ■

EXAMPLE 2.4. Illustration of exposure groups indicated in a sanitation map



The broad exposure groups (U, F, C, etc.) can be refined and defined into subgroups to aid the detailed hazard risk assessment, as shown in tool 2.2. For instance, the exposure group "U: sanitation system users" can be divided into U1: users of pit latrines, U2: users of flush toilets with a septic tank, and U3: users of toilets connected to the sewer system. It is important to estimate the number of individuals in each subgroup, how they come into contact with system flows (e.g. wastewater, excreta) and the frequency of exposure.

TOOL 2.2. Template to characterize exposure groups

SANITATION STEP	EXPOSURE GROUP	WHO ARE THE EXPOSURE GROUPS? (Description of these people)	HOW MANY ARE THERE? (Actual numbers, if known; otherwise estimate)	WHAT ARE THEY DOING THERE? (Circumstances under which they might be exposed to hazards in the system flow)	WHAT ARE THEY EXPOSED TO? (Which system flows and which types of hazards they have contact with)	HOW OFTEN ARE THEY EXPOSED TO THIS? (Exposure frequency: daily, weekly, once a year, etc.)
Containment–storage/ treatment	U1	Users of flush toilets connected to septic tanks on their properties	400 households (around 2000 people); about half are children	Septic tanks are usually outside the house, in the backyard. Children play and adults perform different activities in the vicinity of the tank.	They could have contact with wastewater during overflows. They are exposed to microorganisms.	It could happen every 3 years, but is more frequent during heavy rainfall.
Disposal	WC1	Visitors to the nearby river	About 5000 people; about 70% are children	These are local tourists who come to the river for recreation. They swim and gather along the river during weekends.	Microbial contamination when the treatment ponds overflow. They could ingest contaminated river water.	Daily contact during summer months.

Although some exposure groups, such as formal workers, are relatively easy to identify, others will be more difficult – for example, communities accessing nearby groundwater sources, seasonal and informal workers, and people living in informal settlements or immigrant populations. Demographics of the exposure groups, such as gender, age and potential social exclusion, should be noted. Keep in mind that climate change or climate variability may increase or decrease the frequency of exposure.

2.4 Gather supporting information

The SSP team should compile and summarize information that will affect SSP development and implementation (see guidance note 2.4). Where no information is available, the team should note the lack of, for example, data, national standards or specifications. The steering committee should consider whether there is a need to develop monitoring or regulatory instruments where they are lacking.

Information should be assembled for:

- relevant quality standards, and certification and auditing requirements;
- system management and performance, including during and after hazardous events;
- demographics and land-use patterns and plans; and
- known or suspected changes relating to weather or other seasonal conditions, including climate change projections; this includes information from existing risk assessments (e.g. disaster risk reduction plans; climate change vulnerability, resilience or adaptation assessments).

GUIDANCE NOTE 2.4.

Collating supporting information for system description

The following information may be gathered to support the system description.

a) Relevant quality standards, and certification and auditing requirements.

Examples include:

- relevant laws and by-laws;
- effluent discharge or odour regulations;
- planning specifications and restrictions relating to spatial planning of urban areas, vulnerable environmental areas and agricultural/pasture land;
- specific national regulations relating to agricultural products;
- specific national guidelines for climate change preparedness or disaster planning;
- regulations relating to quality monitoring, surveillance and system auditing (not financial); and
- certification requirement relating to agricultural end products.

b) System management and performance.

This should provide supporting documentation relating to follow-up and enforcement of points noted in a) above. Both documented and undocumented actions should be noted.

Consider:

- data relating to earlier monitoring and surveillance;
- frequency of documentation;
- if faults and/or deviations were followed up;
- epidemiological data;
- existing vulnerability, resilience or adaptation assessments of the area; and
- types and amount of products generated.

c) Demographics and land-use patterns.

Consider:

- land-use pattern, settlements (including informal settlements) in the area, population and special activities that may affect sanitation and wastewater production;
- specific equity considerations, such as ethnicity, religion, migrant populations and disadvantaged groups; and
- areas predicted for significant population growth or change.

d) Known or suspected changes relating to weather or other seasonal conditions.

Consider:

- mean variability of the load to the treatment plant over the year;
- seasonal variation of use associated with types of crops and harvest;
- additional inflow areas during heavy rain and implications for treatment steps;
- climate change projections (see guidance note 2.8);
- changes in use patterns at times of water scarcity.

Note: Not all the information above may be useful and relevant to every system.

Potential health hazards become evident through defining system flows in step 2.2. Potential biological, chemical and physical hazards, including climate-related hazards, can be characterized using guidance notes 2.5, 2.6, 2.7 and 2.8. Epidemiological and environmental data are preferable for biological hazards, where available.

For example, if helminths have been identified as a potential health hazard, the characterization aims to determine which species are endemic and to what extent.

The quality of data needed and possible information sources vary among the hazard categories.

2

GUIDANCE NOTE 2.5.

Compiling microbial hazard information

Microbial hazards are grouped into four pathogen classes: viruses, bacteria, protozoa and helminths. Information on excreta-related pathogens and methods for their detection in the environment can be found in Chapter 6 of the 2018 WHO *Guidelines on sanitation and health* (WHO, 2018).

Considerations

- **Environmental testing of pathogens**
  Microbial testing of environmental samples often relies on indicators of faecal contamination, such as *Escherichia coli*, enterococci and, more recently, *Bacteroides* phages. Testing for indicator organisms is easier and cheaper than testing for each individual pathogen that may be present in the sample. However, in certain situations, such as disease outbreaks (e.g. cholera), it may be useful to identify the source and movement of a specific pathogen in the environment. *E. coli* concentrations are commonly used for assessing pathogen loads in faecal wastes and treatment efficiency of control measures.
- **Helminths**
  Species and concentrations of helminth eggs in waste influence the design of control measures. When waste-fed aquaculture is of concern in the sanitation system, special attention needs to be paid to foodborne trematodes and *Schistosoma* trematodes (which cause schistosomiasis), since transmission of these disease agents involves fish, aquatic plants or exposure to contaminated surface water (see WHO, 2006, vol. 3).
- **Vector breeding**
  Unsafe sanitation, and improper drainage leading to stagnant water or ponds can contribute to mosquito breeding and facilitate transmission of mosquito-borne diseases. Unsafe disposal of excreta can also facilitate breeding of insects such as flies and cockroaches, which can mechanically transport pathogens in the environment and contaminate food.

Examples of data sources on possible microbial hazards in the SSP area

Multiple data sources should be consulted for obtaining reliable information, including:

- desktop literature review
- public health authorities that have access to routine health information systems; and
- personnel working in health facilities within, or near, the SSP area.

Compiling chemical hazard information

Considerations

- Chemical constituents that enter sanitation systems may include organic chemicals, inorganic trace elements (e.g. cadmium, lead, cooper, nickel, mercury) and nutrients (nitrogen, potassium and phosphorus). These can pose health and environmental risks, damage the sewerage system, interfere with treatment processes, and limit potential options for reuse of end products. Therefore, to the extent possible, chemical contamination should be removed or treated at source (e.g. though pre-treatment of industrial discharges to sewers).
- Most sewer systems collect wastewater from domestic premises, commercial and public buildings, and industrial premises (sometimes unlicensed and unregulated) and also stormwater.
- Industries normally contribute the most hazardous chemical pollution to wastewater. Examples include surfactants, organic solvents, dyes, heavy metals, bleaching agents, acids and surfactants from textile manufacturing; high levels of organic compounds from rubber, plastic and paper manufacturing.
- Chemical pollutants are also found in domestic wastewater arising from greywater from the kitchen sink, laundry and bath is responsible for most of the metals (e.g. copper, cadmium, lead, zinc) and total dissolved solids in household wastewater originating from laundry detergents, disinfectants and personal care products. Urine is the major source of nitrogen (75%), phosphorus (50%) and potassium (54%) in domestic wastewater.
- Combined sewers also collect stormwater including substances deposited on impermeable surfaces from motor vehicles (e.g. leaking fuel), settled atmospheric particles and spills of industrial effluent into stormwater systems (WHO, 2007). The nature and concentrations of urban runoff can vary considerably over short periods.
- Pharmaceuticals for veterinary and human health care, such as analgesics, antimicrobials and contraceptives, are also sources of chemical pollution from manufacturing sites and in wastewater containing excreta of individual using medicines. Antimicrobial pollution is a potential driver of antimicrobial resistance (WHO, FAO & OIE, 2020).
- On-site sanitation systems, such as pit latrines and septic tanks, can be sources of chemical hazards when they are badly sited, constructed or maintained. Nitrate concentrations in shallow groundwater commonly exceed drinking-water guidelines in areas with on-site sanitation (Lawrence et al., 2001). In some urban settings, other chemicals (e.g. petroleum hydrocarbons, household chemicals, solvents) may be disposed of through latrines, leading to localized water contamination (WHO, 2007).

Examples of data sources on possible chemical hazards in the SSP area

- In the first instance, environmental authorities should be contacted for information on potential data sources (e.g. existing environmental monitoring programmes) for chemical concentrations in different media (e.g. wastewater, river water). Wastewater treatment plants may have ongoing monitoring activities that can provide valuable data on chemical hazards. Industrial entities or published references (e.g. Thompson et al., 2007) may also be consulted where industrial waste is of concern. If limited data are available, environmental samples from specific waste fractions or environmental media may be collected and analysed. National regulations and standards should also be consulted.

GUIDANCE NOTE 2.7.

Compiling physical hazard information

Physical hazards such as sharp objects (e.g. broken glass, razor blades, syringes), inorganic materials and malodours are often general characteristics of a given waste or linked to a mixture of different waste streams (e.g. razor blades and plastic bags being mixed in faecal sludge). Since the presence or absence of physical hazards has important implications for health risk mitigation, it is important to build a thorough understanding of the composition and characteristics of the waste as part of waste characterization.

Additional data sources only need to be consulted based on specific needs identified.

GUIDANCE NOTE 2.8.

Compiling key climate information

Information on the local climate and its variability needs to be collected to understand climate-related causes of hazardous events. At a local level, this can include records of extreme weather events (e.g. floods, droughts), future climate projections, historical water quality data, trends in water supply and land use (particularly relating to new sources, population growth or agriculture), and assessments of climate-related hazardous events that might affect water and sanitation services. For coastal and low-lying areas, elevation and the potential for inundation due to sea level rise or flooding should also be considered.

Since this information is not always easy to synthesize and interpret at a local level, the Climate-Resilient Water Safety Plan approach proposes regional climate vulnerability assessments to inform the system description (WHO 2017a). Because of uncertainty about predicted climate changes, variations in possible scenarios and sometimes limited data availability at a local level, it is advisable to focus initially on the data that are available or have higher certainty and incorporate new or updated data when they become available (Rickert et al., 2019). In addition to collected data, community knowledge and experience of past events and their impacts could be included to inform risk assessments in different climate change scenarios (e.g. through community consultation workshops or community elders).

2.5 Confirm the system description

The system description is confirmed through field or other investigations while conducting steps 2.1, 2.2, 2.3 and 2.4 to ensure that the information is complete and accurate. This process should also provide evidence of the system characteristics and performance (e.g. claimed treatment efficiency).

Several methods can be used for field investigations, such as sanitary inspections, review of service provider records, focus group discussions or key informant interviews, and collection of samples for laboratory testing (see example 2.5).

EXAMPLE 2.5. Approach used for confirmation of system description in Kampala, Uganda

The team mapped and described the system using records and field visits. Additional data were collected for confirmation by independent people not directly involved in the initial system description. Network data were collected by non-network staff. This ensured confidentiality, and avoided bias in the responses and data analysis. Data collectors (at least two) observed the actions of the network operator teams during field visits.

Before and after data acquisition, the data collection tools and results were analysed and discussed within the technical team, and opinions were captured.

Watch: Health risk assessment along the wastewater and faecal sludge management and reuse chain of Kampala, Uganda: a visualization | Geospatial Health

Following the confirmation step, the system map, system description, system flow characterization, and factors affecting performance and vulnerability of the system should be updated.

MODULE

3

IDENTIFY HAZARDOUS EVENTS, AND ASSESS EXISTING CONTROL MEASURES AND EXPOSURE RISKS

MODULE 3

IDENTIFY HAZARDOUS EVENTS, AND ASSESS EXISTING CONTROL MEASURES AND EXPOSURE RISKS

What could go wrong?
What existing control measures are in place and how effective are they?
How significant are the risks?

STEPS

3.1 Identify hazards and hazardous events
3.2 Identify and assess existing control measures
3.3 Assess and prioritize the exposure risk

TOOLS

Tool 3.1. Template for identification of hazards and hazardous events, and validation of existing controls
Tool 3.2. Simple sanitary inspection forms
Tool 3.3. Suggested risk category descriptions for team-based descriptive risk assessment
Tool 3.4. Template for team-based descriptive risk assessment
Tool 3.5. Suggested risk definitions for semi-quantitative risk assessment

TOOLS cont'd

Tool 3.6. Semi-quantitative risk assessment matrix
Tool 3.7. Template for semi-quantitative risk assessment
Tool 3.8. Template to prioritize hazardous events according to results of semi-quantitative risk assessments

OUTPUTS

- **A risk assessment table that includes a comprehensive list of hazards, and summarizes hazardous events, exposure groups, and existing control measures and their effectiveness**
- **A prioritized list of hazardous events to guide system improvements**

Overview

Module 3 ensures that investments in system monitoring and improvements first respond to the hazardous events that pose the highest risk to health.

On completion of Module 3, the SSP team will have identified the hazardous events with the highest risks. In Module 4, improvement plans will be developed to address events that have a high risk because existing control measures do not exist or are ineffective. Where existing control measures are adequate, only operational monitoring to ensure that the controls continue to function as intended is needed, as described in Module 5.

Step 3.1 Identify hazards and hazardous events – lists circumstances of how the risk occurs during use, operation and maintenance of the sanitation system for the exposure groups.

Step 3.2 Identify and assess existing control measures – determines how well the existing sanitation system protects those at risk.

Step 3.3 Assess and prioritize the exposure risk – uses a structured approach to identify and prioritize the highest risks for which system improvements are needed.

In practice, there may be overlap and iteration between steps 3.1–3.3. For instance, it may be appropriate to adjust the initial assessment of hazards and hazardous events once more thought has been given to the types of exposure groups and exposure routes, and where they are in the system.

3.1 Identify hazards and hazardous events

Identification of hazards and hazardous events (see guidance note 3.1) focuses efforts in the subsequent risk assessment. It is important to understand the difference between hazards and hazardous events.

- A **hazard** is a biological, chemical or physical constituent or acceptability aspect that causes harm to human health.
- A **hazardous event** is any incident or situation that:
  - introduces or releases a hazard to the environment in which humans are living or working, or
  - amplifies the concentration of a hazard in the environment in which people are living or working, or
  - fails to remove a hazard from the human environment.

GUIDANCE NOTE 3.1.

3

How to describe hazards and examples of typical hazard types in sanitation systems

HAZARD TYPE	DESCRIPTION AND EXAMPLES
Microbial	Microorganisms (pathogenic bacteria, viruses and parasites, such as protozoa and helminths) for which there is evidence of diseases being caused by exposure to excreta, sludge and wastewater (e.g. *Vibrio cholerae*, *Giardia intestinalis*, coxsackievirus, hepatitis E virus, *Ascaris lumbricoides*, hookworm) or where excreta, sludge and wastewater promote vector-borne pathogens (e.g. dengue virus, *Schistosoma* spp.).
Chemical	Chemical constituents that can cause the sanitation system to malfunction and/or cause adverse health effects, typically after longer-term exposure. Examples are heavy metals (e.g. arsenic, cadmium, mercury) in sludge and biosolids from industrial sources, herbicides and pesticides, nitrate accumulating in groundwater from on-site sanitation systems, and harmful algal blooms in fresh water caused by untreated wastewater discharge.
Physical	Physical characteristics that may cause injury or irritation. Examples are sharps such as needles and razor blades disposed of in toilets, injury to workers from unsafe equipment or repetitive use, and skin irritants.
Acceptability	Aspects that affect user acceptance of sanitation facilities, which may lead to rejection of services in favour or more culturally acceptable but less safe practices (such as open defecation) by users and workers. Examples are odour, safety, privacy and accessibility.

In a hazardous event, people are exposed to a hazard in the sanitation system. A single hazard may be realized through multiple hazardous events, and each event many have a different cause, needing different approaches to minimize the risk. The groups of people exposed to the hazard may be different for each hazardous event. A well-described hazardous event will include a brief comment on the circumstances under which the event occurs, or its cause (see example 3.1).

EXAMPLE 3.1. Examples of hazardous events and their causes

HAZARD	HAZARDOUS EVENT	CAUSE OF THE HAZARDOUS EVENT AFFECTING ITS FREQUENCY OR SEVERITY	APPROACHES TO CONTROL THE HAZARDOUS EVENT	PEOPLE GROUP EXPOSED TO THE HAZARD
Pathogens in wastewater	Dermal exposure to wastewater from overflow of a sewer pipe in high- rainfall event	• Conveyance system undersized for rainfall events • Lack of screening of overflows	• Design standards to establish overflow frequency • Regular maintenance of sewer system before rainy season	People living adjacent to the sewer or downstream of the overflow
	Ingestion after contact with wastewater during repair and maintenance of a sewage pump	• Pumps in poor condition or unsuitable for the operating conditions, resulting in frequent blockages • Poor staff training or ability, or poor equipment • Lack of bypass during maintenance work	• Planned asset maintenance to reduce frequency of pump failure • Selection of pump types and screens during the design and construction phase • Personal protective equipment for workers • Standard operating procedures • Design standards of pump stations	Sewage maintenance workers

The team should identify hazards and their associated hazardous events at each step of the sanitation chain. When doing this, they should consider:

- hazardous events associated with normal use, operation and maintenance of the system (e.g. faulty infrastructure, system overloading, lack of maintenance, unsafe behaviours);
- hazardous events due to a system failure or accident (e.g. partial or full treatment failure, power failures, equipment breakdown, operator error);
- hazardous events related to seasonal variation (e.g. seasonal farm workers, changes in weather; seasonal behaviour changes);
- indirect hazards and hazardous events – that is, hazards that potentially affect people not directly involved in the sanitation chain (e.g. through vermin or vectors, effects on downstream communities); and
- cumulative hazards (e.g. chemicals in soils).

Descriptions of hazardous events should describe how exposure groups are exposed to hazards. This requires understanding of the exposure route (see guidance note 3.2). The exposure route for excreta-related pathogens may be either primary (e.g. through direct contact or short-distance airborne transmission) or secondary (e.g. through consumption of contaminated produce). Having explicit exposure routes in the description of the hazardous event aids understanding of the risk and identification of controls that will break transmission.

GUIDANCE NOTE 3.2.

3

Common exposure routes to consider in SSP

EXPOSURE ROUTE	DESCRIPTION
Ingestion after contact with wastewater or excreta	Transfer of excreta (urine or faeces) through direct contact with the mouth from the hands or items in contact with the mouth, including ingestion of contaminated soil via contact with hands (e.g. farmers, children).
Ingestion of contaminated groundwater or surface water	Ingestion of water, drawn from a ground or a surface source, that is contaminated from wastewater or excreta/sludge, including unintentional ingestion of recreational waters by swimmers.
Consumption of contaminated produce (vegetables)	Consumption of plants (e.g. lettuce) that have been grown on land irrigated or fertilized with a sanitation product.
Dermal contact with excreta or wastewater	Infection where a pathogen (e.g. hookworms) enters through the skin via the feet or other exposed body part following contact with wastewater, excreta, open defecation or contents of leaking sanitation technologies, or during operation (e.g. pit emptying).
Vector-borne (via flies or mosquitoes)	Transmission routes include mechanical transfer of excreta by flies to a person or food items, and bites from mosquitoes or other biting insects that are carrying a pathogen.
Inhalation of aerosols and particles	Inhalation of micro-droplets of water and particles (which may not be noticeable) emanating or resulting from a sanitation technology, which may carry a pathogen.

Notes: Primary transmission includes direct contact with faeces or faecally soiled surfaces, and person-to-person contact, which, in this context, relates to personal hygiene. Secondary transmission includes vehicle-borne transmission (food, water) and vector-borne transmission. Vehicle-borne transmission is through contamination of, for example, crops or water sources. Vector-borne transmission is mainly through creation of breeding sites for vectors. Airborne transmission may also occur (e.g. during wastewater irrigation).

Source: Based on Stenström et al. (2011).

EXAMPLE 3.2. Examples of hazardous events in each step of the sanitation service chain

SANITATION STEP	EXAMPLES OF HAZARDOUS EVENTS
Toilet	• Vector-borne transmission of pathogens to users, due to wrong design and/or construction of the toilets (e.g. lack of water seal or lid) • Ingestion of pathogens after contact with excreta in toilets, due to lack of maintenance and cleaning
Containment–storage/treatment	• Ingestion of groundwater contaminated via leachate percolating from pits or septic tanks • Ingestion of groundwater contaminated via leakage from cracked/damaged septic tanks • Dermal contact with pathogens due to effluent discharging into open drains or water bodies • Trauma or asphyxiation caused by falling into collapsed pits as a result of reduced soil stability or structural failure of containment structure
Conveyance	• Ingestion of pathogens after contact with excreta during manual emptying of pits using buckets • Ingestion of pathogens after contact with contaminated soil, caused by discharge of faecal sludge without treatment to open grounds • Dermal contact with pathogens in open channels and surface waters caused by discharge of untreated faecal sludge • Ingestion of pathogens after contact with wastewater during sewer cleaning and maintenance
Treatment	• Ingestion of surface water contaminated with effluents from treatment plants that have not been designed based on pathogen removal, reduction or inactivation • Inhalation of aerosols while manual handling of the dried faecal sludge • Ingestion of pathogens in incompletely treated effluent, resulting from discharge of fresh faecal sludge in wastewater treatment ponds, causing overload and failure
Enduse or disposal	• Ingestion of pathogens in surface waters due to discharge of partially treated or untreated effluent • Inhalation of particles and aerosols containing pathogens during spray irrigation with partially treated or untreated wastewater on nearby farms • Ingestion of pathogens after contact with faecal sludge during application on farmland for soil improvement

Identification of hazardous events may include consideration of regulatory and policy shortcomings. For example, illegal dumping of faecal sludge in water bodies or open land may be due (wholly or in part) to lack of enforcement of discharge regulations.

Identification of hazardous events caused by chemicals (see guidance note 3.3) can be challenging because information is often scarce. Many hazardous events associated with chemicals are related to co-mixed chemicals flushed down toilets or introduced through industrial discharges to sewers. Such chemical inputs can cause treatment technologies to malfunction, leading to microbial hazardous events and illness from untreated wastewater and sludge, and accumulation of chemicals in soils, plants and end-use products.

3

GUIDANCE NOTE 3.3.

Hazardous events caused by chemical hazards

As presented in guidance note 2.6, chemical hazards can exist in sanitation systems from sources, such as industrial discharges, and household disposal of chemical (e.g. cleaning products, expired/unused chemicals) into sanitation systems and toxic gases emitted by decomposing wastewater and sludge .

Chemical compounds in sanitation systems can negatively affect the functioning of sewer systems and wastewater treatment processes increasing risk of exposure to untreated waste for local communities and posing direct risk to sanitation workers. Examples include: (Bennett, 1989).

- Low pH can cause sewer degradation, and high pH can cause burns to sanitation workers.
- Hydrogen sulfide can be formed from sulfates, leading to death of sanitation workers.
- Oil and grease can cause blockages or fire, or interfere with operation of the wastewater treatment plant.
- Heavy metals and organic compounds can inhibit biological processes or contaminate the sludge.

Toxic chemicals and heavy metals persist and may accumulate in water bodies, soil and animals. Nitrate and nitrite can have adverse effects on health if they enter drinking-water supplies after accumulating in groundwater due to pit and tank leachate. The WHO *Guidelines for drinking-water quality* (WHO, 2017b) provide information on chemical contaminants in drinking-water, including guideline values, treatment performance and health effects.

Use of wastewater in agriculture normally poses a low risk to human health from chemical hazards since concentration for plant survival and growth is normally much lower than thresholds for human health effects and the effects from chemical exposure are usually cumulative over a long period (WHO, 2006).

In identifying hazards and hazardous events, the SSP team should use Part A of tool 3.1.

TOOL 3.1. Template for identification of hazards and hazardous events, and validation of existing controls

Part A				Part B		
COMPONENT	HAZARD IDENTIFICATION			EXISTING CONTROLS		RISK ASSESSMENT (Will depend on the risk assessment methodology chosen by the SSP team)
Sanitation step	Hazardous event	Hazard	Exposure groups	Description of existing control measure	Validation of control	

Text

Identification of hazards and hazardous events should be carried out as a combination of desk exercises, using the descriptive information gathered under Module 2, and field investigations (step 2.5).

Climate change may create new or unprecedented hazardous events. The SSP team can draw on climate projections, and existing vulnerability, resilience and adaptation assessments to identify hazardous events mostly likely to arise as a result of climate change (see guidance note 3.4). SSP teams may define a specific hazardous event caused by climate change, or estimate how the risks under current conditions (identified in step 3.3) increase, decrease or remain the same under different climate change scenarios (see guidance note 3.8).

GUIDANCE NOTE 3.4.

Major climate change effects and resulting hazardous events

Below are examples of climate change effects and resulting hazardous events that can be reviewed relevant to the local context and sanitation systems.

CLIMATE CHANGE EFFECT	CAUSES OF HAZARDOUS EVENTS	EFFECT ON THE SANITATION SYSTEM	EXAMPLE OF HAZARDOUS EVENT	HAZARD	EXPOSURE GROUPS
More intense or prolonged precipitation	Increased flooding	Damage to infrastructure on which sanitation systems rely (e.g. electricity networks for pumping, road networks used by FSM vehicles)	Ingestion of surface water contaminated with raw sewage due to nonfunctioning wastewater treatment plant	All pathogens	LC, WC
		Flooding of on-site systems, causing spillage and contamination	Ingestion of pathogens after contact with faecal sludge during overflowing of on-site systems	All pathogens	U, LC
			Dermal contact with faecal sludge due to overflowing of on-site systems	Hookworm	U
		Treatment plants receiving flows that exceed their design capacities, resulting in flows bypassing the treatment processes	Ingestion of contaminated water with raw sewage due to bypassing of wastewater treatment plant	All pathogens	LC
	Increased erosion and landslides	Destruction of, or damage to, sanitation infrastructure	Ingestion of water contaminated with raw sewage due to nonfunctioning wastewater treatment plant	All pathogens	LC
	Contamination of, and damage to, surface water and groundwater supplies	Treatment plants receiving flows with concentrations of pollutants that exceed their design capacities, resulting in lower treatment performance	Ingestion of water contaminated with partially treated sewage due to higher pollutant concentration	All pathogens	LC
	Changes to groundwater recharge and groundwater levels	Floating of septic systems due to groundwater levels	Ingestion of pathogens after contact with faecal sludge due to floating of septic tank	All pathogens	U, LC
		Collapse of pit latrines via groundwater	Injury to the body and possible asphyxiation, after falling into the pit due to collapsing latrine structure	Injury to the body, including drowning	U, W
More intense or prolonged dry periods and drought	Insufficient water for flushed and cleaning	Toilets become blocked, dirty or unusable	Dermal contact with excreta in unclean toilets. Dermal contact and ingestion of excreta and loss of privacy and safety if users resort to open defecation	All pathogens, personal safety and dignity	U, WC
	Insufficient water to convey wastewater and sludge	Blocking of sanitation systems, particularly sewers due to low flow rates	Dermal contact with wastewater and sludge, injury to the body and possible asphyxiation due to entering the sewer for unblocking	All pathogens, injury and asphyxiation	W
	Increased demand for wastewater as a irrigation water source	Untreated (if diverted before treatment) or insufficiently treated wastewater (is used for purposes the treatment processed are not fit for) is used to irrigate crops	Ingestion of excreta carried on irrigated crops, particularly for crops eaten raw. Dermal contact and inhalation of irrigation water	All pathogens	W, LC, WC

CLIMATE CHANGE EFFECT	CAUSES OF HAZARDOUS EVENTS	EFFECT ON THE SANITATION SYSTEM	EXAMPLE OF HAZARDOUS EVENT	HAZARD	EXPOSURE GROUPS
Sea level rise	Saline intrusion in coastal/low-lying zones	Damage to wastewater treatment works (which are often coastal/low-lying) from exposure to salt water	Ingestion of pathogens in surface water contaminated with partially or untreated sewage	All pathogens	LC
		Reduced effectiveness of biological treatment processes due to saltwater exposure from saline intrusion into wastewater influent	Ingestion of pathogens in surface water contaminated with partially treated sewage due to higher pollutant concentration	All pathogens	LC
	Rising groundwater levels in coastal/low-lying zones	Damage to underground infrastructure from rising groundwater levels	Ingestion of groundwater contaminated with faecal pathogens	All pathogens	LC
	Higher risk of inundation, especially from extreme weather events (potentially contributing to flooding, erosion, landslides)	Damage to infrastructure on which sanitation systems rely (e.g. electricity networks for pumping, road networks used by FSM vehicles)	Ingestion of surface water contaminated with raw sewage due to nonfunctioning wastewater treatment plant	All pathogens	LC WC
		Flooding of on-site systems, causing spillage and contamination	Ingestion of pathogens after contact with faecal sludge during overflowing of on-site systems	All pathogens	U, LC
			Dermal contact with faecal sludge due to overflowing of on-site systems	Hookworm	U
		Treatment plants receiving flows that exceed their design capacities, resulting in flows bypassing the treatment processes	Ingestion of water contaminated with raw sewage due to bypassing wastewater treatment plant	All pathogens	LC
More variable or increasing temperatures	Higher freshwater temperatures	Proliferation of algal blooms or microbes carried by vectors in water	Ingestion of contaminated surface water during bathing	All pathogens	LC, WC
	Hot and cold temperature extremes	Reduced efficiency of biological wastewater treatments (if temperature exceeds or falls below operational limits)	Ingestion of water contaminated with partially treated sewage due to higher pollutant concentration	All pathogens	LC
		Increased corrosion of sewers	Ingestion of groundwater contaminated with faecal pathogens leaking from broken sewers	All pathogens	LC
More frequent or intense storms or cyclones	Increased flooding	Damage to infrastructure on which sanitation systems rely (e.g. electricity networks for pumping, road networks used by FSM vehicles)	Ingestion of surface water contaminated with raw sewage due to nonfunctioning wastewater treatment plant	All pathogens	LC
		Flooding of on-site systems, causing spillage and contamination	Ingestion of pathogens after contact with faecal sludge during overflowing of on-site systems	All pathogens	U, LC
			Dermal contact with faecal sludge due to overflowing of on-site systems	Hookworm	U
	More extreme winds	Damage to infrastructure on which sanitation systems rely (e.g. electricity networks for pumping, road networks used by FSM vehicles)	Ingestion of surface water contaminated with raw sewage due to non-functioning wastewater treatment plant	All pathogens	LC, WC

FSM: faecal sludge management.

Note: This table has been adapted from Table 4 ("Examples of climate variability and change effects on sanitation systems") in WHO (2019a). Examples provided depend on context; those provided here are illustrative and not exhaustive.

3.2 Identify and assess existing control measures

For each hazardous event identified in step 3.1, the SSP team should identify what control measures are already in place to mitigate the risk associated with that hazardous event.

Control measures are any action or activity (or barrier) that can be used to reduce, prevent or eliminate a sanitation-related hazard, or reduce it to an acceptable level. A control measure substantially reduces the number of pathogens along a pathway or contributes to reduction in transmission of the hazard. It is associated with any part of the sanitation chain (including toilet, containment–storage/treatment, conveyance, transport, treatment, and end use or disposal).

Once existing control measures are identified, the SSP team should determine how effective they are in reducing the risk of hazardous events. When assessing how effective the control measure is, consider:

- how effective the existing control measure **could be** (theoretically, assuming it was always working well, including under climate change scenarios); and
- how effective the existing control measure **is in practice** (bearing in mind the actual site conditions, actual enforcement of existing rules and regulations, and actual operating practices).

Establishing the theoretical and practical effectiveness of a control measure, by evidence or by judgement from experience, is referred to as control measure validation. Part B of tool 3.1 can be use for control measure identification and validation.

Assessing how effective an existing control measure could be is often based on literature or detailed technical assessments. Annex 1 of this publication, WHO (2006; Chapter 5 in volumes 2, 3 and 4) and WHO (2018; Chapter 3) summarize the potential effectiveness of a range of treatment and management control measures.

Log reduction values can be used to assess the effectiveness of certain control measures provided reliable data are available (see guidance note 4.6).

Operational data over a long period can also assist in understanding performance capability. Guidance note 3.5 gives recommendations on how to validate control measures.

GUIDANCE NOTE 3.5.

Documents to check to validate existing control measures

Control measure validation proves that the control measure is capable in practice of meeting specified targets (e.g. microbial reduction targets). For sanitation systems, control measure validation may mean:

- checking system loading against its design capacity;
- checking literature for performance capability of individual treatment process units;
- checking historical performance under unusual conditions;
- checking WHO (2018) for pathogen reduction levels for well-designed and well-functioning systems (e.g. see Tables 3.1, 3.2 and 3.3 for treatment performance of containment, wastewater treatment and sludge treatment technologies and processes, respectively, and Table 3.4 for pathogen levels in end-use sanitation products).
- checking WHO (2006) for reductions of pathogens for nontechnical control measures in reuse systems (e.g. see volume 2, Table 4.3 and Chapter 5; volume 3, Chapter 5; and volume 4, Chapter 5).
- checking the WHO pathogen fact sheets and/or Global Water Pathogen Project database, part 4 ("Management of risk from excreta and wastewater"), which has chapters describing pathogen reduction in non-sewered and sewered system technologies.

For many control measures, the effectiveness in practice of the existing control measure might be different from the theoretical effectiveness (see example 3.3). For example, a treatment plant may not be properly operated because of operator errors or periods of overloading. Some control measures, such as use of personal protective equipment, are dependent on the behaviour of the user. Consider the potential for climate change to influence the effectiveness of the control measure.

EXAMPLE 3.3. Examples of control measures, their expected control performance and common performance failures

CONTROL MEASURE	EXPECTED CONTROL LEVEL	COMMON CONTROL FAILURE IDENTIFIED THROUGH VALIDATION
Flush toilets installed at the household level	High, flush toilets safely remove excreta from houses, avoiding both active contact (touching) or passive contact (via flies or vectors) with users.[a]	Lack of water to flush creates a focus of contamination inside the household.
Flush toilet with twin pits for alternating use	High pathogen reduction level $\geq 2 \log_{10}$ (except *Ascaris* eggs)[a]	Operation is inconsistent with the technology design. In this case, one pit is required to be closed for 2 years, while the second pit is being used. However, both pits have been used at the same time.
PPE	Barrier to dermal and aerosol contact for workersb	Waste handlers only use PPE during cool season, leading to exposure risk during 7 months of the year.
Waste stabilization ponds	Treating waste to a specified number of coliforms per 100 mL[b] Reduction of helminth eggs to less than 1/L[b]	Poor design, overloading or short circuiting, leading to reduced retention times and lower-quality effluent.
Irrigation application: use of localized drip irrigation	High level of worker protection (potential 2 log reduction)[b]	Clogging of the pipes means that workers are potentially exposed to wastewater during repairs.
Irrigation application: pathogen die-off after last irrigation and before harvest	Actual log reductions depend on crop type and temperature, and are site-specific.[b]	Inconsistent use in the field in dry conditions when alternative fresh water supply is limited. As the reduction rate is highly variable, if helminth eggs remain viable for long periods (e.g. in cooler weather with little direct sunlight), irrigation water with more than targeted maximum number of helminth eggs is vulnerable to failure of control.
Food preparation methods: vigorous washing of rough-leafed salad crops	1 log reduction[b]	Inconsistent use by householders, especially the poor and those with limited water supply.

PPE: personal protective equipment.

[a] See Chapter 3 of WHO (2018).

[b] Based on WHO (2006), vol. 2, sections 3.1.1 and 5.

Note: See Module 4 and Annex 1 for more information on how to judge the effectiveness or the expected outcomes of control measures.

GUIDANCE NOTE 3.6.

Suggested questions to validate the practical effectiveness of existing control measures

Chapter 3 of WHO (2018) provides guidelines for safe management at each step of the sanitation system, including design, construction, operation and maintenance aspects. To validate existing control measures, the SSP team should consider how effective the control measures are in practice. The table presents examples of control measures and questions that can be used to validate their effectiveness.

SANITATION STEP	EXAMPLES OF CONTROL MEASURES	EXAMPLES OF QUESTIONS FOR VALIDATION
Toilet	Installation of toilets	Are the toilets correctly designed? Are they well constructed? Is the slab made of durable material?
	Maintenance of toilets	Are they cracked or damaged?
	Cleaning of toilets	Are they clean? Is cleaning material available?
	Access to shared sanitation	Is the public toilet being used? Is it near? Is it accepted and open?
Containment–storage/ treatment	Septic tank	Is it sealed? Does the effluent go to a soak pit, leach field or piped sewer? Is it accessible for emptying?
	Single pits	Is the bottom of the pit located at least 1.5–2.0 m above the water table? Is it elevated?
	Twin pits for alternating use	Is it used as intended (alternating)? Is the storage/idle time of each pit at least 2 years?
Conveyance	Preventive emptying	Do households call the emptying trucks before the tanks are full?
	Use of PPE	Do the sanitation workers use the PPE?
	Assignment of a legal place of disposal of faecal sludge	Are the desludging trucks bringing the faecal sludge to the assigned site? Is there illegal dumping?
	Cleaning of sewer systems	Are the sewers free of solid waste?
Treatment	Wastewater treatment plant	Was it designed with the aim of pathogen removal? Is it working as planned? Is it overloaded? Can the staff operate it?
	Effluent quality control	Is a laboratory available? Do they run pathogen load tests?
	Use of PPE	Do sanitation workers use the PPE?
End use or disposal	Treatment of wastewater for reuse	Was it designed with the aim of pathogen removal? Is it working as planned? Is it overloaded? Can the staff operate it?
	Restrictions on produce	Are farmers only growing the products indicated?
	Use of PPE	Do farmers use the PPE?

PPE: personal protective equipment.

Control measure validation helps the SSP team critically assess the control measure in detail. Such understanding strongly supports the subsequent risk assessment (in step 3.3).

Commonsense judgement by experienced members of the SSP team or other professionals may be adequate to validate control measure effectiveness. Once more data are available, the risk assessment can and should be revisited, and a formal validation undertaken if desired and appropriate.

3.3 Assess and prioritize the exposure risk

The hazard identification in step 3.1 will yield a large number of hazards and hazardous events, some of which will be serious, whereas others will be moderate or insignificant. Step 3.3 establishes the risk associated with each, so that the SSP team can prioritize system improvements.

Different approaches to risk assessment are possible, with varying degrees of complexity and data requirements (see guidance note 3.7).

- **Simple sanitary inspection** – suited to simple sanitation systems, primarily on-site systems, focusing on the toilet and containment steps.
- **Team-based descriptive risk assessment** – suited to more complex systems with limited data and teams that are relatively new to conducting risk assessments.
- **Semi-quantitative risk assessment** – uses a matrix of likelihood and severity; suited to more complex systems and more experienced or well-resourced teams.
- **Quantitative methods** (e.g. quantitative microbial risk assessment) – specialized assessments that can complement SSP; generally not used by SSP teams.

GUIDANCE NOTE 3.7.

Data requirements for risk assessment approaches

The table shows which type of supporting data gathered in step 2.4 might be relevant to implementing the different risk assessment approaches. If some piece of information is missing, teams could consider using a team-based or semi-quantitative method.

	SIMPLE SANITARY INSPECTION	TEAM-BASED DESCRIPTIVE	SEMI-QUANTITATIVE
RELEVANT QUALITY STANDARDS, AND CERTIFICATION AND AUDITING REQUIREMENTS			
Relevant laws and by-laws	✓	✓	✓
Effluent discharge and odour regulations		✓	✓
Regulations relating to quality monitoring, surveillance and auditing		✓	✓
Specific national regulations relating to agricultural products			✓
Certification requirements relating to agricultural end-use products			✓
INFORMATION RELATING TO SYSTEM MANAGEMENT AND PERFORMANCE			
Data relating to earlier monitoring and surveillance			✓
Epidemiological data		✓	✓
Existing vulnerability, resilience or adaptation assessments of the area		✓	✓
DEMOGRAPHICS AND LAND-USE PATTERNS			
Land-use pattern	✓	✓	✓
Settlements (including informal settlements) in the area	✓	✓	✓
Population and number of households served by the sanitation system	✓	✓	✓
Special activities that may affect sanitation/wastewater production			✓
Specific equity considerations, such as ethnicity, religion, migrant populations and disadvantaged groups	✓	✓	✓
Areas predicted for significant population growth or change			✓
KNOWN OR SUSPECTED CHANGES RELATING TO WEATHER OR OTHER SEASONAL CONDITIONS			
Mean variability of the load to the treatment plant during the year			✓
Seasonal variation of use due to type of crops and harvest			✓
Implications for treatment of additional inflow during heavy rain		✓	✓
Climate change projections			✓
Changes in usage patterns at times of water scarcity	✓	✓	✓

Risk assessment should be done by the SSP team, either on an individual basis or as a group, to increase the objectivity of the risk assessment and produce consolidated ratings. Teams should be specific in the risk assessment and relate it to the hazardous event. The team could treat control measure failure as a separate hazardous event in its own right, with its own likelihood and consequence.

The team should draw on climate change projections to consider the potential for climate change to increase the likelihood, severity or geographical range of hazardous events. Where climate change projections are not available or have significant uncertainty (e.g. future changes in rainfall), the SSP team may consider how risk would change under different climate scenarios (e.g. drier conditions, wetter conditions, conditions with more severe storms).

Risk levels should be reality checked to ensure that they make sense. If in doubt, re-examine the information and rankings.

Simple sanitary inspections

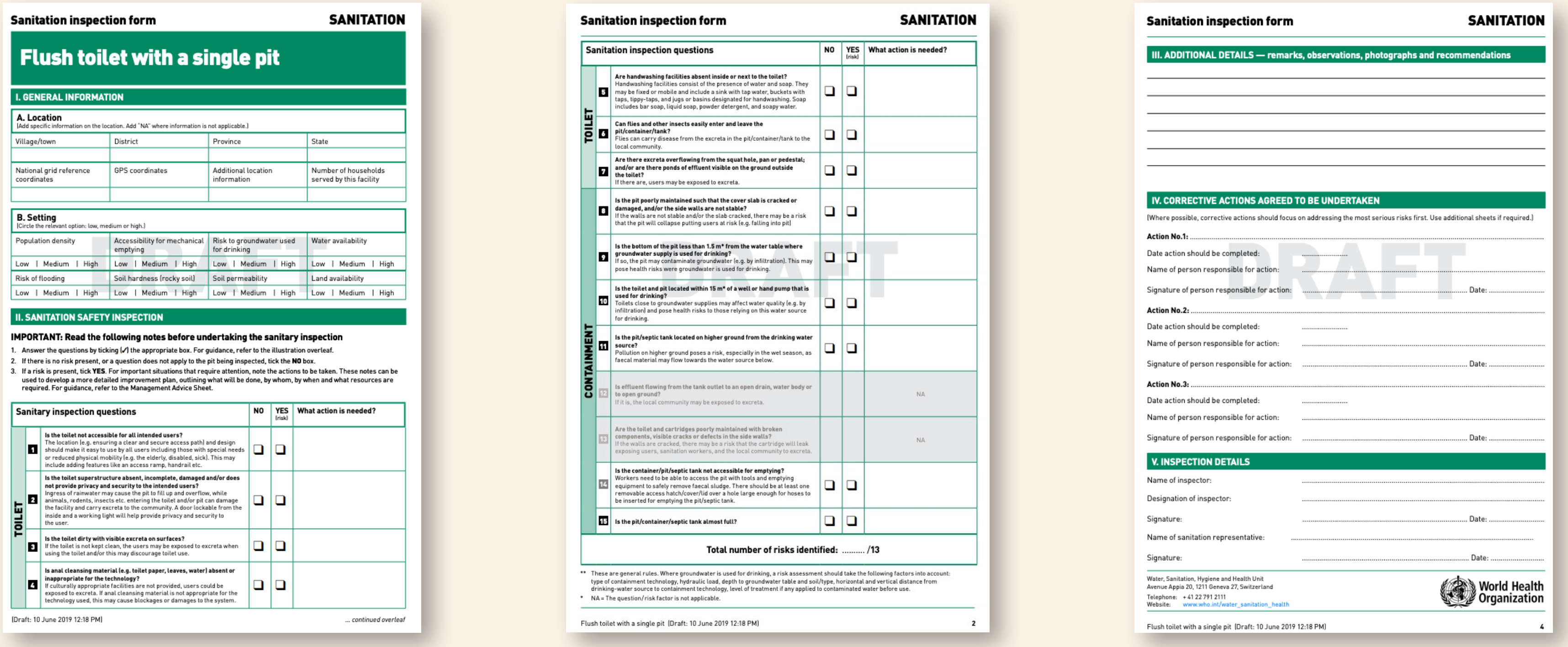
WHO sanitary inspection forms, consisting of short, standardized observation checklists, can be used and adapted during field investigations to assess risks. Sanitary inspection forms are best suited to lower-density rural areas. They can easily be applied by community representatives, environmental health inspectors and field officers (see tool 3.2).

TOOL 3.2. Simple sanitary inspection forms

Sanitary inspection forms are short, standardized observation checklists that can be adapted and used to assess risk factors in a sanitation system. WHO (2019b) includes sanitary inspection forms for the most common sanitation system types.

These forms are used during field investigations to identify the presence of a predefined risk. As a first step, an SSP team member should note general information about the locality, including the number of facilities. They then judge predefined risks, such as the risk of flooding. The sanitary form presents several questions; a response of "yes" indicates the presence of a risk. Once all questions are answered, the SSP team will know what risks the sanitation system poses to the community.

WHO sanitary inspection forms are complemented by a set of management advice sheets that provide guidance on operation and maintenance of sanitation systems and possible remedial actions for the risks identified. The SSP team can use these to select the actions needed to mitigate the identified risks. These prioritized control measures can be used to develop a more detailed improvement plan in Module 4. For illustration, the following figure shows an excerpt of a WHO sanitary inspection form.



Sanitary inspection forms for sanitation systems and management advice sheets can be downloaded from the WHO website.

Team-based descriptive risk assessment

A team-based descriptive risk assessment uses the SSP team's judgement to assess risk by classifying hazardous events as high, medium or low risk. Definitions in tool 3.3 can be used, or the SSP team can develop their own health-related definitions.

TOOL 3.3. Suggested risk category descriptions for team-based descriptive risk assessment

RISK DESCRIPTOR	NOTES
High	The event could result in injuries, acute and/or chronic illness or loss of life. Actions need to be taken to minimize the risk.
Medium	The event could result in moderate health effects (e.g. fever, headache, diarrhoea, small injuries) or discomfort (e.g. noise, malodours). Once the high-priority risks are controlled, actions need to be taken to minimize the risk.
Low	No health affects are anticipated. No action is needed at this time. The risk should be revisited in the future as part of the review process.

Teams can account for the effect of climate change for each hazardous event by recording whether the risk is likely to increase, decrease or stay the same under anticipated climate change scenarios (see guidance note 3.8 and use tool 3.4).

If the team-based descriptive approach is used, the team may choose to conduct a semi-quantitative risk assessment in the next revision of the SSP.

TOOL 3.4. Template for team-based descriptive risk assessment

COMPONENT	HAZARD IDENTIFICATION (Including new or unprecedented hazardous events associated with climate change scenarios; see example 3.2 and guidance note 3.4)				EXISTING CONTROLS		TEAM-BASED DESCRIPTIVE RISK ASSESSMENT: UNDER CURRENT CONDITIONS, ALLOWING FOR THE EXISTING CONTROLS	TEAM-BASED DESCRIPTIVE RISK ASSESSMENT: UNDER THE MOST LIKELY CLIMATE CHANGE SCENARIOS (In the cells below, record two scenarios, e.g. drought, heavy rainfall. + means increased risk, – means decreased risk, = means the same risk)		BASIS OF THE DECISION (Justification of risk assessment, under current conditions or climate change scenarios, or effectiveness of the control)
Sanitation step	Hazardous event	Hazard	Exposure groups	Number of people at risk	Description of existing control measure	Validation of control	Risk priority (e.g. high, medium, low)	Scenario 1	Scenario 2	

Semi-quantitative risk assessment

Semi-quantitative risk assessment is more rigorous than team-based descriptive risk assessment. It is appropriate for organizations in more well-defined regulatory environments and for SSP teams that are already familiar with hazard analysis and critical control points (HACCP) or WSP methodology, or SSP teams working on a revision of the SSP process.

The SSP team consistently assigns a likelihood and severity to each identified hazardous event using a risk matrix, to arrive at a risk category or score. A suggested risk matrix and definitions of likelihood (e.g. unlikely, possible, likely) and severity (e.g. minor, major) are provided in tools 3.5 and 3.6. When assessing the severity of the hazardous event, consider the characteristics of system flows (determined in Module 2), as well as the magnitude of associated health outcomes.

3

TOOL 3.5. Suggested risk definitions for semi-quantitative risk assessment

	DESCRIPTOR	DESCRIPTION
Likelihood (L)		
1	Very unlikely	Has not happened in the past and it is **highly improbable** it will happen in the next 12 months (or another reasonable period).
2	Unlikely	Has not happened in the past but **may occur in exceptional circumstances** in the next 12 months (or another reasonable period).
3	Possible	May have happened in the past and/or **may occur under regular circumstances** in the next 12 months (or another reasonable period).
4	Likely	Has been observed in the past and/or is **likely** to occur in the next 12 months (or another reasonable period).
5	Almost certain	Has often been observed in the past and/or **will almost certainly occur** in most circumstances in the next 12 months (or another reasonable period).
Severity (S)		
1	Insignificant	Hazard or hazardous event resulting in **no or negligible health effects** compared with background levels.
2	Minor	Hazard or hazardous event potentially resulting in **minor health effects** (e.g. temporary symptoms of irritation, nausea, headache).
4	Moderate	Hazard or hazardous event potentially resulting in **self-limiting health effects or minor illness** (e.g. acute diarrhoea, vomiting, upper respiratory tract infection, minor trauma).
8	Major	Hazard or hazardous event potentially resulting in **illness or injury** (e.g. malaria, schistosomiasis, food-borne trematodiases, chronic diarrhoea, chronic respiratory problems, neurological disorders, bone fracture), and/or may lead to **legal complaints** and concern, and/or major **regulatory noncompliance**.
16	Catastrophic	Hazard or hazardous event potentially resulting in **serious illness or injury, or even loss of life** (e.g. severe poisoning, loss of extremities, severe burns, drowning), and/or will lead to **major investigation by regulator**, with prosecution likely.

TOOL 3.6. Semi-quantitative risk assessment matrix

			SEVERITY (S)				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	4	8	16
LIKELIHOOD (L)	Very unlikely	1	1	2	4	8	16
	Unlikely	2	2	4	8	16	32
	Possible	3	3	6	12	24	48
	Likely	4	4	8	16	32	64
	Almost certain	5	5	10	20	40	80

Risk score R = L × S	<6	6–12	13–32	>32
Risk level	Low risk	Medium risk	High risk	Very high risk

The SSP team may choose to develop its own definitions for likelihood and severity, based on the system and local context. The definitions could include aspects relating to potential health impacts, regulatory impacts, and impacts on community or customer perceptions. However, the principle of safeguarding public health should never be compromised in any definitions.

Tool 3.7 can be used to record results. Teams should account for the effect of climate change for each hazardous event by recording whether the risk is likely to increase, decrease or stay the same under anticipated climate change scenarios (see guidance note 3.8).

Tool 3.8 allows the team to summarize the highest risks. It is essential to consider the number of people who are at risk while prioritizing the hazardous events. These will be addressed in the improvement actions selected in Module 4.

Annex 2 provides summary statements on microbial health risks to assist assessment of the severity of hazardous events relating to the use of wastewater for agriculture.

TOOL 3.7. Template for semi-quantitative risk assessment

COMPONENT	HAZARD IDENTIFICATION				EXISTING CONTROLS		RISK ASSESSMENT						COMMENTS JUSTIFYING RISK ASSESSMENT (Under current conditions, climate change scenarios, or effectiveness of the control)
							UNDER CURRENT CONDITIONS, ALLOWING FOR THE EXISTING CONTROLS L = likelihood; S = severity; R = risk level (e.g. high)				UNDER THE MOST *LIKELY* CLIMATE CHANGE SCENARIOS (In the cells below, record two scenarios, e.g. drought, heavy rainfall. + means increased risk, – means decreased risk, = means the same risk)		
Sanitation step	Hazardous event	Hazard	Exposure groups	Number of people at risk	Description of existing control measure	Validation of control	L	S	Score (LxS)	R	Scenario 1	Scenario 2	

3

TOOL 3.8. Template to prioritize hazardous events according to results of semi-quantitative risk assessments

Sanitation step	Hazardous event	Exposure group	Number of people at risk	Risk (Low, medium, high or very high)	Projection of changes in risks with climate change scenarios	Priority (Low, medium, high or very high)

GUIDANCE NOTE 3.8.

Risk assessment for climate change and climate variability

Climate change and climate variability can change both the likelihood and the severity of hazards and hazardous events. The likelihood that particular hazards or hazardous events will occur may increase or decrease as a result of climate change. For example, under drought conditions, sewer overflow frequency may decrease, but use of untreated wastewater may increase. Although it can be difficult to place firm values on the likelihood for future scenarios, these future likelihoods must be considered in the risk assessment.

Similarly, the consequences of hazards and hazardous events may become either more or less severe. For example, the discharge of effluent to a river is more significant in drought conditions when receiving water levels are low, compared with high-rainfall events when there is greater dilution. Where climate projections have significant uncertainty, consider how different climate scenarios would affect the severity score. The climate scenarios that result in the largest increase in risk should be prioritized.

To simplify the risk assessment under climate change and climate variability, the SSP team can choose the most likely climate change scenarios and decide whether the risk will increase, decrease or remain the same. The table shows an example of a semi-quantitative risk assessment using this approach.

COMPONENT	HAZARD IDENTIFICATION				EXISTING CONTROLS		RISK ASSESSMENT: UNDER CURRENT CONDITIONS, ALLOWING FOR THE EXISTING CONTROLS (L = likelihood; S = severity; R = risk level (e.g. high))				RISK ASSESSMENT: UNDER THE MOST LIKELY CLIMATE CHANGE SCENARIOS (In the cells below, record two scenarios, e.g. drought, heavy rainfall. + means increased risk, – means decreased risk, = means the same risk)		COMMENTS JUSTIFYING RISK ASSESSMENT (Under current conditions, climate change scenarios, or effectiveness of the control)
Sanitation step	Hazardous event	Hazard	Exposure groups	Number of people at risk	Description of existing control measure	Validation of control	L	S	Score (LxS)	R	Scenario 1: Drought	Scenario 2: More intense precipitation, floods	
Conveyance	Ingestion of contaminated groundwater due to leakage from sewers into shallow groundwater	All pathogens	Local community	50 000	Awareness-raising campaigns to encourage families to use household water treatments (HWTS) such as filters and chlorination	Not effective – household-level surveys show that families are not using HWTS	4	4	16	H	+	+	Under drought, the likelihood of collecting water for drinking from shallow sources increases. Under flooding scenarios, the quality of groundwater is affected by pollutants.

Other examples can be found in the worked example: SSP in Newtown.

MODULE

4

DEVELOP AND IMPLEMENT AN INCREMENTAL IMPROVEMENT PLAN

MODULE 4

DEVELOP AND IMPLEMENT AN INCREMENTAL IMPROVEMENT PLAN

What needs to be improved and how?

STEPS

4.1 Consider options to control identified risks
4.2 Develop an incremental improvement plan
4.3 Implement the improvement plan

TOOLS

Tool 4.1. Template to list and analyse control options
Tool 4.2. Template for an SSP incremental improvement plan

OUTPUTS

- **An incremental improvement plan that protects all exposure groups along the sanitation chain**
- **Progressive investment to implement the plan**

Overview

In Module 3, the SSP team identified the highest-priority risks. Module 4 selects new control measures (policy/regulatory change, technology upgrades, changes in management or behaviour) that address these risks at the most effective places in the system. This process helps ensure that funding and effort target the highest risks with greatest urgency.

The improvement plan developed and implemented under Module 4, and the monitoring plan developed and implemented under Module 5, are the central outputs of SSP. In the unlikely event that the risk assessment and ranking in Module 3 identifies no need for improvements, proceed to Modules 5 and 6.

Step 4.1 Consider options to control identified risks – considers options to control highest risks along the sanitation chain, including technology upgrades, changes in management and operation, behaviour change measures, and policy and regulatory measures.

Step 4.2 Develop an incremental improvement plan – consolidates the selected options into a clear plan of action.

Step 4.3 Implement the improvement plan – mobilizes investment and action by the responsible entities to implement the improvement plan.

4.1 Consider options to control identified risks

Following Module 3, the SSP team will have a comprehensive list of prioritized hazards and hazardous events.

The SSP team should consider options to control the prioritized hazardous events to reduce the risk level. Improvement options can fall into the following categories.

Regulatory measures are mechanisms to regulate the sanitation service chain. Because sanitation cuts across many sectors, relevant legislation and regulation may be found under building and planning codes and standards, local government legislation, public utility regulations, licensing agreements, and so on. SSP measures should focus on ordinances and local by-laws passed by local authorities. In some cases, local authorities could advocate for changes in the national regulation.

Chapter 4 of WHO (2018) presents the scope of legislative and regulatory frameworks for sanitation, as well as mechanisms to regulate sanitation systems. Guidance note 4.1 introduces some regulatory mechanism options.

GUIDANCE NOTE 4.1.

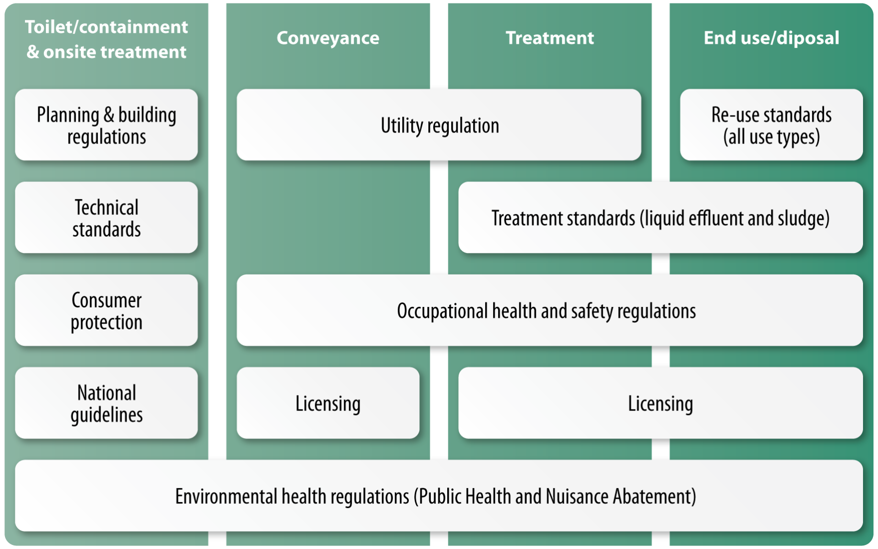
Regulatory mechanism options for the sanitation service chain

The diagram presents regulatory mechanisms through which the steps of the sanitation service chain can be regulated (WHO, 2018).

Relevant legislation and regulation may be found under:

- local government public health, occupational health and safety, environmental, water resources, and consumer protection legislation;
- legislation and regulations covering agriculture, energy and food safety with regard to safe use of faecal sludge;
- local by-laws;
- building and planning codes and standards; and
- public utility regulations.

For more details, refer to section 4.4 ("Legislation, regulations, standards and guidelines") of WHO (2018).



Source: Figure 4.4 in WHO (2018).

Technical control measures, also called technology upgrades, refer to the construction or refurbishment of the sanitation system. Examples include constructing or repairing toilets in households or other settings, upgrading or repairing containment technologies (e.g. pits, septic tanks), providing or upgrading faecal sludge emptying and transport equipment, repairing sewers, constructing faecal sludge transfer stations and sewer discharge stations, and providing additional or new treatment plant or process elements.

Chapter 3 ("Safe sanitation systems") of WHO (2018) shows key technical and managerial features to ensure that people's risk, as a result of exposure to excreta, is minimized at each step of the sanitation service chain. Guidance note 4.2 highlights some recommendations to reduce risk and examples of incremental control measures for each step of the sanitation service chain.

Management and operational control measures refer to methods, procedures and routines to carry out a specific activity within the sanitation service chain. They include arrangements for how people are organized and trained to carry out their work. Examples include development of, and adherence to, standard operating procedures and emergency response plans; training of key actors in service delivery; establishment of information management systems; vector-control programmes; and operational measures specific to reuse, such as crop restrictions and withholding times.

Guidance notes 4.3 and 4.4 present more information about two key management control measures that should be integrated in all SSP.

GUIDANCE NOTE 4.2.

Examples of technical incremental control measures

The following examples of incremental control measures have been extracted from Chapter 3 of WHO (2018), and might serve as tips for SSP teams in areas with limited resources.

- **Toilet**: "In remote rural areas, for example, where the availability of materials is a limiting factor and/or the cost of transporting a durable slab from a local town is considered too high, households should at least cover any wooden squatting slab with a coating of mortar. This approach should therefore limit exposure" (WHO, 2018).
- **Containment**: There are no incremental control measures for containment. However, where there is a risk of groundwater contamination, consider elevating the pits or implementing container-based sanitation.
- **Conveyance**: Options include "minimizing risks from manual emptying", which refers to making motorized and/or manual pumps available to workers; and construction of "transfer stations and sewer discharge stations".
- **Treatment**: Co-treatment of faecal sludge in existing wastewater treatment is possible. However, make sure that a first dewatering step is included, so it is possible "to co-treat the liquid fraction with municipal wastewater, and co-treat the solid fraction with the wastewater sludge from the wastewater treatment technology" (WHO, 2018).
- **End use or disposal**: Options include low-contact irrigation methods (e.g. drip irrigation).

GUIDANCE NOTE 4.3.

Standard operating procedures

All systems require instructions on how to operate them. Standard operating procedures (SOPs) are written instructions describing steps or actions to be taken during normal operating conditions, and for corrective actions when operational monitoring parameters reach or breach operational limits. If not written correctly, SOPs are of limited value. In addition, the best-written SOPs will fail if they are not followed.

SOPs and manuals should be available for individual technical components of the system, such as for a pump or a treatment process. In addition to the technical information needed to run the system, management procedures should be developed outlining the tasks to be undertaken in managing all aspects of the sanitation system, including during emergency situations. Example management procedures are:

- operation and maintenance schedules;
- procedures for all aspects of the treatment of the system (e.g. screening aeration, filtration, chlorination);
- procedures for during and after extreme weather events or disasters;
- operational monitoring procedures (as identified in Module 5);
- procedures relating to managing inputs to the sanitation system; and
- schedules and procedures to monitor wastewater quality and reuse, and statutory requirements.

Copies of the current SOPs need to be readily accessible for reference in the work areas of people performing the activity, in either hard-copy or electronic format. Personnel need to be appropriately trained to implement the procedures and other management protocols.

Members of the management team, preferably the direct supervisor, should periodically review the SOPs (e.g. every 1–2 years), to ensure that the policies and procedures remain current and appropriate. If a SOP describes a process that is no longer followed, it should be withdrawn and archived. Whenever procedures are changed, SOPs should be updated and reapproved. Following any reassessment of risks, check whether the associated SOPs are still suitable.

Documenting operating, maintenance and inspection procedures is important because it:

- helps build confidence that operators and backup support know what actions to take, and how and when to take them;
- supports consistent and effective performance of tasks;
- captures knowledge and experience that may otherwise be lost when staff members change;
- helps in training and competency development of new operators; and
- forms a basis for continuous improvement.

GUIDANCE NOTE 4.4.

Emergency response plans

Emergency response plans (ERPs) are designed to cover emergencies for which there is no specific SOP. They should also be considered as part of operational control measures. For example, operators should know how to respond to overflows and flooding, which could result in uncontrolled release of faecal sludge, or raw or partially treated wastewater.

ERPs allow for preparedness and adaptive management processes suitable to respond to emergent and unforeseen conditions, such as climate-related hazards. Sanitation should be included as part of disaster preparedness, and therefore sanitation and hygiene materials should be purchased along with other emergency supplies.

It is important to assess the effectiveness of the ERPs and the readiness of key actors in the sanitation service chain to respond to emergencies by conducting regular training and exercises (e.g. once per year). ERPs require review after the situation has occurred, and SSP should be updated accordingly based on lessons learned. ■

Behaviour change measures refer to programmes designed to foster behaviour change at the levels of the individual, the household, the community and key stakeholders involved in sanitation delivery. A number of behaviour change approaches can be used: information, education and communication-based messaging approaches; community-based approaches; social and commercial–marketing approaches; and approaches based on psychological and social theories. A key example in SSP is the use of personal protective equipment by sanitation workers and farmers.

Communication campaigns play a significant role in disseminating behaviour change messages, and marketing of sanitation-related products and services to members of the public. Citizens are responsible for implementing and sustaining some SSP control measures, particularly at the toilet and containment steps. They therefore need to be informed of their responsibilities and why they need to meet them; how to access products and services (including subsidies, where applicable) for construction, maintenance and monitoring; and the consequences of inaction (i.e. enforcement). Local authorities implementing SSP should seek partnerships with local media outlets to increase the impact of their communication efforts. Existing communication programmes may need to be reconsidered in light of the extent to which they support the SSP improvement priorities.

Sanitation systems should provide a series of barriers against different types of hazards. That is, a **multibarrier approach** is recommended. Put another way, good sanitation systems provide several controls along the entire pathway to reduce the risks to human health. Example 4.1 shows examples of improvement options along the sanitation service chain for a faecal sludge management system.

EXAMPLE 4.1. Examples of improvement options along the sanitation service chain

STEP OF THE SANITATION SERVICE CHAIN	TYPE OF IMPROVEMENT OPTION			
	REGULATORY[a]	TECHNICAL[b]	MANAGERIAL AND OPERATIONAL[b]	BEHAVIOUR CHANGE[c]
Toilet	Technical standards on material, dimensions and location	Installation of flush toilets	Training of masons for correct installation	Communication campaign to encourage correct use and maintenance of the toilet
Containment–storage/treatment	Guidelines on periodic inspection of on-site systems	Installation of sealed and impermeable septic tanks	Building a database of on-site sanitation infrastructure	Programme to encourage refurbishment of nonsealed containment tanks
Conveyance	Licensing of emptying service providers	Installation of faecal sludge transfer stations	Establishing a call centre for septic tank emptying	Consumer protection programme indicating rights and responsibilities of users of faecal sludge emptying services
Treatment	Liquid effluent standards; guidelines on control of nuisances (odours, flies, noise) from treatment facility	Construction of, or improvements to, a faecal sludge treatment plant	Developing standard operating procedures for operation and maintenance	Internal awareness-raising programme to ensure occupational health and safety
End use or disposal	Standards for sludge products, categorized by type of use	Additional treatment of dried sludge (e.g. co-composting)	Training farmers in crop selection (e.g. only crops not eaten raw)	Household food safety programme (to encourage washing of products)

WHO (2018) provides:

[a] guidance on strengthening the legislative framework, particularly regulatory mechanisms (Chapter 4);
[b] recommendations for reducing risk at each step of the sanitation service chain (Chapter 3); and
[c] principles on sanitation behaviour change at the individual, household and community levels (Chapter 5).

A recurring concern of SSP teams relates to the management of chemical hazards in sanitation systems. As explained in guidance notes 2.6 and 3.3, chemical hazards can arrive from multiple sources, given the widespread use of chemicals in human settlements, as well as industrial and agricultural systems. Following a multibarrier approach, guidance note 4.5 presents recommendations on how to consider different types of control measures to reduce the risks posed by chemical hazards.

Annex 1 gives many examples of reuse-related control measures (mostly technical) and comments on their effectiveness in reducing risks. Guidance note 4.6 provides information on ways to achieve pathogen reduction for consumer protection in systems where wastewater is used in agricultural settings.

GUIDANCE NOTE 4.5.

Mitigating the risks of chemical hazards

The increasing production and use of chemical substances causes higher exposure and higher risk to human health. To reduce the risk of chemical hazards associated with sanitation systems, a combination of regulatory, technical, management, operational and behaviour change measures should be adopted.

One key management measure refers to data availability and data collection (Weiss et al., 2016). Policy development requires comprehensive data and evidence, including information on the complete chemical life cycle and assessments of effects on human health at various scales. Weiss et al. (2016) suggested that existing data on exposure routes and concentrations, and evidence of impacts on human health should be made available. Furthermore, additional data should be collected that will contribute to the identification of the most hazardous pollutants, processes with major risks, areas where awareness is lacking, areas of limited human capacity and knowledge, bad handling practices or even missing legislation (Weiss et al., 2016).

Another key control measure is regulation. Environmental protection agencies, as well as health ministries, should issue regulations governing industrial discharges of heavy metals, oil and grease, acids and bases, and toxic organic chemicals to municipal sewers. Regulation should be accompanied by government enforcement to reduce the common disregard of laws or regulations for the application, production and disposal of chemicals and other waste material, which has resulted in a vast amount of chemicals entering the environment (UNEP, 2013).

Coordination and capacities among different governmental agencies to build and sustain monitoring systems for chemical hazards is a basic requirement for appropriate management of chemical risks. A clear strategy and training programme to overcome deficiencies in human capacities to oversee the use of hazardous chemicals in industrial activities is a key operational control measure.

Behaviour change measures, to promote corporate social responsibility and community awareness of the impact of human activity on water quality, should accompany other control measures.

WHO (2017b) presents several control measures to control chemical contaminants in drinking-water. ■

GUIDANCE NOTE 4.6.

Understanding log reductions and the multibarrier approach

The efficiency of a particular sanitation system can be expressed as the $\log^{10}$ reduction value (LRV), which is defined as the difference between the log-transformed pathogen concentrations of the influent and effluent across a particular sanitation technology or across the whole system (von Sperling, Verbyla & Mihelcic, 2018). For instance, if the influent concentration is 1.00×10^7 *Escherichia coli*/100 mL and the effluent concentration is 1.00×10^5 *E. coli*/100 mL, the LRV of that sanitation technology is $7 - 5 = 2$.

In centralized sanitation systems, such as advanced wastewater treatment plants found in high-income settlements, the desired concentration is achieved by placing treatment steps in series. The overall efficiency of the treatment system results from the additions of the individual treatment steps: $LRV_{overall} = LRV_{UNIT\ A} + LRV_{UNIT\ B} + LRV_{UNIT\ C}$. For instance, a complete wastewater treatment system could comprise three sanitation technologies (sedimentation, activated sludge and microfiltration) placed in series, with the following reduction efficiencies: Unit A = 90% (LRV = 1), Unit B = 99.9% (LRV = 3) and Unit C = 99.9% (LRV = 3). In this situation, the overall pathogen reduction efficiency will be: $LRV_{overall} = LRV_{UNIT\ A} + LRV_{UNIT\ B} + LRV_{UNIT\ C} = 1 + 3 + 3 = 7$. These treatment systems are usually very expensive and might not be feasible in areas with scarce resources.

To reduce the risk of pathogens in sanitation systems, a multibarrier approach should be implemented. Here, a sequential combination of control measures should be planned, considering the intended end use or disposal, and the national effluent limits and standards.

On-site sanitation systems, such as septic tanks with subsurface soil adsorption systems, usually serve large proportions of the population. The overall pathogen reduction efficiency of these systems depends on many factors, such as hydraulic residence time, proper operation and maintenance, geology and soil characteristics, and the functionality of the soil absorption system. Adegoke & Stenstrom (2019), as contributors to the Global Water Pathogen Project, described a broad range of LRVs in septic systems – they can be as high as 8 and a low as 0. Therefore, these systems should be accompanied by several barriers, such as technical standards for construction, behaviour change programmes for households, and management measures to establish monitoring systems at the municipality level.

In many low-income countries and middle-income countries, untreated, partially treated and treated wastewater is directly and indirectly used in agriculture. In these cases, the pathogen reduction targets should aim to protect farmers and consumers, and should be planned depending on the type of crops grown, irrigation practices and farming practices, as in the following examples.

- In a wastewater reuse system, in which the crops grown are eaten cooked, the priority should be protecting farmers. According to WHO (2006), an LRV of 4 reduces the count from 10^7 to 10^3 (1000) *E. coli*/100 mL, which is a very safe effluent standard to protect farmers (see WHO, 2006, vol. 2, Table 2). This can be achieved with waste stabilization ponds (LRV = 2–3) plus exposure control measures such as personal protective equipment, handwashing and personal hygiene.
- In a wastewater reuse system, in which the crops grown are eaten raw, farmers and consumers should be protected (see WHO, 2006, vol. 2, Fig. 4). In this case, an LRV of 6–7 should be the target. This can be achieved by a combination low-degree treatment options (e.g. sedimentation and detention ponds; LRV = 1–2); on-farm options, such as localized irrigation (e.g. drip irrigation of low-growing crops; LRV = 2) and pathogen die-off before consumption (LRV = 2); and off-farm barriers (e.g. washing the crops with water before consumption; LRV = 1). See Annex 1 and WHO (2006), vol. 2, Table 4.3.

The irrigation water quality verification limit is less than 1 human intestinal nematode egg per litre (see WHO, 2006, vol. 2, pp. 66–8 for more details on use in agricultural land; vol. 3, section 4.2; and vol. 4, sections 4.1 and 5 for use in aquaculture or use of excreta).

When analysing control measures, consider the:

- potential for improving existing controls;
- cost of the control option relative to its likely effectiveness;
- most appropriate location in the sanitation chain to control the risk (e.g. at the hazard source, at another point later in the sanitation chain);
- technical effectiveness of a proposed new control option;
- acceptability and reliability of the control in relation to local cultural and behavioural habits;
- responsibility for implementing, managing and monitoring the proposed new control;
- training, communication, consultation and reporting needed to implement the proposed control measure;
- extent to which the control measure will provide benefits under expected changes in the climate or, where future climate change is uncertain, provide benefits under any climate scenario (often referred to as "no regret" or "low regret" options); and
- potential for the control measure to fail if the climate changes in unexpected ways.

Tool 4.1 proposes a template to list and analyse control options for prioritized hazardous events, according to responsibility, effectiveness, level of resources required and effectiveness under climate change scenarios.

4

TOOL 4.1. Template to list and analyse control options

Step of the sanitation service chain: ____________________

Description of the hazardous event: ____________________

Exposure group: ____________________

Improvement options					
Option of new or modified control measure for this hazardous event	What is the likely effectiveness of this control measure option? (High, medium, low)	What is the level of resources required? (Including financial, human resources, political support; high, medium, low)	To what extent will this control measure be effective under the most likely climate change scenarios? (Effective, ineffective, detrimental)	Comments/discussion	Priority for improvement plan (Immediate, short term, medium term, long term)

Example 4.2 shows a prioritization method for control options based on potential to improve health, technical effectiveness, and likelihood of being accepted by those involved. Each team should decide how to select the most appropriated improvement measures to control the highest-risk hazardous event.

EXAMPLE 4.2. Comparison of control options

To prioritize the proposed measures, options are evaluated according to their potential to improve the human and environmental health of the system, their technical effectiveness and the likelihood of their being accepted by those involved. The table below shows the values established for each of these, and the weighting attributed to each category.

POTENTIAL	TECHNICAL EFFECTIVENESS	ACCEPTABILITY
Weighting: 1.5	*Weighting: 1*	*Weighting: 1.5*
High = 3	High = 3	High = 3
Medium = 2	Medium = 2	Medium = 2
Low = 1	Low = 1	Low = 1

Priority score = (potential × its weighting) × (effectiveness × its weighting) × (acceptability × its weighting). Highest priority is given to the options with the highest scores.

This allows the SSP team to prioritize improvement measures according to financial and resource limitations.

Note: Based on SSP experiences in Peru.

Where possible, the root cause of a problem should be addressed in the improvement plan. An important risk-based principle is to prevent the hazardous event, or locate the control measure or improvement as close as possible to the source of the risk. This is not always possible. Often, a combination of hazardous events may be most effectively managed through a single control in another part of the system. Notice that some of the control measures may only apply for short durations (e.g. during severe flooding events) or particular periods (e.g. drought conditions) and need to selectively apply. This is the case, for example, for some behaviour change measures.

EXAMPLE 4.3. Improvement plan options for helminth egg control

Hazard: Helminth eggs

Hazardous event: Exposure to partially treated wastewater in the field for farmers or children (under 15 years of age), causing helminth infections

Control measure options and considerations:

- Wearing shoes or boots can reduce the likelihood of exposure to the hazard. However, because this control measure is often not practical or used by the farmers or children in the field, it cannot be relied upon.
- Providing some simple wastewater treatment upstream of the irrigation area (e.g. properly sized simple detention pond to reduce the concentration of helminth egg to less than 0.1 egg/L) can reliably reduce the number of helminth eggs to desirable concentrations (see WHO, 2006, vol. 2, pp. 84–6).
- Regularly providing de-worming medicines to waste handlers (e.g. workers exposed to faecal sludge) can reduce the duration and intensity of infection. In settings where helminth infections are very common, de-worming medicines may also be regularly distributed at community level (e.g. to school children) for reducing prevalence rates.

EXAMPLE 4.4. Improvement plan options in typical labour-intensive farming in low-resource setting

In this example, current irrigation uses untreated wastewater in furrows. The produce is leafy vegetables for the local market. The lettuce crop is often in contact with the soil and is generally eaten uncooked. Manual, labour-intensive farming is practised.

This is a low-resource setting, and the wastewater is critical to the livelihoods of the farmers. The farmers value the nutrients in the irrigation water. Centralized wastewater treatment is not considered viable in the short to medium term. Consumers typically wash the produce before consumption.

Guidance note 4.5 shows that, with the existing practices, the target total log reduction is 6. Of this total, a log reduction of 3 in irrigation water should be aimed for to protect agricultural workers. The existing practice does not meet the target in relation to microbial (including helminth eggs) irrigation water quality, and agricultural workers are at high risk.

Options considered to protect the agricultural workers include:

- on-farm short-retention-time anaerobic ponds to reduce the helminth eggs and, to some extent, other pathogen loads;
- drip irrigation (noting that an additional 4 log reduction is still required to fully protect consumers); and
- improved farmer personal protection controls (e.g. personal protective equipment, handwashing, personal hygiene).

Options considered to protect consumers of the produce include:

- pre-harvest irrigation control (e.g. cessation of irrigation before harvest);
- pathogen die-off before consumption (providing an interval between final irrigation and consumption);
- washing produce in fresh water before transporting it to the market; and
- education programmes to ensure consistent good practice in food preparation.

Given the constraints of this setting, the targets are unlikely to be met in the short to medium term, but a combination of the options above can reduce health risks to both farmers and consumers.

Example 4.5 shows an improvement plan with short- and medium-term improvement options for an on-site system with collection of faecal sludge from pit latrines and co-composting with organic solid waste as treatment.

EXAMPLE 4.5. SSP improvement plan for an on-site sanitation system, Vietnam

Some key components of the improvement plan for this system are as follows.

Short-term plan:

- Internal training on the importance of workplace health and safety, specifically relating to the risks identified.
- Review of technical operations and procedures to reduce risks related to vacuum tanker operation and addition of wastes to compost from the on-site treatment plant (e.g. reinstatement of broken pump to transfer treated effluent from the sewage plant to the compost piles, rather than using vacuum tanker).

Medium- to long-term plan:

- Improved and increased vehicle and equipment maintenance to reduce the likelihood of mechanical breakdowns (during which workers are more exposed to hazards).
- Upgrading of the toilets to reduce risks to workers and the public using the facilities.

When the health risk assessment shows an increased risk during the most probable climate change scenarios, such as prolonged droughts and heavy rain, the SSP team should include specific adaptation measures to build resilience (see guidance note 4.7).

GUIDANCE NOTE 4.7.

4

Examples of climate adaptation options for a specific sanitation system

The table shows some examples of adaptation options to build climate-resilience in certain sanitation technologies (WHO, 2018).

SANITATION TECHNOLOGY	MOST PROBABLE CLIMATE CHANGE SCENARIO	EFFECT ON SANITATION SYSTEM	HAZARDOUS EVENT	EXAMPLE OF ADAPTATION OPTIONS
Dry and low-flush toilets	More intense or prolonged precipitation	Reduced soil stability, leading to lower pit stability	Injury to the body, possible asphyxiation, caused by falling into the pit due to collapsing latrine structure	Line pits using local materials. Use locally adapted toilet designs: raised toilets; smaller, frequently emptied pits; vault toilets; raised pit plinths; compacting soil around pits; etc.
Septic tanks	More intense or prolonged precipitation	Rising groundwater levels, causing structural damage to tanks	Ingestion of groundwater contaminated with faecal pathogens	Install sealed covers for septic tanks and non-return valves on pipes to prevent backflows.
Conventional sewerage	Sea level rise	Rising water levels in coastal sewers, causing back-flooding	Ingestion of pathogens in surface water contaminated with partially treated sewage due to higher pollutant concentration	Use special gratings and restricted outflow pipes. Install non-return valves on pipes to prevent backflows.
Faecal sludge/wastewater treatment	More frequent or intense storms or cyclones	Destruction and damage of treatment systems, causing discharge of untreated excreta flows and environmental contamination	Ingestion of surface water contaminated with raw sewage/faecal sludge due to nonfunctioning treatment plants	Install flood, inundation and runoff defences (e.g. dykes), and undertake sound catchment management. Invest in early-warning systems and emergency response equipment (e.g. mobile pumps stored off-site, non-electricity-based treatment systems). Where feasible, locate systems on sites less prone to floods, erosion, etc.
Wastewater reuse for food production	Prolonged droughts	Increased water scarcity, leading to increased reliance on wastewater for irrigation	Ingestion of pathogens after contact with wastewater treatment plant effluent during irrigation or in-field farming practices	Improve crop selection, irrigation type, withholding times. Include climate change and climate variability in assessing, monitoring and establishing controls.

Note: This table has been adapted from Table 3.6 of WHO (2018).

4.2 Develop an incremental improvement plan

Once the most appropriate control measures for each risk have been identified, the SSP team can organize the selected new controls in an incremental improvement plan (see tool 4.2 for a Gantt chart version). This plan should indicate how the existing sanitation system, or mix of sanitation systems, should change over time as progress is made. Improvement measures should be prioritized and sequenced to maximize their positive impacts on public health and well-being. The SSP team may also choose to select and implement more affordable interim control measures until sufficient funds for more expensive options are available. This can deliver much greater improvements in the short to medium term than the master planning approach that sets long-term targets but tends to miss intermediate steps (WHO, 2018).

The incremental improvement plan should allow for preparedness and adaptive management processes suitable for responding to emergent and unforeseen conditions. For instance, it may incorporate an emergency management plan for specific climate-related hazards.

For improvement plans to be implemented and managed, the person or agency responsible for the proposed action, the completion time frames, the cost and, where possible, the funding source must be identified. Some improvement options may need actions from more than one organization represented in the SSP team or another stakeholder. The SSP lead organization should take responsibility for coordinating the different parts involved, and ensuring that implementation responsibilities are understood and accepted by each responsible party.

It is essential that the SSP incremental improvement plan is aligned with existing local development programmes. Improvement measures, and the sanitation services and systems resulting from SSP should be delivered in conjunction with other locally delivered services to increase efficiency and health impact. Therefore, SSP should be included in the overall local planning process for land use, water supply and drainage, transport, communications, and solid waste management.

TOOL 4.2. Template for an SSP incremental improvement plan

Improvement measure	Cost	Source of funds	Lead organization	Year 1												Year 2				Year 3			
				1	2	3	4	5	6	7	8	9	10	11	12	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8

4.3 Implement the improvement plan

Once the incremental improvement plan is ready, major coordination and implementation efforts must be made to implement the prioritized control.

Ideally, part of the funds should be secured up-front to ensure that immediate actions are taken. However, many activities will require commitment from the responsible organizations rather than special funding. This is the case with regulatory and managerial control measures, as local ordinances and guidelines can be prepared within the daily work of the authorities involved. For behaviour change measures targeting the general population, coordination is needed with local departments working with community mobilization and awareness-raising campaigns to include the SSP messages.

Other improvement measures will require special funding, particularly technical measures such as physical infrastructure. The burden of fundraising should not rely only on the SSP lead organization, and the steering committee should advocate and secure resources for implementation.

Sources of financing could be public national funds (e.g. through specialized WASH [Water, Sanitation and Hygiene] budget lines and programmes), provincial budgets for municipal service delivery, taxes from citizens and local businesses, transfers such as international aid and loans, and tariffs paid by users of the service. The SSP team may consider strengthening the market for sanitation goods and services, so that households make full or partial contributions towards the purchase, construction, upgrade and/or maintenance of their sanitation system from service providers (utilities and private informal actors, such as vacuum truck operators) (UNICEF, 2020). For instance, a sanitation utility may decide to upgrade the sewer system and pass on the cost to the connected households in their monthly bill.

Like other interventions, SSP implementation requires project management skills and tools. The SSP leader should carefully plan, delegate, monitor and control all aspects of implementation, motivating the individuals involved to achieve the objectives, while meeting the expected performance targets for time, cost, quality and scope. The SSP leader should periodically monitor and report on implementation progress and, where applicable, brief the steering committee regularly.

MODULE 5

MONITOR CONTROL MEASURES AND VERIFY PERFORMANCE

MODULE 5

MONITOR CONTROL MEASURES AND VERIFY PERFORMANCE

Is the sanitation system operating as intended? Is it effective?

STEPS

5.1 Define and implement operational monitoring
5.2 Verify system performance
5.3 Audit the system

TOOLS

Tool 5.1. Template for operational monitoring overview plan
Tool 5.2. Template for operational monitoring

OUTPUTS

- **A functional operational monitoring plan**
- **A functional verification plan, which may include independent assessment**

Overview

Sanitation systems are dynamic. Even the most well-designed systems can underperform, resulting in unacceptable health risk and loss of confidence in the service or products. Module 5 develops a monitoring plan that regularly checks that the system is operating as intended and defines what to do if it is not. Operational monitoring by service providers and verification by oversight authorities provide assurances to the public of adequate system performance and trigger corrective action when monitoring results exceed critical limits.

The improvement plan in Module 4 and the monitoring and verification plans in Module 5 are the central outputs of SSP. Monitoring outputs also generate system-specific evidence to justify existing operations or the need for ongoing improvements in later iterations of Module 4.

Step 5.1 Define and implement operational monitoring – regularly monitors critical control measures to give simple and rapid feedback on how effectively the control is operating so that corrections can be made quickly, if required.

Step 5.2 Verify system performance – periodically verifies whether the system meets the intended performance outcomes, such as quality of effluents or products. Verification may be undertaken by the operator or oversight agency. It will be more intensive in situations with greater resource requirements and/or strict regulatory requirements.

Step 5.3 Audit the system – provides additional independent evidence of system performance and quality of the SSP. Audits can be part of the monitoring functions above. Audit and certification will be most relevant in countries where such requirements exist (e.g. certification requirements for wastewater-irrigated produce).

5.1 Define and implement operational monitoring

In Modules 3 and 4, a range of existing and proposed control measures were identified. The purpose of step 5.1 is to select monitoring points and parameters to give simple and rapid feedback that selected control measures are operating as intended and to provide performance trends over time.

Typically, operational monitoring collects data from:

- **simple observations and measures** (e.g. flow rate to check on detention times, temperature of composting, observations of on-farm practices, frequency of septic tank dewatering, appropriate use of toilets and containment technologies); and
- **sampling and testing** (e.g. chemical oxygen demand, biochemical oxygen demand, suspended solids, total solids).

Guidance note 5.1 gives some examples of typical operational monitoring at each step of the sanitation service chain.

GUIDANCE NOTE 5.1.

Typical operational monitoring in SSP

Operational monitoring is the routine monitoring of parameters that can be measured rapidly (through tests that can be performed quickly or through visual inspection) to inform management decisions to prevent hazardous conditions from arising. The table shows examples of operational monitoring parameters and their sources of information for each step of the sanitation service chain.

STEP OF THE SANITATION SERVICE CHAIN	OPERATIONAL MONITORING PARAMETERS	SOURCES OF DATA
Toilet	• Availability, accessibility and privacy of toilet facilities • State of the superstructure (e.g. absent, incomplete, damaged) • Cleanliness (visible excreta on the surface) • Availability of cleansing material and handwashing facilities	• Sanitary inspections (see tool 3.2) • Inspections may be done routinely, in periodic/ special surveys or in the national census.
Containment–storage/treatment	• State of the cover slab (e.g. cracked/damaged) • Visible/reported overflow • Resting time of dry sanitation technologies	
Conveyance	• Use of personal protective equipment by sanitation workers • Use of predefined roads to transport faecal sludge • Cleanliness of sewers	• Inspection • Surveillance programmes • Visual inspection
Treatment	• Flow rates • Retention times • Chemical oxygen demand, biochemical oxygen demand and suspended solids • Composting temperatures	• Data collected from operators and verified by occasional sampling and independent laboratory analysis
End use or disposal	• Correct application and irrigation processes • Duration of withholding periods • Physical barriers in place • Frequency with which farmers are correctly wearing personal protective equipment	• Inspection of nearby farms • Routinely, in periodic surveys

Monitoring of all control measures may not be practical. The most critical monitoring points, based on control of the highest risks, should be prioritized. The following aspects should be identified for each of the monitoring points:

- parameter (may be measured or observational)
- method of monitoring
- frequency of monitoring
- who will monitor
- a critical limit
- an action to be undertaken when the critical limit is exceeded.

Critical limits are usually numerical limits based on a parameter measurement. In some cases, qualitative limits are appropriate (e.g. "all odours to be acceptable", "flies not a nuisance").

SSP teams may use the formats shown in tools 5.1 and 5.2 to record the operational monitoring plan. They can also adapt and use the WHO sanitary inspection forms for sanitation systems introduced in Module 3 (see guidance note 3.2).

Example 5.1 shows a typical operational monitoring plan for the performance of the co-composting pile in a faecal sludge treatment plant. Note that pathogens are inactivated at high temperatures, rendering the product safe to use in agriculture. Therefore, temperature was chosen as a key parameter.

TOOL 5.1. Template for operational monitoring overview plan

Sanitation step	Control measures to have a detailed operational monitoring plan List the control measures for which a detailed operational monitoring plan is required, and use tool 5.2 for each of these).
Toilet	
Containment–storage/ treatment	
Conveyance	
Treatment	
End use or disposal	

TOOL 5.2. Template for operational monitoring

OPERATIONAL MONITORING PLAN				
Operational monitoring plan for: (Give control measure short description)				
Operational limits[a]	Operational monitoring of the control measure		Corrective action when the operational limit is exceeded	
	What is monitored?		What action is to be taken?	
	How is it monitored?			
	Where is it monitored?		Who takes the action?	
	Who monitors it?		When is it taken?	
	When is it monitored?		Who needs to be informed of the action?	

[a] If the monitoring is outside this limit(s), the control measure is deemed to be not functioning as intended.

EXAMPLE 5.1. Operational monitoring plan for co-composting step in a faecal sludge treatment plant

OPERATIONAL MONITORING PLAN				
Operational monitoring plan for: Temperature reached in co-composting piles to treat dewatered faecal sludge with organic solid waste				
Operational limits[a]	**Operational monitoring of the control measure: Co-composting step of the faecal sludge treatment plant**		**Corrective action when the operational limit is exceeded**	
>60 °C (temperature should not fall below 60 °C)	What is monitored?	Temperature	What action is to be taken?	Inform the Quality Manager. Actions: check the C:N ratio and the moisture content by mixing different waste streams together. Water the pile and turn the heap.
	How is it monitored?	Using the pile thermometer		
	Where is it monitored?	At the centre and outside the pile	Who takes the action?	Quality Manager
	Who monitors it?	Co-composting worker	When is it taken?	Immediately when the temperature of the pile falls.
	When is it monitored?	Every day at 9:00 am and 4:00 pm during the first 30 days of the composting process (exothermic step)	Who needs to be informed of the action?	Quality Manager should annotate in the logbook to discuss in management meetings.

[a] If the monitoring is outside this limit(s), the control measure is deemed to be not functioning as intended.

Operational monitoring plans are usually implemented by service providers. Therefore, service providers should lead the development of monitoring plans according to their capacities and resources. Environmental health authorities might be involved in monitoring control measures at the toilet and containment steps. SSP teams should support them with training and field-friendly monitoring tables, logbooks or other recording systems. The monitoring should be mainstreamed into normal operating duties. Training on the use of logbooks and worksheets should also be undertaken.

Operators should receive information from meteorological early warning systems (e.g. drought and cyclone warnings) and consider their likely impact on the parameters being monitored. Likely impacts can be judged based on past experiences with climate-related hazardous events. Where enough data exist, the likely impact may be able to be quantified (e.g. how much flow rates will be reduced by a certain number of days without rain).

Operational monitoring data provide important feedback on how the system is working and should be frequently assessed. Service providers or others responsible for operational monitoring must regularly examine, scrutinize and critically review the monitoring results, and ensure that corrective actions are carried out, if required. Any operational trends should also be noted.

5.2 Verify system performance

Verification is done periodically to show whether the system is working as intended, and to provide trends over time of compliance with agreed standards and quality. Step 5.2 involves verifying the achievement of the intended outcomes of the system. Guidance note 5.2 presents a typical verification plan of a san¬itation service chain that has been improved through new control measures.

5

GUIDANCE NOTE 5.2.

Typical verification in SSP

Verification checks the effectiveness of the implemented control measures. It shows whether the system is achieving the desired objectives (e.g. toilet use, to block infection routes; microbiological removal). The table shows examples of the objectives of control measures and their verification parameters for each step of the sanitation service chain.

STEP OF THE SANITATION SYSTEM	OBJECTIVE OF THE CONTROL MEASURE	VERIFICATION PARAMETER
Toilet	Public toilet facilities were installed to decrease open defecation in a locality.	Use, cleanliness, safety and functionality of the toilet facility
Containment–storage/treatment	Septic tank effluent discharging to ground surfaces and open drains were upgraded to treatment/disposal in soak pits.	Microbial water quality testing (e.g. *E. coli*) of nearby groundwater drinking-water supplies to check for potential contamination from septic tanks
Conveyance	Vacuum truck drivers were licensed and trained to eliminate illegal dumping of excreta in open fields.	Amount of faecal sludge transported to the treatment site
Treatment	An extra treatment process was included to decrease pathogen concentrations in the effluent.	Microbial testing of effluents (e.g. *E. coli*)
End use or disposal	Crop selection, new irrigation processes and withholding periods were implemented to reduce presence of pathogens in crops.	Microbial testing of crops

Key (critical) points along the sanitation chain should be selected to verify system performance. Compared with operational monitoring, there will be fewer points at which verification occurs. Verification focuses on system end-points such as quality of effluent water or final end product, microbial and chemical testing of produce, and health status of exposed groups. As with operational monitoring, parameters, methods, frequency, the responsible agency, a critical limit, and remedial actions when the limit is exceeded should all be identified. Verification may require more complicated forms of analysis (e.g. *E. coli*, helminth eggs) than operational monitoring. Verification can be done by the SSP team or an external authority, such as the sanitation regulator, as part of the surveillance function described in the introductory chapter.

Guidance note 5.3 provides additional information on operational monitoring and verification.

GUIDANCE NOTE 5.3.

Monitoring and verification recommendations in WHO (2006)

WHO (2006) provides guidance on typical parameters, frequency and limits for operational monitoring and verification for reuse systems. This guidance can be found in the locations in the table.

VOLUME OF GUIDELINES	RELEVANT SECTION FOR MONITORING
Volume 2 (Wastewater use in agriculture)	Section 4.3 (Verification monitoring), Table 4.6 (Minimum verification monitoring frequencies for health protection control measures) Section 6.4 (Operational monitoring) Section 6.5 (Verification monitoring)
Volume 3 (Wastewater and excreta use in aquaculture)	Section 6.5 (Operational monitoring) Section 6.6 (Verification monitoring)
Volume 4 (Excreta and greywater use in agriculture)	Section 6.4 (Operational monitoring) Section 6.5 (Verification monitoring)

Example 5.2 shows a typical example of a verification plan.

EXAMPLE 5.2. Hypothetical verification plan

SANITATION STEP	VERIFICATION				
	What	Limit	When	Who	Method
Conveyance	Number of overflows per year	Depends on local contexts and prevailing background data	Annual	Sewerage company or regulator	Annual reports
Conveyance (fences and warning signs in critical locations)	Cases of accidents, falling into the canal	None	Annual	Sewerage company or regulator	Annual survey
Treatment	Effluent quality testing (e.g. treatment plant effluent water quality): • *E. coli* • helminth eggs	<10 000/100 mL <1/100 mL	Twice per month	Wastewater treatment plant operator	Standard testing methods
Reuse	Farmers' health status: • percentage of farmers and family members with helminth infections • occurrence of skin infections	Depends on local contexts and prevailing background data	Annual	District health department	Annual survey
Reuse or disposal	Chemical contaminants in soil	Soil limits – see Annex 3	Every 2 years	Department of health or agriculture	Sampling and testing survey
Reuse (waste application, including timing)	Microbial plant concentration of pathogens at harvest and at point of sale	No worm eggs or *E. coli* in vegetables, as per national criteria	Every 3 months	Hygiene and food safety branch – health department	Sampling and testing survey
Reuse (produce preparation and consumption)	Microbial testing of hygienic food preparation spaces in markets and restaurants, and product testing	No worm eggs or *E. coli* in vegetables, as per national criteria	Annual	Hygiene and food safety branch – health department	Survey
Reuse (produce preparation and consumption)	Occurrence at household level of food preparation control measures	No worm eggs or *E. coli* in vegetables, as per national criteria	Annual	Hygiene and food safety branch – health department	Annual survey

5.3 Audit the system

System audits are an important element of SSP. They may be a regulatory requirement for risk assessment management approaches.

Audits ensure that SSP continues to contribute to positive health outcomes by checking the quality and effectiveness of SSP implementation. Auditing can be done by internal, regulatory or independent auditors. Suitably skilled and experienced personnel for auditing will need to be identified.

Audits should demonstrate that the SSP has been properly designed, is being implemented correctly and is effective. They can assist implementation by identifying opportunities to improve the accuracy, completeness and quality of implementation of SSP; improve use of limited resources; and identify needs for training and motivational support.

Guidance note 5.4 gives suggestions for key questions to consider in audits.

Auditing frequencies should be commensurate with the level of confidence required by the regulatory authorities.

The principles used in WSP auditing (WHO & IWA, 2015) can be adapted for use in SSP.

GUIDANCE NOTE 5.4.

Questions to consider in audits

- Have all significant hazards and hazardous events been identified?
- Have appropriate control measures been included?
- Have appropriate operational monitoring procedures been established?
- Have appropriate operational or critical limits been defined?
- Have corrective actions been identified?
- Have appropriate verification procedures been established?
- Have the hazardous events with the most potential to affect human health been identified, and has appropriate action been taken?

MODULE

6

DEVELOP SUPPORTING PROGRAMMES AND REVIEW PLANS

MODULE 6

DEVELOP SUPPORTING PROGRAMMES AND REVIEW PLANS

How should SSP be supported?
How can we adapt to changes?

STEPS

6.1 Identify and implement supporting programmes
6.2 Periodically review and update the SSP outputs

OUTPUTS

- **Supporting programmes that improve implementation of SSP, and inform national-level policy, planning and regulatory instruments**
- **Up-to-date SSP outputs responding to internal and external changes**

Overview

Module 6 supports embedding SSP in the day-to-day operations of a local authority, and ensuring the engagement of stakeholders such as service providers, the private sector, decision-makers and academics. This module also shows how SSP teams use SSP experience to inform evidence-based policy, planning and regulation at the national level.

Supporting programmes and regular reviews will ensure that SSP remains relevant and responds to current or anticipated operating conditions.

Step 6.1 Identify and implement supporting programmes – ensures that SSP implementation is supported with sustainable sanitation enterprises, research programmes, and evidence-based engagement in national-level policy and planning.

Step 6.2 Periodically review and update the SSP outputs – responds to a dynamic environment, adapting SSP as new controls are implemented, or new hazards and hazardous events emerge.

6.1 Identify and implement supporting programmes

Supporting programmes cover a range of activities and partnerships that enable the implementation of the incremental improvements identified. They differ from control measures in that they do not directly control hazardous events. However, they support the adaptation, development and take-up of control measures selected in Module 4. Supporting programmes may include the following.

Sanitation service provider support. Sanitation actors that directly provide products and services to users – such as hardware supply, toilet construction or pit/septic tank emptying – can often function well as private businesses, provided that they are regulated to ensure safety and affordability (WHO, 2018). In many localities, private operators, such as traditional service providers and innovating sanitation entrepreneurs, are key actors in the sanitation service chain, and local authorities should aim to work closely with them. Supporting programmes for sanitation businesses should ensure that SSP control measures and monitoring are incorporated within their business operations. These programmes may extend to additional mechanisms, such as formalization of informal service providers, equity contribution or grants, assistance in obtaining equipment and capital, advance purchase agreements, training in business and technical skills, and formation of associations of service providers (e.g. faecal sludge emptying trucks, sanitation workers) to facilitate dialogue between the service providers and authorities. Supply-side activities should be activated concurrently with sustained demand-side initiatives (as described in Module 4) and judicious enforcement of regulations (WHO, 2018).

Use of SSP results as evidence to revise national policies, plans and regulations. SSP implementation may identify gaps or inconsistencies in national policy, planning and regulation that impede local-level risk management. It may also identify improved implementation approaches that could be adopted at the national level and scaled for other localities. SSP results should be presented to policy-makers at the national level to demonstrate which aspects are relevant for review and adaptation of sanitation policies and plans. SSP results serve as local-level, context-specific evidence to inform change.

Research programmes. Partnership with academic institutions can support both initial development and ongoing adaptation of services. Research and innovation programmes with local universities support the adaptation of technologies and service models to the local context. Research programmes can also fill knowledge gaps, such as current and future impacts of climate change in the local area (see example 6.1).

EXAMPLE 6.1. Research programmes: indirect agricultural use of wastewater, Peru

- Determination of the maximum permissible limits for various soil and grass contaminants found in green spaces and agricultural areas, particularly heat-resistant coliforms and parasites.
- Efficient use of reservoirs for achieving the water quality required for irrigating vegetables, as a function of the holding period in different seasons of the year and effluent management.

6.2 Periodically review and update the SSP outputs

SSP should be systematically reviewed and revised on a periodic basis. Updates are necessary because SSP can become out of date as a result of changes in the sanitation system (through changes in context and implementation of improvements), changes in the SSP team or changes in key institutions. These all affect system descriptions, risk assessments, implementation, and monitoring of control measures.

SSP reviews are usually conducted in regular SSP team meetings, planned and periodic review meetings, and meetings to discuss an incident or near-miss.

- **Updates during regular SSP team meetings.** Members of the SSP team should regularly meet to examine progress with the improvement plan's implementation and the performance of control measures. The latter can include reviewing operational monitoring data to identify noncompliance with operational critical limits. The frequency of regular meetings will depend on the stage of SSP operations.
- **Updates during planned and periodic review meetings.** These SSP team meetings occur at pre-planned dates – for instance, after an audit or evaluation to incorporate findings and recommendations, or in response to situations such as changes in the SSP team members or service providers, installation of new infrastructure or equipment, or new data on health risks or climate becoming available.
- **Updates during meetings to discuss an incident or near-miss.** Following any incident, near-miss or emergency (e.g. caused by an extreme weather event), it is crucial to review the SSP, to ensure that all risks are adequately managed, and that the frequency or severity of a repeat event is realistic and impacts are minimized. An investigation should also be conducted to discuss performance and key lessons learned, assess whether current procedures are adequate, and address any issues or concerns.

As good practice, all SSP team meetings should be documented in minutes, which can be used for follow-up actions in subsequent meetings and by auditors.

Example 6.2 shows some SSP review triggers used in SSP in Peru.

EXAMPLE 6.2. SSP review: direct use of treated wastewater for irrigating the green spaces of a large public park, Peru

Review after incidents, such as:

- frequent spillages of raw wastewater and solids from the grit chamber and sludge disposal system;
- significant escapes of foul-smelling gases that cause a frequent nuisance to visitors to the park, neighbours and the hospital;
- a significant increase in levels of *E. coli* and parasites in the effluent from the plant used to irrigate the park's green spaces;
- excessive accumulation of sludge generated by the plant that cannot be disposed of quickly; and
- death of fish in the boating lake, indicating a serious situation and requiring the lake to be closed to visitors.

Review after improvements or significant changes in the system, such as:

- changes in wastewater treatment processes; and
- any significant change in the irrigation system, such as using the boating lake as a reservoir for treated wastewater.

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ANNEX 1

Example control measures for biological hazards

The following tables provide example control measures, mostly technical and managerial, for use in SSP along the entire sanitation service chain: toilet, containment–storage/treatment, conveyance, treatment, and end use or disposal. Effectiveness of the control measures is rated as very low to high, depending on the treatment and, where available, the microbial log reduction values.

A1-1 Toilet

Table A1-1. Control measures at the toilet step

Measure	Effectiveness and log reduction	Remarks	Further reading
Correct design and construction of toilets (dry toilets, flush toilets and urine diversion toilets)	Varies depending on design and construction	• Toilets are compatible with water availability for flushing (if required), cleaning and hand hygiene. • Toilets are compatible with containment, conveyance and treatment technologies (on-site or off-site). • Toilets are accessible (e.g. sufficient number of facilities). • Toilets provide safety and privacy (e.g. lighting, doors lockable from the inside, especially for shared toilets). • Superstructure prevents intrusion of rainwater, stormwater, animals (e.g. rodents). • Slab is appropriate for all intended users (including children and older people). • Stormwater is prevented from infiltrating the containment technology. • Flush toilets are fitted with a water seal or trapdoor; dry toilets are fitted with removable, tight lids to control odour and prevent rodents or insects entering the containment technology.	WHO (2018), Chapter 3, section 3.2. Tilley et al. (2014), section U (user interface), pp. 42–54.
Correct operation and maintenance of toilets	Varies depending on operation and maintenance	• Anal cleansing materials are available. • Waste bins are available for menstrual hygiene management. • Cleaning arrangements (especially for public or shared toilet facilities): o Cleaning materials and personal protective equipment are available. o Regular cleaning schedules are in place. o Standard operating procedures are in place for cleaners to observe safe working practices.	WHO (2018), Chapter 3, section 3.2. Tilley et al. (2014), Section U (user interface), pp. 42–54.

A1-2 Containment–storage/treatment

Table A1-2.1. Control measures relating to toilet and excreta containment–storage/treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
Dry toilets with single pit latrines (abandoned when full)	High >2 logs	• Treatment objectives are pathogen reduction and stabilization/nutrient management. • Single pits should not be emptied by hand. • The result is humus with low pathogen content.	WHO (2018), Chapter 3, section 3.3. Tilley et al. (2014), Section S (collection and storage/treatment), pp. 60–3.
Flush or pour toilets with single pit or open-bottomed tank	Low <1 log	• Material for treatment is liquid sludge with high pathogen content. • Liquid (leachate) high in pathogens is adsorbed aerobically into soil. Pathogen removal is dependent on soil conditions. • Pathogen die-off occurs with time. Risk relates to emptying practices. On-site contamination relates to siting, soil and hydrological conditions. • Unlined pit (or no liner on base) at least 1.5 m above water table to prevent groundwater contamination and an adequate hydrological horizontal distance. • Adequate pit ventilation is needed, appropriate to toilet type. Smell may discourage use, and wetness may increase fly breeding.	Stenström et al. (2011), pp. 14, 28–9, 32. WHO (2006), vol. 4, pp. 80, 83. Tilley et al. (2014), section S (collection and storage/treatment), pp. 60–3.
Flush toilet with twin pits for alternating use	High >2 log (except Ascaris eggs)	• Duel pits on toilets allow extended storage without fresh additions (designed for >1.5–2 years storage). • Pit alternation should be ensured. • Extended storage to protect waste handlers. • Unlined pit (or no liner on base) at least 2 m above water table to prevent groundwater contamination. • Adequate pit ventilation is needed, appropriate to toilet type. Smell may discourage use, and wetness may increase fly breeding. • Observe handling of water for anal cleansing. • "High" effectiveness refers to: o 1.5–2 years of storage at 2–20 °C where helminth infections are prevalent, or o at least 1 year storage at >20 °C, or storage of at least 6 months if pH is adjusted to >9 (e.g. with lime or ash).	Stenström et al. (2011), pp. 34–6, 87, 96. WHO (2006), vol. 4, pp. 69, 80, 82–3. Tilley et al. (2014), section S (collection and storage/treatment), p. 68.
Dry toilet with twin pits (fossa alterna)	High >2 log (except Ascaris eggs)	• Duel pits on toilets allow extended storage without fresh additions. • Pathogen reduction mechanism is storage of at least 2 years. • Extended storage provides protection to workers. • Temperature- and pH-dependent. • Adequate pit ventilation is needed, appropriate to toilet type.	Stenström et al. (2011), p. 87. WHO (2006), vol. 4, pp. 69, 82–3. Tilley et al. (2014), section S (collection and storage/treatment), p. 66.
Composting toilets	Sludge: medium 1–2 log Leachate: low <1 log	• Moisture content in composting chambers that is too high provides anaerobic conditions; moisture content that is too low will slow down the biological degradation. • Dewatered stabilized sludge (compost) with medium number of pathogens. • Leachate with high pathogen content.	Stenström et al. (2011), pp. 19–20, 38–9, 43–4, 96. WHO (2018), Chapter 3. Tilley et al. (2014), section S (collection and storage/treatment), pp. 72–5.
Flush toilets with septic tank connected to a soak pit or leach field	Low <1 log	• Water availability may affect suitability (e.g. if water supply is limited, operation may be affected and there may be unhygienic conditions in the toilet). • Prevent blockages to minimize exposure to maintenance workers during cleaning operations. For example, pour flush latrines are not suitable if it is common practice to use bulky materials for anal cleansing. Maintenance workers should wear necessary protective equipment (e.g. gloves). • Pathogen removal in septic tanks is poor, and bacteria and viruses remain in both liquid and solid phases. Removal of helminth eggs can be expected to be <0.5 log.	Adegoke & Stenstrom (2019). Tilley et al. (2014), section S (collection and storage/treatment), p. 74.

Table A1-2.2. Control measures relating to urine containment–storage/treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
Urine storage in sealed containers to prevent human or animal contact	Low to high	• Observe whether faecal cross-contamination could occur. • Microbial reduction is time-dependent. Time for 90% reduction in initial concentration (T90) is <5 days for gram-negative bacteria, 1 month for Cryptosporidium, approximately 1–2 months for viruses. • Reduce nitrogen losses. • Reduce human contact. • Reduce odour.	Stenström et al. (2011), pp. 40–1. WHO (2006), vol. 4, pp. 70–1. Tilley et al. (2014), section S (collection and storage/treatment), p. 58.

A1-3 Conveyance

Table A1-3.1. Control measures relating to wastewater conveyance

Measure	Effectiveness and log reduction	Remarks	Further reading
Sewer systems (simplified sewer, solids-free sewer and conventional gravity sewer)	Low to high	• If well designed, constructed, operated and maintained, sewers are an efficient means of transporting wastewater, requiring comparatively little maintenance. • However, all sewer pipes can become clogged with solid waste and other solids, which require removal by rodding, flushing, jetting or bailing. Where used, pumps, interceptor tanks and access chambers require maintenance. • Carrying out sewer maintenance may expose workers to hazardous wastewater and/or toxic gases. • Leakage from sewers poses a risk of wastewater exfiltration and groundwater infiltration. Exfiltration to groundwater and water supplies could expose the local community and wider community to faecal pathogens via ingestion.	WHO (2018), Chapter 3, section 3.4. Tilley et al. (2014), section C (conveyance), pp. 90–4.

Table A1-3.2. Control measures relating to excreta and urine conveyance

Measure	Effectiveness and log reduction	Remarks	Further reading
Human-powered emptying and transport	Medium to high	• Transport of treated rather than fresh waste. • Refer to control measures for workers and local community in section A1-6.	Stenström et al. (2011), p. 57. WHO (2006), vol. 4, p. 89. Tilley et al. (2014), section C (conveyance), p. 86. WHO (2018), Chapter 3, section 3.4.
Motorized emptying (e.g. faecal sludge reduction by suction pump and transport)	Varies depending on exposure group and handling practice	• Transport of treated rather than fresh waste. • Refer to control measures for workers and local community in section A1-6.	WHO (2006), vol. 4, p. 89. Stenström et al. (2011), p. 59. Tilley et al. (2014), section C (conveyance), p. 88. WHO (2018), Chapter 3, section 3.4.
Transfer stations	Varies depending on exposure group and handling practice	• Transfer stations and sewer discharge stations act as intermediate dumping points for faecal sludge when it cannot be easily transported to a remote treatment facility. • Transfer stations have the potential to significantly increase the health of a community by providing an inexpensive, local solution for faecal sludge disposal. • By providing a transfer station, independent or small-scale service providers are no longer forced to illegally dump sludge, and homeowners are more motivated to empty their pits. • The location must be carefully chosen to maximize efficiency, and minimize odours and problems for nearby residents.	WHO (2018), Chapter 3, section 3.4. Tilley et al. (2014), section C (conveyance), pp. 96–7.

A1-4 Treatment

Table A1-4.1. Control measures relating to wastewater treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
Waste stabilization ponds, aerated ponds, wastewater storage and reservoirs	High 2–5 logs	Effectiveness depends on configuration, storage time, loading rates, retention times, hydraulic design details and sedimentation efficiency. Associated issues to consider for risk management for workers and the local community include: • mosquito vector breeding potential; • *Schistosoma* spp. host snail potential and associated vegetation controls; • fencing; and • possible exfiltration from ponds affecting groundwater (e.g. use of pond liners with clay or other material).	Mahassen et al. (2008). Stenström et al. (2011), pp. 68–70, 79, 129–30. WHO (2006), vol. 2, pp. 84–7. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 110–13.
Constructed wetlands	Medium 1–3 logs	Effectiveness depends on design configuration (e.g. surface flow or subsurface flow wetlands), loadings and retention times. Associated issues to consider for risk management for workers and the local community include: • mosquito vector breeding potential; • *Schistosoma* spp. host snail potential; • vegetation controls; • impact of wildlife excreta; and • possible leakage from wetlands affecting groundwater.	Stenström et al. (2011), pp. 71–2, 79, 131–2. WHO (2006), vol. 2, p. 87. WHO (2018), Chapter 3, section 3.5. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 114–19.
Sedimentation tanks	Low <1 log	• Primary treatment is achieved by reduction of suspended solids. • Retention times vary from 2 to 6 hours. • Primary treatment can remove substantial numbers of helminth eggs.	WHO (2006), vol. 2, p. 87. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 102–3.
Advanced or chemically enhanced sedimentation	Medium 2–4 logs	• Uses specific chemicals (e.g. lime or ferric chloride, often with a high-molecular-mass anionic polymer) to facilitate particle coagulation and flocculation. • Increases removal of suspended solids from 30% to 70–80%. • Increases removal of helminth eggs.	WHO (2006), vol. 2, p. 87. WHO (2018), Chapter 3, section 3.5.
Anaerobic upflow sludge blanket reactors	Low <2 logs	• Hydraulic retention time of 6–12 hours. • Wastewater is treated during its passage through a sludge layer (the sludge "blanket") by anaerobic bacteria. • Primarily designed to remove organic matter (biochemical oxygen demand – BOD). • Upflow anaerobic sludge blanket reactors reduce helminth eggs by 1–2 log units.	WHO (2006), vol. 2, p. 88. WHO (2018), Chapter 3, section 3.5.
Anaerobic baffle reactors	Low <2 logs	• Upflow chambers provide enhanced removal and digestion of organic matter. • Hydraulic retention times vary between 48 and 72 hours. • BOD may be reduced by up to 90%, which is far superior to its removal in a conventional septic tank. • Anaerobic baffle reactors produce liquid sludge as well as effluent with a high level of pathogens.	WHO (2018), Chapter 3, section 3.5. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 114–19.

Measure	Effectiveness and log reduction	Remarks	Further reading
Activated sludge	Medium 2–4 logs	• Involves a multichamber reactor unit that makes use of highly concentrated microorganisms to degrade organics and remove nutrients from wastewater to produce a high-quality effluent. • To maintain aerobic conditions and keep the activated sludge suspended, a continuous and well-timed supply of oxygen is required. • Although designed primarily for removal of BOD, suspended solids and often nutrients (nitrogen and phosphorus), it can, with optimized performance, reduce pathogens. • It could also reduce helminth eggs by approximately 2 log units.	WHO (2006), vol. 2, p. 88. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 124–5. WHO (2018), Chapter 3, section 3.5.
Trickling filters	Medium 2–4 logs	• Fixed-bed biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously "trickled" or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material. • Although the effluent produced is of high quality, it still poses a health risk and should not be directly handled. • In the excess sludge, pathogens are substantially reduced, but not eliminated.	Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 120–1. WHO (2018), Chapter 3, section 3.5.
Tertiary treatment methods	High >3 logs	• Include processes such as additional solids removal by flocculation, coagulation and sedimentation, and/or granular medium filtration; disinfection (with chlorine, ozone or ultraviolet irradiation); and filtration with membranes.	WHO (2006), vol. 2, pp. 88–9. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 136–7. WHO (2018), Chapter 3, section 3.5.

Table A1-4.2 Control measures relating to excreta treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
Full incineration (<10% carbon in ash)	High	• Temperature needs to be sufficient to ensure reduction of pathogens.	WHO (2006), vol. 4, p. 68.
Composting for at least 1 week if compost temperature of >50 °C can be maintained	Medium to high	• High if temperature can be ensured for all material; medium if not totally ensured. • For mesophilic composting, validation and verification monitoring applies. • For compost <50 °C, refer to storage periods for excreta (above). • Ascaris spp.: >1.5–2 log reduction (thermophilic co-composting).	Koné et al. (2007). Stenström et al. (2011), p. 77. WHO (2006), vol. 4, p. 68. Tilley et al. (2014), section T ((semi-) centralized treatment), p. 132.
Storage only		Time and ambient temperature as for primary treatment process apply.	
Alkaline treatment and storage	Medium to high	• pH >9 for >6 months (temp >35 °C; moisture <25%). • Elimination time is prolonged at lower pH or for wetter material. • Time is substantially shorter at pH 11 (e.g. lime treatment).	WHO (2006), vol. 4, p. 68.
Drying beds and ultraviolet irradiation	Medium to high	• Helminth eggs: 3 log reduction (1 month). • Bacteria: 2.5–6 log reduction (4 months storage).	Kengne, Akoa & Koné (2009). Nielsen (2007). Stenström et al. (2011), pp. 77, 137. Tilley et al. (2014), section T ((semi-) centralized treatment), pp. 128–31.

Table A1-4.3. Control measures relating to urine treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
Urine storage: no dilution of urine to maximize pathogen die-off	Not applicable	• Undiluted urine has a pH of approximately 8.8, which enhances bacterial die-off. • Mosquito breeding may occur in diluted urine, but not in undiluted urine. • Inactivation of *Schistosoma haematobium*, where applicable.	WHO (2006), vol. 4, pp. 70–1.
No urine storage before application; applied at one family systems – fertilization of family plot	Not applicable	• For an individual one-family system and when the urine is used solely for fertilization on individual plots, no storage is needed. • The likelihood of pathogen transmission between family members is much higher through person-to-person transmission than through the fertilization–crop cycle.	WHO (2006), vol. 4, p. 70.
Urine storage before application, for crops consumed raw	High	• Storage for at least 6 months at >20 °C combined with a 1 month withholding period (no further control measures should be needed if waste is treated to this level).	Stenström et al. (2011), p. 85. WHO (2006), vol. 4, p. 70.
Urine storage before application, for processed food and fodder crops	Medium to high	• Storage for at least 1 month at >20 °C or at least 6 months at 4 °C.	Stenström et al. (2011), p. 85.

Table A1-4.4. Control measures relating to greywater treatment

Measure	Effectiveness and log reduction	Remarks	Further reading
General aspects: see WHO (2006), vol. 4, Fig. 5.11	Medium to high 1–4 logs	• Faecal load is usually 3–5 logs lower than in wastewater. • Easily degradable organic matter may result in regrowth of indicator bacteria. • Treatment methods for wastewater are generally applicable to greywater. • Protect greywater treatment and storage facilities from animal and insect vectors. • Subsurface irrigation is recommended when greywater is heavily contaminated, vector breeding is likely or pond treatment is not possible.	WHO (2006), vol. 4, pp. 66, 77, 93–9, and Fig. 5.

A1-5 End use or disposal

In all agricultural wastewater applications, issues to consider for risk management for workers, farmers and the local community include:

- protection of wastewater treatment and storage facilities from animal and insect vectors; and
- prevention of ponding of treated wastewater at application points, which would promote vector breeding.

Wastewater application rates should be managed to meet crop demands.

Table A1-5.1. Control measures relating to wastewater in agriculture

Measure	Effectiveness and log reduction	Remarks	Further reading
Use of raw wastewater	Very low to low	With respect to pathogen concentrations, raw wastewater should never be considered safe. Associated issues to consider for risk management for exposure groups include: • crop restrictions; • localized (e.g. drip) irrigation; • pre-harvest irrigation control (e.g. cessation of irrigation before harvest) to allow pathogen die-off before crop consumption (providing an interval between final irrigation and consumption); • harvest and post-harvest measures; and • upgrade of treatment or new low-cost treatment.	WHO (2006), vol. 2, pp. 89–91.
Crop selection according to wastewater quality	High	Effectiveness depend on: • use of crop – crops not intended for human consumption, such as cotton and oil crops, eliminate some potential risks; • human access to cropping and irrigation areas – areas with more open access introduce more potential risks; and • adherence to agreed crop restrictions.	WHO (2006), vol. 1, p. 24. WHO (2006), vol. 2, p. 76.
Wastewater application: subsurface irrigation	High	This technique: • minimizes contact by farmers; • facilitates root uptake; • is very efficient with irrigation water use; and • needs selection of non-clogging emitter and/or filtration to prevent clogging of emitters. Subsurface irrigation has great potential to minimize human contact and reduce water losses in water-scarce areas. However, surface entry and ponding (e.g. as a result of pipe blockages or breaks) must be controlled and managed. If surface entry occurs, lower reductions in human health risks will be achieved.	WHO (2006), vol. 1, p. 26. WHO (2006), vol. 2, p. 76.

Measure	Effectiveness and log reduction	Remarks	Further reading
Wastewater application: localized drip irrigation (high-growing crops) – e.g. bubbler irrigation	High 4 logs	This technique: • needs to consider minimizing clogging of drip holes; • needs to control and minimize temporary ground storage of harvested crops to avoid possible crop contamination; • needs to reduce and manage surface ponding (see remarks for subsurface irrigation); and • has improved efficiency and effectiveness with a mulch-bed, which limits and controls surface entry. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), p. 93. WHO (2006), vol. 1, p. 26.
Wastewater application: localized drip irrigation (low-growing crops)	Medium 2 logs	Effectiveness of technique in reducing risk varies according to crop type (e.g. root or leafy vegetable, eaten raw or cooked) and farming technique (degree of mechanization). This technique: • is improved with a mulch-bed, which limits and controls surface entry; • minimizes clogging of drip holes; • needs to reduce and manage surface ponding (see remarks for subsurface irrigation); • needs to limit direct crop contact with irrigation point; and • needs to control and minimize temporary ground storage of harvested crops to avoid possible crop contamination. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), p. 93. WHO (2006), vol. 1, p. 26.
Wastewater application: furrow irrigation	Low to medium	Effectiveness of technique in reducing risks varies according to crop type (e.g. root or leafy vegetable, eaten raw or cooked) and farming technique (degree of mechanization). Issues to consider for risk management for exposure groups include: • control of irrigation load practices to minimize soil wash and drainage to receiving surface waters; • control of withholding time between last irrigation and harvest; and • that the technique is subject to interference during rain. Care should be exercised to: • prevent ponding; and • control temporary ground storage of harvested crops. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	WHO (2006), vol. 1, p. 23.
Wastewater application: spray irrigation (high pressure)	Low to medium	Effectiveness of technique in reducing risk varies according to: • crop type (e.g. root or leafy vegetable, eaten raw or cooked); • location of spray irrigation in relation to local communities and farmers; and • quality/pre-treatment of irrigation water. Care should be exercised to: • provide a spray buffer zone of 50–100 m from local communities; this can provide a 1 log reduction; • control spray drift (e.g. prohibit spraying on days when wind speed and direction exceed agreed limits); • control withholding time between last irrigation and harvest; • control temporary ground storage of harvested crops; and • control loading rates and fertilization practices to minimize runoff to surface waters. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), pp. 91–3. WHO (2006), vol. 2, p. 64.

Measure	Effectiveness and log reduction	Remarks	Further reading
Wastewater application: spray irrigation (low pressure)	Low to medium	Effectiveness of technique in reducing risk varies according to: • crop type (e.g. root or leafy vegetable, eaten raw or cooked); • location of spray irrigation in relation to surrounding local communities and farmers; and • quality/pre-treatment of irrigation water. Care should be exercised to: • Control load per area; • control withholding time between last irrigation and harvest; • control temporary ground storage of harvested crops; and • control fertilization practices;	Stenström et al. (2011), pp. 91–3. WHO (2006), vol. 2, p. 64.
Wastewater application: ponds at farm site and watering cans (vegetables and root crops)	Low	Effectiveness of technique in reducing risk varies according to: • quality/pre-treatment of irrigation water; • mode of application and exposure of farmers to the irrigation water; and • application practices used by individual different farmers. Care should be exercised to: • control withholding time between last irrigation and harvest; • control temporary ground storage of harvested crops; and • control loading rates and fertilization practices to minimize runoff to surface waters. Ponds at farm site have potential for 1–1.5 log reduction in faecal coliforms. Local sand filtration has potential for 2 log reduction in faecal coliforms and 0.5–1.5 log reduction in *Ascaris* spp. eggs.	Amoah et al. (2011).
Pathogen die-off period of 1 week: withholding wastewater application before harvesting	Medium to high	Actual log reductions are dependent on crop type and temperature, and are site-specific. Refer to example 3.3 for more comments.	Stenström et al. (2011), p. 93. WHO (2006), vol. 1, p. 32.
Crop storage before sale	Medium	Effectiveness of technique in reducing risk varies according to: • storage conditions (e.g. additional contamination during storage and climatic conditions); • vermin access; and • storage time. If combined with pathogen die-off period of 1 week, effectiveness is high.	
Additional handling safety	Important but not quantified	See section A1-6. Risk reduction has not been quantified, but the measure is expected to have important positive effects.	WHO (2006), vol. 2, Chapter 5.5.
Post-harvest exposure control measures	Medium to high 2–7 logs	See section A1-6. Includes extended storage, produce washing, disinfection, peeling and cooking.	WHO (2006), vol. 2, Chapter 5.4.

Table A1-5.2. Control measures relating to use of wastewater in aquaculture

Alternative	Effectiveness	Remarks	Further reading
Pond water quality: $<10^3$ E. coli per 100 mL; <1 helminth egg per litre	High	• This would generally protect workers and consumers, and no further control measures should be needed if wastewater is treated to this level. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • Refer to WHO (2006), vol. 3, p. 40 for notes on testing for viable trematode eggs.	WHO (2006), vol. 3, pp. 39–45.
Pond water quality: $<10^4$ E. coli per 100 mL; <1 helminth egg per litre	Medium to high	• This would normally protect product consumers; however, additional worker and farmer control measures are required. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • As a general rule, testing for viable trematode eggs in wastewater, excreta or pond water should be done at the system validation stage. If the plant and fish species raised in the local area are always eaten after thorough cooking, testing for viable trematode eggs will not be necessary. • Refer to WHO (2006), vol. 3, p. 40 for notes on testing for viable trematode eggs.	Section A1-6. WHO (2006), vol. 3, pp. 39–45.
Raw or partially treated wastewater	Medium (if control measures and enforcement are in place; otherwise low)	• Restrict produce to fish species that are only eaten cooked. • Requires processing of fish products before sale. • Refer to control measures for workers and farmers in section A1-6. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • Limit access to waste-fed aquaculture facilities. • Refer to WHO (2006), vol. 3, p. 40 for notes on testing for viable trematode eggs.	WHO (2006), vol. 3, pp. 21, 41, 47–68.
Produce restriction	Low to high	• Restrict produce to plants and fish that are eaten only after cooking. • Ensure extra care for trematode infections in fingerling production.	WHO (2006), vol. 3, p. 55.
Withholding period between waste application and harvest	Medium	• Risk effectiveness is time-dependent, and reduction is related to functionality of facultative ponds or maturation ponds. • For optimum pathogen die-off before fish or plant harvest, a batch-fed process (i.e. all of the wastewater enters the treatment system at one time, and no new wastewater is added until the crop is harvested) could be used. However, in urban areas, larger aquatic ponds will often be receiving untreated wastewater and latrine wastes from surrounding households on a continuous basis.	WHO (2006), vol. 3, p. 57.
Depuration (before marketing, holding fish in clean water to reduce contamination)	Medium	• Time-dependent; 2–3 weeks recommended. • Will not affect trematode concentration.	WHO (2006), vol. 3, p. 57.
Food handling and preparation	Medium	• Prevent fish flesh contamination. • Fish gut should be removed before handling the fish flesh. • Ensure that clean knives and cutting boards are used.	WHO (2006), vol. 3, p. 58.
Produce washing and disinfection	Medium	• Relates to aquatic plants.	WHO (2006), vol. 3, p. 58.
Cooking	High	• Relates to all produce. • Contamination during storage after cooking may occur.	WHO (2006), vol. 3, p. 58.
Health protection measures against trematodes	Low to high	• For a summary, see WHO (2006), vol. 3, Table 5.4.	WHO (2006), vol. 3, pp. 63–8.

Table A1-5.3. Control measures relating to use of excreta in agriculture

Alternative	Effectiveness and log reduction	Remarks	Further reading
Excreta handling		• Refer to control measures for workers in section A1-6. • No further control measures should be needed if excreta is treated to <1 helminth egg per gram of total solids. • Contain faecal sludge/biosolids during any storage to prevent runoff to local waterways. • Consider vermin/vector attraction.	Stenström et al. (2011), p. 99. WHO (2006), vol. 4, p. 66.
Application on agricultural land: full mixing of treated excreta with the soil	Nonquantifiable (reduce contact)	• This use also benefits plant nutrient uptake. • Good personal hygiene during application should be followed.	Stenström et al. (2011), pp. 87, 97. WHO (2006), vol. 4, p. 78.
Application on agricultural land at the time of sowing/planting	Medium to high	• Effectiveness is related to die-off, and withholding time between application and harvest.	
Crop restrictions: restrict application of treated excreta to non-food crops or crops that are cooked or processed before consumption	High	• Limits exposure of farmers during application, handling and harvest. • Farmers should use good personal hygiene during application.	Stenström et al. (2011), p. 87. WHO (2006), vol. 4, p. 77.
Enforce pathogen die-off for 1 month: withholding waste application before harvesting	Medium to high	• Refer to control measures for workers and the local community in section A1-6. • May be combined with crop storage before sale for defined periods (low to medium) or a combination totalling 1 month.	USEPA (1992). WHO (2006), vol. 4, p. 78.
Post-harvest exposure control measures: washing with or without disinfectants (e.g. peeling, cooking)	Medium to high	• These are consumer protection measures. • Control measures are difficult to verify. • 1–7 log risk reduction possible, depending on the measure.	WHO (2006), vol. 4, pp. 78–9.

Table A1-5.4. Control measures relating to use of excreta in aquaculture

Alternative	Effectiveness and log reduction	Remarks	Further reading
Excreta handling		• Refer to control measures for workers in section A1-6. • No further control measures should be needed if excreta is treated to <1 helminth egg per gram of total solids. • Contain faecal sludge/biosolids during any storage to prevent runoff to local waterways. • Consider vermin/vector attraction.	Stenström et al. (2011), p. 99. WHO (2006), vol. 4, p. 66.
Excreta storage before addition to pond	Medium to high	• Time-dependent effect. • Storage times are counted only after the last addition of fresh faeces (i.e. as a batch operation). • Storage for 4 weeks reduces risks for trematodes substantially; storage for 10 weeks is needed for *Fasciola* spp. • Reduction of pathogenic bacteria and viruses will occur.	WHO (2006), vol. 3, p. 50.
Excreta pre-treated in biogas fermentation	Low to medium	• Depends on treatment time and temperature. • Combination with other protection measures is recommended.	WHO (2006), vol. 3, p. 51.

Table A1-5.5. Control measures relating to use of urine in agriculture

Alternative	Effectiveness and log reduction	Remarks	Further reading
Urine storage before application: mixing stored urine with the soil or applying it close to the ground	Nonquantifiable (reduce contact)	• Benefits plant nutrient uptake. • Personal hygiene is needed during application.	WHO (2006), vol. 4, pp. 66, 70.
Urine storage before application: cessation of urine application 1 month before harvest for crops consumed raw	High	• Risk level below 10^{-6} disability-adjusted life years (DALYs) if combined with storage recommendations.	WHO (2006), vol. 4, p. 70.

Table A1-5.6. Control measures relating to use of greywater in agriculture

Alternative	Effectiveness and log reduction	Remarks	Further reading
Greywater irrigation: wastewater treatment methods apply	Low to high	• Crop restrictions are not normally necessary if faecal contamination is low and treatment is applied. • Application of greywater using close-to-the-ground methods is recommended. • Prevent ponding of greywater at application points that could become vector breeding sites.	WHO (2006), vol. 4, p. 78.

A1-6 Examples of control measures to protect exposure groups

Some of these controls have also been noted in Tables A1-1 to A1-5.

Table A1-6. Control measures relating to protection of users, workers, farmers, consumers, and local and wider communities

Type of measure	Users (U)	Workers (W)	Farmers (F)
Regulatory	• Technical standards on material, dimensions and location of toilets • Guidelines on periodic inspection of on-site systems	• Local ordinances that acknowledge and professionalize the sanitation workforce along the sanitation service chain • Licensing of emptying service providers	• Local ordinances or legislation that require occupational health and safety norms to protect farmers
Technical	• Installation of toilets • Refurbishment of existing systems	• Provision of tools that assist in limiting exposure (e.g. vacuum tankers) • Optimized treatment before handling • Design of on-site containment facilities that optimize safe waste removal	• Subsurface irrigation • Providing simple wastewater treatment upstream of the irrigation area (e.g. properly sized detention pond) • Tools that assist in limiting exposure (e.g. hoses vs watering cans).
Managerial and operational	• Training of masons for correct installation of toilets (e.g. water seal) • Establishing a call centre for septic tank emptying and emergencies	• Immunization for typhoid • Treatment for helminth infections (2–3 times yearly) and schistosomiasis, where it is endemic; treatment of skin abrasions and cuts • Standard operating procedures for general handling precautions	• Restricting worker access to field during mechanical application of wastewater • Access to safe drinking-water and toilets in the workplace
Behaviour change	• Communication campaign to encourage correct use and maintenance of toilets and on-site systems • Consumer protection programme indicating rights and responsibilities of users of faecal sludge emptying services	• Staff awareness-raising programme to ensure occupational health and safety • Personal protective equipment (e.g. gloves, masks, enclosed waterproof footwear) • Training on safe handling of excreta	• Personal protective equipment • Personal hygiene and training to promote hygiene for farmers.

Type of measure	Consumers (C)	Local community (L)	Wider community (WC)
Regulatory	• Standards for sludge products, categorized by type of use	• Local ordinances that forbid illegal disposal of fresh faecal sludge in open fields and water streams • Restricted public access to fields or waste-fed aquaculture facilities	• Wastewater treatment plant effluent standards • Prohibition of recreational activities in suspected contaminated water bodies
Technical	• Additional treatment of dried sludge (e.g. co-composting) • Additional polishing step at wastewater treatment plant	• Fencing of waste treatment facility to prevent entry of children and animals • Upgrading of on-site systems that might percolate leachate to groundwater	• Installation or upgrade of wastewater treatment plant to avoid discharge of untreated effluent
Managerial and operational	• Pathogen die-off period of 1 month, either by: • withholding waste application before harvesting; • crop storage before sale; or • a combination of the above totalling 1 month.	• Where wastewater is applied with spray irrigation, maintenance of a buffer zone of 50–100 m from residents • Treatment for helminth infections 2–3 times yearly for vulnerable people.	• Development of standard operationing procedures for operation and maintenance of wastewater treatment plants
Behaviour change	• Training of farmers on crop selection (e.g. only crops not eaten raw) • Household food safety programme (to encourage washing of produce) • Market hygiene through education of vendors and providing safe water in markets	• Education campaigns for residents	• Education campaigns for residents of nearby cities and towns

Sources: Stenström et al. (2011), pp. 74–8, 93, 100; WHO (2006), vol. 2, pp. 79–80; WHO (2006), vol. 3, pp. 21, 43–5, 47–68; WHO (2006), vol. 4, pp. 74–8.

ANNEX 2

Summary of microbial health risks associated with use of wastewater for irrigation

Table A2-1. Summary of microbial health risks associated with use of wastewater for irrigation

Group exposed	Bacterial/virus infections	Protozoan infections	Helminth infections
Farm workers and their families	Increased risk of diarrhoeal disease in children with wastewater contact, if water has $>10^4$ faecal coliforms/100 mL. Elevated risk of *Salmonella* infection in children exposed to untreated wastewater. Elevated serological response to norovirus in adults exposed to partially treated wastewater.	Risk of *Giardia intestinalis* infection is significant for contact with both untreated and treated wastewater. One study in Pakistan has estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with fresh water. Increased risk of amoebiasis observed with contact with untreated wastewater.	Significant risk of helminth infection in adults and children for untreated wastewater. Increased risk of hookworm infections for workers without shoes. Risk remains for children, but not adults, even when wastewater is treated to <1 helminth egg/L.
Populations living within or near wastewater irrigation sites	Sprinkler irrigation using poor-quality water (with 10^6–10^8 total coliforms/100 mL) and high aerosol exposure is associated with increased infections. Use of partially treated water ($\leq 10^4$–10^5 faecal coliforms/100 mL) for sprinkler irrigation is not associated with increased viral infection rates.	No data on transmission of protozoan infections during sprinkler irrigation with wastewater.	Transmission of helminth infection not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact.
Consumers of produce irrigated with wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater. Seropositive responses for *Helicobacter pylori* with use of untreated wastewater. Increase in nonspecific diarrhoea when water has $>10^4$ faecal coliforms/100 mL.	Evidence of parasitic protozoa found on surfaces of vegetables that have been irrigated with wastewater, but no direct evidence of disease transmission.	Significant risk of helminth infection for both adults and children with untreated wastewater.

Sources: Stenström et al. (2011), p. 92; refer to this source for additional comments relating to the health risk evidence.

ANNEX 3
Chemical hazards for wastewater in agriculture and aquaculture

Wastewater chemicals in agriculture

Often, the limits of concentration of many chemicals in wastewater will be determined by crop requirements, not by human health concerns. The concentrations at which chemicals in wastewater become toxic to plants or unsuitable for agricultural production are typically lower than concentrations that would be of concern for human health.

Chemical concentrations in irrigation water are used to determine suitability of wastewater for plant growth. The physicochemical quality of treated wastewater used for crop irrigation should comply with the guideline values set by the Food and Agricultural Organization of the United Nations, summarized in Annex 1 of WHO (2006), vol. 2.

Chemical concentrations in soil are used to determine suitability for human health, as human exposure to chemicals is assessed through transfer of the chemicals through the food chain (from wastewater to the soil), uptake by plants and consumption by humans. During wastewater irrigation, the concentration of inorganic elements in soils will slowly rise with successive applications. However, for many organic pollutants, it is unlikely that they will accumulate in the soil to their threshold concentrations because their concentrations in wastewaters are typically very low.

Wastewater chemicals in aquaculture

Specific information on chemicals in relation to waste-fed aquaculture is presented in section 3.3 of WHO (2006), vol. 3.

The Codex Alimentarius Commission (http://www.codexalimentarius.org/) establishes tolerances for specific chemicals in food products. Users should also check source references for potential updates to standards and limits over time, and any national standards.

The tolerable concentrations of toxic chemicals in fish and vegetables could be used in some verification programmes. Verification monitoring of chemical concentrations in waste-fed aquacultural products should be conducted at 6-month intervals at the point of sale. Comparisons between waste-fed fish or plants and non-waste-fed products sold in the market may provide insight into any specific contaminants that are related to the use of wastewater or excreta. Contaminants that are at elevated concentrations can be singled out for more routine monitoring, as necessary.

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