World Health Organization

GUIDELINES ON SANITATION AND HEALTH

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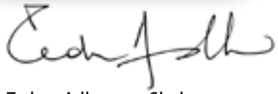
Foreword

Sanitation saves lives. But history teaches us that it's also one of the key building blocks of development.



Dr Tedros Adhanom Ghebreyesus
Director-General
World Health Organization

Ancient civilizations that invested in sanitary improvements became healthy, wealthy, powerful societies. More recently, modernization and economic growth have followed investments in sanitation systems.

Sanitation prevents disease and promotes human dignity and well-being, making it the perfect expression of WHO's definition of health, as expressed in its constitution, as "A state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity".

The right to water and sanitation is foundational to several Sustainable Development Goals. After decades of neglect, the importance of access to safe sanitation for everyone, everywhere, is now rightly recognized as an essential component of universal health coverage. But a toilet on its own is not sufficient to achieve the SDGs; safe, sustainable and well-managed systems are required.

Globally, billions of people live without access to even the most basic sanitation services. Billions more are exposed to harmful pathogens through the inadequate management of sanitation systems, causing people to be exposed to excreta in their communities, in their drinking water, fresh produce and through their recreational water activities. The scale of need is further compounded by urbanization, climate change, antimicrobial resistance, inequality and conflict.

It is with these challenges in mind WHO has developed its first comprehensive guidelines on sanitation and health, filling a critical gap in authoritative health-based guidance on sanitation that results in better health. While clearly setting out the need for action and providing tools and resources, these guidelines also reinvigorate the role of health authorities as champions of sanitation.

The guidelines recognize that safe sanitation systems underpin the mission of WHO, its strategic priorities and the core mission of ministries of health globally. I hope these guidelines will be of great practical use to ministries, health authorities and implementers to make the best investments in the best interventions for the best possible health outcomes for everyone.

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Acronyms and abbreviations

AMR	Antimicrobial resistance
BCT	Behaviour Change Technique
BOD	Biochemical oxygen demand
CBS	Container-based sanitation
CFU	Colony forming units
CHC	Community Health Club
CHAST	Child Hygiene and Sanitation Training
CI	Confidence interval
CLTS	Community-led Total Sanitation
CSO	Combined sewer overflow
DALY	Disability-adjusted life year
DHS	Demographic and Health Survey
DMS	Developing Markets for Sanitation
DNA	Deoxyribonucleic acid
EtD	Evidence to Decision
GC	Gene copies
GDG	Guidelines Development Group
GRADE	Grading of Recommendations, Assessment, Development and Evaluation
GRC	Guidelines Review Committee
GWPP	Global Water Pathogen Project
FFU	focus forming units
HCF	Health care facility
HIV	Human immunodeficiency virus
HMIS	Health management information system
IDP	Internally-displaced person
IEC	Information, Education and Communication
ID50	Dose at which 50% of subjects would become infected; or probability of infection = 0.5
ISO	International Organization for Standardization
JMP	The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene
LMICs	Low- and middle-income countries
MICS	Multiple Indicator Cluster Survey
MoH	Ministry of Health
MPN	Most Probably Number
NGO	Non-governmental organization
NTDs	Neglected Tropical Diseases

O&M	Operation and maintenance
PCR	Polymerase chain reaction
PFU	Plaque forming units
PHAST	Participatory Hygiene and Sanitation Transformation
PPE	Personal protective equipment
PRL	Pathogen reduction level
qPCR	Quantitative polymerase chain reaction
RCT	Randomized controlled trial
RNA	Ribonucleic acid
SaaB	Sanitation as a Business
SanMark	Sanitation Marketing
SDGs	Sustainable Development Goals
SLTS	School-led Total Sanitation
SOP	Standard operating procedures
spp.	Several species within a genus
STH	Soil transmitted helminths
TCID	Tissue culture infectious dose
TIP	Trials for Improved Practice
UDT	Urine diversion toilet
WASH	Water, sanitation and hygiene
WHO	World Health Organization

Executive summary

Introduction and scope

Safe sanitation is essential for health, from preventing infection to improving and maintaining mental and social well-being. The lack of safe sanitation contributes to diarrhoea, a major public health concern and a leading cause of disease and death among children under five years in low- and middle- income countries; poor sanitation also contributes to several neglected tropical diseases, as well as broader adverse outcomes such as undernutrition. Lack of access to suitable sanitation facilities is also a major cause of risks and anxiety, especially for women and girls. For all these reasons, sanitation that prevents disease and ensures privacy and dignity has been recognized as a basic human right.

Sanitation is defined as access to and use of facilities and services for the safe disposal of human urine and faeces. A **safe sanitation system** is 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.

The purpose of these guidelines is to promote safe sanitation systems and practices in order to promote health. They summarize the evidence on the links between sanitation and health, provide evidence-informed recommendations, and offer guidance for encouraging international, national and local sanitation policies and actions that protect public health. The guidelines also seek to articulate and support the role of health and other actors in sanitation policy and programming to help ensure that health risks are identified and managed effectively.

The main audience for the guidelines is national and local authorities responsible for the safety of sanitation systems and services, including policy makers, planners, implementers and those responsible for the development, implementation and monitoring of standards and regulations. This includes health authorities and, since sanitation is often managed outside the health sector, other agencies with responsibilities for sanitation.

The guidelines were developed in accordance with the processes set out in the WHO Handbook for Guideline Development.

Evidence summary

The evidence reviewed in the process of developing the guidelines suggests that safe sanitation is associated with improvements in health, including positive impacts on infectious diseases, nutrition and well-being. In general, however, the quality of the evidence is low. This is common for environmental health research generally due to the paucity of randomized controlled trials and the inability to blind most environmental interventions. The evidence is also characterized by considerable heterogeneity, with some studies showing little or no effect on health outcomes. Heterogeneity can be expected in results from studies where, as here, there was high levels of variability in the settings, baseline conditions, types of interventions, levels of coverage and use obtained, study methods and other factors likely to impact effect sizes. Sub-optimal effects can also be expected from shortcomings in how sanitation interventions are implemented (i.e. problems with delivery of sanitation interventions, sometimes even leading to implementation failure).

Research needs

There is need for further research on the links between sanitation and health, and on the operation of the sanitation service chain and optimal methods for implementation. Research gaps include strategies for encouraging governments to prioritize, encourage and monitor sanitation; creating an enabling environment; improving coverage and securing correct, consistent, sustained use; estimating health impacts from sanitation interventions; improving methods for assessing presence of and exposure to sanitation-related pathogens in the environment; preventing the discharge of faecal pathogens into the environment along all steps of the sanitation service chain; exploring alternative designs and services, including safe emptying and management of on-site sanitation; ensuring that proposed sanitation interventions are culturally-appropriate, respect human rights and reflect human dignity; mitigating occupational exposures; reducing adverse ecological effects; elaborating the links between sanitation and animals and their impact on human health; and investigating the issues around sanitation and gender.

Navigating the guidelines

The Guidelines are organized as described in the table below. The recommendations and actions required to implement them are set out in Chapter 2 following the introduction. Chapters 3 to 5 provide technical and institutional guidance for implementation, and Chapters 6 to 9, as well as the annexes, provide further technical resources.

Introduction, scope and objectives	Chapter 1: Introduction
Recommendations and actions	Chapter 2: Recommendations and good practice actions
Implementation guidance	Chapter 3: Safe sanitation systems Chapter 4: Enabling safe sanitation service delivery Chapter 5: Sanitation behaviour change
Technical resources	Chapter 6: Excreta-related pathogens Chapter 7: Methods Chapter 8: Evidence on the effectiveness and implementation of sanitation interventions Chapter 9: Research needs Annex 1: Sanitation system factsheets Annex 2: Glossary of sanitation terms

Recommendations

The below recommendations are provided for action by national and local authorities.

Recommendation 1: Ensure universal access and use of toilets that safely contain excreta

1.a) Universal access to toilets that safely contain excreta and elimination of open defecation should be prioritized by governments, ensuring that progress is equitable and in line with the principles of the human right to water and sanitation.

1.b) Demand and supply of sanitation facilities and services should be addressed concurrently to ensure toilet adoption and sustained use and enable scale.

1.c) Sanitation interventions should ensure coverage of entire communities with safe toilets that, as a minimum, safely contain excreta, and address technological and behavioural barriers to use.

1.d) Shared and public toilet facilities that safely contain excreta can be promoted for households as an incremental step when individual household facilities are not feasible.

1.e) Everyone in schools, health care facilities, workplaces and public places should have access to a safe toilet that, as a minimum requirement, safely contains excreta.

Recommendation 2: Ensure universal access to safe systems along the entire sanitation service chain

2.a) The selection of safe sanitation systems should be context specific and respond to local physical, social and institutional conditions.

2.b) Progressive improvements towards safe sanitation systems should be based on risk assessment and management approaches (e.g. Sanitation Safety Planning).

2.c) Sanitation workers should be protected from occupational exposure through adequate health and safety measures.

Recommendation 3: Sanitation should be addressed as part of locally delivered services and broader development programmes and policies

3.a) Sanitation should be provided and managed as part of a package of locally-delivered services to increase efficiency and health impact.

3.b) Sanitation interventions should be coordinated with water and hygiene measures, as well as safe disposal of child faeces and management of domestic animals and their excreta to maximize the health benefits of sanitation.

Recommendation 4: The health sector should fulfill core functions to ensure safe sanitation to protect public health

4.a) Health authorities should contribute to overall coordination of multiple sectors on development of sanitation approaches and programmes, and sanitation investment.

4.b) Health authorities must contribute to the development of sanitation norms and standards.

4.c) Sanitation should be included in all health policies where sanitation is needed for primary prevention, to enable coordination and integration into health programmes.

4.d) Sanitation should be included within health surveillance systems to ensure targeting to high disease burden settings, and to support outbreak prevention efforts.

4.e) Sanitation promotion and monitoring should be included within health services to maximize and sustain health impact.

4.f) Health authorities should fulfil their responsibility to ensure access to safe sanitation in healthcare facilities for patients, staff and carers, and to protect nearby communities from exposure to untreated wastewater and faecal sludge.

Good practice actions for enabling safe sanitation service delivery

The recommendations are complemented by a set of good practice actions to help all stakeholders put the recommendations into effect.

1. Define government-led multi-sectoral sanitation policies, planning processes and coordination.
2. Ensure health risk management is properly reflected in sanitation legislation, regulations and standards.
3. Sustain the engagement of the health sector in sanitation through dedicated staffing and resourcing, and through action on sanitation within health services.
4. Undertake local health-based risk assessment to prioritize improvements and manage system performance.
5. Enable marketing of sanitation services and develop sanitation services and business models.

Principles for implementation of sanitation interventions

Safe sanitation systems

Sanitation systems should address the following minimum requirements to ensure safety along each step of the sanitation service chain.

Toilet

- Toilet design, construction, management and use should ensure that users are safely separated from excreta.
- The toilet slab and pan or pedestal should be constructed using durable material that can be easily cleaned.
- The toilet superstructure needs to prevent the intrusion of rainwater, stormwater runoff, animals and insects. It should provide safety and privacy with lockable doors for shared or public toilets.
- Toilet design should include provision of culturally- and context-appropriate facilities for anal cleansing, handwashing and menstrual hygiene management.
- Toilets need to be well maintained and regularly cleaned.

Containment – storage/treatment

- Where groundwater is used as a drinking-water source, a risk assessment should ensure that there is sufficient vertical and horizontal distance between the base of a permeable container, soak pit or leach field and the local water table and/or drinking-water source (allowing at least 15 m horizontal distance and 1.5 m vertical distance between permeable containers and drinking-water sources is suggested as a rule of thumb).
- When any tank or pit is fitted with an outlet, this should discharge to a soak pit, leach field or piped sewer. It should not discharge to an open drain, water body or open ground.
- Where products from storage or treatment in an on-site containment technology are handled for end use or disposal, risk assessments should ensure *workers* and/or downstream *consumers* adopt safe operating procedures.

Conveyance

- Wherever possible motorized emptying and transport should be prioritized over manual emptying and transport.
- All *workers* should be trained on the risks of handling wastewater and/or faecal sludge and on standard operating procedures (SOPs).
- All workers should wear personal protective equipment (e.g. gloves, masks, hats, full overalls and enclosed waterproof footwear) particularly where manual sewer cleaning or manual emptying is required.

Treatment

- Regardless of the source (i.e. wastewater from sewer-based technologies or faecal sludge from on-site sanitation) both the liquid and solid fractions require treatment before end use/disposal
- The treatment facility should be designed and operated according to the specific end use/disposal objective and operated using a risk assessment and management approach to identify, manage and monitor risk throughout the system.

End use/disposal

- Workers handling effluent or faecal sludge should be trained on the risks and on standard operating procedures and use personal protective equipment.
- A multi-barrier approach (i.e. the use of more than one control measure as a barrier against any pathogen hazard) should be used.

Sanitation behaviour change

Behaviour change is an important aspect of all sanitation programmes and underpins adoption and use of safe sanitation.

- Governments are the critical stakeholder in the coordination and integration of sanitation behaviour change activities and they should provide leadership and adequate funding.
- All sanitation interventions should include a robust sanitation promotion/behaviour change programme (including monitoring and evaluation), with all stakeholders and participants aligned around the same set of objectives and strategies.
- To influence behaviour and design successful promotion activities it is important to understand the existing sanitation behaviours and the determinants of those behaviours, noting that specific population groups will have different sanitation needs, opportunities for change and barriers to improvement.
- Behaviour change interventions are most successful when they target the determinants of behaviours; a range of models and frameworks exist to aid understanding and target behavioural drivers and should be drawn upon in the intervention design process.
- Careful consideration should be given to the intervention delivery model (stand-alone behaviour change versus integrated approaches; focused versus comprehensive strategies); for a strategy to be successful it needs to impact on uptake, adherence and long-term practice/use of the safe behaviour.
- Behaviour change programming needs adequate and dedicated resources.

Chapter 1

INTRODUCTION

1.1 The significance of sanitation for human health

Safe sanitation is essential for health, from preventing infection to improving and maintaining mental and social well-being. The lack of safe sanitation systems leads to infection and disease, including:

- Diarrhoea, a major public health concern and a leading cause of disease and death among children under five years in low- and middle-income countries (Prüss-Üstün et al. 2016);
- Neglected tropical diseases such as soil-transmitted helminth infections, schistosomiasis and trachoma that cause a significant burden globally (WHO, 2017); and
- Vector-borne diseases such as West Nile Virus or lymphatic filariasis (Curtis et al., 2002; van den Berg, Kelly-Hope & Lindsay, 2013), through poor sanitation facilitating the proliferation of *Culex* mosquitos.

Unsanitary conditions have been linked with stunting (Danaei et al., 2016), which affects almost one quarter of children under-five globally (UNICEF/WHO/World Bank, 2018) through several mechanisms including repeated diarrhoea (Richard et al., 2013), helminth infections (Ziegelbauer et al., 2012) and environmental enteric dysfunction (Humphrey, 2009; Keusch et al., 2014; Crane et al., 2015) (see Box 1.1).

The lack of safe sanitation systems contributes to the emergence and spread of antimicrobial resistance by increasing the risk of infectious diseases (Holmes et al., 2016) and thereby use of antibiotics to tackle preventable infections. Inadequate management of faecal waste that includes antimicrobial residues from communities and health care settings can also contribute to emergence of resistance (Korzeniewska et al., 2013; Varela et al., 2013).

Box 1.1 Sanitation and complex health outcomes: environmental enteric dysfunction

Environmental enteric dysfunction (EED) is an acquired subclinical disorder of the small intestine, characterized by chronic inflammation and subsequent changes to the gut (such as villous atrophy and crypt hyperplasia) (Crane et al., 2015; Harper et al., 2018), potentially leading to stunted growth and reduced response to enteric vaccines (Iqbal et al., 2018; Marie et al., 2018). The condition has been hypothesized to be an important cause of childhood stunting in low-income settings through nutrient malabsorption, gut permeability, and chronic immune activation that reallocates resources normally directed toward child growth and development (Harper et al., 2018; Marie et al., 2018). It is also thought to affect brain development, with further implications for cognitive function and educational achievement (Oriá et al., 2016; Harper et al., 2018).

Although the causes of EED are difficult to describe precisely, it is assumed to be caused by exposure to bacteria from faecal contamination due to inadequate sanitation behaviours and unsafe sanitation systems (Harper at al., 2018). High levels of undernutrition and diarrhoea in a given population, also related to poor sanitation, are assumed to increase the likelihood of EED (Crane et al., 2015). The potential significance of EED to child health and nutrition, and subsequently other important health outcomes (see Table 1.1) merits greater attention in public sanitation and health policy and programming. However, the continuous and asymptomatic nature of EED, the uncertainty surrounding its causes, prevention and treatment (Crane et al., 2015), and the methodological and ethical challenges associated with its accurate measurement (Harper et al., 2018; Marie et al., 2018), contribute to EED being a persistent blindspot in nutrition and health programmes.

Safe sanitation in health centres is an essential component of quality of care and infection prevention and control strategies, especially for preventing exposure of health service users and staff to infections (WHO, 2016a), and particularly at protecting pregnant women and new-borns from infections which may lead to adverse pregnancy outcomes, sepsis and mortality (Benova, Cumming & Campbell, 2014; Padhi et al., 2015; Campbell et al., 2015). Access to safe sanitation systems in homes, schools, work places, health centres, public spaces and other institutional settings (such as prisons and refugee camps) – is essential for overall well-being, for example through reducing the risks (Winter & Barchi, 2016; Jadhav, Weitzman & Smith-Greenaway, 2016) and anxiety caused by embarrassment and shame (e.g. Hirve et al., 2015; Sahoo et al., 2015;) associated with open defecation or shared sanitation. Table 1.1 summarizes the health impact of the lack of safe sanitation systems.

1.2 Sanitation as a human development issue

Inadequate sanitation systems exist in many parts of the world. Many people worldwide practice open defecation and many more do not have services that prevent faecal waste from contaminating the environment (WHO-UNICEF, 2017). In many low- and middle-income countries (LMICs), rural areas are underserved, cities are struggling to cope with the scale of sanitation needs caused by rapid urbanization, while sanitation system maintenance is challenging and costly worldwide. Challenges caused by climate change require continued adaptation to ensure sanitation systems safeguard public health.

Table 1.1 The health impact of unsafe sanitation

Direct impact (infections)	Sequelae (conditions caused by preceding infection)	Broader well-being
Faecal-oral infections • Diarrhoeas (incl. cholera) • Dysenteries • Poliomyelitis • Typhoid **Helminth infections** • Ascariasis • Trichuriasis • Hookworm infection • Cysticercosis (Taenia solium/ infection) • Schistosomiasis • Foodborne trematodes **Insect vector diseases** (vectors breed in faeces or faecally-contaminated water) • Lymphatic filariasis • West Nile Fever • Trachoma	**Stunting/ growth faltering** (related to repeated diarrhea, helminth infections, environmental enteric dysfunction) **Consequences of stunting** (obstructed labour, low birthweight) **Impaired cognitive function** **Pneumonia** (related to repeated diarrhea in undernourished children) **Anaemia** (related to hookworm infections)	**Immediate:** **Anxiety** (shame and embarrassment from open defecation, shared sanitation) and related consequences and not meeting gender specific needs **Sexual assault** (and related consequences) **Adverse birth outcomes** (due to underuse of healthcare facilities with inadequate sanitation) **Long-term:** School absence Poverty Decreased economic productivity Anti-microbial resistance

Collated from: Bartram & Cairncross, 2010; Bouzid et al, 2018; Campbell et al, 2015; Cumming & Cairncross, 2016; Cairncross et al., 2013; Schlaudecker et al, 2011.

Sanitation has gained importance on the global development agenda, starting in 2008 with the UN International Year of Sanitation, followed by the recognition of sanitation as a human right (with water in 2010, and as a standalone right in 2015) (Box 1.2) and the call for an end to open defecation by the UN Deputy Secretary-General in 2013. Safe management of sanitation, as well as treatment and reuse of wastewater, was given a central place under the Sustainable Development Goals (SDGs) (Box 1.3).

Box 1.2 Human right to sanitation (UN, 2015a)

The human right to sanitation entitles everyone to sanitation services that provide privacy and ensure dignity, and that are physically accessible and affordable, safe, hygienic, secure, socially and culturally acceptable. Human rights principles must be applied in the context of realising all human rights, including the human right to sanitation:

1. **Non-discrimination and equality:** All people must be able to access adequate sanitation services, without discrimination, prioritizing the most vulnerable and disadvantaged individuals and groups.
2. **Participation:** Everyone must be able to participate in decisions relating to their access to sanitation without discrimination.
3. **The right to information:** Information relating to access to sanitation, including planned programmes and projects must be freely available to those who will be affected, in relevant languages and through appropriate media.
4. **Accountability (monitoring and access to justice):** States must be able to be held to account for any failure to ensure access to sanitation, and access (and lack of access) must be monitored.
5. **Sustainability:** Access to sanitation must be financially and physically sustainable, including in the long-term.

The normative content of the human right to sanitation is defined by:

1. **Availability:** A sufficient number of sanitation facilities must be available for all individuals.
2. **Accessibility:** Sanitation services must be accessible to everyone within, or in the immediate vicinity, of household, health and educational institution, public institutions and places and workplace. Physical security must not be threatened when accessing facilities.
3. **Quality:** Sanitation facilities must be hygienically and technically safe to use. To ensure good hygiene, access to water for cleansing and handwashing at critical times is essential.
4. **Affordability:** The price of sanitation and services must be affordable for all without compromising the ability to pay for other essential necessities guaranteed by human rights such as water, food, housing and health care.
5. **Acceptability:** Services, in particular sanitation facilities, have to be culturally acceptable. This will often require gender-specific facilities, constructed to ensure privacy and dignity.

All human rights are interlinked and mutually reinforcing, and no human right takes precedence over another.

Box 1.3 The Sustainable Development Goals (SDGs) and sanitation (UN, 2015b)

The SDGs provide a global framework for ending poverty, protecting the environment and ensuring shared prosperity. Goal 6 on clean water and sanitation (specifically targets 6.2 and 6.3 on sanitation and water quality respectively), and Goal 3 on good health and well-being, are particularly relevant to sanitation. Several other goals for which sanitation contributes or is necessary for achievement, including those on poverty (particularly 1.4 on access to basic services), nutrition, education, gender equality, economic growth, reduction in inequalities and sustainable cities. The SDGs also set out the principles of implementation for States to follow, including increasing financing, strengthening capacity of health workers, introduction of risk-reduction strategies, building on international cooperation and participation of local communities. Goal 1 states the need to improve the flow of information and increase monitoring capacities and disaggregation so that it is possible to identify which groups are being left behind.

1.3 Scope

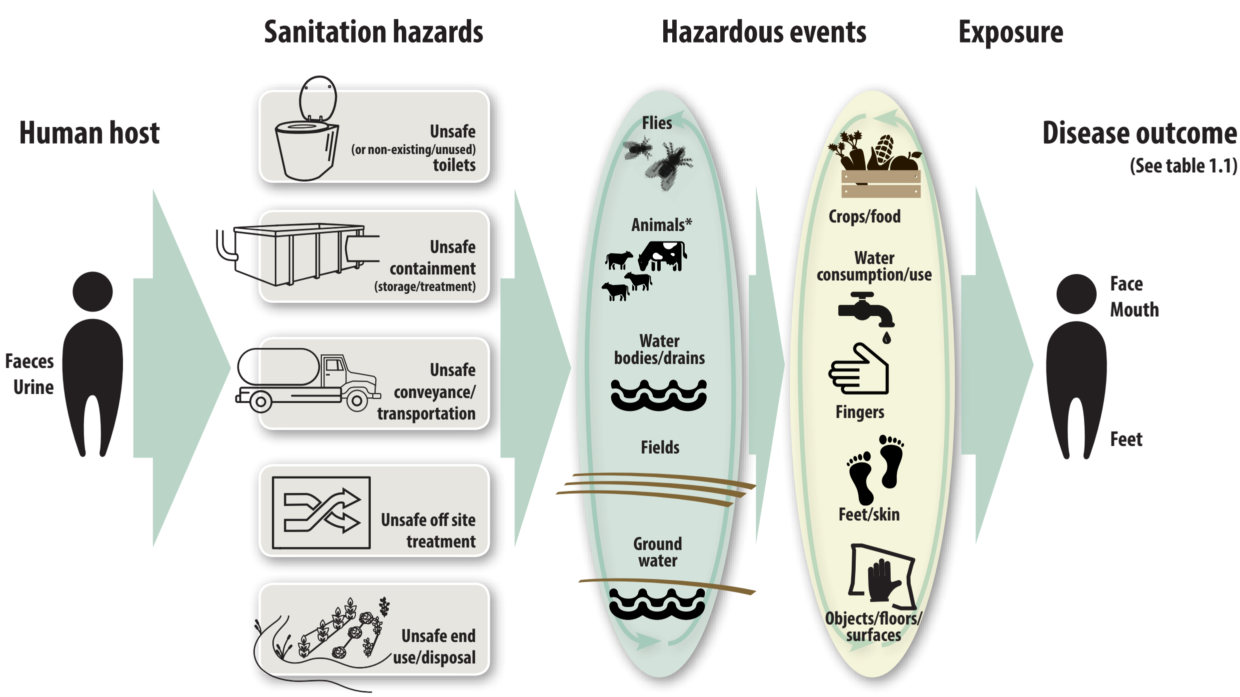
These guidelines are concerned with ensuring that sanitation systems are designed and managed safely to protect human health from microbial hazards caused by human excreta, and consequent adverse health outcomes such as infectious disease, nutritional status and educational outcomes. The guidelines also cover well-being and psychosocial dimensions of health (such as privacy, safety and dignity) needed to encourage and sustain use of sanitation services.

While animal faeces contain pathogens that can cause disease in humans these guidelines do not cover management of animal waste. The guidelines cover solid waste associated with menstrual hygiene management but do not cover other types of solid waste, although the management of solid waste is sometimes included in the definition of sanitation and is also of significance for public health.

1.3.1 Rationale for scope

The primary purpose of safe sanitation services from a public health perspective is to fulfil the human right to sanitation and ensure sanitation services separate human excreta (faeces and urine) from human contact to interrupt pathogen transmission. Figure 1.1 shows the transmission pathways of excreta-related infections from left to right. Excreta enters the sanitation chain,

Figure 1.1 Transmission of excreta-related pathogens



The commonly-used F-diagram on faecal-oral disease transmission (various versions adapted from Wagner and Lanoix, 1958) is not used in these guidelines, although several of its elements can be clearly discerned (human hosts, and the elements described as "hazardous events" in this diagram). The purpose of this figure is to highlight the role of safe sanitation systems as a primary barrier to transmission by showing the way in which unsafe management at each step of the sanitation chain spreads excreta in the environment; additionally, the diagram captures transmission routes that are not faecal-oral and shows the complex ways in which different hazards and hazardous events interrelate. The diagram forms a conceptual basis for risk assessment and management for sanitation systems.

Read from left to right, the diagram illustrates the potential pathogen transmission pathways from a human host leading to disease outcomes, from excretion, to hazards at each step of the sanitation service chain, to hazardous events and exposure of a new host; examples of these pathways include :

- Unsafe/ non-existing (or not used) toilets: open defecation can lead to pathogens discharged on to fields, infecting new hosts through feet or crops (e.g. soil-transmitted helminths); into water bodies, infecting new hosts through water contact (e.g. schistosomiasis from urination/ defecation in surface water) or consumption; and overall spread within the household environment by insects or animals acting as mechanical vectors. Poorly-constructed pit toilets can lead to flies and other insects breeding in excreta or spreading faecal pathogens to food, fingers and surfaces.
- Unsafe containment (storage/ treatment): poor containment such as poorly-constructed latrine pits or septic tanks can cause leakage into ground water and thereby into water consumed by new hosts; and to overflow into the household environment.
- Unsafe conveyance/transportation: poor emptying practices can lead to direct exposure of sanitation workers or others involved in emptying activities to pathogens, as well as discharge of pathogens onto household surfaces and therefore exposure through contaminated surfaces; untreated excreta discharged into water bodies, drains fields and other surfaces can potentially lead to transmission through all types of hazardous events; and unsafe sewers can cause exposure through leakage, overflow and unsafe discharge into drains, water bodies, ground water and open surfaces.
- Unsafe off-site treatment: inadequate treatment can lead to insufficient pathogen removal from faecal sludge, leading to pathogen discharge onto fields (through fertilization) and therefore crops, and into water bodies through runoff or by purposeful discharge, contaminating water for human consumption. Poorly-managed treatment processes can also allow animal contact with untreated excreta, contributing to further exposure
- Unsafe end use/ disposal: discharge of untreated faecal sludge into the environment can lead to all hazardous events through multiple pathways.

The diagram may be read both horizontally and vertically, taking into account the potential interaction between different hazardous events to form complex or indirect pathways. For instance, as well as carrying pathogens to fingers and surfaces, animals may also introduce pathogens to fields and water bodies, thereby indirectly transmitting pathogens to a new host; untreated excreta discharged to fields may lead to contamination of ground water or water bodies; and fingers contaminated during toilet use or from contact with animals or contaminated surfaces can transmit pathogens to food during cooking or eating, or contaminate other surfaces.

** Refers to animals as mechanical vectors. Transmission of animal excreta-related pathogens to human hosts is not represented in this diagram.*

where sanitation hazards translate to hazardous events through which excreta enter the environment and expose new hosts. "Unsafe toilet" includes open defecation and inconsistent use. The diagram allows both vertical and horizontal interaction: horizontally, all hazards have the potential to lead to eventual exposure through most pathways (or "hazardous events"); within the vertical blocks of "sanitation hazards" and "hazardous events", interactions can occur across all elements (e.g. animals can spread human excreta to fields and water bodies, as well as floors and surfaces within homes).

Sanitation is defined as access to and use of facilities and services for the safe disposal of human urine and faeces. 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 (Figure 1.2). Safe sanitation systems must meet these requirements in a manner consistent with human rights, while also addressing co-disposal of greywater (water generated from the household, but not from toilets), associated hygiene practices (e.g. managing anal cleansing materials) and essential services required for the functioning of technologies (e.g. flush water to move excreta through sewers).

Figure 1.2 Sanitation service chain

1.4 Objectives

The purpose of these guidelines is to promote safe sanitation systems and practices in order to promote health. They summarize the evidence on the links between sanitation and health, provide evidence-informed recommendations, and offer guidance for encouraging international, national and local sanitation policies and actions that protect public health. The guidelines also seek to articulate and support the role of health and other actors in sanitation policy and programming to help ensure that health risks are identified and managed effectively. The guidelines are designed to be adapted to local contexts taking social, economic, environmental and health aspects into consideration. The guidelines are relevant everywhere, especially in LMICs where sanitation is most challenging.

Sanitation measures to protect public health are both single- and multi-component, and include technologies (Chapter 3), policies, regulations and financial and personnel resources (Chapter 4), and sanitation behaviour change (Chapter 5). Sanitation measures may target domestic, institutional and commercial premises, including households, schools, healthcare centres and other institutions (such as prisons), as well as work places and all other toilet facilities in public settings. They may be implemented at local, regional, national or international levels, through the health sector or other sectors.

The guidelines cover incremental approaches to achieve:

1. universal coverage of and access to sanitation
2. increased quality of sanitation services and access to higher levels of sanitation services
3. sustainability in terms of sustained functioning of sanitation services, as well as environmental and social sustainability.

All WHO water and sanitation related guidelines are underpinned by the Stockholm framework and its underlying principles of risk assessment and management (Fewtrell & Bartram, 2001). These principles rest on the systematic identification,

Box 1.4 Why are guidelines on sanitation and health needed?

Evaluations of sanitation interventions have shown lower than expected health outcomes, leading to concerns on the quality of implementation of sanitation interventions and programmes. Comprehensive guidelines are needed that consider the full sanitation service chain and its implications for human health, as well as the roles and responsibilities of health actors in securing sanitation-related health gains.

These guidelines build on previous WHO publications, starting from 'Excreta disposal for rural areas and small communities' (Wagner & Lanoix, 1958), and subsequent sanitation-related publications, including:

- A guide to the development of on-site sanitation (WHO, 1992);
- Guidelines for safe use of wastewater, excreta and greywater (third edition), with four volumes covering: Policy and regulatory aspects, Wastewater use in agriculture, Wastewater and excreta use in aquaculture and Excreta and greywater use in agriculture (WHO, 2006a);
- Several guidance documents for specific settings such as:
  – health care settings (Essential environmental health standards in health care, WHO, 2008);
  – schools (Water, sanitation and hygiene standards for schools in low-cost settings, WHO, 2009a);
  – aviation (Guide to hygiene and sanitation in aviation, third edition, WHO, 2009b); and
  – ships (Guide to ship sanitation (third edition): Global reference on health requirements for ship construction and operation. WHO, 2011a).

Other publications provide guidance on related water, sanitation and hygiene topics including drinking-water quality (Guidelines for drinking-water quality, fourth edition, WHO, 2011b); recreational water (Guidelines for safe recreational water environments, WHO, 2003 and 2006b); and surface water (Protecting surface water for health: Identifying, assessing and managing drinking-water quality risks in surface-water catchments, WHO 2016b).

prioritization and management of health risks throughout the system. For sanitation this means the service chain from excreta generation to final disposal or reuse (Figure 1.2). This ensures that control measures target the greatest health risks and emphasizes incremental improvement over time. While the Stockholm framework has been articulated with health-based targets expressed as numerical targets in other guidelines, a more flexible approach to risk assessment and management is reflected in this document. Related normative guidance documents are outlined in Box 1.4.

1.5 Target audiences

The main audience for the guidelines is national and local authorities responsible for the safety of sanitation systems and services, including policy makers, planners, implementers and those responsible for the development, implementation and monitoring of standards and regulations. This includes health authorities and, since sanitation is often managed outside the health sector, other agencies with responsibilities for sanitation.

Within the Ministry of Health, this document is relevant for staff from departments of environmental health and from other health programmes seeking guidance on sanitation interventions in the context of disease prevention and control strategies.

International organizations, funding agencies, non-governmental organizations (NGOs), civil society, academia and others working on sanitation across multiple sectors will also have an interest in these guidelines when developing and contextualizing strategies, programmes and tools for sanitation measures to ensure they protect public health. At their broadest application the guidelines are a general reference on sanitation and health.

1.6 Health authorities mandate

Health sector engagement and oversight are essential to ensure that sanitation policies and programmes effectively and sustainably protect public health (Rehfuess et al., 2009; Mara et al., 2010). The health sector's mandate includes the following functions (detailed further in Chapter 4):

- Sanitation coordination
- Health in sanitation policies
- Health protecting norms and standards
- Health surveillance and response
- Sanitation in health programme delivery
- Sanitation behaviour change
- Healthcare facilities

1.7 Methods

These guidelines were developed following the procedures and methods described in the *WHO handbook for guideline development* (2nd edition 2014) and were reviewed by the Chair and Secretariat of the WHO Guidelines Review Committee. Because the nature of the recommendations was deemed equivalent to good practice statements, they were not formally reviewed by the Guidelines Review Committee. The methods are discussed in more detail in Chapter 7.

Key methodological steps covered:

1. formulating the scoping questions based on a robust conceptual framework
2. prioritizing key questions
3. identifying and/or conducting systematic reviews to address the key questions
4. assessing the quality of the evidence
5. formulating recommendations and good practice actions
6. writing the guidelines and
7. developing a plan for dissemination and implementation.

1.8 Guidelines structure

This document sets out the need for and purpose of the guidelines (Chapter 1), followed by detailed recommendations and good practice actions (Chapter 2). Detailed guidance is then provided on all aspects of sanitation systems, particularly those aspects underlying their health impact and sustainability (principles and technical aspects for safe sanitation systems (chapter 3), service delivery (Chapter 4) and behaviours (Chapter 5)). Technical aspects underpinning the rationale and process for guidelines development follow in chapters 6–9 and Annex 1.

Introduction, scope and objectives	Chapter 1: Introduction
Recommendations and actions	Chapter 2: Recommendations
Implementation guidance	Chapter 3: Safe sanitation systems Chapter 4: Enabling safe sanitation service delivery Chapter 5: Sanitation behaviour change
Technical resources	Chapter 6: Excreta-related pathogens Chapter 7: Methods Chapter 8: Evidence on the effectiveness and implementation of sanitation interventions Chapter 9: Research needs Annex 1: Sanitation system factsheets Annex 2: Glossary of sanitation terms

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Chapter 2

RECOMMENDATIONS AND GOOD PRACTICE ACTIONS

This chapter sets out recommendations for action by governments and partners.

The recommendations are complemented by a set of good practice actions to help all stakeholders put the recommendations into effect.

2.1 Recommendations

Recommendation 1: Ensure universal access and use of toilets that safely contain excreta

This recommendation is in line with human rights principles and reinforces SDG 6 (*"Ensure availability and sustainable management of water and sanitation for all"*) and target 6.2 (*"by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations"*). It emphasizes the general principle that safe sanitation systems should be available to and used by all, starting with universal access to a safe toilet that safely contains excreta as an essential step towards a safe full sanitation service chain. Governments are ultimately responsible for ensuring universal access to toilets with a subsequent safe sanitation service chain.

1.a) Universal access to safe toilets and elimination of open defecation should be prioritized by governments, ensuring that progress is equitable and in line with the principles of the human rights to water and sanitation

The principles of the human rights to water and sanitation state that progress towards universal access should be equitable. Universal access can only be attained through incremental progress. A national level risk assessment can be used to identify highest risk populations and to target interventions to ensure no one is left behind in national targets, policy, legislation, resources allocation and monitoring and reporting on progress. To ensure equitable progress, specific efforts and resources to address the most marginalised groups will likely be required.

Rationale and evidence:

- The human rights to water and sanitation oblige all UN Member States to consider all aspects of access to services, including increasing the number of people with access to at least minimum services, improvement in levels of services, and explicitly targeting poor, marginalised and disadvantaged people (Committee on Economic, Social and Cultural Rights (CESCR), 2010; UN, 2015).
- There is a relationship between inadequate sanitation and eight dimensions of social and mental well-being – lack of privacy, shame, anxiety, fear, assault, lack of safety, embarrassment and lack of dignity. Privacy and safety have been identified as root dimensions (Sclar et al., 2018).

1.b) Demand and supply of sanitation facilities and services should be addressed concurrently to ensure toilet adoption and sustained use and enable scale

Adoption and sustained use of sanitation facilities requires construction of safe toilets and their sustained use. Access to a toilet does not mean it is used or used consistently by everyone at all times. Poorly constructed and managed facilities may lead to households reverting to open defecation.

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Toilets should be available, accessible and affordable to all, constantly, and at least separate excreta from human contact. Their design should be culturally-appropriate, suitable to locally-available materials and physical conditions such as water availability and ground/soil conditions, and in line with ability and willingness to pay.

Promotion strategies may be required to ensure sustained demand for and adoption of toilets, and their use by the whole community, as well as relevant practices such as safe disposal of child faeces, hand washing with soap, and toilet cleanliness. Such strategies must be context-specific and compatible with human rights, and respect individuals and the community. They should address all parts of the community regardless of age, gender, social class and disability. Additional approaches for increasing sustained access and use such as subsidies and sanitation marketing should be considered so that increased demand for sanitation products is met. Such approaches should be suitable and acceptable, and implementation should include review and adaptation to ensure their effectiveness and cost-effectiveness.

Rationale and evidence:

- Access to sanitation facilities is a pre-requisite to ending open defecation, but it is not a sufficient condition (Barnard et al., 2013; Coffey et al., 2014)
- There are several potential reasons for poor latrine use and reversion to open defecation, including high maintenance and repair costs, poor latrine quality and durability, lack of consistent follow up and monitoring, and occasions in which coercive methods have resulted in latrine construction without creating genuine buy-in for sustained use (Venkataramanan et al. 2018)
- Multiple psychosocial (norms and nurturing), non-modifiable (age and gender) and technology (cost, durability and maintenance) factors influence initial and sustained adoption of clean water and sanitation technologies (Hulland et al. 2015).

1.c) Sanitation interventions should ensure coverage of entire communities with safe toilets that, as a minimum, safely contain excreta, and address technological and behavioural barriers to use

Access and use of safe toilets by the *entire* community is needed to achieve health gains from sanitation. Without community level coverage, those using safe toilets remain at risk from unsafe sanitation systems and practices by other households, communities and institutions. Therefore, interventions should ensure consistent use of toilets by everyone in the community. In urban areas, achieving full coverage and safe containment is also important and should be addressed through city-wide planning and implementation, as interlinkages can occur through waterways, groundwater, pipes and drains.

In addition, a minimum quality of toilet and containment – storage/treatment is needed to sustain use, to prevent excreta contaminating the local environment and to allow for connection to a safe sanitation chain (recommendation 2). Interventions to end open defecation should not promote the adoption of facilities that inadvertently increase exposure of users to faecal pathogens or cause users to revert to open defecation due to poor quality, inaccessibility, or breakdown of the toilet. Interventions should therefore ensure use of at least safe toilets and safe containment – storage/treatment by the entire community. Barriers to community toilet access and use should be addressed, including structural barriers (e.g. inappropriate or failed design, poor quality construction and operation, full pits, lack of privacy, lack of water) and behavioural barriers (e.g. cultural or societal preferences, locked facilities at night, burden of maintenance, uncertainty about pit filling and/or emptying).

Communities should be at the centre of the sanitation development process in terms of design, placement, features and amenities and systems for operation and maintenance, considering preferences, priorities, ability to pay, gender needs, and religious and cultural practices. Communities may not be homogenous, especially in urban areas, and preferences and needs may differ among households and individuals.

Rationale and evidence:

- Absence of open defecation is associated with healthier populations in terms of reduced incidence or prevalence of infectious disease (Freeman et al., 2017; Majorin et al., 2017; Speich et al., 2016; Yates et al., 2015), nutritional status (Freeman et al., 2017), cognitive development (Sclar et al., 2017) and general well-being, particularly for women and girls (Sclar et al., 2018; Caruso et al., 2017a & b).
- Health gains are associated with community coverage and use exceeding certain possibly location-specific levels (Garn et al., 2017; Oswald et al., 2017; Fuller et al. 2016).
- Behavioural barriers to use include cultural or societal preferences, locked facilities at night, burden of maintenance, uncertainty about pit filling and/or emptying (Garn et al., 2017; Nakagiri et al., 2016; Routray et al., 2015).
- Barriers are likely to be context specific (Coffey, Spears & Vyas, 2017; Novotný, Hasman & Lepič, 2017).

1.d) Shared and public toilet facilities that safely contain excreta can be promoted for households as an incremental step when individual household facilities are not feasible

It may not be possible in the short term to cover entire communities with safe household toilets. Factors that limit household level access include insecure land tenure and insufficient space for toilets, containment and conveyance, and emergency situations. Under these circumstances, shared or public toilets that safely contain excreta (Chapter 3.2 and 3.3) may be promoted for households as an incremental step to ensure everyone has access to a safe toilet and all excreta is contained at the community level. Shared facilities are only acceptable when they meet the standards for accessibility, safety, hygiene, maintenance and affordability described in Chapter 3.2.2) and user acceptability is prioritized in sanitation promotion strategies.

Rationale and evidence:

- Sharing a sanitation facility with more than one household is associated with increased risk of adverse health outcomes compared to private household facilities, including increased odds of moderate to severe diarrhoea in children <5 years (Heijnen et al. 2014, Baker et al., 2016). However, the additional risk associated with latrine sharing between several households may be attributed to differences in user demographics, access, type of facilities and cleanliness.
- Public and shared sanitation in urban settlements has been linked to stress from lack of cleanliness, anxiety and withholding relief due to long lines, women's and girls' fear of harassment from men and boys, and lack of privacy or safety (Sclar et al., 2018).
- Homeless, itinerant and slum dweller populations are forced to openly defecate when public facilities are broken, unclean, too far away or have long queues preventing individuals from working or attending to childcare. This highlights the need for a shared sanitation policy that addresses maintenance, accessibility, cleanliness and provision of water and hand washing facilities (Heijnen et al., 2015; Rheinländer al., 2015; Alam et al., 2017).
- Shared sanitation can represent an important advantage over open defecation or unsafe sanitation when individual household facilities are not yet in place or are infeasible (Heijnen et al., 2014, 2015).

1.e) Everyone in schools, health care facilities, workplaces and public places should have access to a safe toilet that, as a minimum requirement, safely contains excreta

Universal access implies that toilets are accessible in all aspects of daily life including at home, at school, in healthcare settings, workplaces and public places such as markets and transportation facilities for the entire population.

All toilets in schools, health care facilities, workplaces and public places should meet the standards for a safe toilet and safe containment, paying special attention to the need for availability, accessibility, privacy and security and menstrual hygiene management (Chapter 3.2 and 3.3).

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Rationale and evidence:

- Safe sanitation in health centres is an essential component of quality of care and infection prevention and control strategies, especially for preventing exposure of health service users and staff to infections (WHO, 2008; WHO, 2016), and particularly at protecting pregnant women and new-borns from infections which may lead to adverse pregnancy outcomes, sepsis and mortality (Benova, Cumming & Campbell, 2014; Padhi et al. 2015; Campbell et al., 2015).
- Improved sanitation conditions in schools potentially affect child health and well-being (UNICEF, 2012)
- Sanitation provision in businesses and workplaces can contribute to improving gender equity, increasing productivity and reducing absenteeism (Kiendrebeogo, 2012; WSSCC and UN Women, 2014; WSUP, 2015).

Recommendation 2: Ensure universal access to safe systems along the entire sanitation service chain

Universal access and use of safe toilets that contain excreta (Recommendation 1) is a first step towards health-protective sanitation systems and services. This recommendation area covers safe sanitation systems beyond the toilet and containment step. A safe sanitation chain is needed to realise substantive impact on sanitation-related disease. Sanitation systems should address containment, emptying, conveyance, treatment and end use or disposal of excreta, to achieve safe sanitation.

This recommendation area highlights the need to ensure systems and services are selected to respond to the local context and that investment and system management are based on local level risk assessments along the entire sanitation chain (e.g. Sanitation Safety Planning) to ensure users and the community are protected. In addition, it recognizes the need for protection of sanitation workers through safe working conditions.

Selection of sanitation systems should be context-specific, responding to physical, social and institutional conditions.

2.a) The selection of safe sanitation systems should be context specific and respond to local physical, social and institutional conditions

No single type of sanitation system is ideal in all settings. Sanitation systems must be context specific, evolving over time and taking into consideration population density, hydrological conditions (e.g. potential for groundwater contamination), life cycle cost and financing options, capacity for installation, operation and maintenance, and disposal/reuse options. The design and implementation process should incorporate extensive stakeholder consultation, which includes the local community.

Well-managed and well-used on-site sanitation, for example, can effectively reduce exposure to excreta, and represents a low-cost option in resource-constrained settings where safe sewer solutions are prohibitively costly. It should be recognized that typical on-site septic tanks provide only primary treatment, and therefore pathogen removal from sludge and effluent is low. When not functioning properly, on-site sanitation systems may lead to unsafe discharge of excreta into the environment, for instance through release to drains. Decentralised or small-scale systems are also available, and well-designed and maintained sewer systems offer a popular and effective means of addressing the full sanitation chain, especially in urban and other high population density settings, yet they have higher capital and operating costs and can cause excreta exposure if sewage flows through open drains, or is not effectively treated, and if there are leaks; additionally, large scale sewer systems are generally less resilient to the impact of climate change.

Rationale and evidence:

- The importance of the social, institutional and physical context for the successful implementation and sustainability of sanitation technologies and interventions is increasingly acknowledged in sanitation planning (Ingallinella, 2002; Overbo et al., 2016; Mills et al., 2018).
- In their seminal book on faecal sludge management, Strande et al (2014) set out the necessary conditions for the successful implementation of technologies and system options, including soil conditions, climate and population density, as well as the importance of operation and maintenance. Among the success factors for the implementation of institutional frameworks for faecal sludge management, they include political prioritization, coordination, holistic response to entire areas and populations, financial, environmental and social sustainability, and capacity for monitoring, operation and maintenance and financial management, among others.
- Water supplies may become contaminated with faecal pathogens from pit latrines, sewage pipes and poor sewage treatment systems (Williams et al., 2015). The impact of latrines and septic systems on groundwater quality is dependent on soil type, distance between groundwater and pit or drain field, and hydrological conditions. Seasonal effects on well contamination in areas with a high density of latrines or septic systems have also been reported.
- There is an inverse relationship between the distance of a water supply from a latrine and risk or level of faecal contamination of the same water supply, although the effects may not only depend on distance but also seasonality and latrine density (Sclar et al., 2016).

2.b) Progressive improvements towards safe sanitation systems should be based on risk assessment and management approaches

It may take many years and long- term investment to achieve universal access to safe sanitation systems. A locally-specific risk assessment and management approach can identify (e.g. Sanitation Safety Planning) incremental improvements at each step of the sanitation service chain to allow progressive implementation towards sanitation targets and allows investment to be prioritized according to the highest health risk and thereby maximize gains.

The risk assessment should account for hazards associated with normal conditions as well as variability of the population, seasons and climate change, and should assess potential exposure and risks to all groups along the chain – users, local communities, workers and wider communities. When considering new controls, it should assess the effectiveness of existing controls and introduce a combination of technical (e.g. improved containment or conveyance infrastructure), management (e.g. appropriate regulations) and behavioural interventions (e.g. to improve service provider or user practices) to manage risks.

Rationale and evidence:

- The Stockholm Framework provides the theoretical risk assessment and management framework that underpins all WHO guidance on managing health risks associated with water and sanitation (Fewtrell & Bartram, 2001).
- Where systems lack integrity at any point, leakage of excreta may occur, providing opportunities for human exposure (Sclar et al., 2016) and potential infection with a range of faecal pathogens (e.g. Freeman et al., 2017, Speich et al., 2015, Mills et al., 2018).

2.c) Sanitation workers should be protected from occupational exposure through adequate health and safety measures

Sanitation workers are typically at high risk from faecal pathogens in their daily work through handling of faecal sludge and wastewater and equipment used in emptying, conveyance and treatment of faecal sludge and wastewater, work in confined spaces, proximity to aerosols created by treatment processes, and cuts and abrasions from co-disposed solid waste. They are also exposed to other chemical and physical risks from use of hazardous cleaning agents and heavy labour.

Occupational health risks should be included in the risk assessment and management approach (recommendation 2b) and protection should be provided to workers by formal sanitation service providers. Technical protection measures such as phasing out manual emptying and replacing it with motorized systems should be combined with other measures such as appropriate personal protective equipment, standard operating procedures and regular health checks and necessary prophylactic or responsive treatments.

Rationale and evidence:

- Manual desludging poses the greatest risk from faecal pathogens (Thye, Templeton & Ali, 2011; Eales, 2005)
- Sewage workers experience headaches, dizziness, fever, fatigue and gastrointestinal symptoms (Jegglie et al., 2004; Thorn & Kerekes, 2001; Tiwari, 2008). Other occupational health issues include infections such as hepatitis A and leptospirosis due to exposure to animal urine, and respiratory problems such as asthma due to the inhalation of bacterial endotoxins (Glas, Hotz & Steffen, 2001; Thorn & Kerekes, 2001; Tiwari, 2008).
- Sanitation workers may be exposed to 'sewer gas' produced during the breakdown of faecal sludge, which is composed of hydrogen sulphide, methane, nitrogen, carbon dioxide and ammonia. This is toxic, and inhalation can have fatal consequences (Knight & Presnell, 2005; Lin et al., 2013; Tiwari, 2008).
- The manual labour required of sanitation workers can result in musculoskeletal disorders including back pain (Charles, Loomis & Demissie, 2009; Tiwari, 2008).
- Sanitation workers undertaking cleaning tasks may experience skin irritation due to persistent use of latex gloves and exposure to cleaning agents (Brun, 2009).

Recommendation 3: Sanitation should be addressed as part of locally delivered services and broader development programmes and policies

Sanitation services should be provided within the context of a package of basic local services, for which government is responsible and accountable, even where services are delivered by non-government entities.

Planning and delivering sanitation services in conjunction with other services increases efficiency of implementation, sustainability of services, and the likelihood of improved public health outcomes.

3.a) Sanitation should be provided and managed as part of a package of locally-delivered services to increase efficiency and health impact

Sanitation services should be included in local planning processes (for land use, water supply and drainage, transport and communications and solid waste management) to avert the higher cost and complexity of retrofitting sanitation services and infrastructure where there is insufficient space and where sanitation clashes with other local services and infrastructure. Special consideration is needed when solid waste and excreta are co-disposed at the toilet step (eg: solid waste disposal in dry toilets, child or adult faeces disposed in solid waste) or mixed at the end-use and disposal steps (e.g. sludge disposal in landfill, co-composing of sludge and organic solid waste).

Efficiency can also be gained during construction by working on multiple services at the same time, ensuring that any development, such as road construction, is utilized as an opportunity for expanding sanitation services coverage, for example by concurrent construction of sewers and drains. Effectiveness may also be enhanced through integrated consideration of water, stormwater and wastewater at appropriate scales, particularly in urban areas.

Rationale and evidence:

- Inadequate links between urban sanitation planning and overall urban planning and budgeting results in unequal progress, with the urban poor living in slums being left behind (WaterAid 2016).

3.b) Sanitation interventions should be coordinated with water and hygiene measures, as well as safe disposal of child faeces and management of domestic animals and their excreta to maximize the health benefits of sanitation

Multiple barriers are needed to address all pathways of faecal pathogen transmission. While sanitation is a primary barrier, secondary barriers such as safe water, handwashing with soap, animal waste management and fly control are needed. Interventions to address all pathways may be delivered together in a transformative water, sanitation and hygiene (WASH) approach or separately, drawing on specific disciplines for safe water supply, sanitation, hygiene and environmental health. However, ultimately all pathways need to be addressed to achieve significant health gains.

Water supply: Access to adequate water supplies is a vital part of ensuring a safe sanitation service chain for operation (e.g. flushing, sewerage), maintenance and cleaning of facilities and various parts of the sanitation service chain (containers, personal protective equipment, etc), as well as for personal and domestic hygiene purposes. In some cultures, water is necessary for cleansing after defecation, so its absence may encourage open defecation near surface water bodies. Piped water to the household can incentivize all householders in a community to build and use toilets, and must be available year-round to enable this outcome. No minimum requirements are prescribed, as these depend upon the context and include aspects such as water availability, type of facilities, number of users, cleansing requirements and other local factors. These all require consideration when designing and implementing a comprehensive sanitation programme. All water supply for human consumption should follow WHO Guidelines on Drinking Water Quality (WHO, 2011).

Hand washing with soap: Handwashing with soap after defecation and any potential contact with faeces (for example child faeces) should be promoted and supported by the availability of soap and water close to sanitation facilities. In public facilities (such as schools, health care centres, food establishments, markets etc.) handwashing facilities should be mandatory and included in routine inspection and monitoring schemes.

Other environmental considerations: Sanitation interventions should be developed considering the full range of relevant transmission pathways of excreta-related diseases. Specific aspects inconsistently addressed through the sanitation service chain include safe disposal of child faeces, measures for fly control, consideration of animals as mechanical vectors of human faeces, and food hygiene. Despite having a higher pathogen load than adult faeces, **child faeces** are often considered innocuous and therefore not disposed of safely even by those with access to sanitation facilities. Disposal of child faeces in a toilet connected to a safe sanitation chain is the only safe method where solid waste management systems for children's absorbent underclothes (nappies) disposal are not safe. Policies encouraging the safe disposal of child faeces should include the promotion of supporting products such as nappies/diapers, potties and sanitary scoops (Sultana et al., 2013) and behaviour change strategies to overcome barriers to disposal of child faeces and water used for child bathing after defecation. Potties, sanitary scoops and nappies should be cleaned with water that is safely disposed of, and non-reusable nappies and child wipes should be properly disposed of. **Flies** and **animals** can act as mechanical vectors for faecal pathogens. Flies land on or breed in exposed human faeces, including on toilet surfaces, and transport faecal matter and pathogens onto surfaces, food and people. Household and livestock animals may spread faecal matter around households and water sources, through contact with exposed faeces and faecal sludge. Measures for reducing these transmission pathways should be considered alongside all other sanitation service chain aspects, and include household waste management, removal of animal faeces, keeping livestock away from living quarters, and use of drying racks to reduce flies, and restricting animals from entering household living and cooking areas and water sources. Exposure to excreta-related pathogens through ingestion of **fresh**

produce contaminated during growing, marketing or household preparation is also an important exposure pathway that needs to be addressed though food hygiene practices in the home, as well as control measures to achieve pathogen reductions along the sanitation chain from toilet to table.

Rationale and evidence:

- Having a handwashing station close to toilet facilities encourages handwashing behaviour (Aunger et al., 2010; Biran et al., 2012). Handwashing promotion can reduce diarrhoea by about 30% in both child day-care centres in high-income countries and among communities in LMICs (Ejemot-Nwadiaro et al., 2015).
- Safe disposal of child faeces remains a major challenge (Morita, Godfrey & George, 2016; Majorin et al., 2018; Miller-Petrie et al., 2016). Child faeces are often considered innocuous and, as such, are not disposed of safely (Majorin et al., 2017; Rand et al., 2015). Child faeces may have higher pathogen loads than those of adults (Lanata et al, 1998). Even those with access to sanitation facilities often fail to use them for disposal of child faeces (Miller-Petrie et al., 2016; Majorin et al., 2017; Freeman et al., 2014). In 15 out of 26 locations more than 50% of households reported that the faeces of their youngest child under three years were disposed of unsafely (not into a latrine); the percentage of faeces ending up in improved sanitation facilities is even lower (Rand et al., 2015).
- Flies are mechanical vectors of a variety of enteric pathogens including bacteria and protozoa (Cohen et al., 1991; Fotedar, 2001; Khin et al., 1989; Szostakowska et al., 2004).
- Use of wastewater in crop irrigation (as well as other sanitation end use products in crop fertilization), can lead to adverse health impacts through pathogen exposure, at the same time that such use can contribute to improved food security and nutritional outcomes (WHO, 2006).

Recommendation 4: The health sector should fulfill core functions to ensure safe sanitation to protect public health

While implementation of sanitation programmes is often delivered through infrastructure ministries, agencies and utilities, the overall responsibility to ensure these investments result in improved public health lies with health authorities. This implies roles that includes sanitation considerations within all functions of the health system, including target setting according to public health considerations, coordination of all relevant sectors, use of sanitation and sanitation-related epidemiological data for decision making, standard setting and regulatory, monitoring and accountability measures.

4.a) Health authorities should contribute to overall coordination of multiple sectors on development of sanitation approaches and programmes, and sanitation investment

Coordination is required to accommodate the multi-sectoral nature of sanitation and facilitate action by multiple stakeholders including overall health, education, housing, agriculture, development, public works and environment programmes. These should be coordinated with corresponding government ministries and agencies when sanitation interventions are implemented in institutional settings such as schools and health care facilities, and with broader sectors and industries that produce, treat or use sanitation services, products or by-products. Institutions responsible for water, sanitation and hygiene should collaborate with health care authorities for implementation.

4.b) Health authorities must contribute to the development of sanitation norms and standards

This includes contribution to the development (or revision) and implementation of safety standards and regulations such as minimum standards reflecting the principles of safe management of excreta at each step of the sanitation service chain and establishing risk assessment and management approaches along the entire service chain.

4.c) Sanitation should be included in all health policies where sanitation is needed for primary prevention, to enable coordination and integration into health programmes

This involves developing and strengthening national public health strategies, so that they highlight the importance of sanitation as the basis for primary prevention and include measures to improve sanitation by each of the responsible agencies. It also includes the generation of evidence on the health risks and burden related to poor sanitation, and provision of that evidence to other ministries, to inform investment and planning.

4.d) Sanitation should be included within health surveillance systems to ensure targeting to high disease burden settings, and to support outbreak prevention efforts

Health surveillance includes the strengthening of health management information systems (HMIS) and making better use of epidemiological data and risk factors for sanitation-related diseases to inform investment and planning of sanitation interventions and improve targeting of sanitation services to populations with high disease burden. This includes harmonized monitoring systems and mechanisms to link health and sanitation data and early warning tools to prevent and control sanitation-related diseases.

4.e) Sanitation promotion and monitoring should be included within health services to maximize and sustain health impact

Sanitation promotion should be included in health programmes designed to improve maternal and child health, food safety and nutrition, and to prevent vector borne, zoonotic and neglected tropical diseases. The health sector is responsible for ensuring that health programmes adequately reflect sanitation where relevant. This may include:

- including sanitation-related disease prevention measures and promotional approaches in the curricula of medical, nursing and other health profession training certificates
- embedding sanitation in health outreach programmes by providing frontline health workers and/or volunteers with adequate skills, resources and incentives to promote and monitor sanitation practices
- embedding sanitation-related responsibilities in the job descriptions, supervision and performance management systems for frontline health cadres
- including sanitation-related activities in local health budgets

Sanitation promotion is an important function that should be embedded to the extent possible in community-based, school-based and population-wide initiatives and campaigns. Health authorities should provide, directly or through procurement of advisory services, guidance, technical expertise and support on the design of effective approaches to create demand for sanitation services at scale through sanitation promotion.

4.f) Healthcare authorities should fulfil their responsibility to ensure access to safe sanitation in healthcare facilities for patients, staff and carers, and to protect nearby communities from exposure to untreated wastewater and faecal sludge

Health authorities are directly responsible for ensuring that all healthcare facilities have adequate sanitation systems for staff, patients and caregivers and that there are effective procedures in place to ensure the safe management of faecal waste. Additionally, measures must be taken to ensure that surrounding communities are protected from excreta (as well as other waste) generated within healthcare facilities. This requires adequate ongoing financial resources, dedicated and trained staff and regular operation and maintenance. The WHO has provided specific guidance on WASH in healthcare facilities (WHO, 2008; WHO/UNICEF 2018), setting out guiding principles and standards.

Chapter 2

Rationale and evidence:

- Environmental health delivered through critical health sector functions is essential in preventing a significant proportion of the burden of disease globally; these functions are: (i) ensuring that environmental health issues are adequately reflected in inter-sectoral policy development and implementation; (ii) setting and overseeing the implementation of health-protecting norms and regulations; (iii) incorporating environmental health in disease-specific and integrated health programmes; (iv) practising environmental health in health-care facilities; (v) preparing for and responding to outbreaks of environment-mediated diseases; and (vi) identifying and responding to emerging threats and opportunities for health (Rehfuess, Bruce & Bartram, 2009).
- Successful programming outcomes for sanitation are more likely where coordination and collaboration between different sectors and stakeholders exists (Overbo et al., 2016), affecting both the scale and effectiveness of sanitation programmes.
- Lower prevalence or incidence of disease is associated with greater access to sanitation, particularly for diseases and conditions that continue to inflict a heavy burden in low-income settings including diarrhoea, soil-transmitted helminth infections, trachoma, cholera, schistosomiasis and poor nutritional status (Freeman et al., 2017; Speich et al., 2016).
- Sanitation plays a role in improving broader aspects of health, including gender, security, quality of life and overall well-being (Sclar et al., 2018).

2.2 Good practice actions

1. Define government-led multi-sectoral sanitation policies, planning processes and coordination

- Set targets based on situation analysis, linked to the sustainable development agenda, to allow incremental progress towards universal access to safe sanitation systems and services in all settings (i.e. households, health facilities, schools, workplaces and public places).
- Define sanitation as a basic service in national and sub-national plans, for which government is responsible and accountable.
- Review and update existing policies to identify impediments to improving sanitation along the whole service chain and in all settings including linkages with related sectors such as agriculture and urban planning.
- Define policies and plans that:
  - Prioritize groups based on risk (e.g. low coverage, endemicity, disability, conflict, informal settlements, flood prone areas) and in line with human rights principles.
  - Reflect the needs of women and girls for security, privacy and menstrual hygiene management.
  - Are informed by research in implementation science, technology and engineering, exposure science, epidemiology and behaviour science.
  - Use lessons from existing programmes to respond to barriers to sanitation adoption and use and allow implementers to tailor programmes that address them.
  - Provide the policy basis for addressing affordability gaps and access for vulnerable populations, including linking to social protection policies and financing mechanisms.
- Officially recognize that safe sanitation systems can be delivered through a mix of technologies, implemented through approaches tailored to the local context and based on sound risk assessment.
- Define roles and responsibilities for sanitation functions avoiding gaps and overlaps and distinguishing responsibilities for all settings.
- Establish a coordination function (e.g. a sanitation secretariat or working group) in a senior ministry such as planning or finance.
- Establish dedicated government budget lines for sanitation and define mechanisms for disbursement and reporting at all levels of government.
- Establish accountability frameworks with targets, clear timelines, indicators and milestones, linked to the budget and process and covering both government funds and external funding though grants and loans.
- Establish a robust sanitation monitoring mechanism at the lowest administrative level

under the responsibility of existing structures within the health system, linked with reporting and accountability structures.

2. Ensure health risk management is properly reflected in sanitation legislation, regulations and standards

- Review the public health effectiveness of existing national and local legislation, regulations and standards along the whole service and in all settings (including in related sectors such as agriculture and urban planning) to identify and address impediments to improving sanitation.
- Explicitly recognize sewered and non-sewered sanitation system types (including decentralized systems), including the full service chains of both, in relevant legislation and regulations at national, sub-national, municipal and local levels.
- Regulate service quality for all steps in the sanitation service chain, based on public health risk assessment and management.
- Formulate sanitation technology performance criteria and standards, including operation and maintenance criteria and incremental standards if appropriate for specific settings.
- Formulate standards for products made or grown with sludge or wastewater that include risk assessment and management approaches to ensure appropriate controls in treatment, production and use.
- Ensure legislation, regulations and standards consider willingness and ability of users to pay, and include tariff structures and access to subsidies and other financial resources.
- Where regulatory enforcement is challenging or unlikely due to capacity and other constraints, put in place incentive-based approaches to encourage compliance and improve the ability of poor households to access safe sanitation technologies.
- Ensure that legislation and regulations allow for and regulate participation of the private sector in sanitation service provision.
- Protect sanitation workers and others who may engage in emptying on-site systems from occupational hazards through adequate health and safety standards and standard operating procedures.

3. Sustain the engagement of the health sector in sanitation through dedicated staffing and resourcing, and through action on sanitation within health services

- Review environmental health institutional hierarchy and staffing needs at all levels, and put in place a public sector service scheme, training programmes, and mechanisms for staff development and retention.
- Create senior posts with dedicated responsibility for sanitation.
- Build capacity of environmental health staff to fulfil health sector functions – contribution to sanitation coordination, health in sanitation policies, health protecting norms and standards, health surveillance and response, sanitation in health programme delivery, sanitation behaviour change, sanitation in healthcare facilities.
- Establish sanitation oversight, monitoring and enforcement mechanisms within the health system, including routine monitoring of sanitation in healthcare facilities.
- Gather and analyze relevant health and epidemiological data to identify risks and high priority areas for sanitation improvement and to support setting of targets, priority intervention areas and approaches and standards.
- Develop inspection and accreditation mechanisms to manage sanitation-related risks in other sectors (e.g. agriculture, environment, hospitality).

4. Undertake local level health-based risk assessment to prioritize improvements and manage system performance

- Define sanitation at sub-national level as a basic service for which local government is responsible and accountable.

- Establish local government coordination groups with senior representation from all relevant local government departments and implementation partners to align and coordinate sanitation activities.
- Define health-protecting technologies in local standards and guidelines and promote their use.
- Implement targeted and contextualized sanitation promotion through dedicated sanitation programmes addressing barriers to adoption and use to create toilet demand as a necessary precondition for toilet adoption and use.
- Design, implement manage and improve sanitation systems for the entire sanitation service chain to minimize health risks among users, workers and communities using sanitation safety planning principles.
- Allocate sufficient financial and human resources for long-term implementation.
- Establish a robust sanitation monitoring mechanism with public health oversight at the lowest administrative level strengthening existing structures and staff.
- Facilitate exchanges between local governments to disseminate good practices and promote peer competition on achievement of programme targets.

5. Enable marketing of sanitation services and develop sanitation services and business models

- Design the mix of sanitation services based on an assessment of local level housing and sanitary conditions, prioritizing institutionally and financially feasible interventions that address the greatest identified public health risks in the shortest time.
- Establish a sustained marketing effort for safe sanitation services to eliminate open defecation and unimproved toilets.
- Promote private sector service provision for those parts of the sanitation service chain with high customer benefit (e.g. toilet construction, and some safe emptying services), considering public-private partnership arrangements where appropriate.
- Use public funds to cover the affordability gap between minimum sanitation service standards and users' ability and willingness to pay, with specific measures to ensure that services also reach the poorest and most vulnerable people.
- Invest in safe and effective solutions for emptying on-site systems and treatment of faecal sludge from on-site or off-site systems.
- Introduce financial arrangements to facilitate large, infrequent user costs such as sewer connection and desludging fees, or facilities in rocky or flood prone areas in line with policies, legislation, regulations and standards that consider willingness and ability to pay.
- Acknowledge the informal sanitation service providers, recognizing that improved services will have to compete and that their experience is a valuable resource that should be utilized within the formal system.
- Build sustainable service provider capacity to meet national and local level targets and requirements of legislation, regulations and standards.
- Enhance the market for sanitation services through introduction of competition.
- Encourage innovation and experimentation accompanied by rigorous monitoring and evaluation of systems and proposed solutions.

Table 2.1 Evidence to recommendation table using the WHO-INTEGRATE framework (Rehfuess et al.)

Criteria	Guiding question	Rationale and evidence	Judgement
Balance of health benefits and harms	Does the balance between desirable and undesirable health effects favour the intervention or "business as usual"?	If the intervention is implemented as set out in these guidelines, undesirable effects are very unlikely. Desirable effects include reduced exposure to faecal pathogens, reduced incidence and prevalence of various infections and consequences of infection such as stunting, and positive influences on various dimensions of social and mental well-being such as privacy, dignity, safety and reduction in shame, anxiety, fear, assault, and embarrassment. If the intervention is not implemented, or not implemented as set out in these guidelines, undesirable effects may happen at each step of the sanitation service chain, such as increased exposure to excreta of users through open defecation or poor maintenance of toilet facilities; of the *wider community* through poor containment and conveyance of faecal sludge; and of *workers* through poor management practices. Inadequate shared and public toilets can also result in harmful effects on broader well-being, such as shame and anxiety, exposure of certain groups to other risks (for example, assault or harassment when using public or shared facilities), or reinforcing stigmatization of specific groups by targeting them, thereby compounding the likelihood of reversion to open defecation. Increased access to and use of toilets may still result in adverse public health impacts if poor quality of the toilet or poor sanitation service chain management results in discharge of untreated sludge into the environment in which people live and work.	☐ Favours "business as usual" ☐ Probably favours "business as usual" ☐ Does not favour either the intervention or "business as usual" ☐ Probably favours the intervention ☒ **Favours the intervention**
Human rights and socio cultural acceptability	Is the intervention in accordance with universal human rights standards and principles?	The intervention, taking into account availability, accessibility, quality, affordability and acceptability of safe sanitation services, is in accordance with the Human Right to Water and Sanitation, which obliges all UN Member States to consider all aspects of universal access to services. This includes increasing the number of people with access to at least minimum services, improvement in levels of services, and explicitly targeting poor, marginalised and disadvantaged people. It also contributes to the realization of the Human right to Health, and the achievement of Universal Health Coverage. Construction and management of sanitation services without due consideration of all human rights criteria can result in exclusion of marginalized groups on the basis of physical, cultural and gender discrimination.	☐ No ☐ Probably not ☐ Uncertain ☐ Probably yes ☒ **Yes**
	Is the intervention acceptable to key stakeholders?	If the intervention is implemented as set out in these guidelines, i.e. if it is designed and delivered in a way that responds to cultural, social and economic context, as well as the needs and preferences of individuals, households and communities, it is likely to be acceptable to all key stakeholders. If the intervention is not implemented as set out in these guidelines, acceptability of services may be reduced (e.g. inadequate privacy and safety of the toilet and inadequate provision for menstrual hygiene management for women and girls, or use of hardware or technologies such as pedestals and flushing options that do not meet user preferences), resulting in lack of uptake of services, lack of use (including reversion to open defecation), and lack of willingness to pay for higher quality services. Compliance with sanitation standards may result in additional economic burden on poor households, in terms of increased housing costs (including for construction of toilets, septic tanks etc. where households own their home, as well as possibly higher renting costs). This should be considered in intervention design and pricing structures for consumer services. Landlords and informal sanitation service providers may resist regulation and enforcement due to cost and inconvenience implications. Punitive measures for sanitation enforcement may be intrusive if these result in substantive inspection and penalties.	☐ No ☐ Probably not ☐ Uncertain ☒ **Probably yes** ☐ Yes

Criteria	Guiding question	Rationale and evidence	Judgement
Health equity, equality and non-discrimination	What would be the impact of the intervention on health equity, equality and non-discrimination?	The intervention has the potential to address health inequalities at various levels, including global (between countries), national (between geographic regions, urban/rural populations and income groups) and local (in terms of gender, age, social class and disability). The intervention, when applied at sufficiently large scale (such as entire communities) and resulting in increased access to and use of safe sanitation services, is particularly beneficial for poor and vulnerable groups, including women and children, who are more likely to be affected by excreta-related infections and subsequent health outcomes, and less likely to be able to afford the cost of treatment and other economic consequences of ill health and poor well-being. If delivered appropriately, the intervention ensures access to services in a way that enables improved social and economic inclusion. Safe sanitation services may not be affordable to poor and marginalized groups, and infrastructure may not be sufficiently accessible to all groups (such as children, people with disabilities and older people). The impact of the intervention on health equality and/or equity therefore depends on the way in which it is delivered, and whether all forms of poverty and marginalization have been adequately considered. Some forms of sanitation behaviour change interventions that encourage incremental increases in access based on household investment may increase health inequalities in the short-term. However, the availability of low-cost technologies, as well as shared and public facilities, potentially reduces cost to a sufficiently low level to allow affordability, while reducing the opportunity costs of not having access to a toilet (in terms of time, illness and other well-being aspects that affect economic productivity and poverty). Low-lying communities may be negatively affected by untreated wastewater and facial sludge discharges if toilets are not coupled with a safe service chain. No alternative to the intervention exists, a key principle that underpins the Human Right to Water and Sanitation.	☐ Increased ☐ Probably increased ☐ Neither increased nor decreased ☒ **Probably reduced** ☐ Reduced
Societal implications	Does the balance between desirable and undesirable societal implications favour the intervention or "business as usual"?	If the intervention is implemented as intended, ensuring non-exclusion from access to services, particularly of poor and marginalized individuals and groups, if infrastructure is constructed in a sustainable manner, and if toilets are connected to a safe sanitation system, undesirable societal or environmental implications are unlikely. In addition to the positive societal impact in the reduction of infections, the intervention potentially contributes to other social aspects such as poverty reduction and increased earnings in the medium to long term, education (through improvement of the schooling and teaching environment) and uptake of healthcare services (through improvement in healthcare settings). If not implemented as intended, undesirable implications may include discharge of excreta to the environment in a way that exposes the wider community to pathogens, and damages the ecosystems on which communities depend, e.g. in terms of drinking water, recreation and livelihoods.	☐ Favours "business as usual" ☐ Probably favours "business as usual" ☐ Does not favour either the intervention or "business as usual" ☒ **Probably favours the intervention** ☐ Favours the intervention

Criteria	Guiding question	Rationale and evidence	Judgement
Financial and economic considerations	What would be the impact of the intervention on financial and economic considerations?	Large (national) scale implementation of the intervention is likely to require significant government, corporate and household investment in capital and operational expenditure, including initial infrastructure construction and ongoing operation and maintenance. Further public spending will be required to meet the needs of sanitation and health systems, such as training, recruitment of environmental health staff (technical and managerial), monitoring systems, and development of behaviour change programmes. The impact on the economy will depend on the resources used for such investments. Substantial loans to government will result in interest implications, while substantial grants may have inflationary consequences. These costs should be considered in comparison with the likely benefits over the medium to long term. Every USD spent on sanitation yields cost savings in terms of reduced costs to the health system, increased available income for poor households over the longer term and therefore more spending power, and increased workforce productivity and efficiency that ultimately contribute to economic growth.	☐ Negative ☐ Probably negative ☐ Neither negative nor positive ☒ **Probably positive** ☐ Positive
Feasibility and health system considerations	Is the intervention feasible to implement?	The capacity to deliver universal safe toilet access and promote use varies significantly among and within countries. Efforts will be required to ensure a sufficient legal framework for sanitation, including coordination to address overlap and inconsistencies. Efforts to address the relatively low influence and resourcing of environmental health within health ministries are likely to be required in order to enhance health leadership and governance for sanitation. In many low- and middle-income contexts, significant investment will be required to increase the capacity of health authorities and other government departments to improve the demand for and supply of safe toilets. Delivery of sanitation behaviour change interventions through health programmes may impact on the workload of health workers (potential increase in terms of activities and supervisory responsibilities, and potential decrease in terms of treatment of infections as well as reliance on mass anthelminthic treatments). Substantial investment may be required in improving sanitation infrastructure in healthcare facilities at all levels of care, to enhance capacity for infection prevention and control in healthcare settings, to improve uptake of health care services, and to improve the working conditions of health care staff. Despite these challenges, experience from several LMICs shows that this is feasible if sanitation is politically prioritized and if resources are allocated rationally.	☐ No ☐ Probably not ☐ Uncertain ☒ **Probably yes** ☐ Yes

Chapter 2

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Chapter 3

SAFE SANITATION SYSTEMS

3.1 Introduction

Safe sanitation systems separate human excreta from human contact at all steps of the sanitation service chain carrying excreta from the toilet to its eventual safe use or disposal. Health hazards associated with the sanitation chain may be microbial (the focus of these guidelines), chemical or physical. The definition of health is not merely the absence of disease or infirmity but also a state of mental and social well-being. Therefore, it is important to acknowledge the importance of safe sanitation systems in addressing psychosocial hazards that impact on acceptability and use (i.e. aspects that impact on well-being, such as toilet privacy) at the toilet and containment steps.

A combination of technologies at each step of the chain can be used and, when linked and properly managed, can form a safe chain. The type of technology needed is highly context specific depending on local technical, economic and social factors, and should be considered in the context of the whole sanitation service chain, as well as a citywide perspective. The impact of climate change on the safety and sustainability of technologies and technologies' impacts on the national greenhouse gas emissions profile should be taken into account.

This chapter identifies the key technical and management features to ensure that users' well-being is improved and that all people's risk as a result of exposure to excreta is minimized for each step of the sanitation service chain, from the toilet, through containment – storage treatment on-site, conveyance, treatment and end use/disposal. A glossary is provided at the end of the document for technical terms.

The focus of these guidelines is on human excreta emanating from all sources, including households, commercial settings, institutions such as schools and healthcare facilities, as well as workplaces and public settings. The guidelines do not cover risks to humans from hazardous substances within industrial wastewater and sludges or their effect on wastewater and sludge treatment processes.

Box 3.1 International Organization for Standardization (ISO) standards relevant for sanitation services

- ISO/FDIS 30500 (2018): Non-sewered sanitation systems – Prefabricated integrated treatment units – General safety and performance requirements for design and testing
- ISO 24521 (2016): Activities relating to drinking water and wastewater services – Guidelines for the management of basic on-site domestic wastewater service
- ISO 24510 (2007) Activities relating to drinking water and wastewater services – Guidelines for the assessment and for the improvement of the service to users
- ISO 24511 (2007) Activities relating to drinking water and wastewater services – Guidelines for the management of wastewater utilities and for the assessment of wastewater services

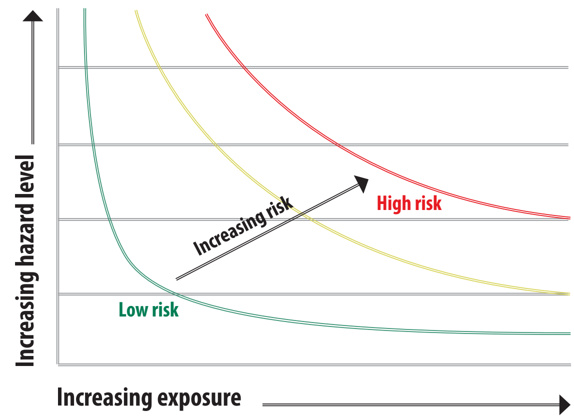
3.1.1 Hazard and exposure reduction

Box 3.2 Definitions (WHO, 2016)

Risk: The likelihood and consequences that something with a negative impact will occur.
Hazard: A biological, chemical or physical constituent that can cause harm to human health.
Hazardous event: any incident or situation that introduces or releases the hazard (i.e. faecal pathogens) to the environment in which people are living or working, or amplifies the concentration of the hazard in the environment in which people are living or working, or fails to remove the hazard from the human environment.

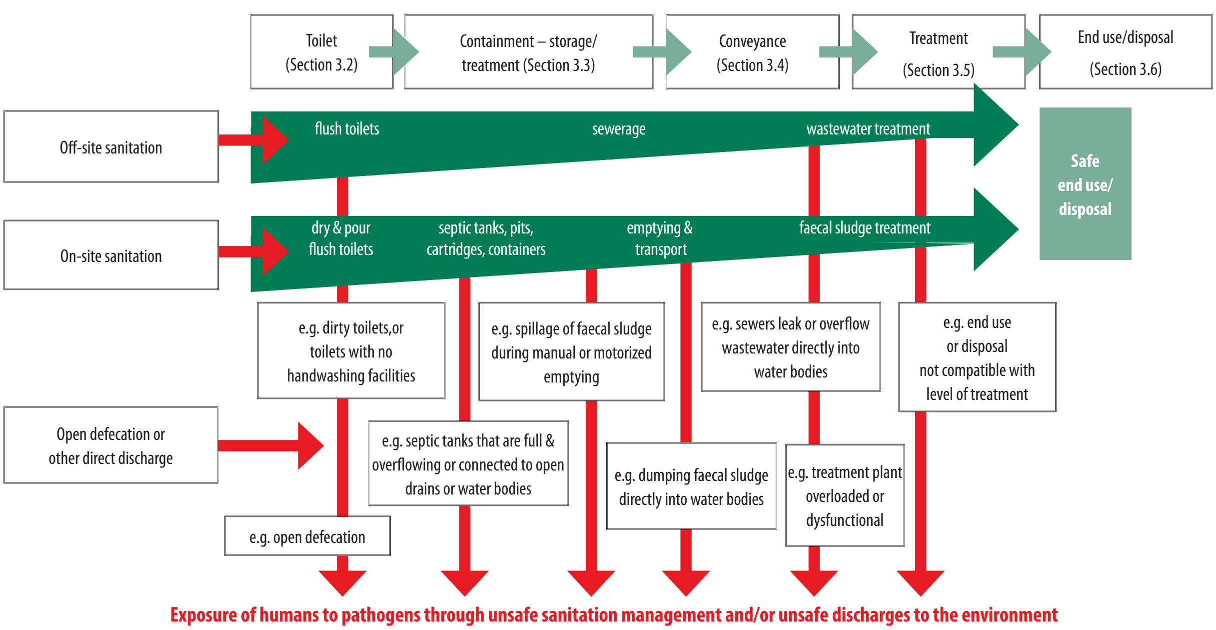
The risk of infection from exposure to faecal contamination is a combination of the likelihood of exposure to the hazard and the impact of the pathogen hazard itself on the person exposed. The hazard itself does not present a risk if there is no exposure to it. This relationship is shown in Figure 3.1. Reducing the risk from faecal contamination is therefore about reducing the faecal pathogen hazard level (i.e. concentration or numbers of the pathogen) and/or reducing exposure to the hazard of a potential human host (Mills et al., 2018; Robb et al., 2017).

Figure 3.1 Faecal contamination risk



To describe the principles of safe management it is necessary to identify the various hazardous events that could occur. Figure 3.2 shows an illustrative excreta flow diagram highlighting that exposure to

Figure 3.2 Excreta flow diagram showing examples of hazardous events at each step of the sanitation service chain (adapted from Peal et al., 2014)



faecal pathogens in excreta can potentially occur from hazardous events from every type of sanitation system and at each point on the sanitation service chain. The hazardous events caused by unsafe excreta management can lead to exposure.

Hazardous events, control measures and exposure groups

This chapter describes each step of the sanitation service chain and the control measures that could be used to reduce the risk of exposure.

Control measures are defined as any barrier or action that can be used to prevent or eliminate a sanitation-related hazardous event or reduce it to an acceptable level of risk.

The people most likely to be exposed belong within one of four risk groups:

- Sanitation system *users*: all people who use a toilet.
- Local *community*: people who live and/or work nearby (i.e. people who are not necessarily users of the sanitation system) and may be exposed.
- *Wider* community: the wider population (e.g. farmers, lower lying communities) who are exposed to (e.g. through recreation or flooding) or use sanitation end use products (e.g. compost, faecal sludge, wastewater) or consume products (e.g. fish, crops) that are produced using sanitation end use products intentionally or unintentionally, and may be exposed.
- 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.

3.1.2 Incremental control measures

In many countries, achieving safe sanitation systems will require stepwise implementation. Incremental control measures are highlighted for each step of the sanitation service chain below that can be later upgraded to safe sanitation when local technical, institutional, economic, social and financial capacity allows.

3.1.3 Sanitation system fact sheets

The sanitation system fact sheets in Annex 1 provide guidance on some of the most frequently-used sanitation systems. Each describes the applicability of the system in different contexts; design, operation and maintenance considerations; and mechanisms for protecting public health at each step of the sanitation service chain. Depending on the setting, various sanitation technology and infrastructure options can be designed, combined, operated and managed at different scales to form a functional service chain. Table 3.5 towards the end of this chapter provides a summary of the systems included in the fact sheets and their applicability in relation to physical and enabling factors.

3.2 Toilets

3.2.1 Definition

The term 'toilet' here refers to the user interface with the sanitation system, where excreta is captured, and can incorporate any type of toilet seat or latrine slab, pedestal, pan or urinal. There are several types of toilet, for example pour- and cistern-flush toilets, dry toilets and urine-diverting toilets.

The superstructure of the toilet may be a stand-alone structure, or the toilet may be located within a building (e.g. private house, a school, health care facility, work place or other public setting).

3.2.2 Safe management at the toilet step

The key principle for safe toilet management is that the design, construction, management and use is arranged so that users are safely separated from excreta, avoiding both active contact (e.g. from soiled surfaces) and passive contact (e.g. via flies or other vectors).

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Toilets should be maintained through cleaning (which removes any faecal material and pathogens), so that the risk for users is minimized. Those responsible for toilet cleaning and maintenance should do so using methods and equipment that protect them from the hazard.

The health of users extends beyond consideration of exposure to pathogens in excreta; these include issues related to accessibility, security, privacy and menstrual hygiene management. Consideration of these aspects is important to ensure the facility is suitable for the intended *users* with suitable operation and maintenance arrangements, so that they are less likely to revert to unsafe sanitation practices (e.g. open defecation). These aspects are discussed further in Chapter 5 on sanitation behaviour change.

Reducing risk at the toilet and encouraging use

In order to reduce the (a) likelihood of exposure; (b) the severity of any exposure to hazardous events; or (c) both likelihood and severity, as well as to encourage use, toilets must have a number of features (outlined below).

Design and construction

Toilets should be:

- Compatible with current and predicted future water availability for flushing (if required), cleaning and hand hygiene.
- Compatible with the subsequent containment, conveyance and treatment technologies (on-site or off-site) for safely managing excreta generated through toilet use.
- Suitable, private and safe to use for all intended users, taking into consideration their gender, age and physical mobility (e.g. disabled, sick etc.).

The slab (or pedestal) should be designed and constructed:

- From a durable material that can be cleaned easily (e.g. concrete, fibreglass, porcelain, stainless steel, durable plastic or smooth wood).
- So that the size and arrangement is appropriate for all intended users (including e.g. children and older people).
- So that stormwater is prevented from infiltrating the containment technology.
- For flush toilets – fitted with a water seal or trap-door to control odour and prevent rodents or insects entering the containment technology.
- For dry toilets – fitted with a removable, closely-fitted lid, to prevent rodents or insects entering the containment technology and, if fitted with a ventilation pipe, a corrosion resistant fly screen.

The superstructure should be designed and constructed so that it prevents intrusion of rainwater, stormwater, animals, rodents or insects. It should provide safety and privacy with doors that are lockable from the inside for public toilets, or toilets shared between households.

Culturally-appropriate anal cleansing materials should be available within the toilet (i.e. water supply and container for washing, or materials for wiping – with a disposal container where required) and accessible handwashing facilities with soap and water should be available nearby in a location that encourages use.

Operation and maintenance

- Cleanliness: the toilet and all surfaces of the room that it is in (e.g. bathroom, washroom, rest room, cubicle etc.) should be kept clean and free of excreta.
- Cleaning arrangements: Locally-available cleaning materials should be safely stored and used, and all people carrying out cleaning should observe safe working practices. Where the toilet is public or shared, a regular cleaning schedule should be in place, with provision made for supply of cleaning materials and personal protective equipment (PPE).
- Where dry toilets are used, a ready supply of ash, soil, lime or sawdust should be available within the facility, with which users can cover faeces after defecating. This helps to prevent flies and minimize odours.

Additional features

In addition to design, construction, operation and maintenance aspects there are several other features that respond to human rights criteria (see Box 1.1) and that affect toilet adoption and use and the likelihood that users will keep the facility clean (and not revert to open defecation). These include:

- Availability: There should be sufficient facilities that limit waiting to an acceptable length of time that does not discourage use or cause inconvenience, including in households, health facilities, schools, work places and public places.
- Accessibility: The facility should be accessible at all times for all intended users, taking into consideration age, gender and disabilities of users. Where toilets are sex separated, users should be able to access the toilet matching their gender identity.
- Acceptability: The superstructure should provide privacy and safety for the user, for example through provision of light and a door lockable from the inside; this is particularly important where the toilet is shared or public or in a school, health care facility or workplace. Facilities for safe menstrual hygiene management should be provided, such as a covered container for disposal of menstrual hygiene products. Where the toilet is shared or public, the container should be sized according to the expected usage, with an emptying and safe disposal arrangement and schedule. Used menstrual hygiene products should not be flushed down- or disposed into the toilet.

Aspects related to quality are covered in the above section on reducing the likelihood or severity of hazardous events at the toilet and encouraging use.

In contrast, examples of toilets that do not reduce the likelihood or severity of hazardous events include:

- Toilets that are not well constructed and/or made of a non-durable material that prevents cleaning of the slab (or pedestal).
- Toilets that are not kept clean and where excreta remain on the toilet and/or surfaces of the room housing the toilet.
- Toilets where no anal cleansing products, and/or handwashing facilities and/or facilities for disposal of menstrual hygiene products are available.
- Toilets that are kept locked for long periods of the day or night, and/or do not offer sufficient security and/or privacy.

Toilets that do not meet safety, comfort and cleanliness criteria may contribute to users resorting to open urination and defecation.

Incremental control measures

This section highlights measures that can be considered to overcome specific contextual issues such as poverty, availability of resources and population density. 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 allow the slab to be cleaned more effectively and therefore limit exposure; however, it will not be durable and may need replacing before the pit has filled.

Shared or public toilets

Wherever possible, each household should use and manage their own toilet, which is not shared with another family or other users. However, there are contexts where this is not practical, such as:

- in dense urban settlements where there may be issues relating to land tenure and/or land availability for the construction of individual household toilets;
- in emergency situations where circumstances dictate that the construction of individual toilets is not feasible.

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Where these situations are encountered, *shared* or public toilets are a possible incremental control measure.

A single toilet *shared* between two or more households or a public toilet can provide a satisfactory solution provided each member of the households has equal and ready access to the facility and that the toilet is kept clean.

All shared or public toilets should have:

- a safe location and access route;
- doors that can be locked from the inside, and lights;
- handwashing facilities with water supply and soap; and
- menstrual hygiene management facilities;
- separate cubicles for men and women, or gender-neutral cubicles that include handwashing and menstrual hygiene management facilities
- suitable modifications for all users e.g. an access ramp and handrails for people with disabilities;
- A management system in place to operate and maintain all the facilities provided.

Shared and public toilets may include shower and laundry facilities. A well-run shared or public toilet can provide a focal point or meeting place for the local population, which can indirectly benefit the users.

Management and maintenance of a public toilet is potentially more challenging than management of a shared, especially in popular or busy locations, where the high use and diffused responsibility means that more frequent cleaning is required to maintain each toilet. If users are charged fees, these should be affordable for all to ensure that it does not limit access to the facilities, which would potentially serve to encourage open urination and defecation.

3.3 Containment – storage/treatment

3.3.1 Definition

The containment step is only relevant to non-sewered sanitation systems and refers to the container, usually located below ground level, to which the toilet is connected. These include containers that are designed for either:

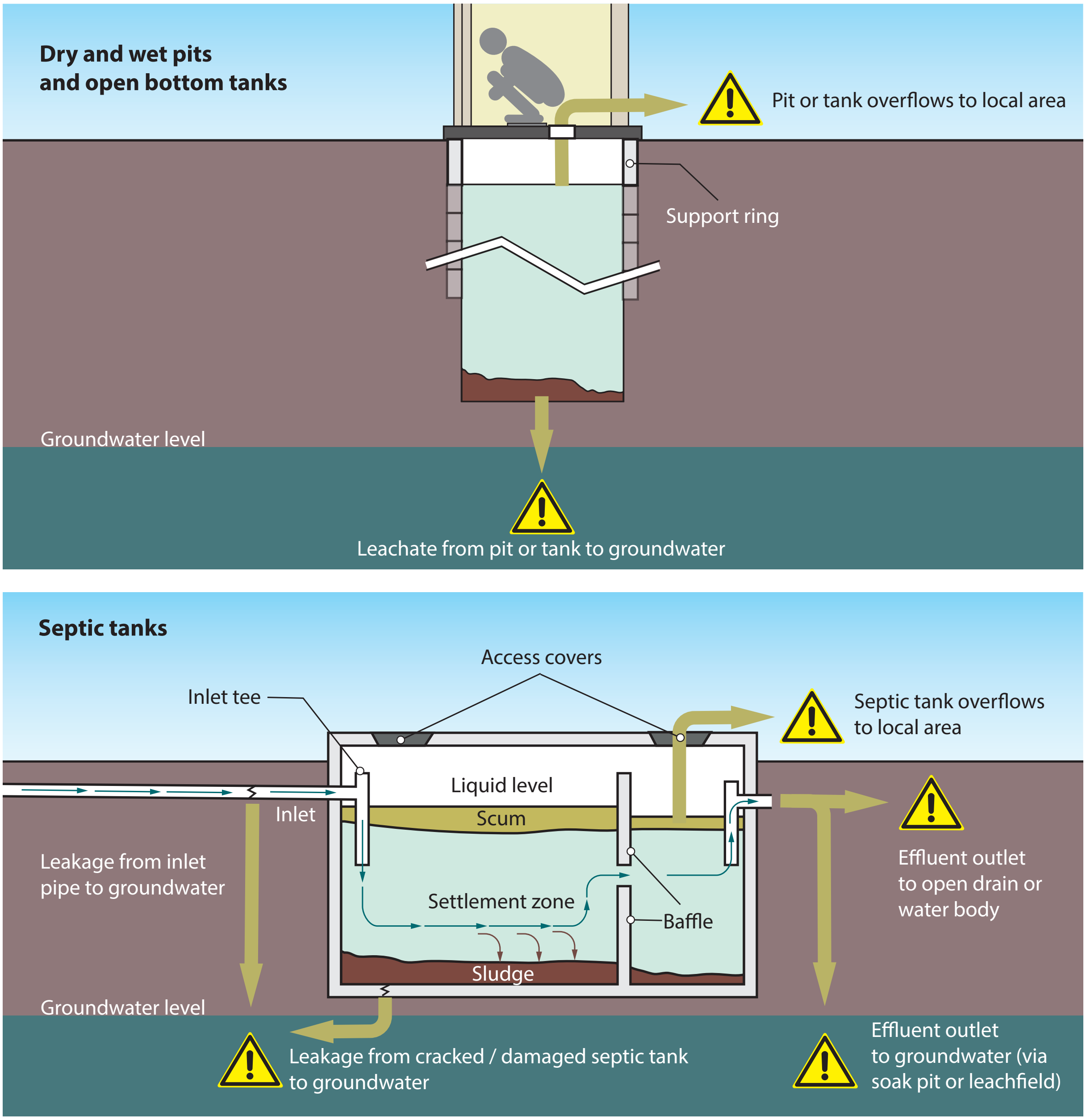
- containment, storage and treatment of faecal sludge and effluent (e.g. septic tanks, dry- and wet-pit latrines, composting toilets, dehydration vaults, urine storage tanks etc.); or
- containment and storage (without treatment) of faecal sludge and wastewater (e.g. fully lined tanks, container-based sanitation).

3.3.2 Safe management at the containment – storage/treatment step

The key principle related to this step is that the products generated from the toilet are retained within the containment technology and/or discharged to the local environment in a manner that does not expose anyone to the hazard.

Faecal sludge, for example, should be contained in an impermeable technology (such as a septic tank) or in a permeable technology such as a wet-pit that leach directly into the subsoil. In either case sludge should not enter the environment where it could directly expose *users* and the local *community* to faecal pathogens. Liquid effluent from an impermeable container should discharge to a sewer or subsoil structures via a soak pit or leach field or should be fully contained for later conveyance. It should not be discharged to an open drain or water body where, through contact or consumption, it could result in exposure of the *local community* and/or *wider community* to faecal pathogens.

Figure 3.3 **Hazardous events for permeable and impermeable containment – storage/treatment technologies***



* It should be noted that most of the hazards associated with a septic tank are also associated with non-engineered tanks of various types.

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Where leachate from permeable technologies or effluent from impermeable technologies leaches into subsoil structures, there is a risk that groundwater and nearby surface water could be polluted, potentially contaminating local water sources used for drinking and domestic tasks (e.g. dish washing). If groundwater is not used for domestic purposes and other safe drinking-water sources are available, then the risk from groundwater will be lower but may still pose a risk if groundwater is occasionally used (e.g. when the safe source is unavailable or unaffordable).

Where groundwater is used for drinking, a risk assessment should take the following factors into account (Schmoll et al., 2006):

- the type of containment technology or technologies in the area and degree of pathogen removal;
- hydraulic load from the container(s) on groundwater;
- depth to groundwater table and soil/sub soil type;
- the horizontal and vertical distance from the drinking-water source technology to the containment technology or technologies in the areas; and
- the level of treatment (if any) applied to the contaminated water before use.

As a general rule and without the risk assessment outlined above, in order to reduce the risk from contamination, the bottom of permeable containers and soak pit or leach fields should be no less than 1.5 m to 2.0 m above the water table at its highest level during the year, permeable containers and leach fields should be located down gradient, and at least 15 m horizontal distance from any drinking-water source (Banks et al., 2002; Graham & Polizzotto, 2013; Schmoll et al., 2006). If these distances cannot be achieved due to population density or geographic conditions, alternative designs (e.g. elevated pits) should be considered. Figure 3.3 shows the possible hazardous events for permeable and impermeable containment technologies.

Reducing risk at the containment storage/treatment step

Several design and construction, and operation and maintenance aspects need to be considered to ensure safe containment and on-site treatment.

Design and construction

The containment technology should be appropriate for the local context, taking into consideration:

- the type and frequency of and accessibility for any subsequent emptying (i.e. conveyance – Section 3.4);
- subsequent treatment technologies (if any) (section 3.5);
- soil and sub-soil type;
- density of population and other containment technologies;
- groundwater table and local drinking-water sources used;
- potential for flooding;
- the toilet it is connected to; and
- number of users and type of input products (e.g. faeces, urine, greywater and flushing water, personal hygiene and anal cleaning products).

Where the toilet is connected to a:

- Septic tank: this should be functioning correctly, sealed and impermeable, with two chambers and the effluent outlet discharging to a soak pit, leach field or piped sewer (solids-free sewers are sufficient when the connections are via septic tanks).
- Fully lined tank: this should have no effluent outlet and therefore frequent (and likely costly) emptying or container exchange is needed (e.g. container-based sanitation service models).
- Pit latrine or open-bottomed tank: this should be functioning correctly through percolation to soil sub-structures.

On-site treatment

Table 3.1 shows typical containment technologies and their performance in terms of pathogen reduction level (PRL). The table highlights that the products

Table 3.1 Treatment performance of containment technologies

Toilet and containment technology	Treatment objectives	Pathogen reduction mechanism	Pathogen Reduction Level*	Treatment products and pathogen level**
Flush toilet with septic tank connected to a soak pit or leach field	Biochemical oxygen demand (BOD) reduction (small) Stabilization	Storage Adsorption (in soak pit)	Low	Liquid sludge with high pathogens. Effluent has high pathogens, but these are adsorbed aerobically in the soak pit or leach field.
Flush toilet with single pit or open-bottomed tank	Stabilization/nutrient management	Adsorption	Low	Liquid sludge with high pathogens. Liquid (leachate) high in pathogens is adsorbed aerobically into soil. Pathogen removal dependant on soil conditions.
Dry toilet with single pit (abandoned when full)	Pathogen reduction Stabilization/nutrient management.	Storage NB: single pits should not be emptied by hand	High	Sludge stabilized into humus with low pathogens.
Flush toilet with twin pits for alternating use	Pathogen reduction Stabilization/nutrient management	Storage (At least 2 years) Adsorption	High (except Ascaris eggs)	Sludge in pit 'at rest' stabilizes into a humus with low pathogens. Liquid (leachate) is adsorbed aerobically into soil.
Dry toilet with twin pits (fossa alterna)	Pathogen reduction Stabilization	Storage (at least 2 years)	High (except Ascaris eggs)	Sludge in pit 'at rest' stabilizes aerobically into a humus with low pathogens.
Composting toilet	Pathogen reduction Stabilization/nutrient management	Temperature Storage	Sludge – Med Leachate – Low	Dewatered stabilized sludge (compost) with medium amount of pathogens. Leachate with high pathogens.

Sources: Adapted from WHO (2006); Tilley et al. (2014); Strande et al. (2014).
* PRL Pathogen reduction level (log_{10} reduction) for well-designed, well-functioning systems: L - Low = <1 log_{10}; M - Medium = 1 to 2 log_{10}; H - High = >2 log_{10}. PRL for bacteria used by way of illustration, and may not apply to viruses, protozoa and helminths
** Pathogen level (pathogens per litre): Low = <2 log_{10}; Medium = 2 to 4 log_{10}; High = >4 log_{10}

from some systems, such as alternating twin pits and compost toilets, can produce a stabilized sludge which is safe to handle and use as a soil conditioner, if operated properly (which can be hard to do in practice) and provided that the contents remain dry. In contrast, sludge emptied from a septic tank may have a high pathogen level, depending on the amount of time it has been stored, and requires further treatment before use (section 3.5). Likewise, the effluent from any septic tank should either discharge to a soak pit (or leach field) where it can be adsorbed aerobically or conveyed in a piped or solids-free sewer to a treatment plant. Conveyance and off-site treatment of both sludges and wastewater are explained in sections 3.4. and 3.5.

Operation and maintenance

- Where dehydration vaults or composting chambers are used (i.e., dry twin pit toilets, urine diversion toilets, container-based sanitation), a small amount of ash, lime, dry soil or biomass waste (e.g. sawdust, shredded bagasse, crushed peanut shells) should be used to cover faeces after each use. This helps to prevent flies, minimize odours and encourage drying and decomposition.
- Any containment technology should be emptied (or closed and sealed – see Section 3.6 on end use/disposal) before there is a risk that the contents flow into the local environment. As a guide, this should be done when the distance from the

underside of the top of the container to the surface of the faecal sludge (or supernatant) is around 0.5 metres (Franceys, Pickford & Reed, 1992; ARGOSS, 2001). Sludge accumulation rates vary widely by setting, habits and technology (Strande et al, 2014).

- Twin pit toilets should be carefully managed, ensuring that only one pit is used consistently until it is full, and then sealed off and stored for at least two years, while using the other pit.
- When full, some containment technologies are not emptied at the household level but the whole container has to be removed from the premises and transported away. In exchange for the full container, the household receives a clean, empty container. This approach is known as container-based sanitation.
- Full consideration of how emptying and transport operations should be managed for all containment technologies is discussed in the next step – conveyance.
- Effluent discharge pipes (if any) should be kept clear of blockages.

In contrast, examples of containment technologies that do not reduce the likelihood or severity of exposure to hazardous events include:

- Any containment technology (septic tank, fully lined tank, pit latrine, open-bottomed tank etc.) that has an effluent outlet discharging to an open drain, a water body or to open ground.
- Any containment technology that is poorly designed or constructed and where there is a high likelihood that the leachate is contaminating groundwater, local drinking-water sources or drinking-water within underground pipes.
- Where bucket latrines are provided. This containment technology does not separate the user or workers from excreta.
- Where hanging toilets are provided, for instance where a toilet is provided but there is no containment technology or connection to a sewer, and instead the toilet discharges direct to a water body or the ground. This arrangement poses a risk to the *local community* and *wider community*.
- Operation and maintenance procedures that result in:
  - Operation inconsistent with the technology design (e.g. twin pits used in tandem rather than alternating)
  - any effluent discharge pipe becoming blocked, causing the faecal sludge and/or effluent to overflow into the toilet and/or into water bodies or on to open ground; or
  - any containment technology that is either physically not emptiable, not emptied when full (for technologies that require periodic emptying) or not closed and sealed, causing the faecal sludge and/or effluent to overflow into the toilet and/or into water bodies or onto open ground.

Incremental control measures

There are no incremental control measures for containment.

In some locations, where containment technologies discharge to open drains, the drains are covered or partially covered with concrete or stone slabs. However, this is not considered to be a suitable incremental control measure. The impermeable covering reduces some of the risks from faecal pathogens in the effluent for the local community. However, open roadside-drainage is provided for stormwater management, and covering the drain will not facilitate cleaning which, if they become blocked, can cause flooding during periods of heavy rainfall – leading to increased exposure to wastewater (and therefore pathogens) for the local community and wider community. The practice is impractical and/or costly where the drain dimensions are large.

3.4 Conveyance

3.4.1 Definition

Conveyance refers to the deliberate movement of wastewater or faecal sludge from a containment technology to off-site treatment, and/or end use/disposal. Conveyance systems can be sewer-based or based on manual or motorized emptying and transport.

Sewer-based systems

Sewer-based systems comprise networks of underground pipes. Types of sewerage include (Tilley et al., 2014):

- conventional gravity sewers: convey blackwater from toilets and greywater along with, in many cases, industrial effluents and stormwater through large diameter pipes to a treatment facility, using gravity (and pumps when necessary)
- simplified sewers: a lower cost design installed using smaller pipes at a lower depth and shallower gradient than conventional gravity sewers.
- solids-free sewers: similar design to simplified sewers but including pre-treatment of sludge to remove solids.

Simplified and solids-free sewers can be implemented as condominial sewerage schemes that incorporate user and authority networking and consultation.

Manual and motorized emptying and transport systems

Manual and motorized emptying and transport refers to the different ways by which faecal sludge can be removed from the facility location.

Manual emptying of pits, vaults and tanks can be done in one of two ways:

- using buckets and shovels; or
- using a portable, manually operated sludge pump (while this may be mechanized, it still requires manual/physical handling)

Both manual and motorized emptying may carry risk of possible contact with the faecal material and in some cases motorized emptying needs to be combined with manual emptying to remove the densest material. Some containment technologies can only be emptied manually (e.g. fossa alterna or dehydration vaults). These technologies are emptied most commonly with a shovel because the material is solid and cannot be removed with a vacuum or a pump. The emptied faecal sludge is collected in barrels or bags or put into a cart and transported away from the site.

Motorized emptying and transport (also known as mechanical emptying and transport) refers to the use of any vehicle or device equipped with a motorized pump and a storage tank for emptying and transporting faecal sludge. People are required to operate the pump and manoeuvre the hose, but the faecal sludge is not manually lifted or transported. Wet systems such as septic tanks and fully lined tanks are commonly emptied using motorized emptying and transport.

Containers used with container-based sanitation are not emptied at the household level; instead, the sealed container and its contents are manually removed from the premises and should be conveyed to a treatment facility. Unlike bucket toilets, sealed containers removed from the premises prevent contact by users and workers with fresh faeces.

3.4.2 Safe conveyance

The key principle for safe conveyance is limiting exposure of the workers carrying out operation and maintenance, the community living and working in the vicinity of the work, and wider community who could each be exposed to pathogens through ingestion and inhalation of faecal pathogens while at home or work, in recreational and drinking-water supply and food supply chains.

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Sewers

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 removing 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. Where there is concern that groundwater or piped water quality is being compromised, risk assessment should be based on (Schmoll et al., 2006):

- the frequency of sewer breaks;
- age and method of construction of the sewer;
- depth of the sewer relative to water supply pipes;
- grading of material surrounding the pipe; and
- groundwater level.

Active monitoring programmes (e.g. the use of sewer inspection cameras) may assist in identifying the extent and nature of contamination from sewers.

Manual and motorized emptying and transport

Both manual and motorized technologies require workers (service providers, emptiers, desludgers and exhausters) to handle tools and equipment that have contact with faecal sludges (including the liquid supernatant or effluent if any) Workers entering pits should be avoided due to the risk of injury or death from pits collapsing or inhalation of toxic gases. Emptying may put the users and community at unacceptable risks resulting from exposure to spillage as the work proceeds. The key principle for safe emptying and transport is therefore limiting the exposure of these groups to the hazardous faecal sludge.

The level of risk depends on the type and quantity of faecal sludge being emptied. For instance, fresh faecal sludge emptied from a septic tank connected to a busy public toilet is more hazardous to human health than the faecal sludge that has been accumulating slowly in a household's dry pit latrine for two years or more because there will have been some pathogen die off in the older accumulated sludge.

From a public health perspective, manual emptying carries a greater risk than motorized emptying, as there is greater likelihood of workers having contact with the faecal sludge. Manual emptying is stigmatized, low status work affecting the personal and social well-being of sanitation workers. Therefore, wherever possible motorized emptying and transport should be prioritized over manual emptying and transport.

Reducing risk at the conveyance step

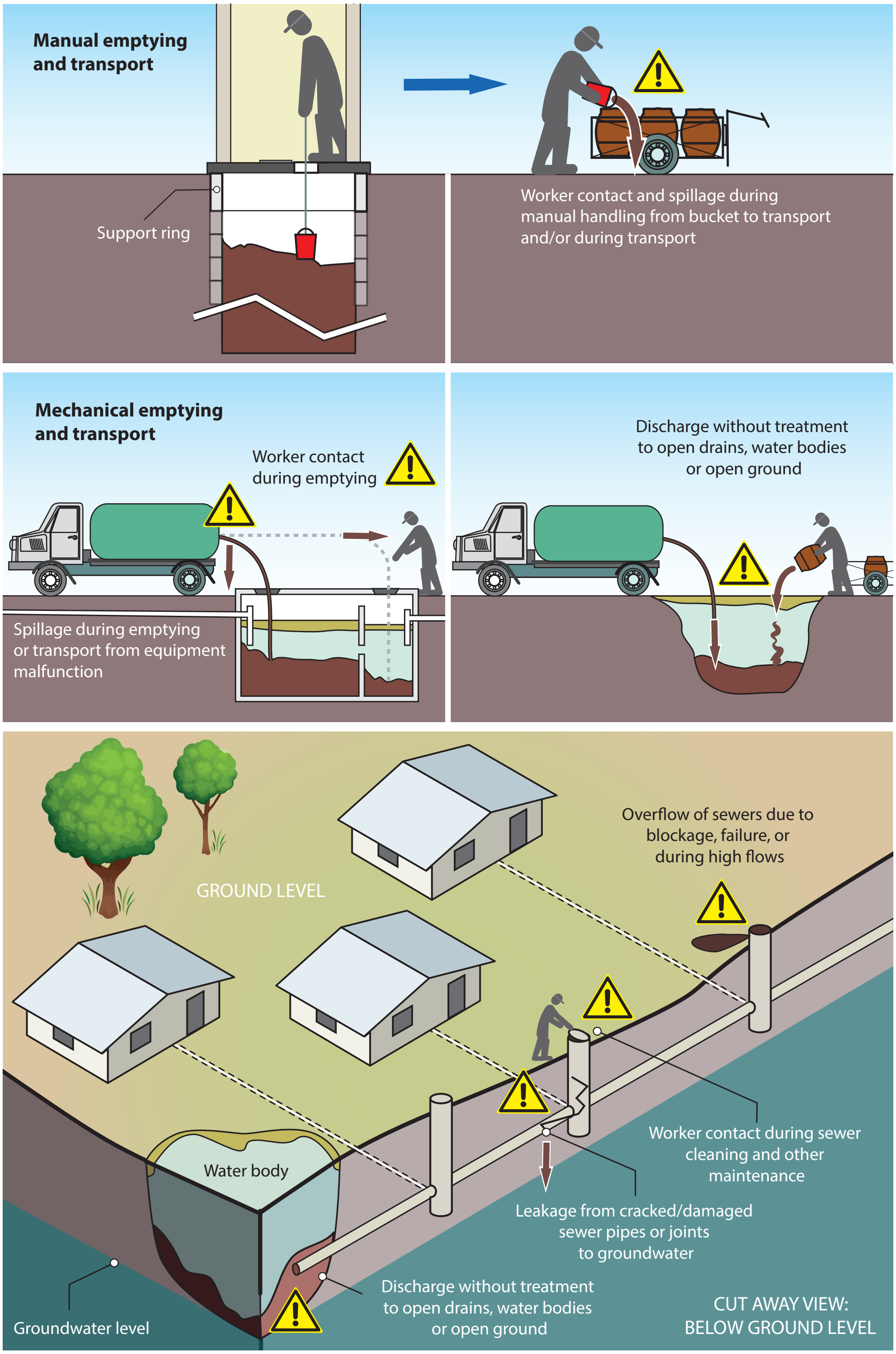
Design and construction of the conveyance system should be:

- compatible with the containment technology;
- compatible with the characteristics of the contents to be emptied;
- compatible with the following treatment and end use/disposal technologies; and
- appropriate for the local context taking into consideration the hazardous events identified in Figure 3.4 and, in particular, minimizing the need for manual handling of faecal sludge by sanitation workers.

Operation and maintenance considerations include:

- All workers should be trained on the risks of working with sanitation systems, including handling wastewater and/or faecal sludge, and be equipped to follow standard operating procedures.
- All workers should consistently and correctly wear PPE – gloves, masks, hats, full overalls and enclosed waterproof footwear – particularly where manual sewer inspection and cleaning or manual emptying is required.

Figure 3.4 Hazardous events for conveyance technologies



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- To avoid asphyxiation, adequate ventilation should occur before entering any confined space (containment or sewers), using ventilation equipment when necessary. Entering confirmed space should never be done alone.
- Workers should avoid entering the pit either by using equipment that avoids the need to enter or by only partially emptying the pit.
- Only dedicated tools and equipment should be used, which are fit for purpose (e.g. long handled shovels and long suction hoses) and cleaned with water between uses. Wash water should be directed into the containment technology.
- All workers should wash thoroughly with soap immediately after coming into contact with hazardous wastewater and/or faecal sludge.
- All clothing (both PPE and under layers) should be laundered daily and all rubber boots and gloves should be cleaned with water. Wash water should be directed into the containment technology.
- Spillage should be minimized, and spills should be contained and cleaned up when they do occur. For example, having completed the emptying of a containment technology any affected property in the immediate vicinity of the event, should be washed down/cleaned with water.
- All workers should be provided with regular health checks, receive medical advice and treatment (e.g. deworming), and be adequately vaccinated against potentially relevant infections (such as tetanus, polio, typhoid fever, hepatitis A and B (CDC, 2015), depending on the epidemiological context).

Examples of conveyance methods that do not reduce the likelihood or severity of exposure include:

- Any untreated wastewater in sewerage, which is not delivered to treatment plants but is released to open drains, water bodies or to the ground. Examples include sewer blockages or pump failures that cause wastewater overflows into surface waters and sewer defects that cause infiltration to overload the system, or exfiltration to contaminate groundwater and/or local water supply pipelines.
- Any untreated faecal sludge transported manually or mechanically, which is not delivered to treatment plants but discharged elsewhere. For instance, where untreated faecal sludge is discharged into open drains, nearby streams or rivers, or where it is used as a soil conditioner.
- Use of flooding out (or gravitational emptying) of pits. This is where pits are emptied by washing the contents out through a pipe inserted into the pit. The pipe is connected to a lower lying drain, water body or hole dug to receive the faecal sludge.
- Any manual or motorized transport carrying faecal sludge which, while being driven or operated, causes the faecal sludge to leak or spill onto other road users. For instance, faecal sludge from septic tanks carried in a tractor-pulled trailer that leaks out of the trailer onto the road.

Incremental control measures

Minimizing risks from manual emptying

While motorized emptying and transport is preferred for conveying faecal sludge from containment technologies, there are context specific reasons why manual emptying is used in some settings. These include:

- Availability of motorized emptying services: In many locations, despite high demand, few public or private motorized emptying service providers are present.
- Access to the containment technologies: Large vacuum trucks are unsuitable for emptying containers in dense, urban settlements that are hard to access. Often these facilities can only be emptied using a combination of portable pumps, shovels and manual transport.
- Informality: In most locations manual emptying remains an informal and low-cost service. Informal services are perpetuated though lack of regulation of service quality or worker protection, and customer demand for comparatively low-cost

services. However, informal services are not always satisfactory for the household, or from a public health perspective.
- Pumpability: Relatively fresh, wet sludge can be pumped with a vacuum truck, while drier, typically older faecal sludge usually requires removal with a shovel. The presence of solid waste in containers also reduces pumpability.
- Availability and accessibility of treatment plants: Where treatment plants are available and are designed to receive faecal sludge, the sites are often located remotely from populations, with attendant costs that lead to high fees. Households may resort to manual emptying that is not always done safely. In this circumstance households should either bury and cover faecal sludge nearby or construct a new latrine.
- Acceptability: In contexts where discussion of excreta or how to manage it is taboo, emptying at night when the activities are perceived to be hidden from view is often favoured and manual rather than motorized emptying is a discrete option in these circumstances. Working in the dark can be difficult and dangerous.

Where these conditions prevail, manual emptying of containment technologies may be the only viable solution. Nevertheless, manual emptying should be minimized; for instance, motorized and/or manual pumps should be used to remove as much of the contents as possible before using shovels and buckets to empty the remainder. Where manual emptying is used, the exposure control measures in the section on reducing the risk of exposure at the conveyance step should be followed. However, where manual emptying is informal, these measures may be hard to implement.

Transfer stations and sewer discharge stations

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. A vacuum truck empties transfer stations when they are full and transports the faecal sludge to a treatment plant. Sewer discharge stations are connected to a conventional gravity sewer main. Faecal sludge emptied into the discharge station is released into an adjoining sewer main either directly or preferably at timed intervals (e.g. by pumping) to optimize the performance of the sewer and of the treatment plant and/or reduce peak loads.

Transfer stations and sewer discharge stations are a good choice for use in urban areas where treatment plants for faecal sludge distant. Establishing multiple stations may reduce transport costs and help to reduce faecal sludge dumping, especially where manual emptying and transport is common, and the treatment plant is remote. Siting and land requirement for transfer stations may also be less onerous than for treatment plants.

Sewer discharge stations need to be properly designed and/or operated, especially if retro-fitted to an existing wastewater system. If thick faecal sludge is discharged into a sewer that is not designed to receive such sludge, it may cause a blockage and result in the sewer overflowing or, if the associated treatment works is not designed to receive concentrated faecal sludge, it may cause a failure of the treatment process. Both problems can be expensive to rectify.

Combined sewer overflows

A combined sewer system collects any combination of rainwater, stormwater, domestic wastewater and industrial wastewater into one sewer. Under normal (dry) weather conditions, the combined system transports all collected wastewater to a wastewater treatment plant, before discharge for end use/disposal. However, under high (peak) flow conditions, for instance as a result of heavy rainfall or snow melt, the volume of wastewater can exceed the capacity of the treatment plant. When this occurs, untreated stormwater and wastewater discharge without treatment to nearby streams, rivers and other water

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bodies. These events are referred to as combined sewer overflows (CSOs) and, if the contents of the combined sewer include untreated domestic wastewater, can result in high pathogen loads in the receiving waters (US EPA, 2004), with a corresponding high risk to wider community. Increased intensity of rainfall associated with climate change is likely to increase the frequency and volume of CSOs.

Due to the high risk as a result of exposure to pathogens caused by CSOs, combined sewers are not considered to provide safe sanitation. However, in many locations worldwide, combined sewers continue to operate. In these situations, it is advised that any combined sewer system be considered as an incremental control measure and should be combined with other measures to prevent exposure (e.g. public awareness or overflows and temporary closure of contaminated bathing site) during CSO events. In preference, context specific schemes for retention and infiltration or discharge of stormwater and/or a separate drainage system for stormwater should be provided.

3.5 Treatment

3.5.1 Definition

Treatment refers to the process(es) that changes the physical, chemical and biological characteristics or composition of faecal sludge or wastewater so that it is of a quality that is fit for purpose for the intended next use or disposal (Blockley, 2005; Strande et al., 2014) taking into account additional barriers in place at the end use/disposal step.

Treatment can be sub-divided into three groups:

- those comprising technologies for containment and storage/treatment of wastewater and faecal sludge on-site (Section 3.3);
- those comprising technologies for the treatment of wastewater (containing one or more of blackwater, brownwater, greywater or effluent) treated off-site; and
- those comprising technologies for the treatment of sludge off-site.

3.5.2 Safe treatment

To safeguard public health, it is imperative to design and operate the facility for a specific end use/disposal objective. This is the key principle at the treatment step. For instance, where effluents are to be used for irrigation or discharged into water bodies used for drinking or recreation, or where sludge is to be used as a soil conditioner for crop production, the treatment process should be designed on the basis of pathogen removal, reduction or inactivation. With the hazard eliminated or reduced to an acceptable level, the risk to wider community exposed to the hazard is also reduced. The risk level is dependent on the likely exposure of humans (i.e. use by consumers) to the pathogens in the effluent or sludges.

In general, a treatment plant with a good pathogen removal performance will also have a good physical and chemical removal performance but the converse is not necessarily true (Cairncross & Feachem, 2018). A focus on the pathogen removal (reduction or inactivation) is therefore advised during treatment process design. However, as well as an understanding of the required treatment effectiveness and effluent or sludge usage downstream, there are many issues to consider in selection of a treatment process (for further guidance see Strande et al., 2014; Metcalfe & Eddy, 2014), including:

- the predicted inflow and characteristics of the influent or faecal sludge;
- available land;
- available energy sources;
- available human resource capacity;
- location of population centres;
- topography;
- soil characteristics;
- water table;
- local climate and prevailing winds;
- seasonal and climatic variations;

- overall capital cost; and
- likely operation and maintenance costs.

Workers' health is also important, as people operating and maintaining treatment technologies are at risk from exposure to hazardous wastewater and faecal sludge. The people they regularly interact will (e.g. their families and co-workers) may also be indirectly at increased risk. Therefore, all workers should be trained in the correct use of all tools and equipment they operate, wear PPE and follow SOPs. The level of exposure is influenced by the design and construction of the treatment technologies and, where more than one technology is used, their configuration. For instance, to avoid manual handling, faecal sludge and wastewater flow should minimise the production of aerosols flow by gravity, be pumped, or moved mechanically between technologies.

Liquid effluent and sludges from treatment

The output from wastewater treatment and from faecal sludge treatment processes consists of both liquid effluent and solid sludge. The characteristics of each of these fractions will vary, depending on the source, process used and other factors. However, a key principle for safe management is that, regardless of the source (e.g. wastewater from sewer-based technologies or faecal sludge from on-site sanitation), both fractions may require further treatment before end use/disposal. For example, when wastewater is treated in a waste stabilization pond the sludge that settles in the bottom of the anaerobic and facultative ponds requires not only periodic removal but, depending on the intended end use/disposal, it may also require further treatment. Similarly, where faecal sludge treatment generates a liquid effluent, for instance from unplanted drying beds, it typically requires further treatment before its intended end use/disposal.

Established treatment technologies

Table 3.2 shows the established off-site technologies commonly used for treatment of wastewater, which can also be applied to treat the liquid effluent produced from faecal sludge treatment. Table 3.3 shows the established technologies commonly used for treatment of faecal sludge and these can be applied to treat the wastewater sludge produced from wastewater treatment.

For each technology, the treatment objectives, pathogen reduction mechanisms, likely pathogen reduction level (PRL) and output treatment products are given. The tables highlight the wide range of treatment objectives (from suspended solid reduction and dewatering to nutrient management and pathogen inactivation) and the treatment products produced. For each treatment product produced, an estimate of the likely pathogen level is also given.

The listed processes can be applied at different scales, from large centralised plants for an urban area to smaller decentralised units serving a district, neighbourhood or institution, although the characteristics of each technology influences its suitability for these different settings.

Wastewater treatment processes

The established wastewater treatment technologies in Table 3.2 are grouped under two categories: high flow rate technologies, and low flow rate technologies, which are all biological processes. The high flow rate processes are mostly engineered structures with short retention times. The technologies are listed as either primary, secondary or tertiary treatment technologies. Typically, the processes are combined in series, with a primary treatment step to settle solids followed by a secondary treatment step to biodegrade organic substances and may include tertiary technologies for the removal of specific contaminants (e.g. nutrient removal, filtration, ultrafiltration or disinfection for removal of pathogens). When tertiary treatment technologies are used, the overall wastewater treatment process is generally described as "advanced wastewater treatment."

Table 3.2 Established wastewater treatment technologies

Treatment process	Level	Treatment objectives	Pathogen reduction measures	PRL*	Treatment products & pathogen level**
		Low flow rate			
Waste stabilization ponds	NA	BOD reduction Nutrient management Pathogen reduction	Aerobic ponds (maturation) Ultraviolet radiation	H	Liquid sludge with low pathogens Effluent with low pathogens
Constructed wetlands	Secondary or Tertiary	BOD reduction Suspended solid removal Nutrient management Pathogen reduction	Natural decay Predation from higher organisms Sedimentation UV radiation	M	Plants – no pathogens Effluent with medium pathogens
		High flow rate			
Primary sedimentation	Primary	Suspended solid reduction	Storage	L	Liquid sludge with high pathogens Effluent with high pathogens
Advanced or chemically enhanced sedimentation	Primary	Suspended solid reduction	Coagulation/flocculation Storage	M	Liquid sludge with medium pathogens Effluent with medium pathogens
Anaerobic upflow sludge blanket reactors	Primary	BOD reduction	Storage	L	Liquid sludge with high pathogens Effluent with high pathogens Biogas
Anaerobic baffled reactors	Primary/ Secondary	BOD reduction Stabilization/nutrient management	Storage	L	Liquid sludge with high pathogens Effluent with high pathogens Biogas
Activated sludge	Secondary	BOD reduction Nutrient management	Storage	M	Liquid sludge with medium pathogens Effluent with medium pathogens
Trickling filters	Secondary	Nutrient management	Storage	M	Liquid sludge with medium pathogens Effluent with pathogens
Aerated lagoon and settling pond	Secondary	BOD reduction Pathogen reduction	Aeration	M	Liquid sludge with medium pathogens Effluent with pathogens
High rate granular or slow rate sand filtration	Tertiary	Pathogen reduction	Filtration	H	Effluent with low pathogens
Dual media filtration	Tertiary	Pathogen reduction	Filtration	H	Effluent with low pathogens
Membranes	Tertiary	Pathogen reduction	Ultrafiltration	H	Effluent with low pathogens
Disinfection	Tertiary	Pathogen reduction	Chlorination (oxidation)	H	Effluent with low pathogens
Disinfection	Tertiary	Pathogen reduction	Ozonation	H	Effluent with low pathogens
Disinfection	Tertiary	Pathogen reduction	Ultraviolet radiation	H	Effluent with low pathogens

Sources: Adapted from WHO (2006) (Vol. 2, p.81); Tilley et al. (2014); Strande et al. (2014).
* PRL Pathogen reduction level (log_{10} reduction) for well-designed, well-functioning systems: L - Low = <1 log_{10}; M - Medium = 1 to 2 log_{10}; H - High = >2 log_{10}. PRL for bacteria used by way of illustration, and may not apply to viruses, protozoa and helminths
** Pathogen level (pathogens per litre): Low = <2 log_{10}; Medium = 2 to 4 log_{10}; High = >4 log_{10}

The low flow rate biological processes are mostly pond-based systems with long retention times. They are most commonly the lowest-cost treatment option in warm climate locations, where inexpensive land is available and where the energy/electricity supplies may be unreliable or prohibitively expensive. Waste stabilization ponds generally comprise three ponds connected in series that provide a full treatment process of sedimentation, biodegradation and pathogen removal. Constructed wetland technologies, however, provide either secondary or tertiary treatment only and are generally preceded by a sedimentation and/or biological treatment process.

How these wastewater treatment processes work and their respective pathogen reduction mechanisms and specific operation and maintenance requirements is complex; details can be found in various sources including WHO (2006); Metcalf and Eddy (2014); Cairncross and Feachem (2018).

Sludge treatment processes

The established sludge treatment processes shown in Table 3.3 are grouped according to their treatment objective, namely dewatering, stabilization, nutrient management and pathogen reduction. A full explanation of these sludge treatment processes is available in Strande et al., 2014, Strande, 2017 and Tayler, 2018.

When designing a faecal sludge or a wastewater treatment process, the choice of technologies, and their sequence, must be determined with a full understanding of the output products and their eventual end use or disposal. For instance, if the end use product of faecal sludge is a cement additive, then the sludge requires dewatering and drying but, since the cement manufacturing process destroys all pathogens, pathogen inactivation at the faecal sludge treatment plant is not required. In contrast, if a soil conditioner (such as compost) is the required

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Table 3.3 Established sludge treatment processes

Treatment technology	Treatment objectives	Pathogen reduction measures	PRL*	Treatment products & pathogen level**
Settling-thickening ponds and tanks	Dewatering	Storage	Low	Liquid sludge with high pathogens Effluent with high pathogens
Unplanted drying beds	Dewatering	Dehydration Ultraviolet radiation Storage	Low	Dewatered or dry sludge with high pathogens Effluent with high pathogens
Planted drying bed	Dewatering Stabilization/nutrient management	Dehydration Ultraviolet radiation Storage	Sludge – High Effluent – Low	Plants – no pathogens Dry stabilized sludge with low pathogens Effluent with high pathogens
Co-composting	Pathogen reduction Stabilization/nutrient management	Temperature Storage	Sludge – High	Dewatered stabilized sludge (compost) with low pathogens
Burial	Stabilization/nutrient management Pathogen reduction	Storage Adsorption	High	Trees or plants – no pathogens (and buried, stabilized sludge with low pathogens)

Sources: Adapted from WHO (2006) (Vol. 2, p.81); Tilley et al. (2014); Strande et al. (2014).
* PRL Pathogen reduction level (log_{10} reduction) for well-designed, well-functioning systems: L - Low = <1 log_{10}; M - Medium = 1 to 2 log_{10}; H - High = >2 log_{10}. PRL for bacteria used by way of illustration, and may not apply to viruses, protozoa and helminths
** Pathogen level (pathogens per litre): Low = <2 log_{10}; Medium = 2 to 4 log_{10}; High = >4 log_{10}

end product, the faecal sludge requires a process that ensures pathogen inactivation (e.g. dewatering and drying prior to co-composting with organic solid wastes). When properly designed and operated, the co-composting process inactivates the pathogens making waste safe for farmers, food product handlers and consumers to handle (Cofie et al., 2016).

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Treatment processes need to be properly operated and maintained (following SOPs) and combine multiple barriers WHO, 2006; WHO, 2016) to ensure safety of the end product.

Transferring and emerging faecal sludge treatment processes

Some wastewater treatment processes are also applicable for faecal sludge treatment; these are known as 'transferring' treatment technologies and include mechanical dewatering, alkaline treatment, incineration, anaerobic digestion, pelletizing and thermal drying. These are not widely used but research is ongoing to establish their relevance and effectiveness. Research is also being conducted on emerging faecal sludge treatment technologies. These include nutrient recovery through vermicomposting and opportunities for resource recovery in addition to soil conditioning and water reclamation (e.g. energy reclamation products such as liquid fuel from biogas, biodiesel and synthetic natural gas treatment technologies; and protein for animal feed by feeding black soldier fly larvae on faecal sludge).

These processes are addressed separately because, when compared with the established technologies, the level of expertise required to design and operate them is much higher. However, as further research is carried out, which leads to further refinement and improvement of the processes, it is likely that many of the transferring and emerging processes will become established (Strande et al., 2014; Strande, 2017).

Reducing risk at the treatment step

In order to reduce the likelihood or severity of hazardous events, treatment technologies should have the following design, construction, operation and maintenance features.

Design and construction

- Based on the local context taking into consideration the characteristics of the influent, local climate and seasonal variations and the available energy sources and human resource capacity.
- Compatible with the following end use/disposal type (Section 3.6).

Operation and maintenance

- Treatment plant management should follow risk assessment and management processes to identify, manage and monitor risks throughout the system to meet treatment objectives.
- All workers operating and maintaining treatment technologies should follow standard operating procedures (SOPs) and wear personal protective equipment (PPE).

In contrast, treatment technologies that do not sufficiently reduce the risks include any treatment technology where the level of pathogen removal and end use/disposal type does not safeguard downstream consumers. For instance, where:

- A treatment technology is overloaded so that it works sub-optimally or fails completely. For example, where fresh faecal sludge is discharged to a waste stabilization pond designed for wastewater treatment only, causing failure of the treatment technology resulting in no or very low pathogen removal.
- A treatment technology is dysfunctional. This could be a short-term problem where energy required to operate equipment is not available or, longer-term, when the expertise of workers is insufficient to operate or repair equipment.

As these three situations remain very common, also in locations where emerging safe sanitation systems are present, water bodies have to be used with care for any recreational purposes or productive reuse (Drechsel et al., 2010; WHO, 2003).

Incremental control measures

Treating faecal sludge with influent wastewater (co-treatment) is relatively common in low-income settings where faecal sludge management is not well developed and there are no dedicated faecal sludge treatment facilities. In such locations, vacuum truck operators are permitted to discharge faecal sludge into municipal wastewater treatment plants. This has the advantage that it can reduce the volume of faecal sludge illegally dumped to open drains, water bodies and open ground but can result in failure of the wastewater treatment plant (which in turn can lead to exposure of the downstream consumers to untreated or poorly treated effluent).

The failures are mainly caused by the relatively high concentration of the faecal sludge (compared to that of the municipal wastewater) which can lead to loads which exceed the plant capacity. Faecal sludge may also include mixed solid waste that needs to be removed (e.g. with screens) before co-treatment. There are a number of common problems introduced by co-treatment, including overloading of solids, chemical oxygen demand or nitrogen compounds, increasing the risk of process failure which the treatment processes can take several weeks to recover.

A preferred approach for co-treatment is to first dewater the faecal sludge and co-treat the liquid fraction with municipal wastewater, and co-treat the solid fraction with the wastewater sludge from the wastewater treatment technology. This type of co-treatment has the potential to lead to savings in both capital and operation and maintenance costs. However, whether or not co-treatment is suitable will depend on the quantity and quality of the products being combined. For example, the constituents of the liquid fraction from faecal sludge treatment can be 10 to 100 times more concentrated than the raw wastewater influent to a treatment plant. This needs to be considered alongside the type and design of the existing technologies, and whether the treatment plant is operating at capacity. Co-treatment and the potential advantages and disadvantages of using different technologies is discussed fully in Strande et al., 2014 (chapters 5 & 10) and Strande, 2017.

3.6 End use/disposal

3.6.1 Definition

End use/disposal refers to the different technologies and methods by which treatment products are ultimately discharged into the environment, either as end use products or reduced-risk materials. Where there is an end use for treatment products by which (ideally fully treated) wastewater and sludge are ultimately produced, they can be applied or used; otherwise, additional risk reducing barriers are needed, or the products should be disposed of in ways that are least harmful to the public and environment.

3.6.2 Safe end use/disposal

The key principle at end use/disposal step is reducing the risks to sanitation workers and wider community to the remaining pathogen hazards, for example farmers, who could be at risk from exposure through ingestion following direct contact with pathogen-containing compost used for soil improvement. The wider community also includes the general public who, where effluent is disposed to surface waters or groundwater, could be at risk from pathogens through ingestion of contaminated drinking-water, or from the food chain where contaminated water is used for irrigation.

Table 3.4 outlines end use products that can be obtained from the various treatment processes discussed in Section 3.5.

Table 3.4 Summary of established end use products*

Treatment product	Resource recovered	End use technology or product	Technology description	Pathogen level in end use product
Untreated sludge - buried	Organic matter Nutrients	Soil conditioner fertilizer	Untreated sludge buried and used to grow trees (e.g. arborloo or deep row entrenchment)	Low to high depending on absorption characteristics and travel time. The untreated sludge can contain a high level of pathogens, but once buried they may be adsorbed into soil and inactivated over time.
Dewatered sludge	Organic matter	Soil conditioner fertilizer	Dewatered sludge applied to land	High
Dewatered sludge	Energy	Incineration	Burning of sludge generates heat for cement kilns.	Low. Ash produced is free of pathogens.
Dried sludge	Energy	Solid fuel	Pellets, briquettes, powder burned for fuel	Low but only after conversion by pyrolysis to a pellet, briquette or powder
Dried sludge	Materials	Building materials	Used in the manufacture of cement, bricks and clay-based products	Low but only after being subjected to high manufacturing temperatures.
Compost (powder or pellets)	Organic matter Nutrients	Soil conditioner, fertilizer	Compost, powder or pellets applied to land	Low
Plants	Food	Animal fodder	Plants removed from planted drying beds or wetlands and fed to animals	Low in plants removed, but care needed when harvesting, as sludge and/or effluent may contain medium to high level of pathogens.
Effluent	Nutrients, water	Irrigation water	Treated effluent applied to land	Low to high depending on treatment technology.
Effluent	Water	Surface water recharge	Treated effluent disposed or discharged into rivers, lakes or oceans	Low to high depending on treatment technology.
Untreated effluent	Water	Groundwater recharge	Untreated effluent disposed or discharged into the ground via soak pit or leach field	Low to high depending on absorption characteristics and travel time. The untreated effluent can contain a high level of pathogens, but once in the ground they may be adsorbed aerobically into soil.

Sources: Adapted from Tilley et al. (2014); Strande et al. (2014); and Strande (2017).
* 'Sludge' refers to both faecal sludge and sewage sludge.

Table 3.4 includes a description of the end use products, the resource recovered and the likely pathogen level of each end use product. Untreated faecal sludge contains a high concentration of pathogens but, if buried safely, can be used as a soil conditioner for fruit trees or forestry provided barriers are in place on farm to prevent exposure to worker and local communities and wider communities. For individual households with a full pit latrine, the pit is sealed off from human contact with soil. A tree can then be planted on top, which then benefits from the increased nutrients and organic matter. Deep row entrenchment is similar but involves the filling of a trench dug to receive faecal sludge from a number of containers. Once full, the trench is covered and sealed, and a row of trees is planted. Burial is only suitable in locations and the groundwater table is low enough (refer to section 3.3.2). It is imperative that workers wear PPE and follow SOPs to safeguard against the pathogen hazard.

Similarly, dewatered faecal sludge may contain a high concentration of pathogens (especially helminth eggs, which maintain viability for extended periods) so should not be applied to land used for food production and, apart from burial for its nutrient and soil conditioning value, has little end use potential. Air-dried faecal sludge may also contain a high number of pathogens but has a number of uses. It can be converted for use as solid fuel or building material. For both uses, the sludge is introduced to a manufacturing process that destroys the pathogen hazard, making the end use product safe to handle. Only compost in which all pathogens have been completely inactivated can be safely handled by workers or farmers and applied to land as a soil conditioner and fertilizer. Nevertheless, all workers engaged in the manufacture of solid fuels, building materials or compost from faecal sludge, need to wear PPE and follow SOPs that will safeguard them from potential hazards.

Treated effluent contains nutrients, which can be recovered to support plant and crop growth through use as irrigation water. Wastewater use, whether treated, untreated, raw or diluted, can be found in humid and arid climates. However, even treated effluent should not be assumed to be pathogen free. It should only be applied to land when the risk to workers and the wider community is well assessed and managed through multiple barriers adopted along the sanitation chain (Drechsel et al., 2010).

Where effluent is used for irrigation water, a multi-barrier may include the application of treatment processes, selecting crops that are high growing and/or not eaten raw, low contact irrigation methods e.g. drip irrigation) the use of PPE, and the disinfection, washing and cooking of produce. The WHO Guidelines for the Safe use of Wastewater, Excreta and Greywater (WHO, 2006) provide further guidance. It should be noted that different interventions (barriers) will have different costs, capacity to reduce risks and requirements in terms of behaviour change (Drechsel and Seidu, 2011; Karg and Drechsel, 2011).

Similarly, before disposing of effluent to surface waters or to groundwater, the risks to the wider community, who may use blended wastewater effluent and river water for irrigation water supplies and/or drinking or recreational water, should be considered and necessary control measures put in place. Importantly, where there is concern that effluent disposal may contaminate drinking-water supplies, public health and economic trade-offs between higher levels of wastewater treatment and improved drinking-water treatment or alternative sources need to be considered.

Reducing risk at the end use/disposal step

A multi-barrier approach should be used to manage health risks associated with end use and disposal (for further details see WHO, 2006 and WHO, 2003). To reduce the risk, end use/disposal technologies should be:

- Designed for the local context taking into consideration the characteristics of the effluent or faecal sludge; local climate and seasonal variations; and the available energy sources and human resource capacity.
- Compatible with the preceding treatment technology and treatment product, as outlined in Table 3.4.

Adopting the following additional control measures reduces the risk to workers especially those whose work involves handling treatment products:

- Wearing of PPE, particularly where using/disposing of wastewater and, faecal sludge.
- Training on the risks of handling effluents or faecal sludges and on standard operating procedures.

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- Regular health checks and preventive treatment such as deworming and vaccination.

Examples of additional control measures to reduce the risk to the local community and wider community where wastewater and faecal sludge are used in agriculture and aquaculture (WHO, 2006) are:

- Selection of crops that grow high above ground level (such as fruit trees) or crops not eaten raw
- Low contact irrigation methods (e.g. drip irrigation)
- Withholding periods between application of treated faecal sludge (e.g. compost) or wastewater and crop harvesting.

Examples of additional control measures to reduce the risk to the local community and wider community at recreational bathing sites (WHO, 2003) are:

- Public notices advising of likelihood of faecal pollution
- Restricting access and beach closures

In contrast, end use/disposal technologies that do not adequately reduce the risk are those which result in untreated effluent and/or faecal sludge being left in the open, disposed in recreational waters, or used for food production therefore exposing the local community to pathogens. For instance, in densely populated urban areas where space is limited, and the soil is compacted and/or saturated, soak pits, leach fields or cover and fill approaches are not applicable as the adsorption process will fail.

Incremental control measures

Untreated faecal sludge and wastewater should not be applied on land used for food production, aquaculture or in recreational waters unless accompanied with additional risk reducing measures. Use of untreated sludge has been a long-term practice in parts of China, South East Asia and Africa carries a very high risk from exposing farmers and their families to pathogens, as well as others in the wider community from ingesting pathogens in the food chain. Untreated effluent is also often informally or inadvertently use for irrigation of food crops. Where this practice is known to happen and cannot be avoided additional control measures outlined above should be used while treatment capacity is established.

Untreated sludges should not be disposed to landfill. However, landfill disposal is preferable to illegal dumping or use in agriculture as an incremental measure while treatment capacity is established.

3.7 Applicability of sanitation systems

The choice of sanitation systems for implementation should be driven by the specific physical and institutional context in a given location. This includes aspects such as population density, ground and climate conditions and land availability, as well as human resources and institutional capacity. Changes to these conditions over the design life of the system (20 years as a guiding rule) should also be considered, especially in areas prone to rapid change such as urbanization.

Table 3.5 sets out key factors affecting the applicability of the sanitation systems detailed in the sanitation system fact sheets (Annex 1). Box 3.3 focuses on the implications of climate change on sanitation systems and related health outcomes.

Table 3.5 Applicability of sanitation systems

		Physical factors							Enabling factors							
		Household level (toilet, containment-storage/treatment, conveyance)											Public level (conveyance, treatment, end use/ disposal)			
Each system is most applicable in the conditions shown (Low/Medium/High):		Population density is:	Risk to groundwater used for drinking is:	Water availability is at least:	Risk of flooding is:	Soil hardness (re: excavation) is:	Soil permeability is at least:	Land availability	HR capacity for infrastructure is at least:	HR capacity for O&M is at least:	Financial capacity for infrastructure is at least:	Financial capacity for O&M is at least:	HR capacity for infrastructure is at least:	HR capacity for O&M is at least:	Financial capacity for infrastructure is at least:	Financial capacity for O&M is at least:
On-site sanitation systems	1: Dry or flush toilet with on-site disposal	L	L	L	L	L	M	NA	L	L	L	L	NA	NA	NA	NA
	2: Dry toilet or urine diverting dry toilet (UDDT) with on-site treatment in alternating pits or compost chamber	L	L	L	L	L	M	NA	L	M	L	L	NA	NA	NA	NA
	3: Flush toilet with on-site treatment in twin pits	L	L	M	L	L	M	NA	L	L	L	L	NA	NA	NA	NA
	4: Urine-diverting dry toilet (UDDT) with on-site treatment in dehydration vault	L	L	L	NA	NA	NA	NA	M	M	M	M	NA	NA	NA	NA
On-site systems with FSM and off-site treatment	5: Dry or flush toilet with pit, effluent infiltration and off-site treatment of faecal sludge	M	L	M	L	L	M	M/H	L	M	L	M	M/H	M/H	M/H	M/H
	6: Flush (or urine-diverting flush) toilet with biogas reactor and off-site treatment	M	NA	M	L	L	NA	M/H	M	M	M	M	M/H	M/H	M/H	M/H
	7: Flush toilet with septic tank and effluent infiltration, and off-site faecal sludge treatment	M	L	M	L	L	M	M/H	M	M	M	M	M/H	M/H	M/H	M/H
	8: Urine-diverting dry toilet and container-based sanitation with off-site treatment of all contents	M/H	NA	L	NA	NA	NA	M/H	L	L	L	L	M/H	M/H	M/H	M/H
On-site systems with FSM, sewerage and off-site treatment	9: Flush toilet with septic tank, sewerage and off-site treatment of faecal sludge and effluent	M	NA	H	L	L	NA	M/H	H	H	H	H	M/H	H	M/H	M/H
Off-site systems with sewerage and off-site treatment	10: Flush toilet with sewerage and off-site wastewater treatment	M/H	NA	H	NA		NA	M/H	H	H	H	H	H	H	M/H	M/H
	11: Urine-diverting flush toilet with sewerage and off-site wastewater treatment	M/H	NA	H	NA		NA	M/H	H	H	H	H	H	H	M/H	M/H

Box 3.3 Climate change, sanitation and health

Climate change – a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for decades or longer – exacerbates existing challenges such as rapid population growth, urbanisation, migration, land-use change, and other forms of environmental degradation. Its potential impact on sanitation systems is extensive. Climate variability and climate change exacerbate the risks caused by inadequate sanitation by placing considerable strain on sanitation systems, and should be taken into account to ensure sanitation technologies and services are designed, operated and managed in a way that minimises associated public health risks.

Sanitation is an important vehicle for indirect climate change impacts on health (IPCC, 2014). The health consequences arising from climate impacts on sanitation systems include increased risk of disease/illness from exposure to pathogens and hazardous substances via environmental contamination, and/or increased risk of disease/illness resulting from a lack of adequate sanitation where systems have been destroyed or damaged. Poor and vulnerable groups without access to good quality health care and fundamental public services experience overlapping forms of disadvantage and are likely to face the worst effects (WHO & DFID 2009).

Adaptation measures for building sanitation system's climate resilience could be designed under six broad categories: technologies and infrastructure, financing, policy and governance, workforce, information systems and service delivery (WHO, 2015). Measures such as data collection and monitoring systems, disaster response and rehabilitation plans, and behaviour change programmes can support effective adaptation. Communities, who have existing experience in adaptation for sanitation, should be actively engaged in sanitation system planning processes (Sherpa et al., 2014).

Table 3.6 sets out potential impacts and examples of adaptation measures available for some key sanitation technologies and sanitation management systems to improve sanitation systems and in turn help to protect health.

Source: WHO 2018, unpublished.

Table 3.6 Examples of climate adaptation options for specific sanitation systems

Sanitation system	Potential impact	Example adaptation options	Overall resilience
On-site systems			
Dry and low-flush toilets	• Reduced soil stability leading to lower pit stability • Environmental and groundwater contamination from toilet flooding • toilet owners using floodwaters to flush out pits • Toilet collapse due to inundation or erosion	• Line pits using local materials • Locally adapted toilet designs: raised toilets; smaller, frequently-emptied pits; vault toilets; raised pit plinths; compacting soil around pits; appropriate separation distances; use of appropriate groundwater technologies; protective infrastructure around system • In highly vulnerable areas: low-cost temporary facilities • Site systems in locations less prone to floods, erosion, etc. • Provide regular, affordable pit emptying services • Dispose excreta to secure sewer discharge or transfer stations • Promote toilet maintenance, hygiene and safe behaviours during/after extreme events	High (Good adaptive capacity through potential design changes)

Table 3.6 Examples of climate adaptation options for specific sanitation systems (continued)

Sanitation system	Potential impact	Example adaptation options	Overall resilience
Septic tanks	• Increased water scarcity reducing water supplies and impeding tank function • Rising groundwater levels, extreme events and/or floods, causing structural damage to tanks, flooding drain fields and households, tank flotation, environmental contamination	• Install sealed covers for septic tanks and non-return valves on pipes to prevent back flows • Ensure vents on sewers are above expected flood lines • Promote tank maintenance, hygiene and safe behaviours during/after extreme events	Low to medium (Some adaptive capacity; vulnerable to flooding and drying environments)
Off-site systems			
Conventional sewerage (combined sewers, gravity sewers)	• Extreme rainfall events causing discharge of excess, untreated wastewater into environment • Extreme rainfall events causing back-flooding of raw sewage into buildings • Extreme events damaging sewers and causing leakage, resulting in environmental contamination • Sea-level rise raising water levels in coastal sewers, causing back-flooding • Increased water scarcity reducing water flows in sewers, increasing solid deposits and blockages	• Use deep tunnel conveyance and storage systems to intercept/store combined sewer overflow • Re-engineer to separate stormwater flows from sewage • Where feasible, decentralize systems to localize/contain impacts • Provide additional storage for stormwater • Use special gratings and restricted outflow pipes • Install non-return valves on pipes to prevent back flows • Where appropriate, install small-bore or other low-cost options to reduce costs of separate systems • Promote hygiene and safe behaviours during/after extreme events	Low to medium (Some adaptive capacity; vulnerable to reduced water availability and flooding of combined sewers)
Modified sewerage (e.g. small-bore and shallow sewers)	• Floods and extreme events damaging sewers, especially shallow sewers • Small-bore sewers: damage to pipework infrastructure introducing soil to system and causing solid deposits/blockage risks • Shallow sewers: increased water scarcity reducing water flows in sewers, increasing solid deposits and blockages	• Install non-return valves on pipes to prevent back flows • Construct simplified sewer networks to withstand flooding and flotation, or shorter networks connected to decentralised treatment facilities to reduce sewer overload and failure • Promote hygiene and safe behaviours during/after extreme events	Medium (Some adaptive capacity; vulnerable to flooding, though less vulnerable to reduced water availability than conventional sewerage)
Faecal sludge treatment	• Extreme weather events or floods destroying/damaging wastewater treatment systems, causing discharge of untreated sewage and sewerage overflow and environmental contamination • Extreme rainfall damaging waste stabilisation ponds • Extreme events damaging low-lying treatment plants, causing environmental contamination • Increased water scarcity causing obstruction, reducing capacity in rivers or ponds that receive wastewater	• Install flood, inundation and run-off defences (e.g. dykes) and undertaking sound catchment management • Invest in early warning systems and emergency response equipment (e.g. mobile pumps stored off-site, non-electricity based treatment systems) • Prepare a rehabilitation plan for the treatment works • Where feasible, site systems in locations less prone to floods, erosion, etc. • Provide safe means for manual emptying of sludge with low moisture content	Low to medium (Some adaptive capacity; vulnerable to increases/ decreases in water availability; reduced carrying capacity may increase sludge treatment requirements)

Table 3.6 Examples of climate adaptation options for specific sanitation systems (continued)

Sanitation system	Potential impact	Example adaptation options	Overall resilience
Wastewater reuse for food production	• Increased water scarcity leading to increased reliance on wastewater for irrigation purposes • Without adequate wastewater treatment, increased reuse can expose populations (farmers, their communities and consumers) to health hazards including pathogens, chemicals, and anti-microbial resistance	• Include climate change and variability in assessing, monitoring and establishing control measures for wastewater management • Improve enforcement/ incentives for following regulations for wastewater reuse • Improve crop selection, irrigation type, withholding times • Ensure sanitation worker vaccination and treatment • Promote hygiene practices and use of personal protective equipment	

Sources: adapted from Howard & Bartram, 2010; Charles, Pond & Pedley, 2010.

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Chapter 4

ENABLING SAFE SANITATION SERVICE DELIVERY

4.1 Introduction

Safe sanitation systems require input from a range of stakeholders, but national and local government are central to their effective planning, delivery, maintenance, regulation and monitoring. This chapter presents an implementation framework for sanitation interventions, describing the components within national and local governance functions and examining who is responsible for them.

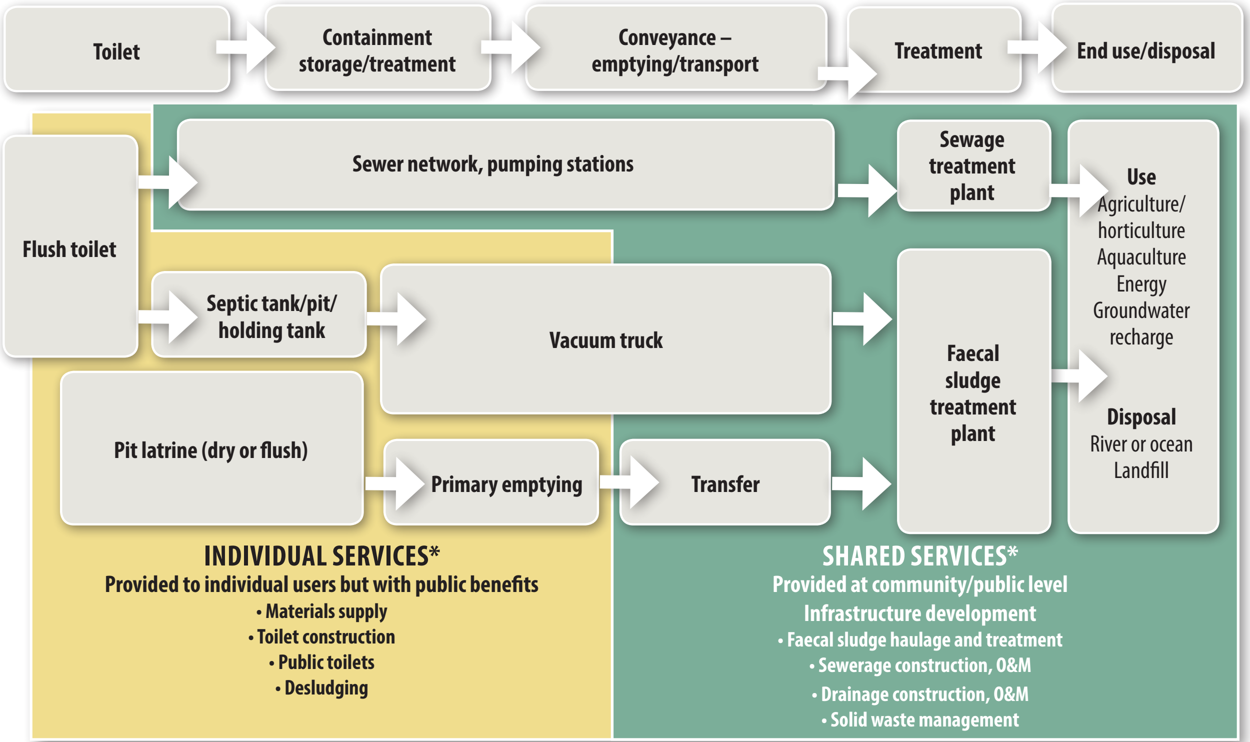
4.2 Components of an implementation framework

Sanitation services – ranging from support for self-provision of simple toilets to the construction and management of complex sewerage systems with technically advanced treatment facilities – must be accessible to people where they live. Thus, the focus for implementation is at the local level. Local government usually has the responsibility to ensure adequate levels of sanitation but, even where it does not, local oversight and coordination are essential to ensure that all the complementary components of the service chain function effectively together.

Sanitation service providers may be formal or informal private enterprises, publicly or privately-owned utilities, local government departments, or (in most cases) a combination of these. The services themselves can be broadly divided into three categories, according to how they are delivered:

- *Individual services*, such as toilet construction, hardware supplies, removal of faecal sludge or containers, and provision of public toilets. These provide direct benefits to users as well as improving public health at the community level. These services are typically suitable for provision by small businesses and they may be commercially viable; however, poorer households are likely to need subsidization to access them.
- *Shared services*, which include operation and maintenance of sewerage and drainage systems and faecal sludge treatment. These are delivered downstream of users, producing public health benefits to the community, and may not be possible or fair to finance entirely by direct user fees. They are usually delivered by local authorities or utility companies but may also be subcontracted to the private sector and may be funded through, for example, local tax revenue, cross subsidy from water supply and government subsidies.
- *Infrastructure development*, comprising the design and construction of sewerage, drainage, faecal sludge transfer stations and faecal sludge and wastewater treatment plants, primary water supply systems or slum upgrading. These also provide public health benefits to the community, but require major investment, which may require recourse to high level (national, state, regional or provincial) authorities or external financing.

Figure 4.1 Categorization of sanitation services



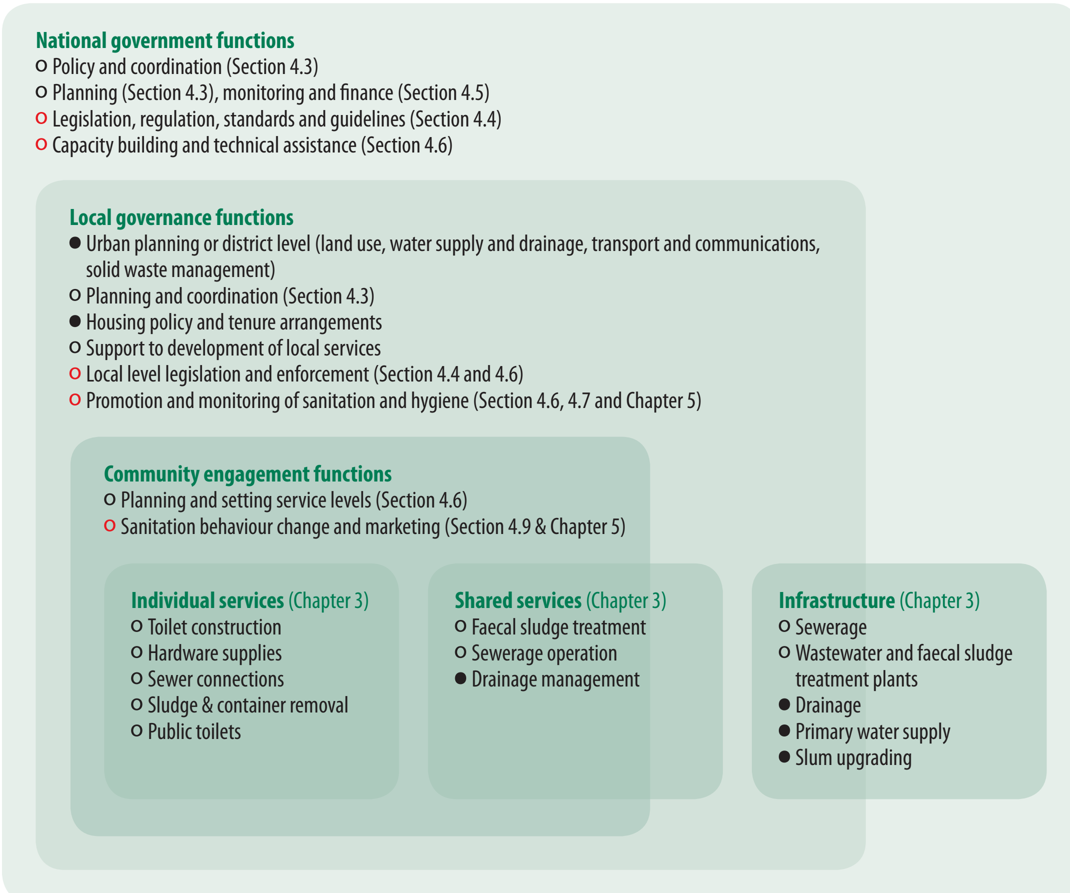
*Delineation of individual services and shared services in this diagram does not signify who should bear the full cost of services

Sanitation services should fit together to ensure coherent sanitation service chains (as illustrated in Figure 4.1) that safely manage excreta from generation to treatment and safe disposal or use. This demands technical alignment (e.g. the design of pits and emptying equipment so that they work together to enable the hygienic removal of faecal sludge) and coordinated planning, so that all components of the service chain are in place (e.g. faecal sludge treatment plants are present and functioning to deal with collected sludge).

The main components and responsibilities for sanitation implementation are outlined in Figure 4.2 and below.

The *national government* role includes the setting of standards and targets and the empowerment of local authorities and other agencies to deliver and oversee sanitation services. It is also responsible to ensure equality in access to services, in line with human rights and the SDGs. Government should provide policy guidance, rules and incentives and promote the development of adequate capacity to deliver sustainable, affordable and safe managed sanitation services, and to provide a favourable environment for incremental improvement to sanitation services, for instance through scaling up or formalising local and pilot initiatives. Coordination, accountability and regulatory mechanisms are also needed, so that the interdependent services required for the delivery of safe sanitation systems function without interruption, and according to the prescribed standards. National authorities guide and support local government and may support the development of major infrastructure.

Figure 4.2 Implementation framework for sanitation



○ Function addressed in these guidelines; ● Function not addressed in these guidelines; ○ Function with primary role for environmental health staff.
This figure indicates how the different levels of the implementation framework interact with each other, and the services and infrastructure that they should deliver.

Local government is responsible for (or oversees) service provision and is accountable for this both to the national government and to local communities. It has direct authority over providers of shared services while overseeing and maintaining dialogue with providers of individual services, whose primary relationship is directly with users. Critically, it also engages with user communities, to negotiate a balance between community needs and their willingness and ability to pay for services, and to encourage communities to play their role in achieving effective sanitation.

4.3 Policy and planning

4.3.1 Policy

Governments need to enact policies to ensure that the entire population within their jurisdiction have access to safe sanitation services, that can be achieved through stepwise targets or milestones for incremental improvements (Box 4.1). Existing policies, regulation and legislation should be regularly reviewed to ensure they do not include provisions that impede sanitation improvements; for instance, provisions

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Box 4.1 Setting targets

National sanitation policies and strategies should include clearly defined objectives based on a systematic analysis of the sanitation situation which includes an understanding of how excreta flow from point of generation to end use or disposal and the associated public health risks.

- As a first step the multi-stakeholder platform should complete a situational analysis of existing legislation, policies and practices, as well as an assessment of levels of access to and overall effectiveness of sanitation in different contexts and geographic areas.
- Sanitation standards and targets should be set in order to improve public health and in alignment with human rights principles (Box 1.2).
- Standards for sanitation should be clearly defined based on a systematic analysis of public health, sanitation access and behaviours, legislative, policy and regulatory landscape, institutional roles, financing and capacity.
- Targets, which are stepping stones towards meeting standards, may be mid- or long-term based on the context and available resources to allow for incremental improvements and increasing equality in access to services. Long-term planning should identify how meeting targets ultimately leads to the attainment of all sanitation standards for universal access to sanitation and improving service levels for the poorest, disadvantaged and most marginalised groups.

Very few governments can immediately achieve the standards that they have set. The process of target setting recognizes this, giving opportunity to prioritize where efforts should be placed to reach the standards and comply with human rights principles of equity and non-discrimination. Targets may be national, and there may also be targets set at the regional or local level, generally set by the relevant level of local government. Targets should include publication of plans and budgets, so that people know how and when they can expect services to improve. National sanitation targets should be based on the results of the situational analysis.

Targets or milestones should define priorities, be time-bound and, as far as possible, measurable, so that those responsible for attaining the targets can be held accountable. These can be defined according to many criteria, including targets based on health, targets for achieving service provision for particular population groups – particularly poor and disadvantaged groups, targets for types of service provision, budgetary targets, targets for particular behaviours, targets for achieving institutional arrangements or for regularity of monitoring.

Most countries have targets for different types of service, technology and system. In order to ensure that they are relevant and supportive, representative scenarios should be developed, including description of assumptions, management options, control measures and indicator systems for verification. These should be supported by guidance addressing the identification of national, regional or local priorities and incremental implementation, thereby helping to ensure that best use is made of available resources. Targets for realising the policies and standards for sanitation must be established by a high-level authority responsible for sanitation and health in consultation with other stakeholders, including local authorities, sanitation service providers and local communities.

against providing services in informal settlements, the outlawing of pit latrines where no realistic alternative exists in the medium term, or legal/regulatory impediments to safe use of treated wastewater, excreta and greywater within other sectors' policies, regulation and legislation (e.g. agriculture, food safety).

Ensuring sanitation for all is challenging and the approaches adopted need to be tailored to the conditions prevailing in each specific situation. This requires the concurrent use of a range of different sanitation systems and services (see Chapter 3), and behaviour change strategies (Chapter 5). Policies must be practical and feasible, preferably based on what is found to work in practice in a given context, rather than an ideal vision or imported approaches from a different physical, economic and social environment. A good approach is to develop national policy referencing existing initiatives that are working well in parallel with innovation in improving sanitation at local level, so that each can inform the other. The policy formulation or revision process should include a wide-ranging and inclusive stakeholder dialogue to develop consensus between the many actors involved in sanitation and allow continued review and course-correction where necessary.

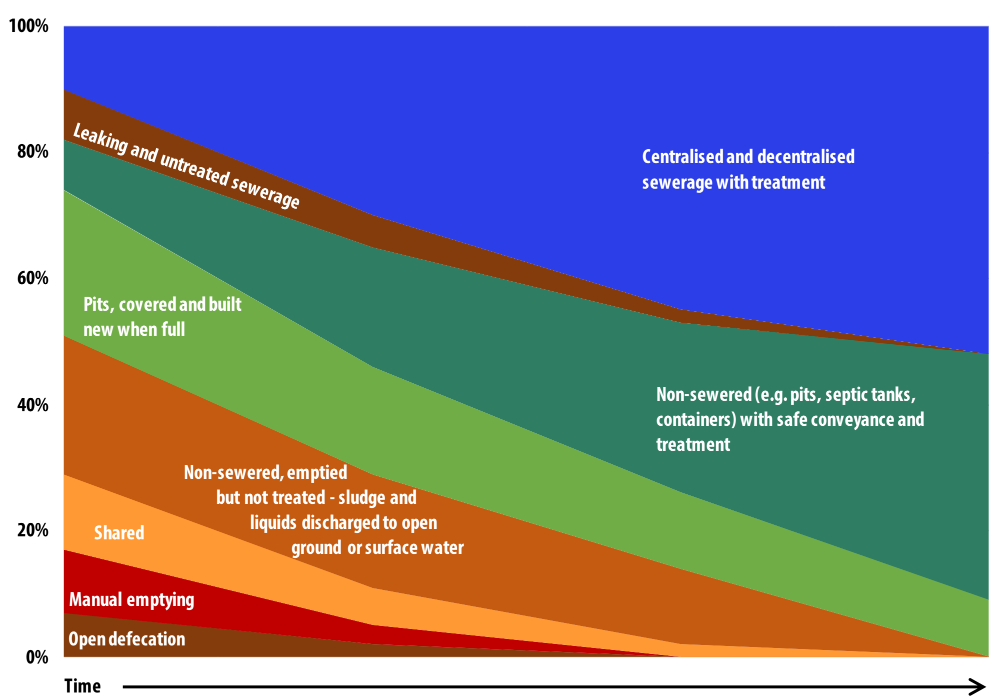
4.3.2 Planning sanitation systems

To formulate inclusive, equitable and practical solutions, it is essential to understand the existing mix of sanitation systems in use, and to plan how that mix should change over time as progress is made towards the targets for sanitation and hygiene established in local and national policies. The mix and targets are different for different types of community (e.g. urban and rural populations), and intermediate as well as final targets should be set for each (Box 4.1). Figure 4.3 is an example of how technology targets can be visualised, showing phasing out of unsafe sanitation systems to achieve universal access to safe systems over time.

A consequence of this approach is the incremental improvement of sanitation in different places and at different times. Interventions can be targeted and sequenced to maximize their positive impacts on public health and well-being. 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.

The time frame to achieve sanitation targets typically falls well beyond the normal time horizons of electoral cycles or externally funded projects (i.e. 3–5 years). Sanitation planning, therefore, should be institutionalized and integrated into government planning, budgeting and financing systems. Establishing specific budget lines, funding windows and expenditure codes for sanitation at central and local government levels can help achieve this. An adaptive approach to planning can be applied, which includes formulation of long-term policies and strategies; continuous links between planning and implementation; regular monitoring, evaluation and ongoing learning from both successes and failures; and continuous dialogue with intended beneficiaries to adjust activities to their needs (Therkildsen, 1988).

Figure 4.3 Example of phasing out unsafe sanitation over time



4.4 Legislation, regulations, standards and guidelines

4.4.1 Scope

The legislative framework for sanitation should cover the whole service chain, including both sewered and non-sewered sanitation, to enable the best use of public funds, achievement of standards and attraction of potential service providers.

Ensuring adequate standards for sanitation is a government function. Standards and regulations should avoid prescribing specific technologies or systems for particular situations as their suitability can be affected by a multitude of factors. In addition, legislation evolves more slowly than technologies and therefore can impede innovation. Instead, standards and regulations should set out what level of performance is required to achieve a safe

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Table 4.1 Areas that may require legislation and regulation

Step in chain	Examples of sanitation aspects covered by legislation and regulation
Toilet/ containment-storage/ treatment	*Toilet:* • Minimum requirements for toilet room/superstructure (household and shared/public) • Accessibility to toilets for users with disabilities (shared/public/institutions)) • Stance/user ratios for school, institutional and other public toilets (shared/public) • Handwashing and water supply facilities for school, institutional and public toilets (shared/public) • Standard of pit latrine slabs and pour flush pans (household and shared/public) • Maximum toilet flush volume (in water scarce areas) (household and shared/public)
	Containment - storage/treatment: • Exclusion of insects and other animals from faecal material • Access to pit or tank for emptying • Design of septic tanks • Management of liquid effluent from latrine pits and septic tanks • Registration of on-site facilities • Standards for effluent discharged to sewers • Safety and performance of container and mobile toilet units
Conveyance	*Emptying:* • Obligation for premises to be connected to sewer system if available • Tariffs for disposal of sewage and faecal sludge at treatment plants • Siting of pits and tanks so they can be emptied • Pedestrian and traffic safety during pit and septic tank emptying operations • Control of nuisances and spillages when emptying faecal sludge • Service standards for container and mobile toilets
	Transport: • Frequency of sewer blockages and overflows • Time taken to resolve sewer blockages and overflows • Rectification of damage caused by faulty sewers and pumping stations • Containment of faecal sludge in transport equipment and transfer facilities • Operational and worker health and safety
Treatment	• Control of public and service provider access to treatment facilities • Control of nuisances (odours, flies, noise etc.) from treatment facilities • Designated facilities and opening hours for faecal sludge dumping • Liquid effluent standards • Standards for sludge disposed of (if not used) • Certification of proprietary systems • Operational and worker health and safety
End use/disposal	• Standards for sludge products, categorized by type of safe use • Standards for use of other products derived from faecal waste • Operational and worker health and safety

sanitation service chain and allow flexibility on how it is achieved.

The provision of sanitation services can include both the public and private sector; while service providers of all types should work to the same standards, different regulatory mechanisms may be needed for different service delivery models. The standards for sanitation provision can be included in local legislation and by-laws and/or in national legislation. The decision as to the appropriate approach depends on country-specific factors.

The legislative and regulatory framework should reflect the national interpretation of safe management at each step of the sanitation service chain (see Chapter 3 and Table 4.1) and could include minimum requirements for toilets, septic tanks, service standards for container and mobile toilets and aspects related to occupational health and safety. It should also define roles and responsibilities and minimize overlapping mandates.

In addition, it may be useful to develop national guidance on sanitation systems covering the whole service chain and criteria for their selection. Each country has different needs, so what is finally included should be determined by a policy dialogue that recognizes that everyone is entitled to sanitation services that are accessible, safe to use and protective of health, affordable and acceptable (De Albuquerque, 2014).

These and any other sanitation attributes selected should be controlled primarily according to public health criteria. However, they also have implications for the environment and public amenity, and for the cost, affordability and equality of access to sanitation services. The circumstances of each country (or local government jurisdiction exercising legislative or regulatory powers) dictate how these factors are weighted.

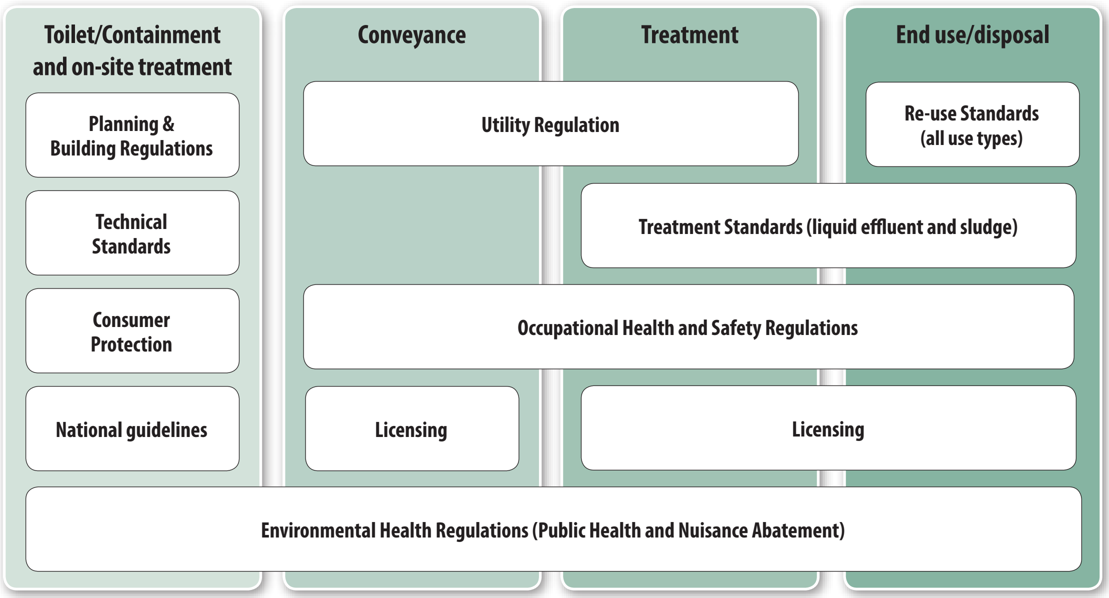
A key area for regulation that applies across the whole service chain, is fees and tariffs for services delivered by utilities, public institutions or entities under their control (e.g. treatment plants under lease or concession arrangements). These may include sewerage connection fees, fees for use of public or shared toilets, sewerage tariffs, fees for pit emptying by utilities or public institutions, faecal sludge tipping fees, etc. They should be regulated at price levels that ensure that sanitation services are accessible to all, including poor households, while remaining financially viable for private or commercially managed operators.

4.4.2 Risk assessment and management

A risk assessment should guide sanitation interventions to ensure sanitation protects public health by managing the risks arising from excreta management along the sanitation chain from the toilet to final disposal or use. The risk assessment should identify and prioritize the highest risks and use them to inform system improvements through a mixture of controls along the sanitation chain. Improvements may include technology upgrades, improved operational procedures and behaviour change.

In the context of regulation and standards the focus should be primarily on specific components of sanitation service chains, but it may also extend to complete sanitation systems or parts of them, for example sanitation by-laws or planning regulations. Public or environmental health sector staff (see Section 4.6) are usually be best placed to identify and analyse the sanitation issues requiring attention, but they will need to work with all relevant stakeholders (such as local authorities, wastewater utilities, sanitation enterprises, the institutions in charge of environmental and building standards, farmers and civil society organizations) to ensure the completion of a robust risk assessment and formulation of realistic risk management options that can then be translated into standards and regulations. The first step in the process is thus the creation of a stakeholder group, with leadership assigned to the group member with the best mix of authority, and organizational and interpersonal skills.

Figure 4.4 Sanitation service chain regulatory mechanism options



Risk assessments should be based, as far as possible, on actual conditions, rather than on assumptions or information imported from elsewhere. Frontline government staff such as public health or agricultural extension workers, students, community leaders and community-based organizations can be effective in data collection if well organized, incentivized and supervised.

4.4.3 Regulatory mechanisms

The various steps in sanitation service chains differ in their nature, requiring a corresponding range of regulatory mechanisms. Ways in which the different steps can be regulated are illustrated in Figure 4.4. The various mechanisms are highlighted in bold in the following text to facilitate cross-referencing.

Additionally, because sanitation cuts across many sectors, relevant legislation and regulation is also widely scattered and elements 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 safe use of faecal sludge;
- local by-laws;
- building and planning codes/standards;
- public utility regulation; and
- others.

Considerable effort may be needed to identify, update and align all the necessary elements, ensuring that they adequately address safe sanitation services, and conflicts and contradictions need to be resolved. It may not be possible to remove all legislative and regulatory overlaps and discrepancies, and coordination should ensure that these do not create unnecessary barriers to service improvements. Goods and infrastructure can be regulated under the relevant national **technical standards**, and procedures for preparing and implementing such regulation are usually clearly defined. However, where illegal or informal settlements are common, these systems may break down. For example, the quality of a toilet cannot be regulated if the whole premises are considered illegal, and the approval of a component of the premises might be taken to imply that the rest is legal, when it is not. In such cases it may be possible to use **public health or nuisance abatement** legislation (which focuses on the effect of an inadequate toilet, rather than the toilet itself), supported by national **guidelines** instead of legal standards.

On-site sanitation facilities present a particular challenge as they are often individually built. Where industrially produced components (e.g. precast or moulded plastic septic tanks) are used, they can be covered by national **technical standards** or **consumer protection legislation**. In premises with formal tenure, contextualized building regulations and their associated inspection mechanisms are a good means of controlling the quality of installation and construction. Such regulations should specify the format and volume of the facility as a function of the number of users, approved methods of managing the liquid effluent, provision for access by desludging equipment (including access into the tank or pit) and accessibility from the road. Where there is no formal tenure, or in rural areas where a self-supply approach is being implemented, national **guidelines** covering the same aspects are more appropriate. These should distinguish between facilities which will be covered over and replaced when full, and permanent facilities which will be emptied. The regulations and guidelines should allow for various types of toilet that may be assessed as adequate by the environmental health authorities (see Section 4.6).

Treatment standards for liquid effluent and sludge discharges usually have a clearly defined basis in law and institutional procedures for setting and enforcing them. It may be necessary to allow a defined period of time to achieve the standards and also to set one or more incremental standards to promote incremental improvements, so that high standards are seen as attainable. Standards should also be developed for each intended use or disposal environment rather than a blanket standard applied to all treatment facilities. Unintended effluents (such as leakages from septic tanks, latrine pits or sewage pumping stations) should be covered by public health or **nuisance abatement legislation**, which should be reviewed and, if necessary, amended to cover such cases.

The regulation of services can be complex, and depends on the nature of the entity providing the services. When it is a national or local government department (i.e. acting to both regulate and provide services) it is unlikely to be feasible to regulate it (as that would require one governmental body taking legal action against another), and applying legal remedies such as fines may be counterproductive. Specific legislation and administrative mechanisms may be needed in such situations. If the service provider is a public utility, there should be **specific regulatory arrangements** in place which can be updated and expanded as needed. If a private enterprise provides services on behalf of a utility, it can be regulated through a contract or service level agreement with the utility.

Where the private sector provides services independently, dealing directly with customers, a **licensing** arrangement may provide a suitable regulatory mechanism. This should specify service standards, an inspection regime and remedies for failure to meet the conditions. It may also (but not necessarily) specify maximum fees, or an equitable tariff structure covering one-time (e.g. connection fees) and regular services. Separate **licensing** arrangements may also be a good option for private sector operators selling processed sludge products (solid or liquid) to ensure that adequate pathogen control measures are in place. Further protection, where the products are used in agriculture, horticulture, aquaculture, groundwater recharge and energy can be provided by **standards for safe use**.

Efforts should be made to simplify and unify the licensing arrangements; for instance, faecal sludge emptying and transportation businesses may be required to have numerous licences, such as a business licence issued by the local government, an operational licence issued by the public health department and a hazardous waste transportation licence issued by the environmental agency. This adds complexity and cost, and may discourage potential service providers from entering the business.

Sanitation workers are exposed to particular health risks, and require specific measures to ensure their health and safety. These should include periodic health checks, vaccinations and treatment (e.g. deworming), medical insurance (if available), PPE (Chapter 3), as well as training on standard operating procedures (Chapter 3). The onus should be on employers to provide all of these, and these requirements should be included in the regulatory arrangements to which employers are subject. Compliance should be verified by health sector personnel (e.g. environmental or occupational health staff).

4.4.4 Enforcement and compliance

Achievement of compliance with standards and regulations requires a broad approach that includes a mix of incentives, promotion and sanctions. Non-coercive means, such as information dissemination, technical assistance, promotion and awards should be used in the first instance. Tax and other fiscal incentives, or privileged access to special services (such as loan guarantees for equipment renovation and purchase) can be economically efficient in some circumstances. Enforcement through legal sanctions is a last resort and this should be applied only when non-coercive options have failed. The legislation should be designed with a series of escalating stages to allow an offender to rectify the infraction before any penalty is finally imposed.

When developing regulatory systems, better results are often achieved when it is done in partnership with those being regulated. In this way it is possible to utilize their experience of what is practical and feasible. Such partnering may appear counter-intuitive (service providers might be expected to resist regulation) but, in most cases, the advantages gained from being formally recognized outweigh any disadvantages that might arise from well-designed regulation.

Sanitation standards need to be monitored and enforced. The capacity for inspection and prosecution needs to be assessed to determine whether it is sufficient to cope with the predicted demands. A risk assessment approach (Section 4.4.2) can be useful in making these decisions, so that the amount of resources required to deliver public health outcomes is clear. Capacity issues may go beyond the public health system to the legal system and should be reviewed together. Related to this is the importance of invoking regulatory actions, which should lead to an instruction to desist from using a certain type of infrastructure or practice, only if there is a realistic alternative. For instance, banning a certain type of toilet is counterproductive if it results in open defecation.

National guidelines should be produced advising how to apply enforcement, and training provided on how to manage legal proceedings, particularly the collection and presentation of evidence. Responsible managers should review the enforcement activity and report on it annually, highlighting any sanitation issues that arise, and checking that it is not being applied abusively.

4.5 Roles and responsibilities

4.5.1 Coordination and roles

Sanitation spans many sectors and requires coordinated action by many stakeholders, and complete responsibility cannot be assigned to one ministry or agency. This means that it is necessary to establish a multi-sectoral platform for dialogue between the main stakeholders and to develop and oversee coordinated plans of action. This requires specific administrative support, such as a secretariat, to function effectively. Experience has shown that this is best situated in a senior ministry or bureau with a governance rather than a service provision role, such as planning, finance, or the prime minister's or president's office.

Political leadership for the coordination and implementation of safe sanitation systems and services is also needed, by a minister from one of the principal ministries involved or another senior political figure ready to assume the challenge of driving progress on sanitation. The secretariat should prepare information (possibly with support from development partners) to help in making the case for allocating resources to sanitation. A short- to medium-term strategy with feasible interventions and potential evidence based quick wins, should also be outlined, so that visible action can follow swiftly from political decisions.

The prepared material should be a consistent set of relatively simple messages, which could include:

- excreta flow diagrams (e.g. Figure 3.1) and diagrams of the sanitation service chain (e.g. Figure 1.1);
- contextualized evidence on implementation approaches that work;
- locally relevant statistics on the burden of a range of sanitation-related diseases and conditions (e.g. diarrhoeal disease outbreaks, levels of stunting, prevalence of diseases such as soil-transmitted helminth infections); and
- estimates of the economic impacts of sanitation, both on productive sectors such as tourism, environment, attraction of employers, etc., and on lost productivity and economic losses to households due to illness and opportunity costs.

The composition of the multi-sectoral sanitation platform depends on how responsibilities are distributed among ministries and public agencies. Institutions that may be involved include ministries of education, environment, finance, health, housing, justice, local government, planning, public works, water, the national statistics office, major utilities, representation of municipal and local governments, civil society and others. The process of joint sector planning and the alignment of the institutions' own internal plans relevant to sanitation are likely to identify gaps and overlaps to be rectified. This may need to be reflected in policies, memoranda of understanding or other official instruments over the medium term, but it should be possible to reach informal agreements to enable progress over the short term.

In some urban areas, sewerage may be managed by a utility, while non-sewered sanitation is the responsibility of local government. Such fragmentation of responsibility for sanitation can lead to poor planning, exclusion of poorer communities and, ultimately, reduced cost-effectiveness. Where an adequately performing utility company exists, consideration should be given to extending its mandate to cover both sewered and non-sewered sanitation.

Responsibility for running sanitation facilities within public buildings (such as schools, health centres, markets, transport terminals, prisons, etc.) should be assigned to the institution responsible for the premises in question, rather than the ministry responsible for the water supply and sanitation sector. This should involve the clear assignment of responsibility and finances for building and maintaining toilets to a department, section or unit within the responsible institution. Standards (such as user ratios), designs and management models should be developed within the institutional unit in collaboration with the health, water supply and sanitation, and public works sectors. These institutional units should ensure that supervision and technical assistance in building and managing sanitation facilities are provided to the local staff who are directly responsible for them.

4.5.2 Accountability and finance

Strong accountability frameworks are essential to ensure that safe sanitation services are maintained. This can be achieved by linking sanitation to the government budget process, since public funds are tracked, and the results of their use need to be demonstrated. The linkage may be made through general allocations to local government which are calculated partly on the basis of indicators, one or more of which can be made to reflect sanitation performance, and/or the adoption of specific good practices. Alternatively, or additionally, dedicated budget lines and funding windows for sanitation can be established.

The pivotal role of local government must be recognized, and resources and technical assistance should be channelled to them. Only a small portion of national functions should be retained at national level.

In some countries, local government may wholly or partially delegate responsibility for water and sanitation to a national or local utility company, and specific arrangements may be needed to channel such support to a utility. Where a utility is required to take on non-sewered sanitation systems, sufficient time should be allowed for the transition to be made to avoid damaging the commercial viability of the utility.

The institutions involved in sanitation need staffing and training in accordance with their agreed roles. This may mean additions and/or changes to government schemes of service and the allocation of budgets for training and peer-to-peer learning.

An additional (and complementary) accountability mechanism to budget linkage is to establish sanitation as an explicitly identified function of local government, to be reported to the layer of government immediately above (e.g. state or province). This type of accountability is driven principally by plans and targets, which should be regularly updated if they are to be meaningful. Accountability can be further strengthened by putting the plans, targets and reports on them into the public domain, were they can be scrutinized by citizens, organized civil society and the media.

Whatever accountability mechanism is used, effective monitoring metrics and indicators are needed that measure progress on all steps of the sanitation service chain. Wherever possible, definitions and monitoring elements should align with nationally relevant elements of global norms (Chapter 3) and the subset used for global monitoring to streamline both the national and global monitoring processes. This is discussed further in the Section on monitoring (4.6.3).

In addition to tracking outputs, it is also important to ensure that elements which allow progress are in place (these are discussed in more detail in Sections 4.6 and 4.7), and these include the existence, at local level, of:

a) plans showing time-bound targets for the various components of a mix of sanitation services covering all people and settings, associated with realistic budgets;
b) a functioning mechanism for coordinating sanitation across the relevant sectors;
c) an active programme of sanitation and hygiene behaviour change and monitoring and community consultation on sanitation (Chapter 5); and
d) service providers with sufficient competence and capacity to meet community sanitation needs.

Sanitation plans should be prepared by the responsible authority to ensure ownership, feasibility and relevance to local conditions.

4.6 Environmental health authorities and their role in sanitation

Ministries of health normally have a team dedicated to environmental health. Environmental health covers topics such as drinking-water safety, sanitation, air pollution, occupational health and chemical safety. Environmental health departments need to engage with many more actors outside the health sector to achieve their public health objectives than other departments within ministries of health.

Environmental health authorities require a broad range of skills encompassing health, biology, engineering, law, sociology and more to fulfil the environmental health functions within the framework of health sector functions (Rehfuess, Bruce & Bartram, 2009). Dedicated posts for sanitation managers reflecting their specialist knowledge may be useful and one role could include briefing other environmental health staff on the importance of sanitation, with an emphasis on the service chain and an inclusive community-wide approach.

Ministries should ensure that environmental health has a sufficient status with the ministry that reflects the foundational preventive health functions of the discipline that underpins progress on many health sector objectives.

The principal functions of the environmental health authorities with regard to sanitation are described below, building on the framework proposed by Rehfuess, Bruce & Bartram (2009):

- Sanitation sector coordination: contribute to the coordination function led by a senior ministry, and engage in intersectoral cooperation.
- Health in sanitation policies: ensuring health considerations are firmly embedded in sanitation policies, and that sanitation is embedded in relevant health policies.
- Health protecting norms and standards: Advising on setting norms, safety standards and sanitary legislation; ensuring that the needs of women and disadvantaged groups are accommodated in public sphere sanitation facilities. This includes provision for menstrual hygiene management and access for people with impaired mobility.
- Health surveillance and response: Assessing sanitation status and risks, linking with and strengthening health surveillance systems, and targeting interventions according to health data.
- Health programme delivery: ensuring sanitation aspects as well as inspection of community level sanitation conditions are embedded in relevant health programmes; and leading control measures in the event of enteric disease epidemics.
- Sanitation behaviour change: overseeing sanitation and hygiene behaviour change interventions (see Chapter 5) and liaising with other relevant health departments and programmes for implementation.
- Healthcare facilities: setting standards and monitoring systems for delivery of sanitation services in healthcare settings for the benefit of patients, staff and carers and for protection of the health of surrounding communities.

In addition to these core health functions, environmental health departments are also accountable for participating in cross-sectoral sanitation planning. They are also responsible for oversight, monitoring and enforcement of sanitation safety standards in private, public and business premises, in the environment, and in the provision of sanitation services. Some of these functions are discussed further below.

4.6.1 Oversight and enforcement

The objective of enforcement is to achieve the best possible public health outcome. On this basis, it should be seen as part of a larger spectrum of activities that includes education and sanitation promotion, with punishment of offenders as a last resort. It must be feasible for people to adopt the desired behaviour (e.g. building and using a toilet, connecting to a sewer, using an improved emptying service, etc.), so enforcement and promotion must be coordinated with services development and information campaigns. In practice, this means joint planning and coordinated implementation by environmental health authorities, service providers, local authorities and funders. Oversight and enforcement is an ongoing task that continues periodically after sanitation adoption and is used to check on sustained use and the integrity of facilities and sanitation service chains.

Certain enabling conditions are required for environmental health staff to undertake their enforcement role including access to inspect the public health conditions of facilities, information management systems for collection, aggregation and analysis of data, enforcement powers to follow up on non-compliant facilities and services.

4.6.2 Monitoring

Monitoring is a key environmental health function to track progress, and inform management decisions. This is especially important given that safe sanitation systems depend on continuously provided services meeting the principles of safe management at each step (Chapter 3).

Monitoring is required at various levels:

- *Individual facility level*: checking that sanitation standards are being met and good hygiene behaviours practiced;
- *Community level:* environmental health inspections to check standards and practices are met in all settings across the entire community;
- *Utility or service provider level*: ensuring sanitation safety plans are present and implemented, and that standards are met along the sanitation service chain
- *Sub-national level*: ensuring by-laws and regulations are set and monitored; measuring sanitation indicators and quantifying progress;
- *National level*: aggregating the local statistics to national level to track progress towards national and global targets;
- *International level*: monitoring progress towards the SDGs.

The indicators used and information required for these different levels of monitoring differ, with a larger number of indicators needed at the individual facility, utility and sub-national levels to inform local programmes and actions, while a smaller number of indicators are used for national and international monitoring to track progress towards sector targets.

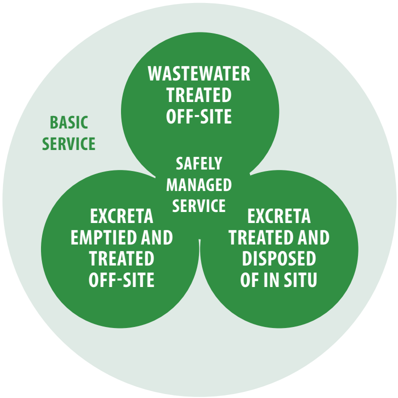
Information on the toilet end of the sanitation service chain can only be obtained by visiting people where they live. This is done systematically, but periodically, in the national census and in some cases through decentralised monitoring mechanisms. Household surveys led by national statistical authorities, as well as externally-supported surveys such as the multi-indicator cluster survey (MICS) and the demographic and health survey (DHS), typically undertaken every four to five years, are usually powered to provide information for national and sometimes sub-national level, but do not provide sufficient detail for comprehensive local planning. It is important that environmental health staff be involved in training enumerators for these surveys, so that the data collected are accurate, consistent, meaningful and linked to standards for targets. Developing a set of support tools for surveyors, such as illustrations, to show which technologies are classified as improved or unimproved, or meeting other national definitions, can improve consistency.

At the individual, utility or service provider and sub-national monitoring level, environmental health officers may do some of the monitoring, and also support local authorities and health workers in monitoring sanitation and hygiene behaviours. Environmental health staff should also monitor the containment, conveyance and treatment and safe use/disposal steps. Where lapses are observed, remedial action should be initiated with the relevant person or institution.

Practical considerations dictate that only a limited number of indicators can be monitored. In any given situation, a risk assessment should highlight critical control points that should be regularly monitored. It is also important that at least the basic indicators tracking the SDG target for sanitation (see Figure 4.5) are monitored.

Figure 4.5 The components of the SDG sanitation ladder (based on WHO and UNICEF, 2017)

SERVICE LEVEL	DEFINITION
SAFELY MANAGED	Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated off-site.
BASIC	Use of improved facilities that are notshared with other households.
LIMITED	Use of improved facilities shared between two or more households.
UNIMPROVED	Use of pit latrines without a slab or platform , hanging latrines or bucket latrines.
OPEN DEFECATION	Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other spaces, or with solid waste.



SDG target 6.2 on sanitation is tracked at the global level through the indicator of *proportion of the population using safely managed sanitation services*, which is defined as the population using an improved **sanitation facility** that is not shared with other households, and where excreta are either:

- treated and disposed of in-situ;
- stored temporarily and then emptied and transported to treatment off-site; or
- transported through a sewer with wastewater and then treated off-site.

Core indicators within national monitoring systems should capture global monitoring elements as a minimum as well as additional nationally relevant elements of safe management (Chapter 3) and implementation (Chapter 4) to monitor nationally relevant service levels, settings, sub populations and enabling environment.

To monitor sanitation, environmental health officers may play an important role in collecting individual and sub-national level information on:

a) Sanitation and related facilities (superstructure, handwashing facilities) and the way they are used.
b) For on-site facilities, the effectiveness and safety of *in-situ* treatment or the emptying and transport of faecal sludge.
c) For sewerage, the extent of leakage and overflow of untreated sewage.
d) The effectiveness of faecal sludge and sewage treatment against national standards or permits.
e) The extent and effectiveness of community engagement on sanitation.

Data on sanitation and handwashing facilities (a) and the *in-situ* treatment for on-site facilities (b) should be collected through the inspection of dwellings and buildings (this may be done routinely, in periodic/special surveys or in the national census). Data on the emptying and transport component for on-site facilities (b) and on leakage or overflow of untreated sewage (c) should be collected from customers, formal and informal operators and, where relevant, licensing authorities or regulatory bodies. When information is collected by operators, it should be backed by periodic observation or audit to ensure that information provided is correct. This component should intentionally capture data on management of full pits, including informal and manual emptying practices. Data on the effectiveness of sludge and sewage treatment (d) should be collected from operators and verified by occasional sampling and independent laboratory analysis. A good basic principle to apply in service provider regulation on (b), (c) and (d) is for them to report specified monitoring information, subject to challenge inspection by environmental health authorities. The frequency of such inspections depends on the level of trust by environmental health staff in the service providers and the potential hazards arising from non-compliance. Information on sanitation community engagement (e) requires discussions with local officials and community members. A comprehensive set of sanitary inspection forms has been developed to assist environmental health officers in this process (see WHO website: http://www.who.int/water_sanitation_health/en/).

Taken together with information on open defecation (collected through community monitoring data or environmental health inspections), these data enable the assessment of sanitation according to and beyond the SDG definitions, as well as to inform planning. Where non-specialist staff are involved in data collection (e.g. in specific surveys or a census) it is important that environmental health staff assist with enumerator training, including some supervised fieldwork, to ensure that the basic concepts are understood and improve consistency.

Incentives to collect monitoring data, and the resources required to do so, may be limited. As mentioned in respect of accountability, the incentive may be that such data are required to release certain government budgets, especially where specific budget lines, funding windows and expenditure codes for sanitation at central and local government levels have been established. Part of these budgets should be assigned to cover the costs of monitoring.

4.6.3 Managing sanitation and hygiene promotion

The consistent use of sanitation facilities and promotion of improved hygiene behaviour is a fundamental and essential component of sanitation intervention and is outlined in 4.7.2 and detailed in Chapter 5. To enable environmental health staff to play their role fully, they should receive training to equip them to manage specialists and contractors and to advocate internally for the allocation of sufficient resources for sanitation behaviour change. It is also necessary to formally train frontline staff, such as extension and community outreach officers.

4.6.4 Risk assessment

Environmental health staff should be involved with the sanitation risk assessment process (4.4.2) and monitor relevant health and epidemiological data (such as that collected through routine surveillance at health care facilities) to help to identify the public health burden related to poor sanitation. They should also check that women, girls and vulnerable groups are adequately served. This may be partially possible from the epidemiological data (depending upon its quality) possibly combined with general observations and focus group discussions. This vigilance needs to extend beyond people's immediate living and working environments to wherever faecal material is being used or discharged into the environment. Based on this, they can identify high risk areas where priority should be given to improving sanitation.

4.7 Delivering sanitation at local level

4.7.1 Sanitation as a basic service

In all environments, maximum health benefits can only be obtained from sanitation when combined with adequate water supply and good hygiene behaviours.

In a high density (urban) environment sanitation is closely linked to land-use patterns, housing occupancy patterns, level of water supply services, drainage and solid waste management and cannot be managed independently of them. Planning and implementing sanitation must therefore be coordinated with these other basic services.

In practice, the only institution empowered to act in all these areas is local government, so overall responsibility for sanitation must be placed with them, even where sanitation service provision has been delegated to a utility company or is delivered by the private sector. As noted earlier, sanitation must be identified explicitly in the planning and budgeting process, which should recognize nationally- and locally-established service level targets. In order to align the activities of the various sectors that contribute to sanitation, a city or district level coordination group with senior representation from all relevant departments, and other key stakeholders, such as service providers and user representatives, should meet periodically.

4.7.2 Sanitation behaviour change

Active user participation is needed to achieve sanitation and good hygiene. Multiple behaviours by different stakeholders require addressing along the sanitation service chain, and may require specific strategies. Chapter 5 examines sanitation behaviour change in detail, using ending open defecation as an example. Behaviour change should be seen as an integral component of providing sanitation, as concentrating on infrastructure and services alone will not deliver the desired public health outcomes.

4.7.3 Local monitoring

Monitoring systems should be based on whatever frontline staff are available in the communities to increase sustainability and reduce costs. They might be formal or informal community leaders, or staff from health, agriculture or other sectors which have a community presence. Budgets should be programmed for the purpose, and a continuous training programme established; the number of people involved is large, so natural attrition generates an ongoing training need, in addition to a requirement for refresher training (see also Section 4.6.3). A database should ideally be maintained, with georeferenced information on sanitation facilities and their condition; this should assist in planning and managing further sanitation interventions and in providing information for the design of sanitation promotion strategies (see Chapter 5).

4.8 Developing sanitation services and business models

4.8.1 Designing services

Sanitation services must respond to the physical, social and economic conditions prevailing in each area, and these factors should be assessed prior to embarking on sanitation improvements. Using the risk assessment (Section 4.4.2) as a basis, inadequacies in the existing sanitation situation can be identified, based on existing documentation, local expert knowledge, dialogue with users, a general survey of the area to identify sanitation issues and, if possible, household surveys. Further assessment, by examining legal and policy documents and interviewing key stakeholders, should be carried out to understand how the formal and informal institutions and service providers, rules and practices create this situation. The assessment process should actively engage with the stakeholders and aim to develop a common understanding of the situation. It should be possible to identify if, and at what stages, the sanitation service chains are failing, where these failures pose the greatest risks to public health, and the market supply, user demand, and institutional factors that have led to this. In an iterative process involving the stakeholders (especially users), possible interventions should be formulated, and their viability assessed, to arrive at feasible solutions that produce the greatest impact on public health. The solutions should address all aspects, including:

- hardware;
- sanitation promotion and behaviour change;
- institutional development;
- legislation and regulation; and
- financing.

Wherever possible, they should build on or make use of existing capacity and infrastructure.

As outlined in Section 4.2, sanitation services may be provided by the private sector (informal and formal), utility companies (commercialized public entities), local government or any of these in combination. Services which provide direct benefit to the user, such as hardware supply, toilet construction or desludging, can often function well as private businesses, provided that they are regulated to ensure safely (Chapter 4.4) and poorer households have access to subsidies to ensure services are affordable. Faecal sludge treatment and, particularly, sewerage systems require major capital investment, which could be difficult for a private company to finance, and so usually require public investment. They may be managed directly by the public sector or a utility company or leased to a private operator. The leasing option is particularly suited to faecal sludge treatment and incentivizes resource recovery.

As cities grow, there is an increasing need for decentralized sanitation systems in urban areas, both small sewerage systems and faecal sludge transfer facilities and treatment sites. These make good sense in engineering terms but may be challenging to implement due to difficulties in acquiring land, or in the face of resistance within the neighbourhood. Land acquisition issues can be partly resolved by adopting planning regulations – which may already exist – that require land to be reserved for sanitation infrastructure, and making allowances in urban zoning and land-use plans.

Where there is local resistance, this can often be overcome by working with communities to explore options and incentives. A number of treatment technologies (such as anaerobic baffled reactors or upflow anaerobic sludge blankets) are installed underground, do not create smell, and can create a hard, flat surface that can be used as a community space. Biogas generated by the process can be given to nearby residents, and other incentives can be negotiated if necessary. In the case of transfer facilities for faecal sludge, mobile units can be used if local resistance to a permanent structure is too strong.

4.8.2 Sanitation service capacity building

Adopting a systematic and inclusive approach to sanitation is likely to create a need for formal services that do not currently exist (or only on a small scale). These services and their support requirements are diverse in their nature, ranging from hardware manufacture and provision to faecal sludge management. Some common factors are outlined below.

A new type of service requires technical development. Partnerships with academic institutions, NGOs or social enterprises can support both initial development and ongoing adaptation of the service. For a more mature service a franchise model can be considered. In this case the franchisor provides training, technical backstopping, quality control, marketing and, possibly, certain specialized equipment to franchisees. In all cases, the partnerships should include people with environmental health knowledge to oversee risk assessment, system improvements and operational monitoring as well as supporting programmes such as training to ensure that the systems developed deliver safe sanitation.

Associations of service providers can be very useful and should be promoted where they do not exist. They facilitate the dialogue between the service providers and the authorities responsible for sanitation, and can be the entry point for training and certification. Associations can play a useful role in informing financial institutions about sanitation businesses (with which they are probably unfamiliar) and help develop lines of credit.

Training is a crucial component of capacity building and peer-to-peer learning and on-the-job mentoring can be particularly effective. Service providers should receive training in business as well as technical skills to promote efficiency, minimize costs and, ultimately, improve sustainability.

Small enterprises may need assistance in obtaining equipment and working capital to make a start. Possible mechanisms include:

- Joint representation to financial institutions to facilitate access to credit.
- Small grants or equity contributions from government or project funds.
- Leasing of equipment.
- A guarantee fund, to facilitate borrowing.
- Results-based financing agreements, often used with repayable finance to provide comfort to the lender.
- Advance purchase agreements – guaranteeing a market to a specified level.

Demand should be activated and sustained, once services are operational, with ongoing marketing and informational campaigns and judicious enforcement of public health regulations. Where there are multiple small service providers, a common brand and marketing campaign enables the use of mass media, which may only be affordable on a collective basis.

4.8.3 Working with existing sanitation service providers

In urban areas, improved sanitation usually competes with traditional unsafe sanitation services. Traditional service providers should be persuaded and encouraged to work with the new, improved services to make use of their acquired knowledge on wastewater and faecal sludge and people's behaviour regarding toilets. This takes them out of the market for unsafe services and discourages them from sabotaging the improved services to protect their livelihoods.

Some of the traditional service providers may be socially marginalized and unwilling or unable to participate in a formalised, regulated service. Encouraging licensed service providers to employ them can reduce this, provided they can conform to acceptable standards of behaviour and safety. It is important to engage with them at an early stage to make them into part of the solution instead of part of the problem. Irrespective of how these workers are incorporated into the improved sanitation system it may be necessary to take specific measures to eradicate any residual bad practice once a market providing a sufficient volume of alternative and safe services has been established.

4.8.4 Financing services

People are prepared to pay (at least partially) for sanitation services at the toilet, containment and on-site treatment, and parts of conveyance (see Chapter 3) that benefit them directly. Other aspects of conveyance, treatment and disposal or use are shared and perceived as services that benefit entire communities, which may require public or joint financing strategies such as tariffs and taxes. Tariff structures should reflect the ability to pay for services to prevent exclusion of poor households from services.

In urban areas, sanitation fees can be combined within the water tariff, especially if all sanitation services (sewerage and non-sewered services) are managed by a utility. They can also be included in local taxes, although it can be harder to ensure that the funds raised through this mechanism are directed towards sanitation.

In low-density rural areas, where the principal activity is sanitation promotion and the safe and consistent use of self-built toilets, there is little alternative to that of using government budgets for these activities. A particular issue arises where toilets need to be emptied, as the extra cost of improving toilets to enable mechanical as opposed to manual emptying also benefits residents in the surrounding area (by avoiding local dumping of the faecal sludge). A similar issue arises if sewerage systems are extended into low-income areas where residents may be unable to meet the cost of the internal plumbing required. In these circumstances it may be justified to partially subsidize the cost to the user from the same sources as used for the other publicly shared costs of sanitation. It should also be noted that large-scale purchase and construction of prefabricated toilets may be able to bring the price down substantially in such programmes.

In very poor communities, or for vulnerable households, even a basic toilet may be unaffordable, and specially targeted subsidization may be needed. Possible mechanisms for owner-occupiers, in low-income urban areas include social security safety nets or community-administered funds. Low-income landlords should access these social security safety nets or community-administered funds for the benefit of their tenants. However, there is a risk that this may result in increased rent and the possible displacement of the poorest tenants to inferior accommodation. An alternative for those living in rented accommodation, especially in high density areas without secure tenure, is container-based sanitation, since it can offer a direct service to tenants without them bearing the full cost of investment in improving a home they do not own. In low-density rural areas where it is assumed that only very limited cash costs will be incurred for toilet construction, community labour could be used.

Services such as desludging may be too expensive for some customers and will, in many cases, have to compete with manual desludging, which usually has a lower cost as it does not include safe transport and safe disposal. This may be countered by smoothing payments through a regular affordable tariff. It may also be necessary to subsidize these services, possibly through a voucher or other output-based system. Demand for desludging services is often seasonal, which can be problematic for a small business. This can be partly offset by taking on other business activities, such as solid waste collection, which can offer a steady income throughout the year, or setting up a scheduled emptying program to implement preemptive rather than reactive emptying and spread demand across the year.

The processing of faecal sludge and sewage into products for sale (e.g. biogas, solid fuel or compost or irrigation water for agricultural use) can help offset some of the costs of treatment, although it rarely covers the full cost (Otoo & Drechsel, 2018). When considering product options, it is important to assess the market for a proposed product to see if the required quantities, quality and delivered costs match the production potential. Environmental legislation to encourage their use, can make such products more attractive than they might otherwise be. The public health implications of the diverse types of end use should always be assessed when deciding on what products to make and the costs of ensuring product safety should be reflected in the final cost. Once an option is chosen and implemented, appropriate control measures and monitoring regimes should be formulated to ensure ongoing safety in the use of the products (WHO, 2006; WHO, 2016).

4.9 Fostering the sanitation services market

A sustained promotion programme is necessary to foster new norms of sanitation behaviour. Marketing and promotion of behaviour change requires substantial resources to produce results. The desired behaviour changes (e.g. Section 4.7.2) and messages should be clearly defined, and interventions should be based on adequate research among the target groups, combined with inputs from experienced professionals as detailed in Chapter 5.

Several types of sanitation services are likely to be supplied by commercial or partly-commercial entities:

- hardware supply and construction of toilets;
- pay-per-use public toilets; and
- desludging or container exchange.

In all cases, lowering prices through competition is good for both customers and providers because it makes the market more accessible to users, while also increasing sales volumes.

In the case of hardware and toilet construction, the first step is to develop combined toilet-containment system products appropriate to the target market – they should meet aspirations, fit comfortably into the type of housing to which they are targeted, be affordable and fit with the rest of the sanitation service chain. Bundling such products with consumer credit (from suppliers and/or micro-finance institutions) and installation in a package can be very effective. Direct marketing sales and marketing efforts for the products or package are essential and a shared branded marketing campaign may be effective.

In the desludging market, the widespread presence of mobile phones in urban areas has allowed, in some cases, the development and use of call centres or automatic digital platforms where customers can find service providers, and where the service providers can compete on price (Aquaconsult, 2018). Creating such an efficient market is likely to be more viable than trying to control prices through regulation, as it can balance willingness to pay against service costs. There is also potential for quality control by gathering customer feedback. Where a database of toilets has been developed, this type of platform can also become a good source of monitoring and planning data. Geo-location chips can be fitted to licensed desludgers' equipment to enrich the database.

Container-based sanitation services are under development. Costs depend strongly on the scale of the service and the density of customers (proportion of all households in a local service area using the service). Marketing is, therefore, crucial to delivering an affordable container-based service.

Although some services require subsidy for the poorest households, managing large one-time payments such as sewerage connection or desludging fees by incorporating them into a regular monthly tariff can make them much more affordable, especially to poorer customers. A database of non-sewered toilets is a necessary component of any schemes including regular scheduled desludging. It is appropriate to mobilize frontline workers and local leaders to undertake the necessary periodic fieldwork as this is useful to the authority responsible for sanitation.

4.10 Management of special sanitation risks

4.10.1 Sanitation in emergencies

Other publications (e.g. the Sphere handbook, 2018) provide specialized guidance on sanitation in disaster situations. These guidelines focus on including sanitation in disaster preparedness planning as an immediate priority action. To facilitate this, sanitation and hygiene materials should be purchased and pre-positioned along with other emergency supplies (such as those for shelter, nutrition and health). These emergency supplies include:

- picks and shovels for digging pit or trench latrines;
- latrine slabs or container-based sanitation cartridges;
- material for superstructures – with full provision for privacy and lockable doors;
- appropriate anal cleansing materials or containers;
- jerry cans and handwashing stations;
- soap; and
- lime for use in faecal pollution incidents.

Chapter 4

If a refugee or internally displaced persons (IDP) camp is established, it is important to ensure that, as far as possible, it is situated in an area where latrines can be dug (i.e. not in areas of high water table or rock). Often camps are sited on marginal land which may be more easily available than land with soil cover and a reasonably low water table, but this presents major problems and risks with regard to sanitation. As camps often effectively end up becoming urban settlements, full service chain sanitation with sewerage or faecal sludge management and effective treatment should be considered once the immediate disaster phase is over, as the densities are too high to support fill-and-cover pit latrines over a long period. Consideration should also be given to situations in which camps are not provided or emerge informally, including assessment of the impact of refugee or IDP influxes on the refugees and IDPs themselves as well as host communities.

Container-based systems can also be used in emergency situations and can be deployed very quickly and can also provide a long-term service. Shared toilets that substitute latrine pits with plastic tanks, which can be replaced periodically and trucked away for off-site treatment, do not need dry organic waste and can provide an effective interim service. Recommendations on other incremental control measures can be found in Chapter 3.

Provision for people with disabilities, for children, and for women's privacy, safety and menstrual hygiene needs are critical and need careful planning during emergencies, when women and girls are especially vulnerable.

4.10.2 Sanitation during enteric disease outbreaks and epidemics

Special attention should be paid to sanitation during disease outbreaks and epidemics of enteric diseases with a faecal-oral transmission route including cholera etc. Preventive action to reduce faecal load in the environment (see Chapter 3) especially in known hotspots with recurrent outbreaks, is more effective than attempts to disinfect faecal material in the environment. Disinfection of faeces is usually futile because organic material in faeces has a very high chlorine demand, it is also time-consuming and expensive.

A rapid sanitation safety planning approach can be applied to identify risks, prioritize action and monitor key actions. While the specific characteristics of each situation are different, the highest-priority actions should be focused on where exposure to sanitation hazards is likely to be highest and cause the greatest risk, such as the toilet and containment part of the service chain near where people live and work. Some measures – typically related to hygienic practices and minor repair and maintenance activities – can be taken immediately, while others requiring more complex interventions may require weeks or months. Some of the immediate and longer-term measures that may be considered at various stages of the sanitation service chain are set out in Box 4.2.

It should be remembered that a major causative factor in enteric disease epidemics is poor sanitation. Such events can be used to sensitize decision-makers to the importance of improving sanitation, and it is important to follow up with longer-term measures to prevent a reoccurrence.

4.10.3 Sanitation in health care facilities

Heath care facilities represent a particularly high sanitation risk, due to both infectious agents and toxic chemicals. From the user perspective they should be a model of hygienic sanitation. Health care facility sanitation should be under the responsibility of the Ministry of Health, with responsibility for its management clearly specified in the job descriptions of health care facility managers and relevant staff.

Recommended numbers of toilets are 1:20 for inpatients and at least two toilets for outpatient

Box 4.2 Immediate preventive measures for areas at high risk of enteric disease outbreaks

Neighbourhood and household level

Immediate measures

Undertake neighbourhood and house-to-house sanitary inspections to identify open defecation sites and leaking or overflowing sewer connections, open drains and pits or tanks of on-site sanitation facilities.

- Where open defecation is prevalent, undertake demand creation and sanitation promotion (see Chapter 5), using properly trained staff if available, with the objective of persuading open defecators to use an existing neighbour's or community toilet, where available.
- In urban areas, using a combination of sanitation promotion/behaviour change strategies and enforcement, persuade owners to empty overflowing but otherwise serviceable permanent sanitation facilities where this is a viable option.
- Carry out intensive hygiene promotion, focusing on: immediate care-seeking; handwashing with soap; prompt disposal of child and infant faeces in a safe toilet; hygienic practices in the care of sick individuals and management of their faeces; hygienic practices in the washing and burial of corpses; avoiding contact with water in drains (especially children); and treatment of drinking-water supplies.

Promote and support the installation of handwashing facilities in homes and institutions.

Medium term measures

- Using a combination of demand creation and enforcement, persuade owners to fix leakages and rebuild or upgrade unsafe toilets, or to build a toilet where there is none.
- Where it is not possible to substitute open defecation with individual household toilets, organize the construction of community toilets shared between limited and defined groups of households, with robust operation and maintenance arrangements.
- Where liquid effluent from on-site sanitation facilities is discharged into drains and waterways, or where there are leaking sewer connections, promote the construction of soakaways and drainfields where feasible. Where this is not feasible, organize mass desludging to increase effluent residence times in the tanks and decrease solids carry-over.

At health posts, hospitals or emergency facilities for infected people

Immediate measures

- Eliminate leakages and overflows of liquid effluents urgently, and carry out all feasible minor repairs and desludging to maximize the efficiency of the existing sanitation system.
- Ensure sanitation facilities are operational, accessible to all, and have handwashing facilities with soap and water nearby.

Medium term measures

- Review sanitation arrangements, to ensure that all faecal material is contained and that all liquid effluents are treated on-site and infiltrated to soil though a leach field or discharged to a sewer and treated and safely disposed (see sewerage and wastewater treatment below).

Faecal sludge management

Immediate measures

- Disseminate messages to promote the use of licensed desludging operators (where applicable).
- If it will result in less open dumping, temporarily suspend the charging of tipping fees.
- Urgently inspect all faecal sludge management equipment and oblige operators to rectify any faults that could result in inadequate containment or spillage.
- Increase vigilance against open dumping of faecal sludge and institute strong measures to ensure that operators discharge at authorized sites.
- Promote, and enforce with follow up inspections, the use of disinfectants to clean up premises which have been serviced, and the desludging equipment used.

Medium term measures

- Review operating practices with all desludging operators to minimize risks for both operators and customers.
- Contact the traditional emptiers and enlist their cooperation to the extent possible, promoting the burial of faecal sludge over dumping it in drains, water bodies or open land.

settings (one toilet dedicated for staff and one gender-neutral toilet for patients that has menstrual hygiene facilities and is accessible for people with limited mobility) (WHO, 2008). They should be culturally acceptable, private, safe, clean and accessible to all users, including provision for those with reduced mobility and for menstrual hygiene management. Bedpans should be used by patients only when needed, and not as a regular substitute for toilets; when used, bedpans should be safely handled avoiding spillage and using appropriate PPE. Faecal waste from bedpans and water used for washing bedpans should be emptied into a toilet or into the sanitation system through other means such as a sluice or macerator. A reliable water point with soap should be available close to toilets for handwashing.

All faecal waste (including from bed pans) and greywater should be fully contained. If a sewer connected to a fully functional treatment plant is available, these wastes can be combined and discharged to it. If no sewer is available, the faecal waste and greywater should be conveyed in separate drains. The faecal waste should be treated in an appropriately sized treatment facility, with the greywater being added at the secondary stage. The liquid effluent should be contained on-site, by way of subsurface infiltration. If that is not possible, the liquid effluent should be disinfected in a baffled tank providing adequate contact time, before discharge into the environment beyond the health care facility. The liquid effluent should never be used, even if disinfected.

A budget for operation and maintenance of the health care facility wastewater system must be consistently allocated. An adequately trained staff member should have officially designated responsibility for the system, with staff allocated to maintenance tasks. Management of the wastewater system should be on the standing agenda of the group in charge of infection prevention and control, as should the management of laboratory wastes, solid waste management and the safe treatment of infectious waste.

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Chapter 5

SANITATION BEHAVIOUR CHANGE

5.1 Introduction

Like many public health programmes, sanitation programmes have historically tried to influence practices through the direct provision of hardware (e.g. by constructing toilets, sewage networks and treatment plants) and with various forms of health education or health promotion. Lessons from practice and behavioural science studies, however, have shown that people choose to use toilets and practice related hygienic behaviours for many reasons other than the desire to improve health (Jenkins & Curtis, 2005; Curtis, Danquah & Aunger, 2009). Behaviour change is now seen as an essential component of sanitation programmes, whether to improve the uptake of sanitation solutions, hygienic practices in households or, indeed, in the institutions responsible for sanitation programming.

Behaviour change among a range of stakeholders is necessary for sanitation interventions to improve public health. Chapters 3 and 4 cover various important behaviours relating to the delivery and management of sanitation services. This chapter focuses on fostering behaviour change at the individual, household and community-level, through behaviour change interventions designed to increase the adoption of household toilets and their consistent use, management and maintenance.

Depending on the specific situation, desired user behaviours may include:

- Abandoning open defecation and adopting safe sanitation facilities.
- Handwashing with soap at critical times.
- Building and using non-emptiable pit latrines, which are covered over when full and new facilities constructed.
- Building and using permanent on-site facilities with access for emptying and accessibly situated for emptying equipment.
- Ensuring the regular desludging of such facilities and the infiltration of liquid effluents to the subsoil or other safe disposal route.
- Connecting to a sewerage system where available, and paying the service charges.
- Safe practices in handling wastewater and faecal sludge in food production and sale.

5.2 Institutional and government responsibilities for sanitation behaviour change

Governments are the critical stakeholder in the coordination and integration of behaviour change initiatives at the local level and should provide leadership and ensure funding. The point is made in Chapter 4 that sanitation behaviour change requires financial and human resources, and that failure to commit sufficient resources may lead to failure to achieve sustained adoption or use of household sanitation services.

Health authorities should ensure that all sanitation interventions include a robust sanitation behaviour change strategy. This applies whether there is a national effort to improve sanitation in general, or when sanitation is included as part of a disease control programme (e.g. as part of environmental improvements for trachoma elimination, in prevention of and response to cholera outbreaks, in nutrition programmes or for reducing intestinal worm infections in children). Sufficient staff with specialized expertise and financial resources must be allocated to sanitation behaviour change and work should be conducted in coordination with those providing infrastructure and services in order to ensure that demand is not created for non-existent services or that services are offered but not purchase, or provided but not used.

While many health authorities have departments dedicated to developing health promotion interventions, where such departments do not exist or lack the necessary skills and resources to design evidence-based behaviour change programming, health authorities should nonetheless be able to provide oversight and direction to programme design. This may involve engaging with organizations with technical and subject matter expertise, such as universities and social marketing and design agencies. At a minimum, health authorities should:

- Provide oversight on suitable approaches and their implementation and monitoring.
- Ensure that sanitation behaviour change efforts are targeted, as far as possible evidence-based, and that there is a solid monitoring and feedback mechanism for learning and adaptation.
- Ensure that all actors are aligned around the same set of behavioural objectives and strategies, so that diverse efforts reinforce, rather than compete with, or undermine, each other.

The Ministry of Health may be involved in the formulation of sanitation behaviour change strategies, in the setting of targets, and in the development of local guidelines. While they may not be involved in the direct management of sanitation behaviour change interventions, they do have a mandate to manage, coordinate and oversee the efforts of other players, including external support agencies and NGOs. The Ministry of Health is also the focal point for knowledge management related to sanitation and sanitation-related behaviours in their country. Accurate and up to date information on current sanitation practices (both nationally and within specific regions or sub-populations) should be maintained. Nationally representative surveys, such as the Demographic and Health Surveys (DHS) and the Multiple Indicator Cluster Surveys (MICS), are commonly used to create these national and sub-national estimates on sanitation coverage and use. Academic studies of sanitation related behaviour may also be available. Data collection on community-level sanitation status should also be integrated into routine (e.g. health management information system (HMIS)) or programme-specific data collection activities. The Ministry of Health may also provide technical support related to standard indicators and methods for measuring behavioural outcomes to ensure that sanitation-specific data is shared between organizations and data collection activities is comparable.

If the Ministry of Health fulfils these roles it allows other institutions to play their proper roles, which include building capacity in local and regional authorities, providing tools and technical support for local programming and in relationships between stakeholders.

5.3 Sanitation behaviours and determinants

To design successful activities to influence sanitation behaviours it is important to understand the range of existing sanitation behaviours and their determinants. From a behaviour change perspective, sanitation and hygiene present several distinct challenges. For example, sanitation and hygiene behaviours may be entrenched within long-standing daily routines – behaviours done in a specific sequence within a specific environment at specific times of the day. Sanitation behaviours may also require an expensive physical modification to a home, namely the building of a household toilet facility.

For sanitation to be effective (i.e. to ensure that people do not have contact with pathogens in human waste and that the pathogens are safely removed from the environment), a variety of inter-related behaviours are important. These include the sustained use of facilities and their maintenance and upkeep, good hand hygiene and the hygienic disposal of child and infant faeces. Having access to a toilet is essential for use to take place, but it does not guarantee consistent use (Garn et al., 2017). There are multiple reasons why existing facilities may not be used, including:

- Facilities may not be adequately accessible to intended users, particularly women, older people or people with disabilities.
- Facilities may not offer sufficient privacy to users given the intimate and often taboo nature of sanitation behaviours (Sahoo et al., 2015).
- Facilities and the use of facilities may not provide a safe environment free from harassment, violence, or other physical and emotional forms of harm (Kulkarni, O'Reilly & Bhat, 2017).
- They may be broken, dirty or uncomfortable to use.
- Individuals may prefer open defecation, particularly when sanitation options are unappealing or unhygienically maintained (Dreibelbis et al., 2015).
- Facilities may not be available at the times users need them, such as when individuals are away from home (school, work place, public places) or may be locked at night (Caruso et al., 2017a, b).
- Users may be concerned about the impact of long-term use on pit-filling and future maintenance, thus avoid using the facility (Coffey et al., 2014).
- Sharing facilities may discourage people from using facilities, even when sharing is limited to members of the same family (Coffey et al., 2014).
- Shared and public facilities may be located at a long distance; queues may also discourage use (Kulkarni, O'Reilly & Bhat, 2017)

The determinants of behaviours of interest may be positive (meaning that they promote the behavioural outcome) or negative (where they act as a barrier to the behavioural outcome). Behavioural determinants are found at different levels (e.g. society, community, individual, etc.) and include factors which can be characterized as being related to context, technology and psychosocial experiences (Dreibelbis et al., 2013).

For example, individual-level determinants of behaviour include knowledge around toilet construction and use, costs and benefits, motivation and desire for sanitation, and the way in which the behaviour fits in with daily routines and habits.

Determinants that operate at the household level could include roles and responsibilities and the division of labour within the household.

At the community-level, determinants include societal norms of toilet use and capacity for the management and maintenance of facilities.

Behavioural determinants are related to the context in which behaviours occur. These include determinants in the physical environment such as climate, geography and access to materials, economic determinants such as access to goods and services, and institutional determinants such as the availability of subsidies or the enforcement of fines and/or penalties. Sanitation technologies can also determine behaviour through, for example, ease of use, location and cost.

The relationships between behavioural determinants and behaviours can be complex and multiple determinants often interact to influence one behaviour, as illustrated for open defecation in Figure 5.1.

Figure 5.1 Example of behavioural determinants for open defecation

Box 5.1 Sanitation behaviour change considerations for urban settings

The determinants of behaviour are likely to differ between settings and for different population groups. While there is often a strong focus within sanitation behaviour change approaches on rural contexts, urban populations present distinct challenges and opportunities. Higher population densities, higher rates of renting (compared to owning), lack of space, and a need for more complex sanitation service chains and or technologies that serve more than one household may limit the opportunity for urban populations to improve their own sanitation services in the way that is expected of rural populations (e.g. through the constriction of simple pit latrines). Social networks in urban areas can be less formal, so social pressures and norms in urban areas may differ from those in rural areas, potentially reducing the effectiveness of interventions that rely on social pressure for stopping open defecation. Violence and physical harm, specifically against women and girls, related to the reliance on shared open defecation spaces or public toilets, is increasingly reported in urban settings, necessitating strategies for improving sanitation that are responsive to these needs. Urban populations typically have better access to cash resources, sanitation markets and technical support than rural populations. Other populations with specific sanitation needs may include those in rented accommodation, those without land tenure, the homeless and populations that are marginalized either socially (such as by class, caste, social status, ethnic or cultural identity) or geographically (O'Reilly, Dhanju & Goel, 2017).

5.4 Changing behaviours

5.4.1 Main approaches

This section describes the different behaviour change approaches commonly used for sanitation and hygiene behaviour change. While myriad strategies have been used, these typically fall into one or more of four major categories (adapted from De Buck et al., 2017):

- information, education and communication-based (IEC) messaging approaches;
- community-based approaches;
- social and commercial-marketing approaches; and
- approaches based on psychological and social theories.

Behaviour change programs often utilize more than one approach.

Information, education and communication approaches (IEC)

Messaging and awareness raising are the cornerstone of conventional information, education and communication (IEC) initiatives. IEC approaches are often used in public health behaviour change communication. IEC can include mass media, group or interpersonal communication and participatory activities. Specific approaches such as Participatory Hygiene and Sanitation Transformation (PHAST) and Child Hygiene and Sanitation Training (CHAST) use IEC methods, are based on individual behaviour change and do not explicitly target changing collective behaviours.

IEC approaches often default to health messaging, particularly around the health risk for children. Often, however, populations are already aware of both the risk of diarrhoeal disease and its prevention (Biran et al., 2009; Curtis, Danquah & Aunger, 2009; Aunger et al., 2010; Brewis et al., 2013), and health-focused messaging fails to result in significant changes in sanitation or hygiene behaviours (Biran et al., 2009). Consequently, IEC is rarely used as a standalone approach.

Community-based approaches

The focus of community-based approaches to sanitation is the collective mobilization of groups of people. Collective processes are used to develop a shared understanding of a local problem, reach a collective agreement on actions and to create new norms around a specific behaviour. These norms help to create new social pressures to comply with the promoted behaviour.

There are multiple variants of community-based approaches that have been applied to sanitation programmes. Community-Led Total Sanitation (CLTS) initiatives are the most widely known and are directed at ending open defecation. CLTS is organized around a "triggering event"; a series of community-based activities, led by trained facilitators, which focus on behaviour change and aim to ignite a sense of disgust and shame in a community related to open defecation and its impact on the community's health and well-being (Kar & Chambers, 2008). Communities are facilitated to conduct their own appraisal and analysis of open defecation and take their own action to become open defecation free (and although traditionally the CLTS method stipulated that this should be free from subsidies and other financial inputs, this is no longer the case). Communities are also facilitated to develop their own approaches to maintaining and improving facility use. CLTS programmes have been implemented in over 60 countries and have evolved in multiple ways to improve outcomes on sustained sanitation use (Cavill et al., 2015; Bongartz et al., 2016), including:

- targeting subsidies to marginalized households (Robinson & Gnilo, 2016; Myers & Gnilo, 2017);
- tailoring initiatives to focus on the inclusion of marginalized groups and households; (Wilbur & Danquah, 2015; Bardosh, 2015; House et al., 2017; Cronin et al., 2017);
- paying increased attention to supply-side interventions such as social and commercial-marketing based approaches discussed below, in order to stimulate progress from basic to safely managed sanitation (Thomas, 2014; Cole, 2015); and
- understanding reasons for slippage and reversion to open defecation (Odagiri et al., 2017; Mosler et al., 2018).

Community Health Clubs (CHCs) are another example of a collective mobilization approach (Waterkeyn & Cairncross, 2005). CHCs involve long-term engagement with target communities, through weekly meetings each addressing a specific health, hygiene or sanitation behaviour. CHCs focus on making changes with local resources and local innovation, and group activities help to establish new positive norms around improved hygiene and sanitation behaviours.

Community-based approaches are thought to be more effective in rural communities with higher social cohesion and where adoption of simpler technologies is feasible, although specific data on the effects of these approaches on sanitation adoption are scarce.

Social and commercial-marketing based approaches

Social marketing refers to the broad set of initiatives that use commercial-marketing principles to change health behaviours. Social marketing assumes that sufficient promotion and demand creation, when met with accessible goods and services that meet a population's needs at an affordable price, results in changes in behaviour (Barrington et al., 2017). These are reflected in the "4Ps" of social marketing: product, price, place and promotion.

Commercial-marketing approaches recognize that most toilets are obtained by householders from local markets and so focus on market development, at the same time as developing and activating demand for sanitation products and services. Market based approaches in India, Cambodia and Vietnam have resulted in the purchase and construction of 10s to 100s of thousands of toilets (Rosenboom et al., 2011), while new technological approaches, for example container-based sanitation toilets in urban Ghana, Kenya and Haiti, have shown promise but have not yet gone to scale (Greenland et al., 2016b). Developing viable business models for sanitation providers offering novel products or services has proven challenging, marketing efforts have not always been optimal and there is, to date, limited evidence of effectiveness of the impact of commercial-based approaches (De Buck et al., 2017). Few market-based sanitation initiatives have achieved scale, and many have required substantial and likely unsustainable heavy subsidies and other external support to remain viable (USAID, 2018). Commercial-marketing approaches (likely) need to be accompanied by targeted subsidies to reach the poorest (to improve access to sanitation as well as to improve business viability through increased reach), as well as demand activation to ensure interest in toilet purchase results in toilet purchase (USAID, 2018).

Approaches incorporating psychological and social theories of behaviour

In recent years, models and frameworks drawing on psychological and social theories (sometimes alongside conventional approaches such as economic utility theory), have been developed and applied to sanitation and hygiene promotion and behaviour change (e.g. Devine, 2009; Michie, van Stralen & West, 2011; Mosler, 2012; Dreibelbis et al., 2013; Aunger & Curtis, 2016). Given the relatively recent development of these approaches for sanitation and hygiene behaviour change, evidence for their efficacy is primarily found from the application of the underlying theoretical principles to other health and development challenges. Approaches include the use of environmental "nudges" to create or sustain new default behavioural patterns and cue desired behaviour (Dreibelbis et al., 2016), and strategies that focus explicitly on habit formation through repetition, fostering stable environments and reducing perceived barriers to a behaviour (Neal et al., 2016). It is currently not known whether the small pilot successes reported thus far are context and behaviour specific or scalable.

Approaches based on psychological and social theory are often associated with specific behaviour change techniques (BCTs). These are the smallest building blocks of a behaviour change intervention and refer to the mechanisms through which intervention or programme activities influence behavioural determinants to result in changes in behaviour. A taxonomy of BCTs (Michie et al., 2013) identified 93 BCTs organized within 16 broad categories. These include categories such as schedule consequences (negative reinforcement, punishment etc.), goal setting (behaviour contract, action planning, commitment) and social support. Most theory-driven sanitation interventions use a range of BCTs, many of which may not be psychosocial. Evidence suggests that the use of multiple BCTs is more effective than interventions that utilize a single or limited number of techniques (Briscoe & Aboud, 2012).

Application of approaches to sanitation behaviour change

The four categories of approaches described are intended to provide a broad typology of potential strategies, which are not mutually exclusive. Each approach has its own strengths and weaknesses and may be more or less applicable depending upon the

Table 5.1 Summary of approaches and factors for consideration in their implementation

Approach	Considerations for implementation
Health-driven approaches (Participatory Hygiene and Sanitation Transformation (PHAST), Child Hygiene and Sanitation Training (CHAST))	
(PHAST, CHAST, IEC)	• **Health risks:** Exclusive focus on the risks to health of poor sanitation practices has not proved to be a powerful motivator of sanitation behaviour change because educational approaches that rely on health messaging to increase knowledge and stimulate behaviour change do not address critical underlying motives and social norms needed for behaviour change. • **CHAST:** Assumptions that children will act as change agents to improve sanitation within their household may not hold. Parallel community level approaches are needed. • Health knowledge is a useful basis for behaviour change but needs to be combined with other approaches to result in sustained behaviour change.
Community-based approaches (Community-led/ School-led Total Sanitation (CLTS/SLTS), Community Health Clubs (CHCs)	
General to all community-based approaches	• **Facilitation:** A network of well-trained, high-quality facilitators is essential for implementation at scale • **Community context:** These approaches more applicable in rural settings where legal and physical factors, such as secure land tenure, space for toilet construction, ability to use low-cost technologies, and social factors, such as community cohesion that enables collective action and community leadership, are supportive.
Collective behaviour (CLTS/SLTS)	• **Sanitation status:** Most relevant in contexts where open defecation is prevalent, as these approaches focus heavily on stopping open defecation towards a minimum level of service. • **Previous subsidies:** may be challenging to implement where heavily-subsidised programmes have been implemented, as household may expect external support for toilet construction. • **Sustainability:** One-off 'triggering' may be insufficient; further steps to ensure sustainability of open defecation free status though sustained use of safe toilets that contain excreta by the entire community and further progress towards a safe sanitation chain should be considered, drawing on other sanitation promotion approaches. • **Culture:** Provocative discussions about excreta as often practiced in CLTS to generate disgust (and sometimes shame) can be instrumental in breaking taboos and generating change in some cultures, while in others it can be counterproductive if considered too offensive or incompatible with local culture. Adaptation of the methodology and good facilitation are needed. • **Peer pressure:** While sometimes applied in CLTS to address open defecation, peer pressure may unintentionally translate into coercion and exclusion. This can be avoided by ensuring sanitation committees represent all groups in the community, and ensuring all households have the opportunity to change their practice before peer pressure is applied. • **For SLTS:** Assumptions that children will act as change agents to improve sanitation within their household may not hold. Parallel community level approaches are needed. These considerations have led to various adaptations, and combinations with other approaches. These include combination with financing approaches (e.g. subsidies), toilet upgrade schemes, increasing supply (e.g. sanitation marketing), non-coercive self-monitoring mechanisms, and utilizing CLTS approaches to trigger/mobilise communities and landlords in urban settings.
Social and commercial-marketing based approaches (Sanitation as a Business (SAAB), Sanitation Marketing (SanMark), Developing Markets for Sanitation (DMS), Micro-financing (loans), Targeted pre-construction hardware subsidies, Output-based subsidies)	
Market-based approaches (SAAB, SanMark, DMS)	• **Context:** Applicable to rural and urban contexts in areas connected to markets, supply chains and marketing centres, and where a range of sanitation products are applicable to the context. Special consideration is needed to each the poorest households with affordable technologies and services. • Can be applied to both **demand and supply sides**: o To secure supply in response to demand, e.g. when there is a lack of desirable products or when adequate supply is a bottleneck for increasing coverage. o To increase demand by using social marketing approaches to enhance the desirability of sanitation and drive household investment in sanitation products. • **Capacity:** Successful application requires in-depth knowledge of the market and the type of products needed, as well as marketing expertise; implementation is therefore challenging in contexts where these skills are absent or rare.

Table 5.1 Summary of approaches and factors for consideration in their implementation (continued)

Approach	Considerations for implementation
Financing approaches: Micro-financing, Targeted hardware subsidies, Output-based subsidies	• **Application:** Usually coupled with promotional or supply-side interventions, rather than used as standalone approaches. • **Sustainability:** Scale up of subsidy schemes beyond a small-scale pilot can be challenging. • **Unintended consequences:** Subsidies can lead to corruption or inaction by non-beneficiaries; comprehensive delivery of the scheme to all target beneficiaries and clear and transparent rules are crucial. Output-based subsidies that reward sanitation practices through community or household incentives such as cash or vouchers are partially a response to the perverse incentives created by pre-construction subsidies. Micro-loans, which are normally applied to productive ventures that enable repayment can lead to increased indebtedness when applied to consumer products like toilets; use of loans should be considered carefully where the targeted beneficiaries include poor households and those without sufficient cash income.
Approaches based on psychological and social theories	
Behaviour change campaigns	• **Research investment:** Because they are newer than other models and contextually-specific, these approaches require a higher investment in formative research and pre-intervention activities. • **Expertise:** The specialized nature of these programs may also require additional expertise because they often focus on activities and strategies that are not traditionally part of public health programs.

target population and target behaviours. Situation analysis, research and consultations with experts can help to identify which approach or combination of approaches is likely to be most effective for a specific context (see Section 5.4.2). For a strategy to be successful, however, it needs to impact:

- uptake (e.g. construction and/or adoption of a new sanitation facility);
- adherence (e.g. use of the sanitation facility over time); and
- sustainability (e.g. long-term use and associated maintenance and replacement).

These apply equally for strategies that aim to change specific hygiene and sanitation practices and behaviours, such as handwashing with soap at key times, safe disposal of child faeces, and hygienic pit emptying.

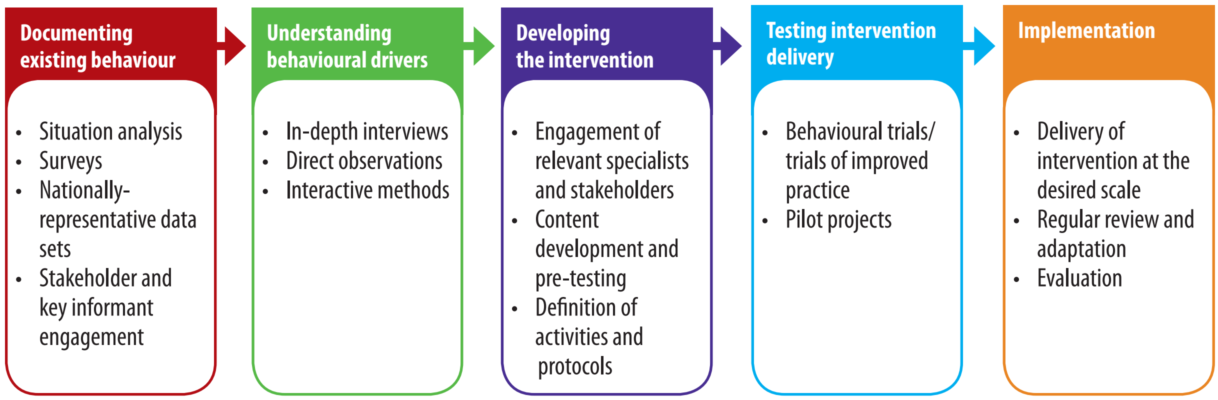
The success of the approaches detailed above in driving and sustaining sanitation behaviour change depends on their application within the specific programme context. Table 5.1 lists the main considerations for the application of each approach.

Given that IEC approaches are rarely used alone, but incorporated into other approaches, they are not discussed separately in the table.

5.4.2 Designing, adapting and delivering behaviour change interventions

Developing and implementing a behaviour change strategy is a multi-stage process (Figure 5.2) that benefits from the input of technical experts throughout the process. The stages outlined present a general set of activities that can be used to help plan and organize the development and implementation of a behaviour change intervention. Investing sufficient resources in designing a robust behaviour change programme up front can save the costs of running a programme that later proves to be ineffective, as many post-hoc evaluations have shown (Biran et al., 2014). Similar steps can also be used to adapt existing interventions. The adaptation may be operational (i.e. how the intervention is delivered or managed) or related to the content (i.e. the specific strategies and materials developed and delivered).

Figure 5.2 Stages in behaviour change strategy design



Documenting existing behaviours (situation analysis)

In order to design a sanitation behaviour change intervention it is necessary to collate available information on the sanitation situation and behaviours within the target population. This involves reviewing published and grey literature and consulting global and local experts. It may include:

- examination of publicly available data sets (e.g. DHS, MICS, census data);
- reviewing what is known about the drivers of the target behaviour from the literature and previous experience (e.g. KAP [Knowledge, Attitude and Practice] studies, market studies, programme evaluations); and
- consultation with key stakeholders from:
  - relevant national and local ministries;
  - civil society organizations
  - subject matter experts, and
  - local communities.

By consulting widely, existing interventions, policies and strategies that could support the intervention can be incorporated into the plan.

Following literature review and stakeholder consultation, the situation analysis can be used to define the specific objectives of the intervention. These may be singular, and organized around a specific behaviour, or they may be broad and include multiple behavioural targets. In general, behaviour change interventions that focus on specific or a limited number of target practices have had greater success than interventions that pursue multiple behavioural objectives at once. In a limited number of examples, large “umbrella” programs (which combine multiple closely-related behaviour change targets within a single overarching programme) have been shown to be effective at eliciting behaviour change (Fisher et al., 2011; Marseille et al., 2014), although programmes with multiple objectives also run the risk of message dilution without careful and deliberate coordination (Greenland et al., 2016a).

The objective of the situation analysis step is, thus, to identify and tightly define the behaviours that need to be targeted for change, and to set out what is known and what is not known about the determinants of these specified behaviours (Aunger & Curtis, 2016). The unknowns then provide an agenda for research.

Understanding behavioural drivers

Context specific or formative research, which may include quantitative, qualitative and participatory methods, is useful in order to understand the behaviour (both what people do now that is unsafe/ risky and the desired safe behaviour), within the actual population (i.e. within the target households and communities where the behaviour occurs) and it should help to:

- document existing sanitation- and sanitation-related behaviours within the target population;
- understand sanitation- and sanitation-related behaviours from the perspective of the target population;
- identify the most important determinants of the target behaviour within the target population; and
- identify and understand the channels of communication that best reach and influence the target populations.

This examination may suggest specific messaging strategies or specific determinants that have the potential to leverage the most change within the population. Understanding the underlying determinants of the behaviour of interest, how those determinants can be changed to enable behaviour change, and testing and adapting delivery strategies can lead to sustained behaviour change and help ensure that limited resources are used in the most effective way possible. It also helps to avoid applying approaches used successfully elsewhere when they are unlikely to work in the given context (although learning from other contexts can also offer valuable insights).

Creating a sanitation behaviour change intervention

Information gathered as part of the previous two steps can be collated and organized using a framework for understanding sanitation behavioural determinants. Based on a clear understanding of the behaviour(s) and behavioural determinants to be targeted by an intervention, a draft theory of change can be constructed. A theory of change offers a description of how a specific change occurs within a specific context; it often includes both text and a graphical depiction of the causal pathway connecting programme or intervention activities to the expected change.

A theory of change should reflect the intervention as planned. This includes both the intervention content and its intended delivery mechanism, all of which require careful consideration and coordination among stakeholders. For a messaging campaign, this includes selecting the key messages, articulating how (and when) those messages are expressed to the target population and defining what specific determinants those messages are intended to change. For community-based approaches, it is necessary to specify the community-level activities that will be used to foster change among participants and who will be responsible for their implementation and delivery. For interventions which provide subsidies to households, it is necessary to define the amount, the form or type of subsidy (e.g. cash transfer, cash rebate, voucher, direct distribution of goods), how they will be targeted (i.e. inclusion and exclusion criteria) and distributed and how they will be verified and outcomes monitored.

There are a range of specialists that can, and should, be engaged in the process of intervention development, and these may include individuals outside of the traditional Ministry of Health and its partners. For example, a creative team (rather than a health education team) can be employed to craft an intervention that is engaging, motivating and addresses the issues that enable or prevent performance of the behaviour at the individual-level in the context of the limitations and realities of the structural environment (Aunger & Curtis, 2016).

Testing, adapting and delivering a sanitation behaviour change intervention

Interventions should be tested, as far as is possible, before they are taken to scale. This can be done in a variety of ways. Behavioural trials are small scale, qualitative-focused projects in which new behaviours are introduced to a group of people who are then left to practice that behaviour on their own for a period of time and their experiences and challenges then documented. Trials of improved practices (TIPS) are a formal methodology for introducing new behaviours to a small group of participants and rigorously documenting adaptations, modifications and barriers to sustained use. The focus of both behavioural trials and TIPs is program adaptation: results are used to inform the development and modification of a potential intervention or programme before introduction to a wider audience. Pilot projects, where the intended intervention is rolled out at a small scale, can help to identify the feasibility and mechanics of delivery for broader implementation.

For the intervention to be successful it needs to be delivered as designed and in the frequency required. Inconsistent, irregular or unspecified delivery of behaviour change interventions is often associated with sub-optimal outcomes (Huda et al., 2012; Boisson et al., 2014).

There is a range of options for delivering a sanitation behaviour change strategy to the target population; delivery can be through a stand-alone, focused behaviour change campaign or through integration and coordination with other public health and development initiatives.

Stand-alone sanitation campaigns can happen at many levels, from local community-based initiatives to national sanitation campaigns (such as the Swachh Bharat Abhiyan in India). These campaigns may involve the use of large numbers of frontline workers focused on sanitation promotion, branded mass media presence and a focus on delivering a primary set of behaviour change messages to a population. Advantages of a focused, stand-alone approach include more control over programme messages, coordination and management of programme resources, along with improved opportunities for monitoring progress and implementation. However, national multiplayer integrated efforts may bear more fruit in the longer run. Sanitation behaviour change strategies can also be integrated into larger behaviour change initiatives that focus on addressing multiple population-level risk factors.

Alternative approaches to delivery of behaviour change interventions involve integration into existing public health and/or development programmes such as health extension programmes, healthcare services (e.g. immunisation or nutrition programmes – Velleman, Greenland & Gautam 2013), or other public or private sector platforms that reach and have influence over the target group. Integrated programmes often benefit from existing implementation and monitoring systems, which can reduce start-up costs. Integrated strategies have the potential to leverage synergies between different public health initiatives. However, they also run the risk of dilution or inconsistent messaging. Health extension workers, in particular, are increasingly targeted for delivering public health and behaviour change interventions and the risk of over-extending a limited and, often, voluntary workforce should not be ignored. In addition, data on the effectiveness of integrated programs is limited.

Regardless of the approach used, attention should be given to the frontline workers who are engaged in the direct delivery of sanitation behaviour change activities. Frontline workers may require training, capacity strengthening and supervision to ensure that the intervention is delivered as designed. In particular, current behaviour change approaches require that these workers shift from traditional educational approaches to new ways of working. Case studies on CLTS in Lao PDR have found that many frontline workers default to education and awareness-based messages rather than utilizing the range of community mobilization approaches central to the CLTS approach and that district teams felt they did not have sufficient training to trigger behaviour change (Baetings, 2012; Venkataramanan et al., 2015). Similar problems were encountered in Zambia (Greenland et al., 2016a). Retraining of frontline workers in new approaches may thus require substantial investment. The behaviour change activities should extend but not overwhelm the world view and education level of those charged with delivering it.

As indicated in Chapter 4, success is likely to be dependent upon a number of factors, including an enabling environment, government and stakeholder support and alignment of policies and regulations, and adequate funding.

5.5 Monitoring and learning for success

Monitoring and oversight of sanitation behaviour change interventions should help to organize stakeholders around common objectives and provide systems for assessing progress. These efforts can inform the adaptation and improvement of future strategies through systematic learning. While monitoring is an important element of sanitation behaviour change programming, and has been suggested as a powerful promotional tool, routine and consistent monitoring data on behaviour change is often lacking (Sigler, Mahmoudi & Graham, 2015). Behaviour change monitoring should be consistent with monitoring approaches used for other sanitation interventions. There are potentially three distinct types of monitoring necessary for successful sanitation behaviour change programs (Pasteur, 2017). These include:

- *process monitoring*, which focuses on the quality and effectiveness of intervention delivery;
- *progress monitoring*, which focuses on behaviour change at the individual- and community-level; and
- *post-intervention monitoring*, which focuses on sustained behaviour over time. Post-intervention monitoring is particularly crucial to ensure the elimination of open defecation and ensure consistent use of facilities.

Standard approaches to measurement should be incorporated into behaviour change monitoring and contain clearly articulated definitions of behavioural outcome, behavioural determinants, individual exposure to, and participation in, behaviour change intervention strategies and the total population reached through behaviour change initiatives.

Defining consistent and clear indicators can ensure that local organizations are both contributing to larger behaviour change objectives and measuring progress in a clear and consistent manner. However, measuring sanitation behaviour can be complex and the choice of measurement (Table 5.2) and method will have resource implications.

Monitoring changes in behavioural determinants should be done with caution. Determinants are often abstract, latent concepts that present unique measurement challenges. Developing valid and reliable measures of these determinants can be time and labour intensive (Dreibelbis et al., 2015). Some behaviour change models provide standardized tools for measuring specific determinants, but indicators may need to be adapted to the local context and the specific behaviour of interest.

Process and progress monitoring can not only ensure that interventions are proceeding as planned, but also inform programmatic adaptation and learning. Sanitation behaviour change is not a singular, one off event, but rather an ongoing process. Interventions may be effective at raising awareness or changing motivations, but not translate into individual or collective changes of behaviour. Effective and efficient monitoring should provide a clear indication of when programme activities are not resulting in expected changes within the target population, and why change is not happening, to inform programme adaptations or revisions when necessary. Programmes should be designed and budgeted from the outset in a way that mandates and enables regular review and adaptation.

Table 5.2 Behavioural monitoring methods and measures

Method	Description	Advantages	Disadvantages
Direct observation	Trained staff observe behaviours in their natural environment and document behaviours	Structured observations are considered the "gold standard" of behavioural measurement	Time, labour, and resource intensive Potential for reactivity – individuals may over perform during observation (Ram et al., 2010; Arnold et al., 2015) Requires training
Proxy indicators	Readily observed or measurable indicator that is assumed to have a strong relationship with behaviour of interest	Low cost Can be easily integrated into routine data collection	Relationship with behaviour not verified Requires training
Self-report	Respondent provides information about behaviour	Low cost Can easily be integrated into routine data collection	High risk of overreporting Limited ability to capture information about anyone other than the respondent (Jenkins, Freeman & Routray, 2014)
New experimental approaches	Electronic sensors that capture toilet use	Objective data (Clasen et al., 2012; Thomas et al., 2013)	High cost Resistance by end-users Limited support for data processing, analysis and interpretation (Jenkins, Freeman & Routray, 2014).

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Chapter 6

EXCRETA-RELATED PATHOGENS

6.1 Introduction

Sanitation interventions and the safe disposal of human excreta have the potential to impact on the transmission of a diverse range of microbial hazards. This chapter outlines the characteristics of the four main groups of pathogenic hazards (bacteria, viruses, protozoa and helminths) considered within these guidelines, and examines their transmission pathways and how infection relates to poor sanitation. The importance of sanitation for control of pathogens varies depending on their size, persistence in the environment and their infectivity. Further information is provided in section 6.3.4. Specific information on individual pathogens is summarised in Table 6.1, and additional information can be found in the Global Water Pathogen Project (GWPP), which is available online (www.waterpathogens.org).

6.1.1 Bacteria

Bacteria are small (typically 0.2-2 micrometres) single celled organisms, many of which are capable of multiplication outside a host under favourable conditions. Most bacteria considered here are enteric, transmitted by the faecal-oral route, and predominantly cause gastroenteritis. Some can cause severe health outcomes and may have long-term effects. While multiplication of pathogenic enteric bacteria in the environment is possible, it is rare. Although many enteric bacteria are zoonotic (i.e. they can be transmitted from animals to humans) the safe disposal of animal faeces is beyond the scope of these guidelines. Bacteria have the ability to enter a viable non-culturable state that allows them to persist in the environment for long periods of time.

Bacteria may develop antimicrobial resistance (AMR), where they become resistant to the effects of antibiotics, biocides and so on. While the development of AMR is a natural phenomenon, it can be accelerated by the selective pressure exerted by the use and misuse of antimicrobial agents in people and animals, and by their environmental release (e.g. antibiotics entering wastewater either unused as waste or (un)metabolized after therapeutic use). Exposure to antibiotic resistant bacteria may lead to infections that are hard, or even impossible, to treat (see Box 6.1).

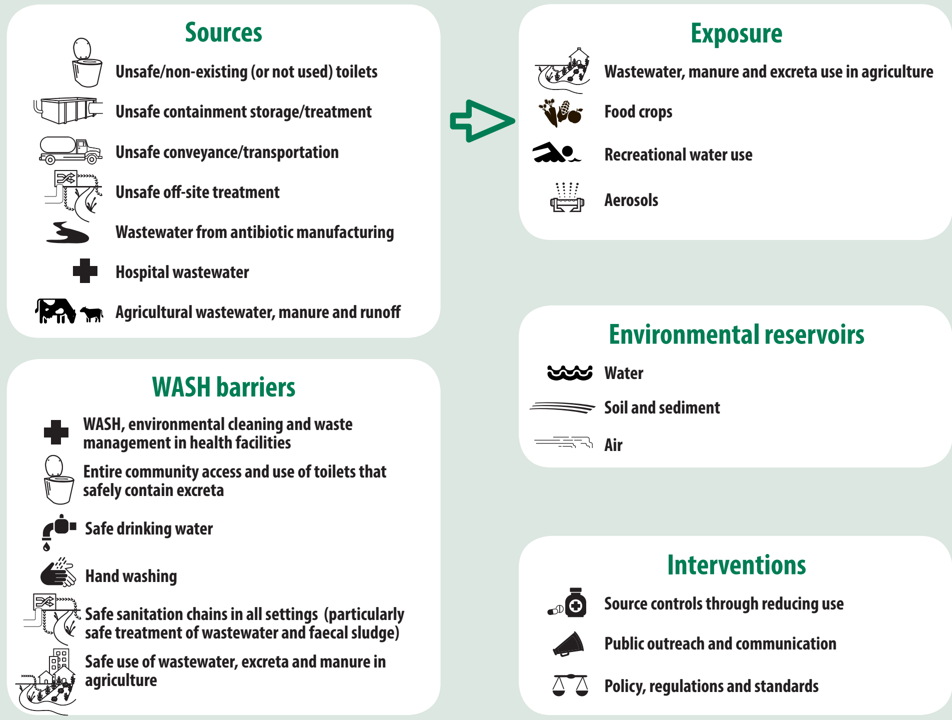
6.1.2 Viruses

Viruses are simple infectious agents, consisting only of genetic material (DNA or RNA) encased in a protein capsid. They are the smallest (typically 20-100 nanometres) organisms considered here and they are obligate intracellular organisms (i.e. they must be within a susceptible host cell to reproduce). Viruses can be excreted in very high numbers and may be transported long distances in water. Viruses cannot metabolize in the environment, so their persistence typically depends upon the extent to which the protein capsid can remain intact under adverse environmental conditions. The viruses covered in this chapter are enteric and predominantly lead to gastroenteritis (although some virus types can lead to other health outcomes such as hepatitis and viral meningitis).

6.1.3 Protozoa

Parasitic protozoa are complex and relatively large (typically 3-20 micrometers) single celled organisms that cannot replicate outside a suitable host. Those covered in this chapter are enteric and cause gastroenteritis of varying duration and severity.

Box 6.1 Antimicrobial resistance and sanitation



Adapted from original work by Emily D. Garner and Amy Pruden, Virginia Tech.

Antimicrobial resistance (AMR) among human pathogens has been identified by the World Health Organization as one of the greatest global threats to human health. AMR arises from genetic mutations that allow the emergence of new bacterial strains that are not affected by an antimicrobial agent. This can occur in the body of a host or in environmental settings where the presence of an antimicrobial agent kills off the main populations of the target bacteria and allows the remaining resistant strains to flourish. In the environment, genetic material (such as plasmids) that includes the genes that code for AMR can be exchanged between metabolizing and/or replicating bacteria, thus spreading the AMR attributes across diverse populations of environmental bacteria and pathogens.

AMR is common among environmental bacteria, including in pristine locations relatively untouched by modern anthropogenic activities, such as caves, permafrost, and glaciers. However, use of antibiotics in humans, livestock and companion animals has been associated with evolution and amplification of antibiotic resistant pathogens and the antibiotic resistance genes (ARGs) that they carry. Environmental reservoirs are the primary source of ARGs and anthropogenic activities are increasing the importance of the environment as a pathway for AMR human exposure. For example, human consumption of antibiotics can contribute antibiotics, resistant pathogens and ARGs to waterways via faecal contamination resulting from open defecation, discharge of raw and treated sewage, septic tank seepage, and seepage from toilets. In particular, wastewater from hospitals and antibiotic manufacturing facilities are likely to contain elevated concentrations of antibiotics and resistant pathogens.

Use of antibiotics in livestock can also contribute antibiotics and clinically-relevant ARGs to waterways via runoff from feedlots or from manure-treated fields. Exposure to AMR pathogens may occur when humans come into contact with water downstream of these sources. For example, wastewater reuse, recreational water use, consumption of contaminated drinking water, and aerosolization of contaminated water for non-drinking purposes such as irrigation, toilet flushing, or cooling towers, may all serve as possible routes of exposure to AMR bacteria and other pathogens. Consumption of contaminated food products can also facilitate spread of AMR from agricultural sources. Further research is needed to better understand the circumstances that promote the development and dissemination of AMR among bacteria in the environment and how to prevent this.

Safe sanitation systems and hygiene practices can serve as critical barriers between sources of AMR and human exposure. Hand washing can limit AMR spread via inter-personal contact, while safe toilets, containment, conveyance, treatment (of wastewater and sludge) and safe end use and disposal as well as drinking water treatment and source water protection, are all critical barriers that can prevent the transmission of AMR pathogens from faecal sources to humans. In addition, population-level interventions can reduce the problem of AMR by limiting antibiotic prescription, increasing public outreach and communication about appropriate antibiotic usage, and establishing policies that limit unneeded antibiotic use or discharge of contaminated wastes.

While excretion densities are orders of magnitude lower than viruses, the production of robust cysts or oocysts enhances survival in the environment. *Cryptosporidium* spp., *Giardia* spp. and *Entamoeba histolytica* are all infective upon excretion, while *Cyclospora* oocysts require a latency period of some days for maturation in the environment.

6.1.4 Helminths

Helminths (also known as parasitic worms) include tapeworms (cestodes), flukes (trematodes) and roundworms (nematodes). They are multi-cellular, complex organisms. Some helminths, referred to as soil-transmitted helminths (STH), can be transmitted by the faecal-oral route (after a period of maturation in the environment), with infection being caused by ingestion of fertile worm eggs or through skin penetration by infective larvae.

Although STH infections are often largely asymptomatic, they can lead to various mild to serious effects such as chronic abdominal pain and diarrhoea, iron deficiency anaemia, growth faltering, recurrent rectal prolapse, bowel/intestine obstruction, appendicitis, pancreatitis and protein energy malnutrition. Excretion of infective eggs can be abundant (see Table 6.1). In some species, especially *Ascaris lumbricoides*, eggs can survive in the environment for years where soil conditions are favourable.

6.2 Microbial aspects linked to sanitation

The role of poor sanitation and excreta in disease transmission depends on the individual pathogen. In the simplest categorization, there are three primary ways in which human excreta may increase the occurrence of human infections:

- as a source of enteric pathogens in the environment;
- by contributing to excreta dependent lifecycles; and
- by facilitating vector breeding.

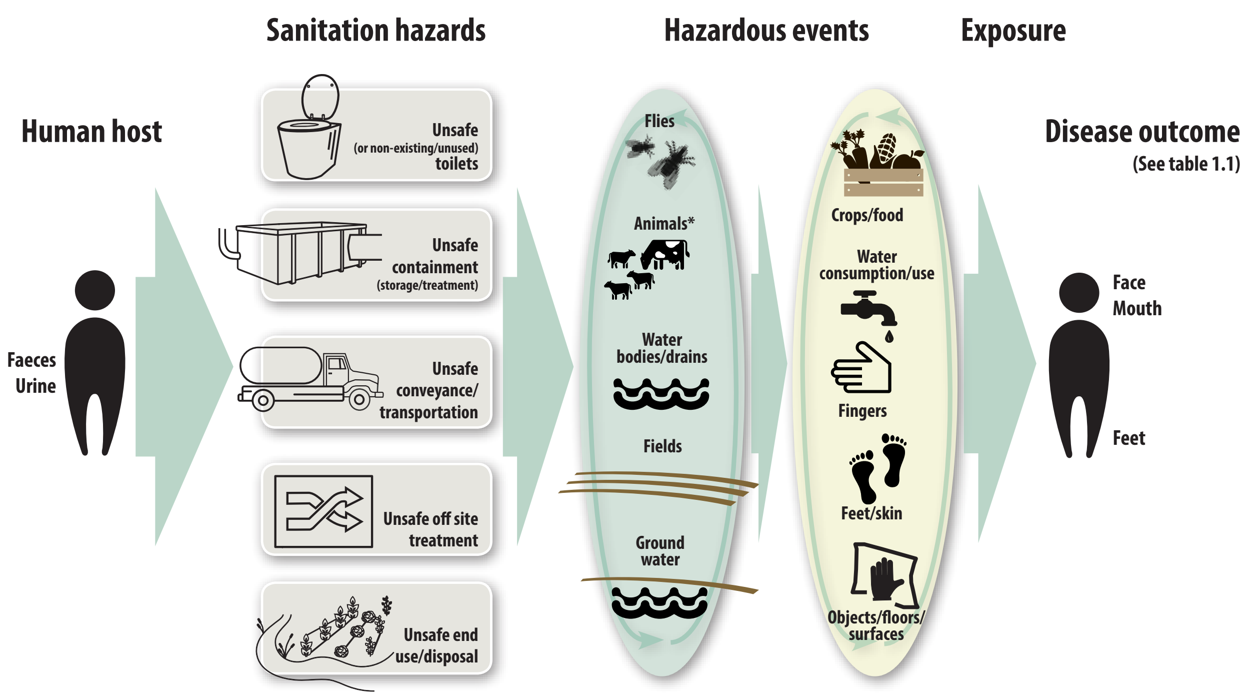
This section briefly introduces these and then outlines the most important excreta-related pathogens (Table 6.1).

6.2.1 Excreta as a source of enteric pathogens in the environment

Enteric pathogens colonize the intestine, multiply within infected individuals (except helminths, which do not multiply but lay eggs), and are subsequently excreted (potentially in large numbers) with faeces. Every excreted infectious pathogen has the potential to cause a new infection if ingested by another person (i.e. faecal-oral transmission). Potential exposure pathways are illustrated in Figure 6.1 and include:

- **Fingers:** Pathogens may be transferred to fingers through touching of faeces or faeces- contaminated surfaces or people and then, subsequently, cause infection as a result of putting fingers in the mouth or nose, or on food.
- **Food:** Fresh produce can become contaminated through the use of wastewater for irrigation, faecal sludge for fertilizing or the use of contaminated wash water. When consumed raw (or lightly cooked) the produce can contain infectious pathogens.
- **Drinking-water:** Drinking-water from surface and groundwater sources can be contaminated with faecal pathogens.
- **Hygiene and household water:** Faecally contaminated water used for washing and food preparation, while consumed in smaller quantities than drinking-water or unintentionally, can also lead to exposure to faecal pathogens.
- **Surface water:** Playing or bathing in contaminated surface waters may lead to unintentional ingestion of water and subsequent infection. Similarly, occupational exposure (e.g. fishing, vehicle washing) can lead to ingestion of surface water.

Figure 6.1 Transmission of excreta-related pathogens



* Refers to animals as mechanical vectors. Transmission of animal excreta-related pathogens to human hosts is not represented in this diagram.

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Faeces-contaminated water may become aerosolized through spraying, flushing or washdown activities. Aerosols may be inhaled into the nose or mouth with regular breathing and can be swallowed with saliva or nasal secretions.

The focus and objective of a safe sanitation system is to interrupt *all* the exposure pathways. An individual's risk of infection from enteric pathogens is driven by their overall exposure via all pathways, thus the impact of a single pathway on a community's burden of disease can be difficult to isolate. Specific sanitation interventions, from toilet construction to safe disposal or use of faecal matter, will impact on each of the pathways in different ways. The relative magnitude of each exposure pathway will depend on:

- the individual characteristics of each pathogen;
- the location and setting;
- the local environmental conditions driving transport and persistence of pathogens; and
- the endemic rate of disease driving the occurrence of pathogens in faeces.

An individual's activities (e.g. occupational risks for workers, household risks for those responsible for daily activities such as washing and food preparation, and personal hygiene) will ultimately influence exposure. Any sanitation intervention can be expected to reduce exposure to microbial hazards, but the extent of that reduction will vary depending on the pathogen, setting and individual. The impact of that reduction on the overall incidence of disease will depend upon the magnitude of other remaining exposure pathways (Robb et al., 2017).

6.2.2. Excreta dependent pathogen life cycles

For some pathogenic helminths, the transmission pathway for infection is complex. For these organisms a life cycle involving broader ecological interactions exists.

The overall management objective is to break the life cycle and prevent re-infection. Sanitation that prevents the release of untreated excreta into the environment is a necessary control point for breaking the ongoing cycle of worm reproduction (for example, for *Schistosoma* spp., STH and tapeworms). Other control points include management of snail populations, minimizing water exposure, maximizing drug therapy for infected individuals (e.g. for *Schistosoma* spp. and STH) and improving food hygiene and animal husbandry practices for tapeworms.

6.2.3 Excreta facilitated vector breeding

Unsafe disposal of excreta including open defecation, unprotected pit latrines and poorly draining water systems, can facilitate vector breeding. Insects (e.g. flies, cockroaches and mosquitos) can act as vectors of disease by mechanically transporting pathogens in the environment, either on their bodies or within their intestinal tract.

Solid faecal waste that is not safely contained can provide a habitat for flies and cockroaches. There is a broad body of evidence showing that insects which breed in excreta, or feed on it, may carry human pathogens on their bodies or in their gut (see the review by Blum & Feachem, 1983 and subsequent studies: Feachem et al., 1983; Graczyk, Knight & Tamang, 2005; Tatfeng et al., 2005; Gall, 2015). For example, cockroaches trapped from the toilets of houses with pit latrines had mean microbial counts of 12.3×10^{10} bacteria/ml and 98 parasites/ml, with the microorganisms representing a wide range of faecal-oral pathogens (Tatfeng et al., 2005). Insects can, therefore, enhance the faecal-oral transmission of pathogens by providing additional pathways from excreta to food and/or kitchen utensils.

Flies have been shown to carry a variety of enteric pathogens including bacteria and protozoa (Khin, Sebastian & Aye, 1989; Fotedar, 2001; Szostakowska et al., 2004). In addition to faecal-oral transmission of particular pathogens, flies are a key mechanism for transmission of ocular strains of *Chlamydia trachomatis*, the causative agent of trachoma. Infection spreads through passage of eye and nose secretions from an infected individual via personal contact (fingers, fomites) and certain species of flies (especially *Musca sorbens*, which lays eggs on human faeces left exposed on the soil). A meta-analysis (Stocks et al., 2014) found evidence to support the role of water, sanitation and hygiene as important components of an integrated trachoma elimination strategy.

The importance of mosquito-borne diseases for public health is widely documented. Unsafe sanitation and improper drainage leading to stagnant water or ponds can contribute to mosquito (particularly *Culex* spp.) breeding, and hence the risk of mosquito-borne diseases such as West Nile virus, lymphatic filariasis Curtis et al., 2002; van den Berg, Kelly-Hope & Lindsay, 2013).

Safe sanitation systems must ensure that excreta are contained in a manner that prevents insect oviposition, and that allows the appropriate draining of water to prevent breeding of mosquitos.

6.2.4 Excreta-related pathogens

Table 6.1 outlines key excreta-related pathogens where sanitation is (or may be) important for the control of infection.

Table 6.1 Excreta-related pathogens (main source: Mandell, Bennett & Dolin, 2009)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control[†]	Concentration excreted in faeces**	Duration of excretion	Additional references
BACTERIA							
***Campylobacter* spp.**	Most common bacterial cause of diarrhoea. Can be associated with serious sequelae.	Predominantly food and water from animal contamination. Person-to-person transmission uncommon.	Poultry and other domestic livestock	Low	$10^6 – 10^9$/g	Up to 3 weeks	
Clostridium difficile	Common cause of diarrhoea globally, predominantly in elderly patients. Important cause of antibiotic-associated diarrhoea.	Person-to-person transmission, predominantly in care settings through poor hygiene practices. Outbreaks seen in institutional settings.	None known	Low	—*	—*	
Enteroagglomerative *Escherichia coli*	Important cause of chronic diarrhoea in low-income countries.	Uncertain	Uncertain	Uncertain	—	—	
Enterohaemorrhagic *E. coli*	Although not common, high risk of mortality and severe sequelae.	Person-to-person, food borne and waterborne.	Livestock	High	—	—	
Enteroinvasive *E. coli*	Causes watery diarrhoea but can progress to dysentery (bloody diarrhoea).	Associated with foodborne outbreaks although person-to-person spread also occurs	Uncertain	Medium	—	—	Hunter, 2003

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Enteropathogenic *E. coli* (EPEC)	Leading cause of infant diarrhoea in low-income countries. Can cause severe diarrhoea.	Person-to-person	No known zoonotic source	High	—	May be prolonged	
Enterotoxigenic *E. coli* (ETEC)	Leading cause of childhood diarrhoea in low-income countries. Common cause of travellers' diarrhoea.	Predominantly food and waterborne; not thought to be person-to-person.	Can lead to diarrhoea in piglets and calves; some evidence on transmission from animals but not a major cause.	Medium	—	—	Gonzales-Sile & Sjöling, 2016
Helicobacter pylori	Causes acute gastritis and peptic ulcers; major risk factor for stomach cancer (an important cause of cancer mortality in low-income countries).	Person-to-person (crowded conditions, poor hygiene) and faecal-oral (untreated water, poor sanitation).	None known	Uncertain	—	—	
***Salmonella enterica ser.* Typhi**	Typhoid (enteric fever) is a severe disease which if left untreated has high mortality.	Food and waterborne transmission	Restricted to humans	High	—	May be extremely prolonged	
Other *Salmonella* strains	Range of symptoms (watery diarrhoea to dysentery); associated with range of severe systemic sequalae.	Predominantly foodborne but waterborne outbreaks have occurred. Person-to-person transmission also occurs (predominantly in carers, e.g. mother of a child with infection or health workers).	Predominantly zoonotic (poultry, pigs and many others).	Low	Large variation	Median 5 weeks	

Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Shigella dysenteriae	Causes severe diarrhoea and dysentery with significant consequences including colitis, malnutrition, rectal prolapse, tenesmus, reactive arthritis and central nervous system effects.	Person-to-person (direct or indirect) transmission; highly infectious. Mostly in low-income country settings. Can cause outbreaks.	None - strict human pathogen.	High	—	—	
Shigella flexneri	Causes diarrhoea and dysenteric symptoms.	Person-to-person (direct or indirect) transmission and highly infectious. Mostly in low-income countries. Can cause outbreaks.	None - strict human pathogen	High	—	—	
Shigella sonnei	Common cause of watery diarrhoea globally.	Person-to-person (direct or indirect) transmission and highly infectious. Can cause outbreaks.	None - strict human pathogen.	High	$10^6 – 10^8$/g	Usually up to 4 weeks	
Vibrio cholerae	Causes acute watery diarrhoea which can be very severe, leading to death by dehydration. Causes outbreaks. Most infected individuals are asymptomatic.	Predominantly food and waterborne. Some person-to-person transmission.	Some transmission linked to uncooked seafood.	High	Asymptomatic $10^2 – 10^5$/g; Symptomatic $10^6 – 10^9$/ml	7 – 14 days	Eddleston et al., 2008
Yersinia enterocolitica	Causes watery diarrhoea and mesenteric adenitis (inflammation of abdominal lymph nodes, at times mistaken for appendicitis). Not a commonly-diagnosed cause of diarrhoea.	Food and waterborne transmission, some person-to-person transmission.	Livestock, wild animals and birds.	Medium	—	—	

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
AMR opportunistic pathogens that may be part of normal faecal flora (e.g. carbapenem-resistant organisms and *Enterobacteriacea* carrying extended spectrum betalactamases)	Colonizing the intestines, causing a wide range of extraintestinal infections in vulnerable individuals and populations, e.g. blood stream infections including sepsis (neonatal, postpartum, postoperative, in immunosuppressed individuals), urinary tract infections, postoperative surgical site infections.	Person-to-person (direct or indirect) transmission; highly infectious. Mostly in low-income country settings. Can cause outbreaks.	None - strict human pathogen.	High	—	—	
VIRUSES							
Adenoviruses	A large group of distinct viruses that cause a variety of conditions. Genotypes 40 and 41 predominantly cause gastroenteritis in children, resulting in prolonged diarrhoea (up to 10 days).	Person-to-person, through both faecal-oral and droplet transmission.	None – strict human pathogen	Low	10^{11}/g (lower with non-enteric adenovirus)	Months after symptoms resolve	
Astroviruses	Common cause of diarrhoea globally, especially in young children.	Predominantly person-to-person, potentially waterborne. Outbreaks usually occur in institutional settings.	None – strict human pathogen	Low	$10^2 – 10^{15}$/g	Up to two weeks after symptoms end	Vu et al., 2017
Enteroviruses	Large number of viruses with a vast array of clinical symptoms (including poliovirus – see below).	Person-to-person and environmental exposure	None known	Uncertain	up to 10^6-10^7/g	10 days to 2 months	

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Hepatitis A virus	Causes acute, usually self-limiting hepatitis. Occasionally associated with death from acute liver failure.	Food and waterborne; person-to-person. Both routes can lead to outbreaks	No (non-human primates have been infected in studies but are not part of the transmission cycle).	Medium	Prevalence in stool higher before symptoms.	Present from 14-21 days before onset to 8 days after appearance of jaundice.	
Hepatitis E virus	Can cause acute hepatitis; genotype 1 associated with maternal mortality in low- and middle-income countries due to acute liver failure.	Genotypes 1 and 2 dominate in LMIC and are predominantly waterborne. Genotypes 3 and 4 dominate in Europe and are associated with consumption of contaminated pork or game meat.	Genotypes 1 and 2: no known animal transmission pathway. Genotypes 3 and 4 are zoonotic, strongly linked with pork consumption.	Medium	10^5/ g-	1 week before symptoms up to 4 weeks following.	Chaudhry et al., 2015; Park et al., 2016
Noroviruses	Leading cause of gastroenteritis outbreaks (characterized by diarrhoea, vomiting and stomach pain) in all age groups.	Predominantly person-to-person through both faecal-oral and droplet transmission; can be spread through food and water. Major cause of sporadic outbreaks in hospitals, nursing homes and other institutional settings.	None – strict human pathogen	Low	10^{11}/ g	8 –60 days	
Polioviruses	Acute poliomyelitis is frequently asymptomatic. A small proportion of people will develop paralysis.	Person-to-person. Some outbreaks have been associated with breakdown in sanitary infrastructure (e.g. during war)	None – strict human pathogen	Medium	—	—	WHO (undated a)

Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Rotaviruses	Major cause of acute gastroenteritis in infants globally. Common symptoms include severe watery diarrhoea, vomiting, fever and abdominal pain. Rotavirus infection is associated with severe dehydration and occasionally death.	Person-to-person.	Most rotaviruses are strict human pathogens; group C rotavirus may be associated with cattle.	Low	10^{10}–10^{12}/ g	2 days before to 10 days after symptomatic illness.	Meleg et al., 2008
Sapoviruses	Cause of acute diarrhoea and vomiting globally.	Predominantly person-to-person through both faecal-oral and droplet transmission; can be spread through food and water.	None – strict human pathogen	Low	—	—	Chaudhry et al., 2015; Park et al., 2016
PROTOZOA							
***Cryptosporidium* spp.**	One of the most common causes of diarrhoea in young children globally. Diarrhoea can be prolonged (several days or more) especially in immunocompromised individuals.	Person-to-person, and there is a large number of foodborne and waterborne outbreaks.	Of the two main species, C. parvum can infect multiple species, and the main reservoir is cattle. C. hominis is restricted to humans.	High	—	—	Hunter & Thompson, 2005
Cyclospora cayetanensis	Uncommon cause of acute diarrhoea and persistent in all ages. Acute illness can last between 1 to 8 weeks.	Waterborne and foodborne, including outbreaks.	Humans are the only natural hosts; animal transmission uncertain.	Low	Up to 10^4/g	—	
Entamoeba histolytica	Can cause diarrhoea, amoebic dysentery and liver abscesses or metastatic abscesses. Common and patchy in distribution.	Foodborne waterborne, infrequently person-to-person.	None	High	Up to 10^7 cysts/ day	Can be prolonged	

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Giardia intestinalis	Most common human protozoan gastrointestinal pathogen. Common cause of diarrhoea. Can be prolonged and associated with growth faltering in children and weight loss in adults.	Typically waterborne, also person-to-person.	Various animal hosts, including wild animals, dogs, cats, cattle, pigs and chickens, associated with transmission of some strains.	Medium	2 x 10^5 cysts/ g	Can be excreted over several weeks	Hunter & Thompson, 2005; Laloo & White, 2013
			HELMINTHS				
Ascaris lumbricoides (roundworm)	One of the most common human helminth infections globally. Largely asymptomatic. Can lead to bowel/ intestine obstruction, appendicitis, pancreatitis and malnutrition.	Via consumption of contaminated soil and food, and hand contamination.	Evidence that both *Ascaris lumbricoides* and the pig *Ascaris suum* can infect humans, and moreover the two can also hybridize together	High	10^5 eggs/g	While infection persists	Bethony et al., 2006 Anderson & Jaenkike, 1997
Diphyllobothrium latum	Intestinal tapeworm; largely asymptomatic. Can lead to anaemia.	Foodborne - consumption of infected fish (eggs excreted in human faeces consumed by small crustaceans that are eaten by smaller fish; these are consumed by larger fish, which are consumed by humans).	Freshwater crustaceans are first intermediate host; Fish are the second and third intermediate hosts. Many other mammals (apart from humans) can serve as definitive host.	Medium	Up to 1 million eggs/ worm/ day	—	Scholz et al., 2009
Hookworm *Ancylostoma duodenale Necator americanus*	Largely asymptomatic. Can lead to chronic abdominal pain, iron deficiency anaemia and protein energy malnutrition.	Most relevant transmission pathway is skin penetration (e.g. walking barefoot on contaminated soil). Ancylostoma duodenale can also be transmitted through the ingestion of larvae (on soil and crops).	There are animal hookworm species that can infect humans.	High	Up to perhaps 50,000 eggs/g.	While infection persists	Bethony et al., 2006.

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Hymenolepis spp. (dwarf tapeworm)	Symptoms usually mild; might include abdominal pains and anorexia in heavy infections.	Humans are infested by ingesting fertile eggs from contaminated food, water, soil and surfaces.	Rodents (minor importance)	High	Uncertain	Uncertain/ may be years	CDC, 2012
Schistosoma haematobium	Largely concentrated in LMIC. Acute illness: skin rashes, blood in the urine, anaemia. Chronic illness: stunting, renal problems, hydronephrosis, bladder cancer, infertility, dyspareunia ,female genital schistosomiasis, bewteen cancer and infertility. Can also cause severely contracted bladder.	Skin penetration by cercariae in contaminated water via life cycle involving snail host.	Some evidence of rodents for pure *S. haematobium*. Extensive evidence of livestock contributing to human infection through viable hybridization of animal schistosome species with *S. haematobium*.	High	Excretion in urine (though zoonotic hybridized pairs may be in both urine and faeces). Each worm pair can produce several hundred eggs per day.	Uncertain	Webster et al., 2016 Leger & Webster, 2017 Catalano S et al., 2018
Other *Schistosoma* spp. (*S. mekongi, S. japonicum, S. mansoni, S. interculatum, S. guineensis*)	Abdominal pain, anaemia, growth faltering, epilepsy, portal hypertension.	Skin penetration by cercariae in contaminated water via life cycle involving snail host.	Major role of animals (particularly bovines, rodents and/ or canines) for *S. japonicum* and *S. mekongi* Asian schistosomes. In Africa, rodents and non-human primates can serve as reservoirs for *S. mansoni*. Hybridized animal intestinal schistosomes can infect humans.	High	Excretion in faeces. Each worm pair can produce from several hundred eggs per day (*S. mansoni*) to several thousand eggs per day (*S. japonicum*).	Uncertain (can be up to 30/40 years)	Webster et al., 2016 Rudge et al., 2013
Strongyloides stercoralis	Abdominal pain, bloating, heartburn, diarrhoea, constipation, cough, rashes. Potentially arthritis, kidney problems and heart conditions. Can remain asymptomatic for decades. Vast majority of infections asymptomatic.	Infection by infectious larvae from contaminated soil through skin penetration. Autoinfection (self-reinfection) can occur, which accounts for prolonged carriage after primary infecting episode.	None	High	Depends on the load and nature of infection.	While infection persists.	

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Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Taenia solium (pork tapeworm)	Tapeworm infection can cause taeniasis1 leading to minor health impacts, or cysticercosis (if a human is the intermediate host) in the muscles, skin, eyes and the central nervous system, with potentially severe health impacts.	Foodborne - taeniasis caused by ingestion of larvae in undercooked pork; larvae develop into mature worms in the human body and eggs are passed in faeces. Person-to-person (poor hygiene), food, water, soil: Cysticercosis caused by egg ingestion; eggs form cysts in body tissues. An individual with a pork tapeworm can be a source of eggs for themselves or anyone at risk of ingesting their faeces.	Pigs are the usual intermediate hosts, infected through consumption of eggs excreted in human faeces.	High	1 or a few proglottids[2] filled with eggs	While infection persists	WHO (undated b); Webber, 2005
Taenia saginata (beef tapeworm)	Taeniasis leading to minor health impacts.	Foodborne - taeniasis caused by ingestion of larvae in undercooked beef; larvae develop into mature worms in the human body.	Cattle are intermediate hosts, infected through consumption of eggs excreted in human faeces.	High	1 or a few proglottids filled with eggs	While infection persists	WHO (undated b); Webber, 2005
Trematode (flatworm) parasites or flukes *Fasciola hepatica, F. gigantica* (F) *Clonorchis sinensis* (C) *Opisthorchis viverrini* (O) *Paragonimus* ssp (P), most common: *P. westermani, P. heterotremus, P. philippinensis*	(F), (C) and (O) cause liver fluke disease and (P) cause lung fluke disease all largely asymptomatic at low. With heavy infection; (F) leads to chronic liver fibrosis and pancreatitis, (C) and (O) lead to liver and bile duct inflammation and fibrosis and bile duct cancer in chronic cases, (P) chronic cases cause cough with blood-stained sputum, chest pain with dyspnoea and fever - pleural effusion and pneumothorax are possible complications.	All foodborne through contamination of freshwater (and freshwater vegetation) by human or animal faeces. All have aquatic snails as intermediate hosts. Fish ((O),(C)), crustaceans (P) are second intermediate hosts for metacercariae; aquatic plants provide substrate for (F) metacercariae. Ingestion of infected raw aquatic vegetables (e.g. water cress) (F); of infected uncooked or partially processed/ cooked fish (C) and (O), or crustaceans (e.g. prawns) (P).	Fish-eating carnivores (C) and (O); crustacean-eating carnivores (P); cattle, sheep, buffaloes, pigs, donkeys (F).	Reduction of contamination freshwater bodies by parasite eggs; animal sources of contamination largely predominant	Several hundreds to several thousands with each stool, depending on infection intensity	While infection persists	(O) Sripa, 2003; (O) and (C) Sithithaworn et al., 2011; (F), (C), (O) and (P) Fuerst et al., 2012; Kim et al., 2011; Heyman et al. 2015

Table 6.1 Excreta-related pathogens (continued)

Pathogen	Health significance	Transmission pathways	Important animal source	Likely importance of sanitation for control†	Concentration excreted in faeces**	Duration of excretion	Additional references
Trichuris trichiura (whipworm)	Largely asymptomatic. With heavy infection – chronic abdominal pain and diarrhoea, iron deficiency anaemia, growth faltering, dysentery syndrome, recurrent rectal prolapse.	Via consumption of contaminated soil and crops. Hand-to-mouth.	None	High	up to perhaps 50,000 eggs	While infection persists	Bethony et al., 2006

† The estimate of low, medium or high impact of sanitation illustrates the potential impact based on the likelihood of continued transmission of the pathogens in conditions of universal access to safe sanitation systems. A low importance indicates that transmission is likely to persist even when universal access to safe sanitation systems is achieved, as other transmission pathways are of greater importance.

** or excreted in urine where applicable (*S. haematobium*)

— no information

1 Taeniasis – adult tapeworm in the intestine

2 Proglottids – worm segment with male/female reproductive organs

6.3 Environmental transmission of pathogens in faecal waste

For any of the transmission pathways (Figure 6.1) to result in additional infections in the population, the pathogens must be excreted in sufficient quantities, persist in the environment (e.g. on surfaces, water, sewage and soil) and be transported (e.g. through hand transfer, aerosol generation, contamination of food crops or contamination of water sources), in an infectious state, to a point of exposure. The overall risk to human health is, therefore, driven by the occurrence (i.e. the amount excreted into the environment by infected people), pathogen persistence in the environment (i.e. the probability of their survival or of remaining infectious), the presence and abundance of any required vectors or intermediate hosts, and the infectivity of the individual pathogens. Following an introduction to pathogen detection methods, an overview of the main data sources and principles of pathogen occurrence, persistence and infectivity is provided below. Further details and information are provided in the relevant chapters of the GWPP.

6.3.1 Methods for detecting pathogens in environmental samples

Microbiological analyses of environmental samples collected in studies of sanitation usually focus on bacterial or phage indicators of fecal contamination – such as *E. coli*, enterococci, and more recently, bacteroides phage (Diston et al., 2012). These indicators are not perfect surrogates for the persistence, transport, and fate of some pathogens, but they are useful, feasible, and economical indicators of faecal contamination in the environment. Under some circumstances, such as disease outbreaks where it may be important to identify the source and movement of a specific pathogen in the environment, it may be useful to test environmental samples for a specific pathogen of interest. The investigators should carefully consider the objectives of the investigation when developing a sample collection and analysis plan because testing environmental samples for pathogens can be challenging and expensive. The investigators should also consider whether it is necessary to detect live infectious pathogens or whether it is sufficient to detect the nucleic acid from the pathogen. Given the limitations of some pathogen concentration and detection methods, negative results should be interpreted with caution.

Unlike testing clinical specimens, where the goal is to identify the presence of an etiologic agent and thereby diagnose an infection, the objective of microbial analyses of environmental samples is to obtain quantitative information on the concentration of fecal contamination (by measuring indicator organisms) or the concentration of pathogens in the sample. This quantitative data can be used to evaluate the risk associated with contact or ingestion of the environmental sample, or to evaluate the effectiveness of a treatment process for removing or inactivating specific pathogens.

Interpretation of enumeration data for public health requires an understanding of the analytical methods and the strengths and limitations of the different approaches. Each method has been developed to isolate and identify a specific agent or group of agents from an environmental sample.

Environmental samples need to be prepared for microbial analysis, to concentrate the pathogen target in the sample in order to increase the chances of detection. The method used for preparation will depend on the type of sample (e.g. sewage, sludge, surface water), the expected concentration of organisms (whether dilution or concentration is required) and the target organism. Some sample types (e.g. faecal sludge) present a considerable challenge for preparation and subsequent enumeration, as the method may consist of numerous steps, each of which can provide the opportunity for loss of the target material (i.e. organisms or nucleic acid). Analytical methods, therefore, have imperfect pathogen recovery and, where possible, quantitative results should be corrected for the method recovery.

Enumeration methods target a specific characteristic of microorganism, and can be grouped according to visual identification, cultured-based and molecular-based methods.

Visual identification is used to count organisms under the microscope based on characteristic morphological features (often using specific staining techniques). Visual identification of microorganisms in environmental samples is rarely used because of poor sensitivity and specificity. Experienced technicians can identify some viruses, protozoan cysts or oocysts, or helminths eggs and larvae, on the basis of their morphology and size. However, microscopic inspection is usually reserved for clinical specimens. Many pathogenic microorganisms in environmental samples can not be identified solely by visual inspection.

Culture-based methods rely on the ability of the target organism to reproduce under a specific set of conditions, and colonies (bacteria) or plaques (viruses) are counted. Culture-based methods only identify infectious organisms. However, as some organisms may be viable but non-culturable (i.e. not able to reproduce in the laboratory, but still infectious to a human host), these methods may underestimate the number of viable organisms in the sample.

Molecular-based methods (e.g. [quantitative] polymerase chain reaction – [q]PCR) are used to identify the presence [and quantity] of a specific target sequence of genetic material in the sample. Molecular methods are used for pathogens that cannot be cultured (or are difficult to culture) and are sometimes favoured in comparison with culture or visual identification owing to their specificity and sensitivity. PCR detection has been a valuable tool for environmental microbiology. There are, however, a number of important drawbacks, including:

- standard PCR techniques cannot distinguish between viable and dead organisms;

- interpreting quantitative results is challenging and depends on the number of target sequences per microorganism (for intracellular pathogens, complexity is further increased); and
- the specificity of the method for targeting the organism of interest depends on the selected probe or primer – the longer the sequence, the more specific the probe or primer is expected to be.

The result from the analysis may be quantitative (a number of organisms, colonies or plaques); presence/absence of the target organism or sequence (which, when done in a series of parallel samples, can be reported as a most probable number (MPN) estimation); or semi-quantitative (such as the output of a qPCR expressed as number or concentration of genome copies in the sample). In many cases, methods for analysis of many human pathogens from environmental samples (including faeces, sewage, sludge and surface water) are not yet standardised. This is an emerging science, with ongoing rapid developments in methodological approaches. Important differences may exist in data reported from different laboratories using valid but different approaches for sample preparation and analysis.

Analytical results from environmental samples should be interpreted in the light of these important methodological constraints. More information can be found in Maier, Pepper & Gerba, 2009, and WHO, 2016.

6.3.2 Pathogen occurrence in faecal waste

Some reported human pathogen concentrations from faeces and sewage are summarised Table 6.2 (adapted from Aw, 2018).

Only infected individuals excrete enteric pathogens. The concentration of pathogens in faecal waste, therefore, depends on the prevalence of infection in the population and the pathogen shedding density (Hewitt et al., 2011; Petterson, Stenström & Ottoson, 2016), and these factors should be considered when interpreting the data in Table 6.2 (additional information can be found in Aw, 2018).

Prevalence of infection: While only infected humans and animals will excrete enteric pathogens, not all infections result in symptoms of disease (some people, in other words, have asymptomatic infections). The infection rate, rather than the disease rate, will drive pathogen occurrence in faecal waste. Higher pathogen concentrations in faecal waste can be expected in communities with a high endemic disease rate. Additionally, the concentration of pathogens in faecal waste from a community increases during an outbreak. For example, during a large outbreak of *Cryptosporidium hominis* infection in Sweden, the oocyst concentration in the community wastewater increased from < to 200 oocysts /10 L before the outbreak to a peak of 270,000 oocysts /10L (Widerström et al. 2014). Over the course of this outbreak it was estimated that nearly one third of the population was infected (27,000 out of around 60,000 inhabitants).

Shedding density: For most pathogens, the information available on shedding density (i.e. the concentration of pathogens in the faeces of infected individuals) is limited to a small number of samples from symptomatic subjects. It is, therefore, difficult to know how representative these values are for all infections (across different age groups and settings) with varying severity of disease. More information is available for norovirus in comparison to other pathogens, following a detailed study involving 102 subjects (71 symptomatic and 31 asymptomatic) to systematically assess the duration and course of shedding (Teunis et al., 2015). The study showed a similar shedding pattern between symptomatic and asymptomatic infections. Virus concentration rose rapidly to a peak within a few days from the onset of infection and then gradually declined. The peak shedding density (determined by molecular analysis methods) varied from 105 to 109 genome copies /g faeces, and the total duration of shedding varied from 8 to 60 days. Six other studies, reviewed

Table 6.2 Pathogen concentrations in faeces and raw sewage (adapted from Aw, 2018)

Pathogen	Concentration / g in faeces	Concentration / L in sewage	Notes regarding sewage data	References
BACTERIA				
***Campylobacter* spp.**	6×10^6 to 10^9 CFU	10^2 to 10^7 CFU 2.5×10^3 to 1.6×10^4 MPN 4.1×10^6 GC	5 Studies in Europe and USA	Pitkanen & Hanninen, 2017
Pathogenic members of E. coli and *Shigella* spp.	10^6 to 10^8 (*Shigella*) 10^2 to 10^5 CFU (pathogenic *E. coli* in cattle faeces)	1.5×10^3 to 1.4×10^7 CFU (Shigella) 10^2 to 10^4 CFU (Pathogenic *E. coli*)	2 studies in South Africa and Spain	Garcia-Aljaro et al., 2017
Helicobacter pylori	No quantitative data	2×10^3 to 2.8×10^4 GC	1 study in USA	Araujo Boira & Hanninen, 2017
VIRUSES				
Adenoviruses	10^{11} particles	1.7×10^2 to 3.3×10^9 GC	8 studies in Brazil, Europe, Japan, USA and New Zealand	Allard & Vantarakis, 2017
Astrovirus	7.6×10^2 to 3.6×10^{15} GC	10^3 to 4.3×10^7 GC	5 studies in Brazil, France, Japan, Singapore and Uruguay	da Silva et al., 2016
Hepatitis A virus	$>10^6$ particles	2.95×10^5 to 9.8×10^8 GC	5 studies in Brazil and Tunisia	van der Poel & Rzezutka, 2017a
Hepatitis E virus	10^5 GC	10^4 GC	2 studies in Norway and Switzerland	van der Poel & Rzezutka, 2017b
Norovirus and other caliciviruses	10^{11} GC	1.7×10^2 to 3.4×10^9 GC	18 studies in Europe, Japan, Uruguay, New Zealand and USA	Katayama & Vinjé, 2017
Polioviruses and other enteroviruses	10^6 to 10^7	0 to 3.4×10^4 (cell culture)	15 studies in Africa, Europe, Japan, New Zealand and USA	Betancourt & Shulman, 2016
Rotavirus	10^{10} to 10^{12} particles	2.2×10^2 to 2.9×10^8 GC	5 studies in Argentina, Brazil, China and USA	da Silva et al., 2016
PROTOZOA				
***Cryptosporidium* spp.**	10^6 to 10^7 oocysts	1.6×10^4 oocysts	20 studies in South and North America, Asia, Europe and Africa	Nasser, 2016
Cyclospora cayetanensis	10^2 to 10^4 oocysts	1.2×10^4 GC	Based on a study in USA	Chacin-Bonilla, 2017
Entamoeba coli, Entamoeba histolytica	1256 cysts	1329 to 2834 cysts 893 cysts	17 wastewater treatment plants in Tunisi	Ben Ayed & Sabbahi, 2017
Giardia duodenalis	56 to 5×10^6 cysts	759 cysts 1 to 10^5 cysts	17 wastewater treatment plants in Tunisia 17 studies in Asia, North and South America, Europe and South Africa	Boarato et al., 2016
HELMINTHS				
***Ascaris* spp.**	204 eggs	46 eggs (Maximum: 175) 455 eggs	1 study in Iran (N=60) 17 wastewater treatment plants in Tunisia	Sossou et al., 2014; Sharafi et al., 2015
Liver flukes e.g. *Clonorchis sinensis*	2.8 x 10^3 eggs	No data		Murell & Pozio, 2017
Schistosoma mansoni	53 eggs	No data		Sossou et al., 2014
***Taenia* spp.**	No data	51 eggs	17 wastewater treatment plants in Tunisia	Ben Ayed et al., 2009

GC: Gene copies; CFU: Colony forming units; MPN: Most Probable Number.

by Katayama & Vinjé (2017), also reported variable norovirus concentrations in faeces. Ajami et al. (2010), for example, reported norovirus concentrations in the faeces of 11 subjects ranging from 3.76×10^7 to 1.18×10^{13} genome copies/g. Considerable variation could therefore also be expected for other pathogens, and the indicative concentrations given in Tables 6.1 and 6.2 are representative of the limited data available. The natural variability in prevalence and shedding density mean that the concentration of pathogens in faecal waste is difficult to generalize, and wide variability both between locations and over time should be expected. The volume of water combined with the faecal waste will also drive the concentration through dilution. In the case of centralized sewer networks, this water may include industrial discharges and stormwater as well as household usage.

6.3.3 Pathogen persistence in the environment

Assessing the survival time of pathogens in the environment is a key component of health risk assessment. In order to present a risk to human health, enteric pathogens must persist in the environment for long enough to infect a new host. Natural die-off and inactivation is an important health protection measure.

Individual pathogens vary widely in their environmental persistence, and environmental conditions are critical. Generalizations are difficult, and factors influencing microbial persistence have been reviewed and summarised in Table 6.3 (Yates, 2017). Most studies, however, have been undertaken using indicator organisms[1] rather than human pathogens, and often conducted in water (marine, fresh surface, or groundwater) rather than wastewater; these present serious limitations to inferences about pathogen behaviour and survival in human excreta.

Pathogens are, typically, adapted to the conditions of the human or animal gut and so persistence under unfavourable conditions is limited. Nevertheless, dark and cool conditions, neutral pH and sufficient moisture may lead to prolonged survival of pathogens. Poliovirus type 1 and Hepatitis A virus,

[1] These tend to be non-pathogenic microorganisms that are natural inhabitants of the gastrointestinal tract. They are relatively cheap and easy to enumerate and they are used to indicate faecal contamination.

Table 6.3 Factors influencing microbial persistence (from Yates, 2017)

Factor	Effect
Temperature	Longer persistence at lower temperatures
Microbial activity	Variable, depending on microorganism and environmental conditions; generally, more microbial activity results in shorter persistence in the environment
Dissolved oxygen	Variable results have been reported
Organic matter	May protect microorganism from inactivation; other studies have shown that the presence of organic matter may reversibly retard virus infectivity
Microorganism type	In general, helminths persist the longest, followed by viruses and protozoa, while bacterial persistence is generally the lowest
Aggregation	Aggregation generally enhances persistence
pH	Varies depending on microorganism, but persistence tends to be best at near-neutral pH values; many enteric viruses are stable over a pH range 3–9
Moisture content	Many microorganisms persist longer in soils with higher moisture content
Adsorption to solid materials	Variable results have been reported. In many cases, adsorption to solid materials increases persistence by providing protection from predation
Soil properties	Effects on persistence are likely related to degree of adsorption to soil
Light	Light, especially ultraviolet light from sunlight or artificial sources, is germicidal. Exposure to sunlight will reduce the survival of viruses, bacteria and protozoa in water and soil surfaces

for example, remained infectious for more than a year in mineral water stored at 4°C (Biziagos et al., 1988). For *Cryptosporidium*, under dark conditions for four different natural waters, the time for 2 $\log_{10}$ inactivation (99% reduction) varied between 10 and 18 days at 30°C but increased to more than 200 days at 5 °C in all cases (Ives et al., 2007). In the case of faecal sludge, a review of the literature (Manser et al., 2016) clearly demonstrated a temperature-time relationship for *Ascaris* eggs during anaerobic digestion; at a digestion temperature of 50 °C a 2 $\log_{10}$ inactivation of eggs was recorded as between less than 2 hours up to 4 days, compared to more than 2500 days at 10 °C. Norwalk virus has been detected for over three years in groundwater held at room temperature in the dark and the virus remained infectious for at least 61 days (Seitz et al., 2011); norovirus outbreaks are often linked to faecal contamination of groundwater.

When assessing the safety of a sanitation system or exposure pathway, the specific environmental conditions and most relevant pathogens need to be considered. As a minimum, individual pathogen groups (i.e. bacteria, viruses, protozoa and helminths) should be addressed separately; however, even within these groups there can be some important distinctions.

6.3.4 Pathogen infectivity

The probability that a pathogen will be able to achieve an infection in an exposed individual depends on both host and pathogen factors. Host factors, including immune status, nutritional status, age and the presence of existing infections or diseases, will all influence an individual's susceptibility to infection. In addition, pathogen-specific factors that can be related to the specific strain and its virulence will drive the infectivity.

Table 6.4 Selection of ID50 values from human challenge data

Pathogen	ID50	Dose unit	Reference
		BACTERIA	
Camypylobacter	890	CFU	Black et al., 1988
E. coli (EIEC)	2,100,000	CFU	DuPont et al., 1971
Salmonella typhi	1,100,000	CFU	Hornick et al., 1966; 1970
Shigella	1,500	CFU	DuPont et al., 1972
Vibrio cholera	240	CFU	Hornick et al., 1971
		VIRUSES	
Adenovirus type 4	1.1	$TCID_{50}$	Couch et al., 1966
Echovirus strain 12	920	PFU	Schiff et al., 1984
Rotavirus	6.2	FFU	Ward et al., 1986
Norwalk virus	18–2800	genome equivalent copies	Teunis et al., 2008; Atmar et al, 2014
		PROTOZOA	
Cryptosporidium parvum[a] Iowa Tamu and UCP isolates	87 9 1042	oocysts	Teunis et al., 2002
Cryptosporidium hominis[a]	10	oocysts	Chappell et al., 2006
Giardia duodenalis	35	cysts	Rendtorff, 1954

$TCID_{50}$ – tissue culture infectious dose; PFU – plaque forming units; FFU – focus forming units; CFU – colony forming units.
[a] From cited references. All other parameters obtained to two significant figures from QMRAwiki (www.qmrawiki.canr.msu.edu).

Quantitative information on pathogen infectivity has been obtained for some pathogens from human challenge studies. These studies provide observations of infection and illness rates following exposure to a known pathogen dose; they do, however, have limitations to their applicability and generalizability as they are typically conducted in healthy adult males using a single strain of a particular pathogen. Table 6.4 provides an overview of some ID50 values (dose at which 50% of subjects would become infected; or probability of infection = 0.5) from human challenge studies (based largely on the QMRAwiki – www.qmrawiki.canr.msu.edu). No human challenge data are available for any parasitic worms. Many studies have been published on norovirus infectivity based on molecular data (reviewed by van Abel et al., 2017); infectivity is high for individuals susceptible to infection, but interpreting the required dose from molecular data is challenging.

6.4 Treatment and control

Wastewater and sludge treatment processes are an essential barrier for protection of human health. These systems, however, are often designed to achieve environmental goals or aesthetic objectives, rather than specific pathogen reduction targets, and some treatment processes have been shown to have a relatively minimal impact on pathogen levels in sewage (with less than 90% reduction of any of the four pathogen groups). When microbial reductions are explicitly considered, they often rely on bacterial indicators (e.g. *E. coli* or enterococci) with little consideration of the other pathogen groups.

To ensure that pathogen reduction objectives are achieved, the mechanism of pathogen inactivation needs to be defined and the critical limits of those mechanisms identified for the key pathogens of interest. Common pathogen inactivation mechanisms include:

- **Time:** Natural inactivation over time is a valuable treatment mechanism incorporated into many systems. The time needed to achieve inactivation will depend on temperature and specific conditions (see Section 6.3.3). Critical limits relate to ensuring that the minimum solid/hydraulic residence time has been achieved.
- **Sedimentation and partitioning to solids:** Sedimentation processes are typically designed for suspended solids removal; pathogens, however, often attach to particulates in wastewater and can be removed simultaneously. It is, thus, relevant to know the extent to which different pathogens adsorb to the particulate matrix to estimate removal capacity. In waste stabilisation ponds, allowing time for sedimentation can lead to removal of larger pathogens (particularly helminths).
- **Solar radiation:** Many pathogens, particularly viruses, are susceptible to inactivation by solar radiation. The extent of removal will be driven by water depth, clarity and exposure time.
- **Thermal treatment:** When storage is combined with a thermal process (either naturally through composted waste or by the addition of heat) pathogen reduction times can be drastically reduced (see Section 6.3.3). To ensure that these reductions have been achieved, it is necessary to know the temperature profile of the waste and to ensure that the required temperature was achieved for adequate duration.
- **Filtration:** Physical filtration processes from natural wetlands to filter beds can effectively remove pathogens. Removal depends upon the filter pore size (with smaller organisms – i.e. viruses – more difficult to remove) and the biological activity of the filter matrix. An established biofilm within the filter will enhance removal and predation of all pathogen groups.
- **Chemical disinfection:** Addition of chemical disinfectants will enhance pathogen reduction. The response, however, will be pathogen-specific and depend on the dose, water matrix and, most notably, the organic content. In situ disinfection

using lime to raise the pH has been shown to be a useful strategy in emergency settings (Sozzi et al., 2015).

- **Attenuation in the subsurface:** Many sanitation technologies rely on pathogen attenuation (physical removal by filtration, adsorption to soil and inactivation) in the subsurface. The fate of pathogens in the subsurface is determined by their survival in soils and retention by soil particles and is mainly determined by local climatic conditions (in particular temperature, sunlight and rainfall), the nature of the soil (e.g. particle size, cation exchange capacity and composition) and features of the microorganism (e.g. size and shape). The capacity of the soil to remove organisms increases with a decrease in soil-water content. Laboratory and field experiments have shown that many soils have a high retention capacity for bacteria and viruses (Drewey & Eliassen, 1968; Gerba et al., 1975; Burge & Enkiri, 1978). In general, retention of bacteria and viruses increases with an increase in clay content, cation exchange capacity of the soil and specific surface area (Marshall, 1971; Burge & Enkiri, 1978).

A wide range of treatment approaches and technologies are presented in Chapter 3. While a general indication of pathogen reduction efficacy is provided in that chapter, it is emphasized that site specific evaluation of the relevant pathogen removal mechanisms (under both expected and event conditions) is needed to assess the actual reduction efficacy and hence safety of each treatment barrier. This reduction efficacy must be assessed for each of the key pathogen groups, and with particular attention to any reference pathogens of local significance.

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Chapter 7

METHODS

7.1 Introduction

These guidelines were developed according to the procedures and methods described in the WHO handbook for guideline development (WHO 2014). The development process included formulating scoping questions, prioritising key questions, conducting systematic reviews to answer the key questions, assessing the quality of the evidence, formulating recommendations, writing the guidelines and developing a plan for their dissemination and implementation. The proposal for these guidelines was approved by the WHO Guidelines Review Committee (GRC) in November 2015. The guidelines were reviewed by the Chair and Secretariat of the WHO Guidelines Review Committee but did not have to undergo formal review by the Guidelines Review Committee, as the recommendations provided are largely considered so-called good practice statements. Good practice statements account for "*situations, in which a large body of indirect evidence, made up of linked evidence including several indirect comparisons, strongly supports the net benefit of the recommended action*"; they are considered "actionable, necessary and of both large and unequivocal benefit" (Guyatt et al., 2016).

This chapter details the methods used in the development of the guidelines.

7.2 Contributors

Contributions to the guidelines development process were made by a number of groups and individuals (including end-users and technical experts from a wide range of disciplines). The groups are outlined below and members of the different groups are listed in the acknowledgements.

7.2.1 WHO steering group

The WHO steering group comprised WHO staff from the Department of Public Health, Environmental and Social Determinants of Health (PHE), the Department for Neglected Tropical Diseases, and the Department for Pandemic and Epidemic Diseases as well as environmental health regional focal points from all six WHO regions. The steering group was involved in the planning, coordination and management of the whole process from the development of scoping questions (see Section 7.3) to final publication of the guidelines.

7.2.2 Guidelines development group

The Guidelines Development Group (GDG) included 30 members with expertise across the various relevant content areas. It was consulted at critical points during the development process, including commenting on the key questions and suggested methods for the systematic reviews, contributing to and/or reviewing systematic reviews, formulating recommendations and supporting the drafting and reviewing of different chapters of the guidelines. The group was balanced in terms of gender and geography, and included technical experts as well as end-users. The GDG also included a methodologist with experience in systematic reviews, the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) approach and translation of evidence into recommendations.

7.2.3 Systematic review teams

The commissioned systematic reviews were conducted by experts with extensive experience in carrying out systematic reviews on environmental health interventions (including water, sanitation and hygiene) using Cochrane-style as well as broader qualitative and mixed-method systematic review methods and application of the GRADE approach for assessing the quality of the evidence.

7.2.4 External peer review group

The external peer review group provided input towards the systematic reviews and appraised and commented on advanced draft chapters of the guidelines.

7.2.5 External partners and observers

Representatives of external partners were invited to participate as observers in the meetings of the GDG.

7.2.6 Management of conflicts of interest

All members of the GDG and external peer review group completed WHO declaration of interest forms. These were then reviewed for potential conflicts of interest. While several conflicts of interests were declared, none of these required any member of the GDG or external peer review group to be excluded from their role.

7.3 Scoping and question formulation

Sanitation, as addressed in these guidelines, is concerned with the complete sanitation service chain, from toilet capture and containment through emptying, transport, treatment (in-situ or off-site) and final disposal or reuse (Figure 1.2).

Interventions to ensure adequate sanitation include both technologies (which could be sanitation facilities [e.g. toilets], services [e.g. safe faecal sludge removal] or systems [e.g. wastewater treatment]) and behavioural change activities. Sanitation interventions often comprise multiple components, which may act independently or interdependently; the components describe the "what?" of the intervention, including aspects of timing (when), dose (how long) and intensity (how often) (Rohwer et al. 2017). Implementation of the intervention or of specific components may involve policies, regulations and provision of financial incentives or resources (including personnel). Implementation has been defined as an actively planned and deliberately initiated effort with the intention to bring a given intervention into policy and practice within a particular setting (Pfadenhauer et al., 2017).

The scoping questions and key questions for the guidelines were informed by critical current evidence needs in sanitation and developed through a number of processes, namely:

- initial discussions among the WHO steering group with selected members of the GDG;
- a survey of selected global sanitation actors within health, public works, sanitation financing, academic institutions, international organizations, development banks and NGOs; and
- consultation with all members of the GDG during the first GDG meeting.

The prioritised key questions were subsequently re-formulated according to the 'PICO' format (population – intervention – comparison – outcome) to focus and improve the scientific rigour of the subsequent systematic reviews. The five key questions fall into two areas, namely implementation-focused (question 1) and intervention-focused (questions 2–5).

Implementation focused

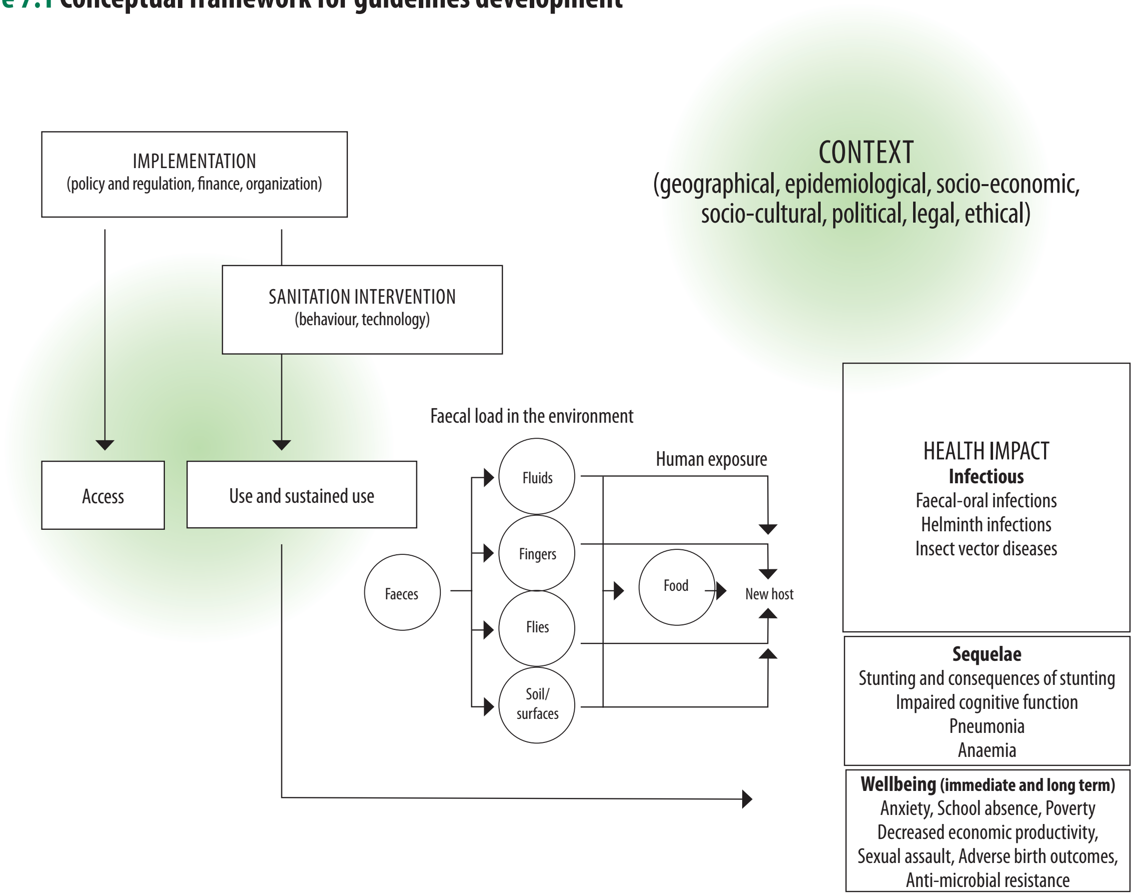
- How do contextual factors (e.g. population, setting, climate) and implementation aspects (e.g. policies, regulations, roles of the health and other sectors, management at different levels of government) influence access to as well as uptake and use of different interventions?

Intervention focused

- How effective are different sanitation interventions in achieving and sustaining access to, uptake and use of sanitation?
- How effective are different sanitation interventions in reducing environmental faecal load?
- How effective are different sanitation interventions in reducing exposure to faecal pathogens?
- How effective are different sanitation interventions in improving specific health outcomes (including infectious diseases, nutritional status, well-being and educational outcomes)?

These questions are presented within the conceptual framework in Figure 7.1, which illustrates the pathways through which the intervention and its implementation are thought to influence health via multiple intermediate outcomes. An important intermediate outcome is access to, as well as short-term uptake and long-term, sustained use of different sanitation interventions, be they technologies or behaviours. These are assumed to influence both the faecal load in the environment and human exposure to faecal contamination. Ultimately, greater access to and use of sanitation interventions and a reduced faecal load are expected to lead to improved health outcomes (i.e. infectious disease and nutritional outcomes) as well as educational outcomes and mental health and social well-being. The conceptual framework also reflects the fact that contextual factors can influence both the way in which an intervention is implemented and the way in which it operates to affect

Figure 7.1 Conceptual framework for guidelines development



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health. These contextual factors are less amenable to change and may explain some of the differences seen in intervention effectiveness between geographical settings and countries.

7.4 Evidence retrieval, assessment and synthesis

The key questions were used to define the required systematic reviews, a core component to inform the formulation of recommendations. The specific research questions derived from the key questions and the conceptual framework are shown in Table 7.1. Examination of the literature revealed that recent independently conducted reviews existed in a number of areas (Yates et al., 2015; Hulland et al., 2015; Speich et al., 2016; De Buck et al., 2017; Majorin et al., 2018; Ejemot-Nwadiaro et al., 2015; Venkataramanan et al., 2018). Other systematic reviews were specifically commissioned (and published or submitted for publication in the peer-reviewed literature) to cover the remaining areas. The commissioned reviews were all conducted largely in accordance with Cochrane standards (Doyle, 2016) and were based on an a priori protocol. The reviews employed systematic search strategies across a large number of relevant major electronic and, where appropriate, grey literature databases, and sought to identify published as well as unpublished studies. Searches were conducted in English but, depending on the review, eligible studies published in several other languages, including Spanish, Portuguese, French, German or Italian, were also included. The systematic reviews developed and applied clearly defined inclusion/exclusion criteria, usually through two independent assessors, extracted data onto pre-specified data extraction forms and assessed the quality of the included studies using a fit for purpose risk of bias or quality appraisal tool, such as the Liverpool Quality Appraisal Tool (Pope et al., personal communication). Heterogeneity across included studies was explored and described and, depending on the nature of the systematic review, evidence synthesis was undertaken using meta-analysis (including pre-specified subgroup analyses), tabular or narrative synthesis or a form of qualitative evidence synthesis.

Methodological details for each of the reviews, including search strategy, eligible interventions, outcomes and study designs, as well as risk of bias assessment or quality appraisal and evidence synthesis, are available in the published reviews (see Table 8.1 and references therein).

7.5 Evidence grading

7.5.1 Grading evidence of effectiveness

The GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach (Guyatt et al., 2008; Schünemann et al., 2008) was used to rate the quality of the reviewed evidence. In GRADE, quality of evidence reflects the certainty that the true effect of an intervention lies on one side of a specified threshold, or within a chosen range (Hulcrantz et al., 2017). In applying GRADE in the guidelines, we were particularly interested in whether the true effect of an intervention would be different from the null, i.e. in knowing whether the intervention shows any effect versus no effect.

In GRADE, the quality of a body of evidence for a given outcome is assessed, initially, based on the design of the underlying studies (where randomized controlled trials start off as high quality and all other study designs start off as low quality). Consideration of additional factors (shown below) may either decrease (five factors) or increase (three factors) the overall quality of evidence (irrespective of study design).
Factors to decrease the quality of evidence:

- **Risk of bias**: The confidence in an effect decreases if studies suffer from major limitations that are likely to result in a biased assessment of the intervention effect.
- **Indirectness of evidence**: The confidence in an effect may decrease if there are important

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differences between the PICO of interest and the PICO examined in the available studies (e.g. if the population of interest are children, but all available studies included only adults, or if only surrogate outcomes are reported).
- **Unexplained heterogeneity or inconsistency of results**: The confidence in an effect may decrease when studies yield widely differing estimates of effect, and when no plausible explanation for this heterogeneity can be identified.
- **Imprecision of results**: The confidence in an effect may decrease when results are imprecise, i.e. when confidence intervals of reported effect estimates are wide and include both the possibility of a relevant effect (defined by the pre-specified threshold or range) and the possibility of no such effect, or when the number of participants or events is small.
- **High probability of publication bias**: The confidence in an effect may decrease when we have reason to assume that relevant studies have been conducted but not published. Indicators of publication bias include asymmetric funnel plots, or a large share of small, industry-sponsored studies.

In considering each of these factors in turn, the quality of evidence can be rated down by -1 (if there are serious concerns with the given factor) or rated down by -2 (if there are very serious concerns with the given factor).

Factors to increase the quality of evidence:
- **Magnitude of effect:** When methodologically well-done observational studies yield large estimates of the magnitude of an effect, one may be particularly confident in the results. The threshold will depend on the review question and the wider context, but it has been suggested that for dichotomous outcomes, a risk ratio (RR) > 2 or a RR < 0.2 may indicate a large effect. For public health interventions lower thresholds may be justified.
- **Residual confounding**: On occasion, all plausible biases from studies may be working to underestimate an apparent intervention effect, or suggest a spurious effect when results show no effect.
- **Dose-response gradient**: When larger doses, or more intensive interventions show larger effects this may increase our confidence in the results.

Quality of evidence can be increased by +1 for all residual confounding operating to underestimate an effect and the presence of a dose-response gradient, and by +1 or +2 for a large or very large effect respectively.

On the basis of this approach the review evidence was rated as one of the following four levels:
- **High quality**: This research provides a very good indication of the likely effect. The likelihood that the effect will be substantially different is low.
- **Moderate quality**: This research provides a good indication of the likely effect. The likelihood that the effect will be substantially different is moderate.
- **Low quality**: This research provides some indication of the likely effect. However, the likelihood that it will be substantially different is high.
- **Very low quality**: This research does not provide a reliable indication of the likely effect. The likelihood that the effect will be substantially different is very high.

For each of the commissioned systematic reviews a summary of findings table was created, which outlines the reasoning behind a given quality of evidence rating (see Table 8.1 and references therein).

7.5.2 Examining the conceptual framework

While the GRADE approach provides a useful framework for assessing the quality of evidence in relation to individual outcomes, it is less suited to a comprehensive assessment of all the types of evidence needed in relation to complex interventions (Rehfuess & Akl, 2013; Montgomery et al.), including those within the sanitation area. Sanitation interventions are complex interventions as they involve multiple components, influence a broad range of health (and non-health) outcomes, are delivered through and influenced by multiple stakeholders and are influenced by many contextual factors, including socio-economic, socio-cultural and geographical aspects (Rehfuess & Bartram, 2014).

To account for the complex nature of sanitation interventions, the evidence was also reviewed from a whole system perspective (illustrated in Figure 7.1). This allowed for:

- the exploration of which links are well-supported (versus less well-supported) by evidence (identifying potential research needs);
- an assessment of the coherence of the insights provided across the system, drawing on information from other disciplines (including microbiology and engineering); and
- the exploration of which links in the pathways may be responsible when a given intervention (or package of interventions) has failed to demonstrate a positive health impact; e.g. poor intervention design ('intervention failure' indicated by poor engineering) versus poor implementation ('implementation failure' indicated by low rates of access to and/or use).

7.6 Evidence-to-Decision (EtD) framework

Several WHO guidelines to date have followed the GRADE EtD frameworks (Alonso-Coello et al., 2016) to formulate recommendations and to assess the strength (strong or moderate) of these recommendations. These guidelines applied the WHO-INTEGRATE framework, an EtD framework that is rooted in the norms and values of the WHO, as agreed upon by all WHO Member States, and reflective of the changing global health landscape. Importantly, this framework is considered particularly suitable for complex multi-sectoral population- and system-level interventions (Rehfuess et al., in press).

The WHO-INTEGRATE framework comprises six substantive criteria – *balance of health benefits and harms, human rights and socio-cultural acceptability, health equity, equality and non-discrimination, societal implications, financial and economic considerations and feasibility and health system considerations* – and *the meta-criterion quality of evidence*. It is intended to facilitate a structured process of reflection and discussion in a problem- and context-specific manner.

For these guidelines, the six substantive criteria were considered at the end of the guideline development process and applied across recommendation areas 1, 2 and 3 combined, conceptualizing technical and behavioural interventions along the entire sanitation service chain and as part of locally delivered services as a single multi-component intervention. The application of these criteria at the level of single recommendations or even at the level of distinct recommendation areas would have resulted in much repetition. Recommendation area 4 is very different in nature: as it does not relate to a specific intervention but rather describes how the health sector can and should play an active role in promoting sanitation, a structured EtD framework was not considered to be applicable. Notably, the meta-criterion quality of evidence, while available and applied in relation to intervention effectiveness (see Chapter 8), was not applied to the other substantive criteria, mostly because suitable methods to do so still need to be developed.

The WHO-INTEGRATE framework template in Table 7.1 was initially filled in by members of the WHO Steering Group and then reviewed by the full GDG group. For each criterion, the evidence (where available) or rationale for making a judgement about how the criterion would influence the formulation and/or strength of a recommendation was summarized to allow for transparent decision-making.

Table 7.1 Evidence to recommendation table using the WHO-INTEGRATE framework (Rehfuess et al.)

Criteria	Sub-criteria	Guiding question	Rationale and evidence	Judgement
Balance of health benefits and harms	• Efficacy or effectiveness on health of individuals • Effectiveness or impact on health of population • Patients'/beneficiaries' values in relation to health outcomes • Safety-risk-profile of intervention • Broader positive or negative health-related impacts	Does the balance between desirable and undesirable health effects favour the intervention or "business as usual"?		☐ Favours "business as usual" ☐ Probably favours "business as usual" ☐ Does not favour either the intervention or "business as usual" ☐ Probably favours the intervention ☐ Favours the intervention
Human rights and socio-cultural acceptability	• Accordance with universal human rights standards	Is the intervention in accordance with universal human rights standards and principles?		☐ No ☐ Probably not ☐ Uncertain ☐ Probably yes ☐ Yes
	• Socio-cultural acceptability of intervention by patients/ beneficiaries and those implementing the intervention • Socio-cultural acceptability of intervention by the public and other relevant stakeholder groups • Impact on autonomy of concerned stakeholders • Intrusiveness of intervention	Is the intervention acceptable to key stakeholders?		☐ No ☐ Probably not ☐ Uncertain ☐ Probably yes ☐ Yes
Health equity, equality and non-discrimination	• Impact on health equality and/or health equity • Distribution of benefits and harms of intervention • Affordability of intervention • Accessibility of intervention • Severity and/or rarity of the condition • Lack of a suitable alternative	What would be the impact of the intervention on health equity, equality and non-discrimination?		☐ Increased ☐ Probably increased ☐ Neither increased nor decreased ☐ Probably reduced ☐ Reduced
Societal implications	• Social impact • Environmental impact	Does the balance between desirable and undesirable societal implications favour the intervention or "business as usual"?		☐ Favours "business as usual" ☐ Probably favours "business as usual" ☐ Does not favour either the intervention or "business as usual" ☐ Probably favours the intervention ☐ Favours the intervention
Financial and economic considerations	• Financial impact • Impact on economy • Ratio of costs and benefits	What would be the impact of the intervention on financial and economic considerations?		☐ Negative ☐ Probably negative ☐ Neither negative nor positive ☐ Probably positive ☐ Positive
Feasibility and health system considerations	• Legislation • Leadership and governance • Interaction with and impact on health system • Need for, usage of and impact on health workforce and human resources • Need for, usage of and impact on infrastructure	Is the intervention feasible to implement?		☐ No ☐ Probably not ☐ Uncertain ☐ Probably yes ☐ Yes

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Chapter 8

EVIDENCE ON THE EFFECTIVENESS AND IMPLEMENTATION OF SANITATION INTERVENTIONS

8.1 Introduction

This Chapter summarizes the systematic reviews for the key questions outlined in Chapter 7. Examination of the literature revealed that recent independently conducted reviews existed in a number of areas (Ejemot-Nwardiario et al., 2015; Hulland et al., 2015; Yates et al., 2015; Speich et al., 2016; De Buck et al., 2017; Majorin et al., 2018; Venkataramanan et al., 2018). Where no existing review was found, or where those identified did not include an assessment of the quality of the overall body of evidence and/or additional rigorous trials had been published post-review, additional systematic reviews were specially commissioned (Williams & Overbo, 2015; Overbo et al., 2016; Sclar et al., 2016; Freeman et al., 2017; Garn et al., 2017; Sclar et al., 2017, 2018). Table 8.1, at the end of the chapter, provides an overview of the scope and conduct of each of these reviews, as well as information on the quality of the included body of evidence (where available).

8.2 Summary and discussion of evidence

The evidence suggests that safe sanitation is associated with improvements in health, including positive impacts on infectious diseases, nutrition and well-being. For some health outcomes, both the magnitude of the observed effects and the quality of the evidence is low. This is common for environmental health research generally due to the paucity of randomized controlled trials and the inability to blind most environmental interventions. The evidence is also characterized by considerable heterogeneity, with some studies showing little or no effect on health outcomes. Heterogeneity can be expected in results from studies where, as here, there was high levels of variability in the settings, baseline conditions, types of interventions, levels of coverage and use obtained, study methods and other factors likely to impact effect sizes. Sub-optimal effects can also be expected from shortcomings in how sanitation interventions are implemented (i.e. problems with delivery of sanitation interventions, sometimes even leading to implementation failure). These difficulties are compounded by the multiple and highly context-specific sanitation-related exposure pathways, making extrapolation from studies problematic.

The overall quality of the evidence as per GRADE criteria was often rated as low or very low, which is common for complex interventions like sanitation (Rehfuess & Akl, 2013; Movsisyan, Melendez-Torres & Montgomery, 2016a, b). This can be explained partly by the fact that many studies are observational rather than experimental, and there is high heterogeneity in the results. The reviews have highlighted important limitations common among multiple studies of sanitation, including:

- lack of details on interventions and implementation quality, settings and ambient conditions; and
- different case definitions, methods of assessment, frequency and length of follow up, method of delivery, definitions and methods of assessment of coverage and use, and pathogens circulating in a given setting.

Few intervention studies have been conducted to examine the impact of sanitation interventions, and those conducted suffer from challenges related to the nature of the evaluation such as lack of blinding, uncertain generalizability and methodological challenges (such as reliance on reported outcomes and susceptibility to bias). Because the contexts of sanitation interventions vary substantially, the external validity of individual trials may also be limited.

Importantly, many studies reviewed lack detailed information on the implementation of the intervention, in terms of whether it was delivered as intended, and whether it resulted in intermediate effects such as reaching intended sanitation coverage levels and achieving uptake and use of sanitation services. The absence of such intervention-specific information makes it difficult to conclude whether the intervention itself was unlikely to deliver the desired health impact, or whether failures in delivery or evaluation methods are at fault.

Finally, the studies reviewed mostly represent LMIC settings; few studies review the impact of sanitation interventions in higher income contexts. Gaps in the evidence and related research needs are detailed in Chapter 9.

8.3 Reviews of intervention effectiveness

8.3.1 Access, uptake and use

How effective are different interventions in achieving and sustaining access to, uptake, and use of sanitation?

Four reviews (Garn et al., 2017; Hulland et al., 2015; De Buck et al., 2017; Venkataramanan et al., 2018) examined intervention effectiveness in relation to coverage and use. These reviews evaluated:

- what types of interventions are the most effective at increasing toilet access and/or toilet use (Garn et al., 2017);
- what structural and design characteristics are associated with increased toilet use (Garn et al., 2017);
- how well interventions to improve adoption of clean water and sanitation work and the characteristics of successful interventions (Hulland et al., 2015);
- how effective different approaches for promoting handwashing and sanitation behaviour change are and the factors that influence their implementation (De Buck et al., 2017);
- quality of evidence, impacts and factors affecting the implementation and effectiveness of community-led total sanitation (Venkataramanan et al., 2018).

Access and use

In their WHO-commissioned systematic review, Garn et al. (2017) identified 40 eligible studies (randomized controlled trials – RCTs; non-randomized controlled trials and controlled or non-controlled before-and-after studies), which assessed intervention impacts on toilet coverage and/or use. Of these, 36 studied household interventions and four were school-based interventions. The interventions included increased access to sanitation facilities or other hardware (e.g. household toilet, sewer connections), subsidy provision, education and the promotion of specific practices (e.g. discouraging open defecation).

Analysis of the household studies showed that, overall, the interventions led to a 14% increase in toilet coverage (95% CI: 10-18%; n=27) compared to the control groups and a 13% increase in toilet use (95% CI: 5-21%; n=10). There was heterogeneity in the results across the different sanitation interventions. The school-based studies were shown to result in a reduction in the number of pupils per toilet, but the change in usage could not be calculated due to inconsistent reporting. Importantly, the impact of interventions on toilet coverage depended upon the baseline prevalence; i.e. the communities with the largest coverage gains often had the lowest baseline coverage levels. The authors suggest that the figures on toilet use should be interpreted with caution as use was defined in different ways across the studies and often relied on self-reported data.

Garn et al. (2017) also reviewed the various structural and design characteristics associated with using or not using a toilet. A total of 24 household- or school-based studies assessing the associations between sanitation structure and design characteristics and toilet use were included. Most of these studies were observational or qualitative. They suggested that accessibility, privacy, access to hygiene amenities, toilet maintenance, toilet type and newer toilets were all associated with increased usage.

Sustained use

In their mixed methods systematic review of the sustained use of water, sanitation and hygiene interventions in LMICs, Hulland et al. (2015) identified 59 eligible sanitation-related studies. All study methodologies were eligible for review and identified studies included RCTs, observational studies, cross-sectional surveys, process evaluations, progress reports and multi-site trials. Most of the studies related to toilet construction, with some interventions providing material for toilet construction (either free-of-charge (n=10), or by selling to the community (n=17)), provision of toilet construction training (n=20), community traditional toilet construction (n=9) or toilet construction by a private company or contractor (n=5). Twelve of the studies did not describe a sanitation technology. The literature did not have a common definition of sustained use/adoption but was defined, by the authors for the purposes of the review, as the continued practice of a behaviour or continued use of a technology for at least six months after the end of the project period. An in-depth analysis was conducted on the studies that explicitly reported on sustained adoption (16 sanitation studies), which included measurements obtained through self-report, observed practice, functionality and recalled knowledge. The behavioural factors, identified in influencing sustained adoption, were split into psychosocial, contextual and technology factors.

Individual psychosocial factors (e.g. perceived benefit and self-efficacy) strongly dominate the literature on sustained adoption. Interpersonal factors (e.g. social norms) were also reported to strongly influence people's continued practice of behaviours.

The overall context and social norms also have an impact on uptake and sustained use: for toilet use and handwashing practice, for example, age and gender were shown to be strong determinants of a person's continued practice – individuals may be barred from using toilets or unable to practice handwashing if they are too young, or restricted (culturally or physically) from accessing facilities.

Finally, cost and durability were the most important technology-related factors. In low-income settings, the cost of toilet building was the major factor related to technology adoption.

Behaviour change

A total of 42 quantitative studies (RCTs, quasi-RCTs, quasi-experimental and observational designs) and

28 qualitative studies were eligible for inclusion in the mixed methods systematic review of behaviour change approaches for water, sanitation and hygiene in LMICs (De Buck et al., 2017). The majority of studies were conducted in rural settings (69% of quantitative and 68% of qualitative studies) and were conducted in South Asia or sub-Saharan Africa.

The studies were grouped into the following categories:

- community-based approaches;
- social marketing approaches;
- sanitation and hygiene messaging; and
- approaches based on psychosocial and social theory.

The review found apparent differences in the short- and long-term sustainability of changes in sanitation behaviours across the four approaches described, although the evidence for the sanitation outcomes was categorized as low to very low quality.

The review suggested that while messaging and awareness raising approaches may result in short term improvements in handwashing with soap, the changes are unlikely to be sustained over time. Further, these approaches seemed to have no effect on open defecation. No specific conclusions about the effectiveness of message-based approaches on toilet use were provided due to either the limited evidence (single studies) or the very low quality of evidence.

Community-based approaches to sanitation are among the most widely studied behaviour change approaches. Results have been varied, but the review suggests that community-based approaches may be effective at reducing open defecation and fostering sustained safe faeces disposal practices.

Robust data on the effectiveness of social marketing approaches are particularly scarce. Approaches based on psychological and social theory are generally viewed as useful but, given the recent nature of these theory-based approaches, there are only limited studies upon which conclusions can be based.

Community-led total sanitation (CLTS)

In a mixed-methods systematic review of community-led total sanitation (CLTS), Venkataramanan et al. (2018) identified 14 quantitative evaluations, 29 qualitative studies, and 157 case studies from journal-published and grey literature. Given the popularity of this rural sanitation behaviour-change approach, the authors aimed to assess evidence quality, summarize CLTS impacts and identify factors affecting implementation and effectiveness. The review found that evidence available to practitioners and policymakers is of variable quality, particularly regarding the ability to estimate the impact of CLTS on sanitation, health or other community outcomes. Journal-published literature was generally of higher quality than grey literature. Over 25% of the literature overstated conclusions, attributing outcomes and impacts to interventions without an appropriate study design, or by making claims about impact using unverified data sources or anecdotes.

Regarding CLTS impacts, latrine ownership, use and quality indicators were identified in most of the literature, but diverse measures were used. Of the 14 quantitative evaluations included in the review, a statistically significant increase was reported in private or shared latrine construction in intervention groups compared to comparison groups. Declaration or certification of open defecation-free status was the second most common indicator, but no consistent definition was reported. A quarter of the studies also reported some anecdotal measure of change in health status in communities after CLTS, while nine quantitative evaluations measured self-reported changes in diarrhoea prevalence or anthropometric measures in children. Overall, there was limited evidence indicating whether or not there had been sustained sanitation behaviour change or health impacts as a result of CLTS.

A qualitative content analysis of the literature identified implementation and community-related factors reported to affect implementation and effectiveness of CLTS. Of the 21 implementation-related factors, the most cited were:

- government awareness and buy-in for CLTS;
- local government ownership;
- institutional capacity; and
- quality of triggering activities.

Of the 22 community-related factors, the most frequently reported were:

- community participation;
- access to supply, financial resources and technical support;
- climate conditions; and
- expectation of latrine subsidies.

Overall, however, there was minimal systematic research of the CLTS implementation process and its adaptations.

8.3.2 Environmental faecal load reduction

How effective are different sanitation interventions in reducing environmental faecal load?

In an exploratory review of the literature, Williams & Overbo (2015) examined studies on the pathways and extent of unsafe return of human excreta to the environment along the sanitation service chain for pit latrines, septic tanks and sewerage. The review focused on leakage of faecal sludge, of the liquid waste fractions from septic tanks and latrines and of sewered wastewater. Numerous studies showed that many of the sanitation systems currently in use do not adequately prevent the unsafe return of excreta to the environment. Several studies showed, for example, that unlined pits and damaged facilities do not provide effective containment and can cause contamination of the household and surrounding area. In some cases, pit latrines may be badly affected by storms, rainfall and floods. Latrine pits and septic tanks are often not emptied and the liquid fraction may be discharged with little treatment to open drains or open ground or groundwater sources. Where pits are reportedly emptied there was very little information on the fate of the collected sludge; this may be dumped or used in agriculture instead of being delivered to treatment. Few countries have dedicated treatment facilities for faecal sludge or wastewater treatment plants designed for co-treatment of faecal sludge. Sewer connections, alone, were not sufficient to ensure adequate separation of faecal waste from people, as misconnections and exfiltration, broken pumping stations and combined sewer overflows are common. Poor performance of wastewater treatment plants due to overloading, poor operation and maintenance and unpermitted industrial loads means wastewater may be discharged untreated or only partially treated.

8.3.3 Exposure to faecal pathogens

How effective are different sanitation interventions in reducing exposure to faecal pathogens?

Sclar et al. (2016) reviewed the literature assessing the direct impact of sanitation on the pathways of faecal exposure. A total of 29 eligible studies were identified, of which 23 examined transmission pathways (eight RCTs, one non RCT, one quasi RCT, 11 cross-sectional studies, one case control study and one cohort study) following improved sanitation measures, and six (all cross-sectional studies) assessed drinking-water supply contamination on the basis of distance from sanitation facilities. Most of the studies employed interventions involving toilet promotion or construction, with or without other measures such as marketing and subsidies. Study outcomes consisted of endpoints used to assess the impact of sanitation on transmission pathways and included microbiological assessments of drinking-water (sources and stored household water), hand contamination, soil from the toilet floor or household compound, and toilet surfaces. Other measures included observations of flies (around the toilets, in food preparation areas or caught on/around eyes) or the presence of faeces in or around the compound.

The studies showed mixed effects of the sanitation intervention evaluated on most of the transmission pathways, with most studies showing no effect. There was no evidence of effects on drinking-water quality, hand or sentinel toy contamination, food contamination or contamination of soil or surfaces. There was some evidence that sanitation was associated with fly reduction and a decrease in observed faeces (although the overall assessment was not statistically significant). Subgrouping of studies on the basis of the level of sanitation coverage suggested that sanitation interventions are more effective at reducing observed levels of faeces when the coverage starts at a low level and when there is a large difference between the coverage experienced by the intervention and control groups. Studies showed an inverse relationship between the distance of a water source from a toilet and the level of faecal contamination of the water source.

8.3.4 Improving health outcomes

How effective are different sanitation interventions in improving health outcomes (including infectious diseases, nutritional status, well-being and educational outcomes)?

Infectious disease and nutrition

This section includes five reviews:

- Freeman et al. (2017) updated a number of previous systematic reviews on a range of health outcomes;
- Speich et al. (2016) examined the relationship between access to, and use of, sanitation facilities and incidence of intestinal protozoa infections;
- Majorin et al. (2018) considered interventions improving the disposal of child faeces and their impact on diarrhoea and STH infections;
- Ejemot-Nwadiaro et al. (2015) assessed the effects of handwashing promotion on diarrhoeal infections; and
- Yates et al. (2015) looked at the impact of water, sanitation and hygiene interventions on people living with HIV.

Freeman et al. (2017) updated reviews on the impact of sanitation interventions on infectious disease (diarrhoea, four soil-transmitted helminth (STH) infections, schistosomiasis, trachoma) and nutritional status outcomes (weight-for-age, weight-for-height and height-for-age.

The eligibility criteria used by Freeman et al. (2017) were based on the original systematic reviews and varied slightly by review; however, eligible study designs included RCTs, quasi-RCTs, non-randomized controlled trials, controlled before-and-after (CBA) studies, interrupted-time-series studies, cohort studies and cross-sectional studies. A total of 171 eligible studies were identified, 84 of which were included in the meta-analyses. For each disease outcome, four types of meta-analysis were conducted:

- all studies – a pooling of the primary effect estimates from the studies to estimate the overall impact of sanitation;
- intervention studies – an analysis of the experimental studies that specifically assessed a sanitation intervention to provide a more rigorous pooled estimate;
- sanitation ladder – an assessment of different types of sanitation on health impacts by pooling estimates for different levels of sanitation service (any sanitation versus none/non-use; improved versus unimproved; improved versus shared); and
- stratified analysis – an exploration of study population characteristics (such as study setting, age group, water and soap availability).

Overall, greater access to sanitation was associated with significantly lower odds of diarrhoea (12% lower odds for all studies combined; 23% lower odds in intervention studies). Significantly lower odds of infection were seen for the four major STH (*A. lumbricoides, T. trichiura,* *hookworm, S. stercoralis*), with the odds associated with sanitation ranging between 20% and 52% lower than with no sanitation. When considering only intervention studies, no reduction with improvements in access to sanitation was seen in *T. trichiura* infection. Better sanitation access was also found to have a protective association against schistosomiasis and active trachoma and to have a positive association with height-for-age. However, most studies used observational designs, pooled estimates showed substantial heterogeneity and the quality of evidence was rated as low or very low. The review by Freeman et al. (2017) found some evidence of a borderline effect of sanitation interventions on height-for-age z-score (MD 0.08; 95% CI0.00–0.16) but no effect of sanitation on weight-for-age z-score nor on weight-for-height z-score.

Speich et al. (2016) identified 54 eligible studies in their systematic review on the effects of sanitation and water treatment on intestinal protozoa infection (*Giardia intestinalis, Entamoeba histolytica, E. dispar, Blastocystis hominis and Cryptosporidium* spp.), of which 36 were related to sanitation; 23 described associations of sanitation availability, 11 examined associations of the use of sanitation and two did not clearly differentiate between use and availability. The majority of the sanitation studies were cross sectional (n=29), with the remainder being case-control (n=3), intervention (n=1), cohort (n=1) or joint cross-sectional/case control (n=1) studies. The availability or use of toilets was associated with significantly lower odds of infection with *Entamoeba* (44% reduction, 95% CI: 26-58%) and Giardia intestinalis (36% reduction, 95% CI: 19-49%), but not *Blastocystis* or *Cryptosporidium*.

The impact of interventions to improve the disposal of child faeces on diarrhoea and STH infection (*A. lumbricoides, T. trichiura, Ancylostoma* duodenale and *Necator americanus*) was reviewed by Majorin et al. (2018). A total of 45 studies met the inclusion criteria (11 RCTs, three CBA, 24 case-control, two controlled cohort and five cross-sectional studies). Interventions included multi-component and education-only interventions. The combined evidence suggested that safe disposal of child faeces was associated with lower odds of diarrhoea. The main evidence for this finding came from case-control studies, which suggested that disposal of child faeces in a toilet was associated with 24% lower odds of diarrhoea (95% CI: 12-34%), while a child defecating in a toilet (rather than elsewhere) was associated with 46% lower odds of diarrhoea (95% CI: 10-67%). In the randomized controlled trials, the sanitation interventions suggested a 7% reduction in diarrhoea (although this result was not statistically significant), while the hygiene education interventions were associated with a 17% reduction (95% CI: 6-27%). Only two RCTs relating to STH and child faeces disposal were identified and neither of the interventions evaluated showed an impact on helminth infection.

In their intervention review of hand washing promotion for preventing diarrhoea, Ejemot-Nwadiaro et al. (2015) identified 22 eligible individual RCTs and cluster-RCTs that compared the effects of hand washing interventions on diarrhoea episodes in children and adults with no intervention. These included trials from child day-care centres or schools in mainly high-income countries (n=12), community-based trials in LMICs (n=9), and one hospital-based trial among people with acquired immune deficiency syndrome (AIDS). The intervention was defined as "activities that promoted hand washing after defecation or after disposal of children's faeces and before eating, preparing or handling foods". Trials focused exclusively on hand washing and those including hand washing as part of a broader package of hygiene interventions were included if they undertook analyses of effects of hand washing on diarrhoea. Intervention outcomes were defined as primary (episodes of diarrhoea defined as: acute/primary diarrhoea, persistent diarrhoea or dysentery) or secondary (diarrhoea-related death among children or adults; behavioural changes, such as changes in the proportion of people who reported or are observed washing their hands after defecation, disposal of children's faeces, or before preparing or handling foods; changes in knowledge, attitudes, and beliefs about handwashing; all-cause-under five mortality; and cost-effectiveness). The authors concluded that hand washing promotion probably reduces diarrhoea episodes in both child day-care centres in high-income countries (30% reduction 95%CI: 15-42% n=9) and among communities living in LMICs by about 30% (LMIC - 28% reduction 95% CI: 17-38% n=8). However, less is known about how to help people maintain hand washing habits in the longer term. The hospital trial with high-risk population showed significant reduction in mean episodes of diarrhoea (1.68 fewer) in the intervention group, as well as increase in hand washing frequency in the intervention group. No trials evaluating or reporting the effects of hand washing promotion on diarrhoea-related deaths, all-cause-under five mortality or costs were found.

Few studies examined the impact of sanitation on specific population subgroups; however, some have assessed the impact on people living with HIV as a specific at-risk group due to biological and social factors. Yates et al. (2015) conducted a systematic review of the impact of water, sanitation and hygiene interventions on the health and well-being of people living with HIV, who are at a greater risk of enteric infections from faecal-oral pathogens and experience more severe symptoms compared to the immunocompetent population. Sixteen studies were included, of which four (one RCT, two cross-sectional studies and one case-control study) considered the impact of sanitation measures. Results were reported in a variety of ways, but lack of access to household sanitation was generally a significant risk factor, in that toilet access was found to be protective for intestinal parasites and diarrhoea morbidity.

Cognition and school absence

In a review of the effects of sanitation on cognitive development and school absence, Sclar et al. (2017) identified 17 eligible studies (three RCTs, one non-RCT, one CBA, nine cross-sectional and three cohort studies). Twelve of the studies reported on school absence, four reported on outcomes of cognitive development and one reported on both outcomes. The studies of access to household sanitation generally found measures of improved cognitive ability. The studies examining sanitation provision (household, community or school sanitation) and school absence, however, were more uncertain and, overall, lacked a clear pattern. The GRADE score was very low for both cognitive development and school absence.

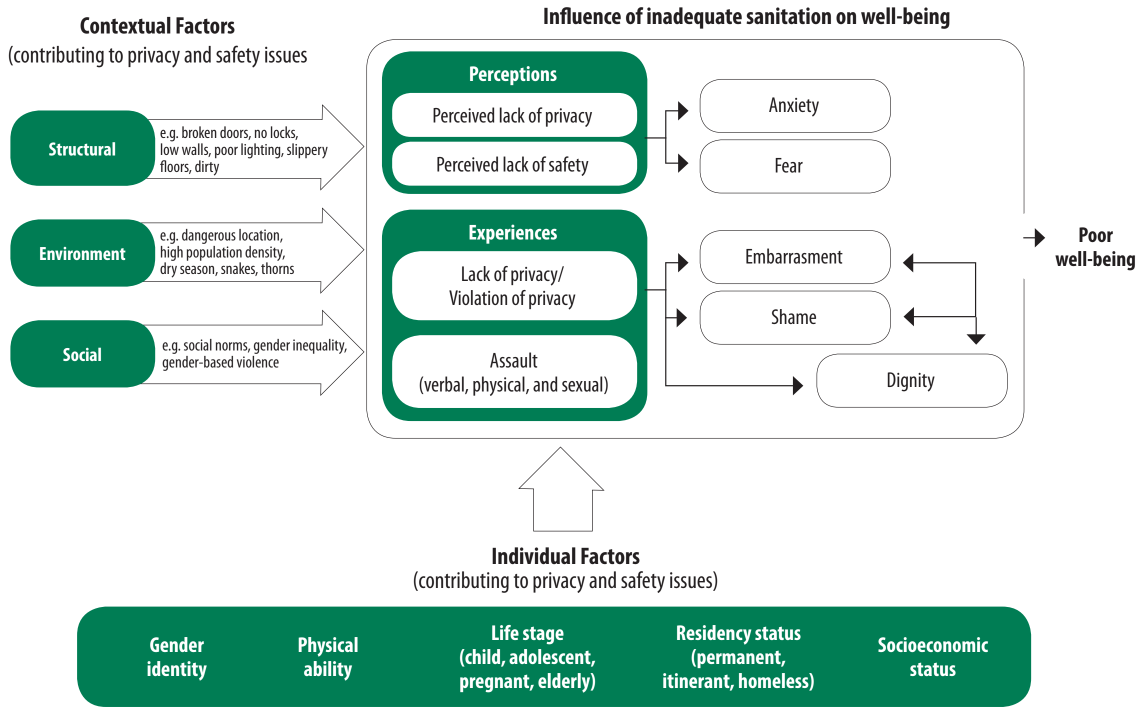
Personal well-being

The relationship of sanitation with eight aspects of well-being (privacy, shame, anxiety, fear, assault, safety, dignity and embarrassment) was examined by Sclar et al. (2018).

They identified 50 eligible studies (35 qualitative, eight mixed methods and seven cross-sectional studies), which considered aspects of relational and subjective well-being for people using private sanitation (n=11), shared sanitation (n=13), school sanitation (n=22) and/or practicing open defecation (n=18).

The study results were analysed using a set of well-being codes and sanitation setting codes. The results suggested that privacy and safety were the core themes that influenced the other aspects of well-being (as indicated in the conceptual framework illustrated in Figure 8.1). The authors noted that due to the skewed geographical distribution of studies (e.g. 14 studies were conducted in India) and a predominant focus on

Figure 8.1 Preliminary conceptual framework of the influence of inadequate sanitation on well-being



the experiences of women and girls (19 studies), the results may have limited generalizability.

8.4 Reviews of implementation

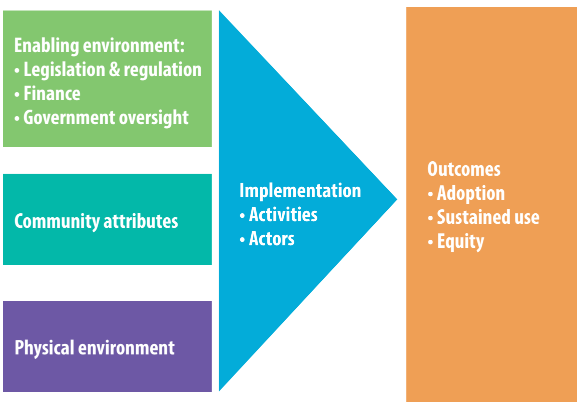
8.4.1 Impact of contextual factors

How do contextual factors (e.g. population, setting, climate) and programmatic factors (e.g. policies, regulation, roles of health and other sectors, management at different levels of government) influence coverage and use of sanitation?

The systematic review conducted by Overbo et al. (2016) drew from both peer-reviewed and grey literature to examine the impacts of various policy and programming strategies and enabling environment factors (such as legislation, finance and politics) on sanitation adoption and sustained use. A total of 68 eligible studies (31 peer-reviewed literature, 37 grey literature) from 27 countries were included in the review (six qualitative, 25 quantitative, nine mixed methods and 28 cases studies). The studies covered improved household sanitation (n=59), household sewer connections (n=8), faecal sludge management (n=1), sewer/wastewater treatment (n=2), public sanitation (n=2) and school sanitation (n=8). Ten of the studies reported multiple sanitation technology types. Fewer than half (28) of the studies reported on the sustained use of sanitation facilities (described, variously, as sanitation use, ending open defecation, or safe disposal of excreta), with studies typically using sustainability data collected through participant selfreporting. All of the studies except one were set in LMICs. The majority of programmes were based in rural settings (62%) or the location was not reported (19%).

Data on factors serving as either enablers or barriers to sanitation adoption and/or sustained use were collated according to the framework shown in Figure 8.2.

Figure 8.2 Sanitation adoption and sustained use review framework



Most of the key findings relate to household sanitation, reflecting the greater number of studies (59 out of 68).

The review reported that:

- Political will and leadership were essential to programme success.
- More successful programming outcomes occurred where there was coordination and collaboration between different sectors and stakeholders.
- Harmonized policies between sectors were found to mobilize political will and support for sanitation programming.
- Access to credit aided success when it was well-managed and there was community demand. The study setting influenced the need for (and effect of) subsidies, but credit access was found to be more effective when coupled with community mobilization and a sense of ownership of the facility.
- Cultural norms and beliefs were found to vary greatly between countries and settings, but widespread acceptance of open defaecation was a barrier to sanitation adoption. Sanitation motivations for adoption and sustained use also varied by setting but privacy, shame and social pressure were frequently and widely reported.
- The physical environment (such as a high water table, seasonal flooding and lack of space) was cited as a barrier to adoption.
- Implementation activities (including house visits, use of mass media and conventional information, education and communication – IEC) were found to be effective for raising awareness of, and demand for, sanitation and they also played a role in community mobilization.
- Monitoring and evaluation was cited as being essential to facilitate strategic planning and create political accountability.

The review identified numerous contextual factors contributing to sanitation adoption and sustained use. Many of these factors are interdependent, and effective planning, monitoring and lesson-learning in programme and policy implementation can help address certain barriers.

8.5 Summary of evidence reviews

Table 8.1 provides an overall summary of the reviews.

Table 8.1 Summary of evidence reviews

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
How effective are different sanitation interventions in achieving and sustaining access to, uptake and use of sanitation?									
Garn et al., 2017 8.3.1	Systematic review	How different sanitation intervention types impact toilet coverage and use.	1950 - 31/12/15. Published, unpublished, in press and grey literature.	English, Spanish, Portuguese, French, German, Italian.	None	Household n=37 Randomized controlled trials (RCT) 10 Non RCT 1 Controlled before-and-after (CBA) 6 Uncontrolled before-and-after 11 Non-randomized control trials 9 School n=4 RCT 1 Non RCT 3	Not stated	Adapted Liverpool Quality Appraisal tool (LQAT) for quantitative intervention studies. Most studies indicated some risk of bias"	GRADE. Low to Very Low.
		How different structural & design sanitation characteristics are associated with toilet use.				N= 24 Experimental and observation designs, quantitative and qualitative. Majority were observational/ qualitative.		N/A	N/A
Hulland et al., 2015 8.3.1	Mixed methods systematic review	Determination of the factors influencing sustained adoption.	End date 01/10/13. Peer-reviewed and grey literature.	English, French, German, Spanish.	LMIC	No restriction on study type N=59	Not stated	Quality assessed using an adapted 7-point scale developed by Harden & Thomas (2005), maximum score 21. Overall rigour scores ranged from 8 to 21.	

Chapter 8

Table 8.1 Summary of evidence reviews (continued)

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
De Buck et al., 2017 8.3.1	Mixed methods systematic review	Quantitative Effectiveness of different approaches for promoting handwashing and sanitation behaviour change.	1980 - March 2016; published, unpublished, grey literature	No language restrictions	LMIC. Studies set in institutions (e.g. hospitals) were excluded.	N=42 RCT 26 Quasi RCT 6 Non-randomized control trials 8 Cohort 2	U 6 R 29	Cochrane risk of bias tool. All the studies had evidence of bias especially in detection, reporting and attribution bias	GRADE. For most assessments Low. Evidence for the sanitation outcomes was Low to Very Low
		Qualitative Factors influencing the implementation of approaches to promote handwashing and sanitation behaviour change.				N=28 Qualitative studies addressing factors influencing implementation of promotional approaches (e.g. grounded theory, case studies, phenomenological studies, ethnographic research, action research & thematic approaches to qualitative data analysis.	U 3 R 19 U & R 3	CASP (Critical Appraisal Skills Program) checklist. Scores ranged between 10 (maximum) and 4.	
Venkataramanan et al., 2018 8.3.1	Mixed methods systematic review	Assess evidence quality, summarize impacts and identify factors affecting implementation and effectiveness of CLTS.	Search conducted in Dec 2015 and updated March 2017	Not stated	None stated	No restriction on study type. N=200. Quantitative 14 Qualitative 29 Case studies & project reports 157	Not stated	A quality appraisal framework for each study type, based on 3 categories: quality of reporting, minimizing risk of bias, and appropriateness of conclusions.	

Table 8.1 Summary of evidence reviews (continued)

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
How effective are different sanitation interventions in reducing environmental faecal load?									
Williams & Overbo, 2015 8.3.2	Literature review	Leakage along the sanitation service chain for pit latrines, septic systems & sewerage	Web of Science & Google Scholar searched between 15/3/15 and 24/4/15. Peer-reviewed journals & grey literature	Not stated	None stated	Qualitative or quantitative findings on sanitation technology functionality, microbial contamination, emptying, transport, treatment or groundwater contamination.	N/A	N/A	N/A
How effective are different sanitation interventions in reducing exposure to faecal pathogens?									
Sclar et al., 2016 8.3.3	Systematic review	Effectiveness of sanitation & sanitation interventions on faecal-oral transmission pathways.	1950 to Dec 2015. Any publication status.	English, Spanish, Portuguese, French, German, Italian.	None	Any. Study design Faecal-oral transmission (n=23) RCT 8 Non RCT 1 Quasi RCT 1 Cross sectional 11 Case control 1, Cohort 1 Water supply distance (n=6) Cross sectional 6	U 10 R 15 U & R 3 Schools 1	Assessed in experimental studies using adapted LQAT. Average risk of bias score 8/12 (with 12 indicating no detection of bias) - so relatively high (range 5-11)	GRADE. Low or Very Low.

Table 8.1 Summary of evidence reviews (continued)

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
How effective are different sanitation interventions in improving health outcomes (including infectious diseases, nutritional status, well-being and educational outcomes)?									
Freeman et al., 2017 8.3.4	Systematic review - updating existing systematic reviews	Updating previous reviews- general points	From previous review's endpoint to Dec 31, 2015.	English, Spanish, Portuguese, French, German, Italian.	Based on original reviews	RCTs, quasi-RCTs, non-RCT, CBA studies, interrupted-time-series studies, cohort studies and cross-sectional studies. Any restrictions followed the design of the original systematic review.	See individual reviews	Abridged LQAT for experimental studies	GRADE.
		Updating diarrhoea review by Pruss-Ustun et al. (2014)				N=33, 27 used in meta-analysis RCT 9 non RCT 7 Cross sectional 5 Case control 7 CBA 4 Case series 1	U 5 R 14 U & R 2 Schools 3	Serious risk (ave 5.3)	Low
		Updating STH review by Strunz et al., 2014				N=65, 40 used in meta-analysis – varied by helminth A. lumbricoides (n=39) RCT 5 Non RCT 4 Cross sectional 27 CBA 1 Case series 1 Mixed methods 1 T. trichura (n=34) RCT 4 Non RCT 3 Cross sectional 24 CBA 1 Mixed methods 1 Hookworm (n=42) RCT 4 Non RCT 2 Cross sectional 30 CBA 2 Case series 1	A lumbricoides U 2 R 22 U&R 3 Schools 8 T. trichura U 1 R 20 U&R 2 Schools 7. Hookworm R 26 U&R 5 Schools 6 S. stercoralis R 6 U&R 1	Serious risk of bias (depending on STH 5 - 7.9)	A. lumbricoides Very Low T. trichura Very Low Hookworm Low S. stercoralis – not assessed.

						Mixed methods 1 Cohort 2 S stercoralis (n=9) Non RCT 1 Cross sectional 7 Cohort 1			
		Updating trachoma review by Stocks et al. (2014)				N=46, 46 used in meta-analysis Active trachoma (n=41) RCT 3 Cross sectional 34 Case control 3 Case series 1 C. trachomatis (n=10) RCT 2 Cross sectional 8	Active U 2 R 27 U&R 4 Schools 1. C. trachomatis R 7 Schools 1	Active trachoma average 8.5 (serious risk) C. trachomatis 10.5 (low risk)	Active trachoma High C. trachomatis Moderate
		Updating schistosomiasis review by Grimes et al. (2014)				N=30, 23 used in meta-analysis depending upon schistosome Mansoni (n=23) Cross sectional 22 Case control 1 Haematobium (n=10) Cross sectional 9 Case control 1	Mansoni U 6 R 10 U&R 2 Schools 1. Haemotobium R 8 Schools 1	No intervention studies - so no score	No intervention studies - so no score
		Updating nutrition review by Dangour et al. (2013)				N=17, 9 used in meta-analysis depending upon measure Wt for age and underweight (n=14) RCT 7 Non RCT 6 Quasi RCT 1 Wt for height & wasting (n=7) RCT 4 Non RCT 3 Ht for age & stunting (n=14) RCT 8 Non RCT 6	Wt for age R 11. Wt for ht R 5 Ht for age R 12.	Stunting & underweight 6 & 5.2. Wasting 3.5	Wt for age Low Wt for ht Low Wt for age Very Low

Table 8.1 Summary of evidence reviews (continued)

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
Speich et al., 2016 8.3.4	Systematic review	Assess the relationship between access to, and use of, sanitation facilities (and water treatment) and infection with intestinal protozoa.	Database inception to June 30, 2014 Published papers.	No restrictions	None	No restrictions on study type. N=36 Cross sectional 30 Case control 3 Intervention 1 Cohort 1 Combined cross-sectional/cohort 1	Not stated	No information	Based on GRADE. Most studies classed as Moderate or Low.
Majorin et al., 2018 8.3.4	Systematic review	Assess the effectiveness of interventions to improve disposal of child faeces on the prevention of diarrhoea and STH infections.	Search dates depend on the database and span between November 2014 and June 2015. Includes grey literature.	Not stated	None	Any controlled trial. N=45 Cluster RCT 11 CBA 3 Case control 24 Controlled cohort 2 Cross sectional 5	Case control studies were classed on recruitment site (e.g. health care settings). For the other study types (n=21) R 16	Risk of bias accounted for in GRADE score. Risk of confounding and adjustment for confounding specified for each study.	GRADE - categorised by outcome. Very Low or Low.
Ejemot- Nwadiaro et al., 2015 8.3.4	Intervention review	Assess the effects of handwashing promotion interventions in diarrhoeal episodes.	1966 to May 2015. Peer-reviewed and grey literature.	English (not specified)	None	RCTs n=22	Both U & R locations, but not part of the findings stratification.	Cochrane risk of bias tool. The risk of any type of bias was predominantly low or unclear in all studies.	GRADE Ranged from High to Low.
Yates et al., 2015 8.3.4	Systematic review	Impact of WASH interventions on people living with HIV. 5 outcomes considered but papers only found for morbidity (n=16) and mortality (n=2).	Jan 1995 to June 2014.	Not stated	Focus was on 'resource-limited countries.'	Sanitation n=4 RCT 1 Cross sectional 2 Case control 1	Not stated	Not stated	Unclear how scored but classed as strong, medium or weak based on study design, cohort population and sample size. RCT was classed as strong, other studies as weak.

Table 8.1 Summary of evidence reviews (continued)

Ref. Chapter section	Type of review	Aim(s)/ Objectives	Literature dates	Languages	Geographic/ economic restrictions	Study designs	Urban (U)/ Rural (R)	Assessment of bias/score	Quality of evidence/ score
Sclar et al., 2017 8.3.4	Systematic review	Assess the impact of sanitation (access, quality or specific sanitation intervention) at household, school or community level on cognitive development and absence from school or work.	1950 and Dec 2015. Any publication status.	English, Spanish, Portuguese, French, German, Italian.	None	No restrictions on study type. N=17 RCT 3 Non-RCT 1 Cross sectional 9 CBA 1 Cohort 3	Not stated	Modified LQAT. Both cognitive development and school absence papers were assessed as have a very serious risk of bias.	GRADE. Both aspects were scored Very Low.
Sclar et al., 2018 8.3.4	Systematic review	Assess the impact of sanitation on well-being.	1950 to November 2016. Any publication status	English, Spanish, Portuguese, French, German, Italian.	None	No restrictions on study type. N=50 Qualitative 35 Mixed methods 8 Cross sectional 7		Quantitative studies LQAT Qualitative studies assessed using a 17-point checklist developed by authors (based on Walsh & Downe, 2006; Harden et al., 2009).	GRADE-CERQual. The assessment was done on a theme basis and results varied from Very Low to High confidence.
How do contextual factors (e.g. population, setting, climate) and implementation aspects (e.g. policies, regulations, roles of the health and other sectors, management at different levels of government) influence access to as well as uptake and use of different interventions?									
Overbo et al., 2016 8.4	Systematic review	Evaluate how sanitation adoption and sustained use have been affected by sanitation programmes, their implementation and the enabling environment in which they are carried out.	Publications after 1990. Peer-reviewed and grey literature.	English	None	No restrictions on study type. N=68 Qualitative 6 Quantitative 25 Mixed methods 9 Case studies 28	Split is reported on a programme (rather than study) basis U 6 R 48 U & R 7	Assessed as strong, moderate or weak using LQAT, quality criteria adapted from Harden et al. (2009) or methods adapted from Atkins & Sampson (2002).	

CASP – critical appraisal skills program; CBA – controlled before-and-after; CERQual – confidence in evidence from review of qualitative research; CLTS – community-led total sanitation; LMIC – low- and middle-income countries; LQAT – Liverpool quality appraisal tool; NA – not applicable; RCT – randomized control trial.

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Chapter 9

RESEARCH NEEDS

9.1 Pursuing a sanitation research agenda

Although the recommendations included in these guidelines are supported by evidence, there is need for further research, particularly to provide more information on effective policies and implementation practices. Research needs emerging from the evidence review (Chapter 8) are detailed below. Execution of the research agenda should include participation by all stakeholders. Research should involve various disciplines (behavioural science, economics, engineering, environmental science, epidemiology, management, medicine, microbiology and public policy, among others) and should be conducted in a cross-disciplinary manner.

It is important that the research actively involves local individuals and institutions to strengthen local insight into study design, to build capacity, and to improve local engagement and uptake of findings within policies at the local and national level.

Much of the required research needs to be done with the cooperation of sanitation intervention teams in the context of programmatically-delivered interventions. While carefully controlled efficacy studies provide valuable information and are useful for proof of concept, there is a greater need for rigorous and long-term evaluations of actual interventions as delivered on the ground and at scale. By combining such studies with economic evaluations, data should be generated which allow reporting on cost-effectiveness and cost benefits, allowing policymakers to compare returns on investments in multiple sectors.

9.2 Research agenda

Areas that require further research emerging for the evidence reviews (Chapter 8) are summarized below. It is not intended to be static and research needs will change as conditions alter and new findings emerge.

9.2.1 Strategies for encouraging governments to prioritize, encourage and monitor sanitation

The recommendations included in these guidelines focus on the role of governments in advancing universal coverage and use of sanitation. There is little research, however, on the policies and strategies (including collaboration with partners from civil society and the private sector) that governments should adopt and implement in order to pursue these recommendations effectively. There is role for policy analysts, political scientists, economists, public sector managers and others to identify strategies, to help formulate policy and to evaluate approaches.

9.2.2 Creating an enabling environment

There is very little information on the effects of enabling environment components (institutions, policy, strategy, planning, regulation, enforcement and capacity) on sanitation adoption and sustained use in the peer-reviewed literature and a recent review had to rely mainly on case study reports from the grey literature (Overbo et al., 2016). Few studies (peer-reviewed or otherwise) analysed the effects of the enabling environment on adoption or use of sewer connections, faecal sludge management services, wastewater treatment, school sanitation or public sanitation. Also, little evidence was found on the impacts of legislation, regulations and programme funding availability. There is a need to understand how governments, NGOs, donors and the private sector can support the large-scale implementation of effective sanitation programmes and strategies, as well as drivers and barriers.

9.2.3 Improving coverage and securing correct, consistent, sustained use

There are currently only limited studies which assess the effectiveness of programmes to achieve coverage of sanitation in an entire community and to sustain toilet use after the conclusion of the programme. This research needs to include an examination of the extent to which the promoted facilities meet the needs of users, while ensuring a safe sanitation system.

Research has shown the challenges of achieving optimal use of sanitation facilities (Garn et al., 2017). To date, however, there have been few rigorous studies demonstrating effective behaviour change strategies and the economic incentives that can be applied to encourage correct, consistent and sustained use of sanitation facilities. It is especially important to undertake formative research and evaluate interventions over the medium and long-term through operational research to address questions on:

- the longevity and quality of facilities and factors influencing them, including as these relate to slippage to open defecation and other poor practices;
- emptying and full pit replacement behaviours (particularly in urban settings);
- treatment/disposal practices;
- differences in need and use depending on factors such gender, age, ethnicity, culture, disability, income etc;
- sanitation technology preferences (and their impact on the sanitation service chain);
- the impact of sanitation by-laws on household investment and behaviours;
- products and materials that enable improved behaviours and practices (human-centred design);
- changes in local norms; and
- factors that may lead populations to return to open defecation.

9.2.4 Estimating health impacts from sanitation interventions

While the evidence on health impacts is sufficient to support broad recommendations on improving sanitation, it is still limited and of generally poor quality. Most research conducted to date has utilized observational (often cross-sectional) study designs. To improve the strength of the evidence on health impacts, there is a need for longer-term studies in multiple settings following randomized or other rigorous designs that evaluate all exposure pathways. A growing body of evidence indicates that disease reduction will not be detected unless the coverage of sanitation use at community-level is high (>70%). While adoption of sanitation by a community offers the potential to benefit those members who are reluctant to adopt, such "herd immunity" has only recently been investigated (Fuller et al., 2016). Further work in this area could help to establish the thresholds necessary to achieve such externalities and help establish sanitation as a service that benefits the entire community, and therefore warrants public investment. Therefore, at lower levels of coverage, studies should focus on well-being and equity outcomes as well as changes in faecal load in the environment or exposure as intermediate outcomes associated with the intervention. Effectiveness studies and programme evaluations can also help to assess the impact of potentially scalable sanitation interventions (Section 9.2.3). Lessons should also be learned from trials that failed to achieve their expected outcomes (e.g. Boisson et al., 2014; Humphrey et al., 2015; Luby et al., 2018; Null et al., 2018; Sinharoy et al., 2017; Patil et al., 2014).

There is need for more research:

- to explore the impact of sanitation on physical and cognitive development and its longer-term effects on productivity and economic development;
- to comprehensively characterize the sanitation facility needs of the target population and desired quality (including gender-related needs) through operational research;
- to examine the potential impacts of sanitation on priority pathogens (see Table 6.1);
- to examine the impact of sanitation on other health outcomes and on the risk of co-morbidities (such as gastrointestinal illness and respiratory infection); including research to: develop cheap and reliable methods for assessing environmental enteric dysfunction (EED) prevalence; compare the health and nutrition impacts of diarrhoeas and EED and the extent to which diarrhoea statistics can serve as a proxy indicators for EED prevalence and severity; and assess the energy and protein demands caused by EED); and
- to examine the impact of climate change on sanitation-related health outcomes, in terms of both the overall sustainability and performance of sanitation systems, and on sanitation-related pathogens and vectors.

9.2.5 Improving methods for assessing presence of and exposure to sanitation-related pathogens in the environment

While field and laboratory methods used to assess the presence of or exposure to environmental contaminants are evolving, the field methods utilized still commonly rely on faecal indicator bacteria (such as *E. coli, S. faecalis* and thermotolerant coliforms). However, evidence indicates that such indicators can have environmental origins and, thus, may not provide accurate estimates of faecal exposure. There is also a need for more widespread use of molecular microbial analysis methods in research, which are currently largely confined to specialized laboratories with substantial requirements for equipment and reagents, as they can be used to target pathogens rather than faecal indicators.

The identification of locally-important key faecal transmission pathways can provide valuable information for the prioritization of interventions. There is also a compelling need for approaches that capture a person's full personal exposure to faecal pathogens, not just methods that assess the presence and quantity of pathogens through the various transmission pathways.

9.2.6 Preventing the discharge of faecal pathogens into the environment

In order to understand and address the hazard to public health resulting from the unsafe return of human excreta to the environment, it is necessary to determine where excreta "leaks" from the sanitation service chain. There is currently limited information, for example, on the proportion of untreated faecal sludge that is being disposed of (via a range of practices) to surface waters, agricultural land and within communities. Future research on pit emptying and faecal sludge management behaviour should report, specifically, on the location of disposal in order to better characterize the associated public health risks. There is also a paucity of literature on the fate of pathogens in effluent from on-site systems as it enters the environment (e.g. into soil, groundwater, drains etc.) and the magnitude of related public health risks. Initial efforts have been made to analyse pathogen entry to the environment, exposure and resultant health risks (Mills et al., 2018), however significant additional empirical evidence is required to develop a robust approach.

Critical gaps identified include the characteristics and fate of collected faecal sludge, and the performance of treatment processes. While some studies reported volumes of faecal sludge collected, treated, and properly disposed in certain cities, there were no estimates or studies found for many regions. Having more reliable estimates from collection through disposal would better illustrate regional gaps and opportunities within the sanitation service chain. Similarly, there are global estimates for wastewater that is treated but the treatment performance and in some case level of treatment is unknown. The results from the reviewed studies show, even with advanced treatment processes, some wastewater effluent still contains high levels of pathogens. There is inadequate evidence, on the fate of different pathogens within treatment systems (e.g. helminths) (Williams & Overbo, 2015). As the effects of climate change continue to unfold, operational research is needed to understand its impact on the effectiveness of sanitation systems in consistently preventing pathogen discharge into the environment.

9.2.7 Exploring alternative designs and services

Increasing population density and environmental stress (including water scarcity) potentially require alternatives to individual household toilets and water-based sanitation systems. While studies have raised concerns about adverse health outcomes associated with shared sanitation (Heijnen et al., 2014; Baker et al.,2016), this may be attributable to factors that can be improved programmatically such as poor access, maintenance and waste management (Heijnen et al., 2014 and 2015). Small scale, innovative solutions at the user interface and throughout the service chain have reduced or eliminated the need for water for flushing toilets and transporting waste.

There is a particular need for innovative solutions driven by evidence from operational research for emptying of on-site sanitation facilities in low-income and high-density settings and for safe and sustainable sludge transport and disposal services to ensure that the waste is properly treated or contained. There is also a lack of solutions for improving containment and the exposure to effluent from on-site systems discharged to open drains. There is also a need for improved decision-making frameworks to assist in appropriate investments across on-site, decentralised and centralised solutions, balancing economic, public health and environmental objectives.

The potential of the private sector, separately or in partnership with governments and civil society, to contribute to the development and scaling up of sanitation solutions especially in neglected or underserved settings requires investigation. Further research is required to create, assess and produce acceptable, affordable and environmentally sustainable sanitation facilities and waste management services that address these and other challenges.

9.2.8 Ensuring that proposed sanitation interventions are culturally-appropriate, respect human rights and reflect human dignity

Sanitation presents major cultural, religious, social and political challenges. However, comparatively little research has been undertaken on the extent to which sanitation initiatives (in terms of both facilities and promotional methods) are consistent with the values, traditions and norms of target populations in a way that both enables use of safe sanitation systems and protects the health and well-being of all individuals. While user preferences and practices are sometime described in literature, operational research is needed to develop and evaluate the extent to which interventions respond to specific cultural needs.

While sanitation has been acknowledged as a human right and promoted as a means of advancing personal dignity, there is little research to provide guidance on the manner in which sanitation can best meet all human rights criteria for sanitation services *for all users* and *communities* in terms of availability, accessibility, quality, affordability and acceptability. For instance, research gaps exist in relation to acceptability (for example, sanitation technology preferences of different groups, and their impact on the sanitation service chain), as well as affordability (for example, consumer financing options/alternatives and the best modalities and targeting methods to enable poor households and groups to gain access to improved services). As these criteria affect the adoption, consistent use, functionality and sustainability of sanitation systems, they should be addressed as a fundamental part of sanitation programme evaluations and studies.

9.2.9 Mitigating occupational exposures

Sanitation workers are at risk of certain occupational health hazards since their work may require heavy labour (Charles, Loomis & Demissie, 2009; Tiwari, 2008), exposure to toxic gases and cleaning agents (Knight & Presnell, 2005; Lin et al., 2013; Tiwari, 2008), and handling of solid waste co-disposed in toilets in addition to the exposure to faecal sludge and sewage. Lack of PPE, unsafe practices and frequent exposure to faecal sludge and sewage can lead to a wide array of adverse health effects (e.g. gastrointestinal and other infections, respiratory problems, dermatological issues musculoskeletal disorders and physical injuries) Glas, Hotz & Steffen, 2001; Jegglie et al., 2004; Thorn & Kerekes, 2001; Tiwari, 2008). Research is needed on effective methods for mitigating the identified risks, particularly in low- and middle-income countries.

9.2.10 Reducing adverse ecological effects

While the focus of these guidelines is on human health, indiscriminate sanitation practices that adversely impact the environment can result in both short- and long-term hazards to health. Water, for example, can be polluted with compounds from on-site sanitation through three main pathways, namely: pit leaching, pit overflow and indiscriminate disposal of untreated or poorly treated wastes. While much of the sanitation literature focuses on microbial contaminants, such pollution is also associated with chemical contaminants, such as nitrates, chloride, phosphate and ammonia (Graham & Polizzotto, 2013). The presence of these chemicals in surface waters can lead to harmful algal blooms, which may result in a build-up of toxins in the food chain (e.g. fish and seafood), reduced oxygen levels and possible fish death. There is a need for research to assess the impacts of these practices on human health and to develop cost-effective mitigation strategies in LMICs.

9.2.11 Elaborating the links between sanitation and animals and their impact on human health

The links between animals and sanitation-related health impacts are inconsistently addressed in sanitation research and programmes. Factors include household animals acting as mechanical vectors transporting human faecal pathogens (Mandell et al., 2009), animal consumption of human faeces as part of the pathogen (usually parasite) lifecycle (WHO, UD; Webber 2005), animal faeces carrying pathogens that infect humans (Penakalapati), and animal faeces contributing to breeding of flies that act as mechanical vectors for human pathogens (faecal and otherwise, as in the case of trachoma) (Fotedar, 2001; Khin et al., 1989; Stocks et al., 2014; Szostakowska et al., 2004). These multiple interactions are complex and difficult to evaluate and may be a significant yet poorly understood factor in sanitation trials that failed to achieve their expected health outcomes.

While animal faeces have not been addressed specifically in these Guidelines, they have a potentially detrimental effect on human health. A systematic review (Penakalapati et al., 2017), which examined the human health impacts of exposure to poorly managed animal faeces transmitted via water, sanitation and hygiene-related pathways found that few studies have evaluated control measures such as reducing cohabitation with animals, provision of animal faeces scoops, controlling animal movement, creating safe child spaces, improving veterinary care and hygiene promotion. Possible areas of further research include: behaviours related to points of contact with animal faeces; animal faecal contamination of food; cultural behaviours of animal faecal management; the importance of animal faeces management for controlling fly and other insect vector populations; acute and chronic health risks associated with exposure to animal faeces; and factors influencing concentrations and shedding rates of pathogens originating from animal faeces. Additionally, the trade-offs between economic aspects of animal husbandry practices, nutrition, food security and disease control objectives need to be studied through formative and operational research, as these and affect the likely effectiveness of sanitation and disease control interventions.

9.2.12 Investigating the issues around sanitation and gender

The special issues around gender and sanitation, which are often location/context specific, and the means of overcoming these challenges warrants further research. Women and girls often face particular challenges in having access to and using adequate sanitation facilities. These include anxiety over personal security, privacy issues and reliance on sanitation facilities for menstrual hygiene management. On the other hand, in some settings (where open defecation is common), research has shown that toilet use is lower among men and children than among women and girls (Sinharoy et al, 2017; Coffey et al., 2014) due to aspects such as work settings or cultural practices. The need to ensure non-exclusion from toilet access and use on the basis of gender, and to explicitly accommodate all binary and non-binary gender identities, is increasingly recognised in sanitation programmes and literature (Benjamin & Hueso, 2017; Boyce et al., 2018); however, social and operational participatory and inclusive research is needed to guide laws and standards that support universal access for all genders, particularly with regards to toilets in institutions, work places and public places and in LMICs.

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Annex 1

SANITATION SYSTEM FACT SHEETS

On-site sanitation systems

Fact sheet 1: Dry or flush toilet with on-site disposal

Fact sheet 2: Dry toilet or urine diverting dry toilet with on-site treatment in alternating pits or compost chamber

Fact sheet 3: Flush toilet with on-site treatment in twin pits

Fact sheet 4: Urine-diverting dry toilet with on-site treatment in dehydration vault

On-site systems with FSM and off-site treatment

Fact sheet 5: Dry or flush toilet with pit, effluent infiltration and off-site treatment of faecal sludge

Fact sheet 6: Flush (or urine-diverting flush) toilet with biogas reactor and off-site treatment

Fact sheet 7: Flush toilet with septic tank and effluent infiltration, and off-site faecal sludge treatment

Fact sheet 8: Urine-diverting dry toilet and container-based sanitation with off-site treatment of all contents

On-site systems with FSM, sewerage and off-site treatment

Fact sheet 9: Flush toilet with septic tank, sewerage and off-site treatment of faecal sludge and effluent

Off-site systems with sewerage and off-site treatment

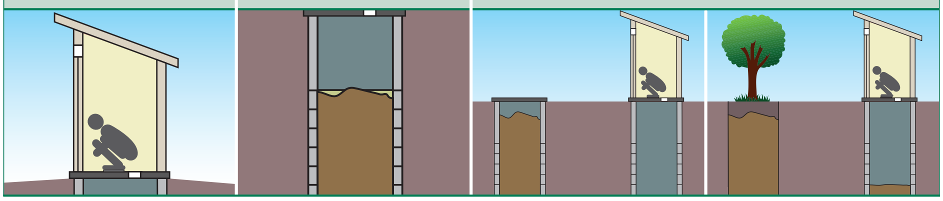
Fact sheet 10: Flush toilet with sewerage and off-site wastewater treatment

Fact sheet 11: Urine-diverting flush toilet with sewerage and off-site wastewater treatment

Fact sheet 1

Dry or flush toilet with onsite disposal

Toilet	Containment	End use / disposal
Dry or pour flush toilet	Single pit or VIP	Onsite disposal: Fill and cover / Arborloo



Summary

This system is based on the use of a single pit technology to collect and store excreta. The system can be used with or without flushwater, depending on the toilet. Inputs to the system can include urine, faeces, cleansing water, flushwater and dry cleansing materials. The use of flushwater, cleansing water and cleaning agents will depend on water availability and local habit. The toilet for this system can either be a dry toilet or a pour flush toilet. A urinal could additionally be used. The toilet is directly connected to a single pit or a single ventilated improved pit (VIP) for containment. As the pit fills up, leachate permeates from the pit into the surrounding soil.

When the pit is full, it can be backfilled with soil and a fruit or ornamental tree can be planted. The sludge acts as a soil conditioner with the increase in organic matter resulting in improved water holding capacity and providing additional nutrients, which are slowly reduced over time. A new pit has to be dug and this is generally only possible when the existing superstructure is mobile.

Applicability

Suitability: This system should be chosen only where there is enough space to continuously dig new pits. In dense urban settlements, there is not sufficient space to continuously dig new pits.

Therefore, the system is best suited to rural and peri-urban areas where the soil is appropriate for digging pits and absorbing the leachate; where hard, rocky ground is found, or locations where groundwater level is high or the soil is saturated are not suitable. It is also not suited to areas that are prone to heavy rains or flooding, which may cause pits to overflow into users' houses or to the local community [2, 3].

When it is not possible to dig a deep pit or the groundwater level is too high, a shallow, raised pit can be a viable alternative: the shallow pit can be extended by building the pit upwards with the use of concrete rings or blocks. A raised pit can also be constructed in an area where flooding is frequent in order to keep water from flowing into the pit during heavy rain [4].

Cost: This system is one of the least expensive to construct in terms of capital cost and maintenance cost, especially if the superstructure is mobile and can be reused [2, 3].

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the pit [2, 3].

Containment: On average, solids accumulate at a rate of 40 to 60L per person/year and up to 90L per person/year if dry cleansing materials such as leaves or paper are used. In many emergency situations, toilets with infiltrating pits are subjected to heavy use, and consequently excreta and anal-cleansing materials are added much faster than the decomposition rate; the 'normal' accumulation rates can therefore increase by 50% [4].

The volume of the pit should be designed to contain at least 1,000L. Typically, the pit is at least 3m deep and 1m in diameter. If the pit diameter exceeds 1.5m, there is an increased risk of collapse. Depending on how deep they are dug, some pits may last 20 or more years without emptying, but a shallow pit may fill up within 6 to 12 months. As a general rule, a pit 3m deep and 1.5m square will last a family of six about 15 years [3].

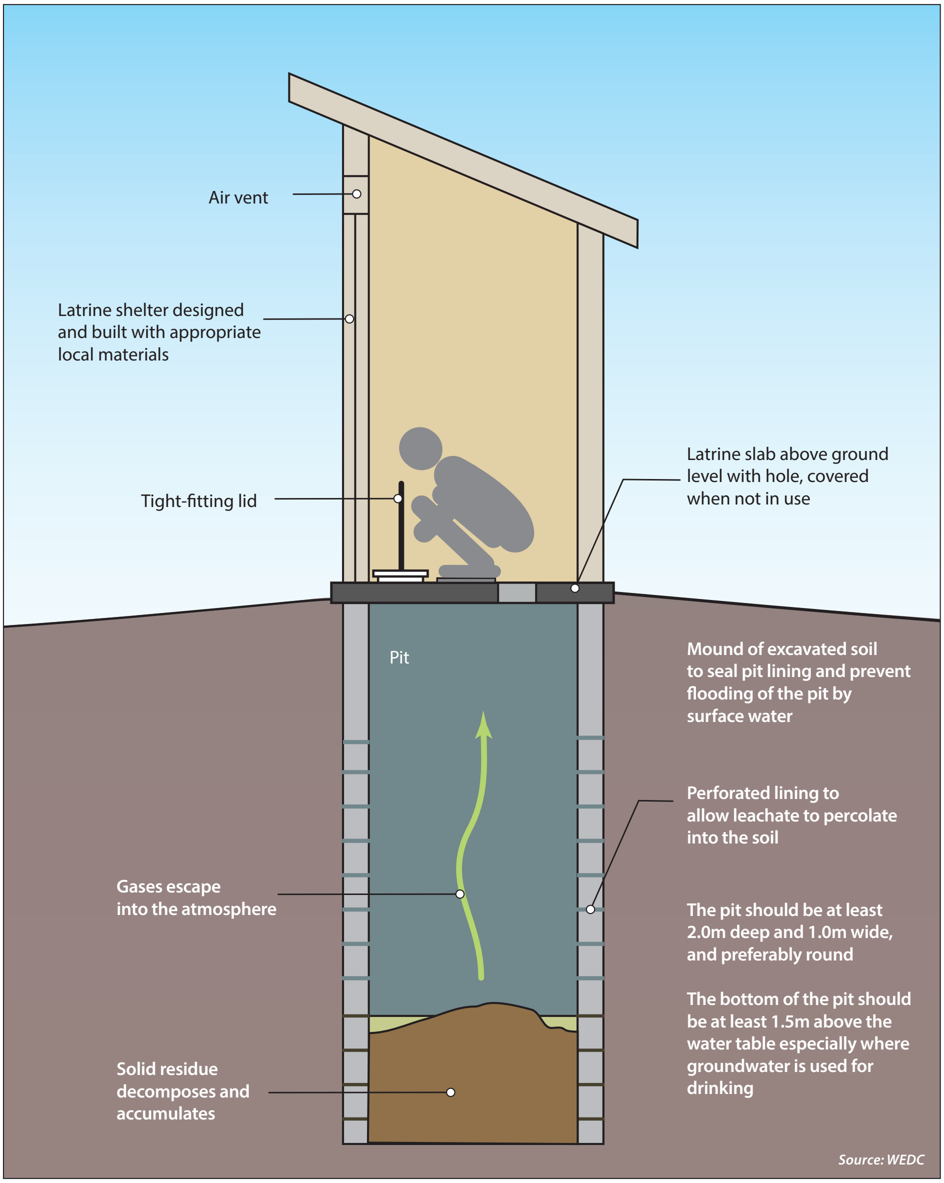


Figure 1. A single pit latrine

The water table level, and groundwater use should be taken into consideration in order to avoid contaminating drinking water. If groundwater is not used for drinking or alternative cost effective sources can be used, then these options should be explored before assuming that groundwater contamination by pit latrines is a problem. Where groundwater is used for drinking and to prevent its contamination, the bottom of the pit should be at least 1.5m above the water table [3]. In addition, the pit should be installed in areas located down gradient of drinking water sources, and at a minimum horizontal distance of 15m [5].

Excreta, cleansing water, flushwater and dry cleansing materials should be the only inputs to this system; other inputs such as menstrual hygiene products and other solid wastes are common and may contribute significantly to pit contents. As this will result in pits filling

Annex 1

up more rapidly and make it more difficult to empty, an appropriate container for disposal of these wastes should be provided in the toilet cubicle. (Some greywater in the pit may help degradation, but excessive amounts of greywater may lead to quick filling of the pit and/or excessive leaching.)

End use/disposal: If the user plans to plant a tree in the covered pit, then space and site conditions for the tree when fully grown need to be taken into account. The tree should not be planted in raw excreta but into the soil filling on top of the pit contents [2].

Operation and maintenance considerations

Toilet and containment: The user is commonly responsible for the construction of the toilet and pit, although they may pay a mason to carry out the work. The user will be responsible for cleaning and repairs to the toilet, including the slab, seat/squat hole, drop-hole, cover/lid and superstructure [2].

To reduce smells and insect breeding, a cup of soil, ash or sawdust is added to the pit after each defecation, while periodically adding leaves will improve porosity [2].

End use/disposal: As no emptying and transport is required, once the pit is full the user is responsible for digging a new pit and transferring the toilet and superstructure, and then covering and filling the old pit and, if required, planting a tree on top [2].

There is little maintenance associated with a closed pit other than taking care of the tree. Trees planted in abandoned pits require regular watering and a small fence of sticks constructed around the sapling will protect it from animals.

Mechanisms for protecting public health

Toilet and containment: The toilet separates users from excreta while the pit isolates the excreta and pathogens within it from physical human contact.

During rains, the toilet and the pit contain the fresh excreta and prevent it from being washed away into surface water bodies[2, 3].

End use/disposal: Users do not come in contact with the faecal material and, thus, there is a very low risk of pathogen transmission. The main mechanism for pathogen reduction is through long storage time in the pit. The conditions in the pit are not favourable for pathogen survival, so over time, generally around one to two years, the pathogens die off and the excreta becomes safer. The die off period can be reduced by adding lime or other alkaline material to raise the pH, raising the temperature or reducing the moisture content. Ascaris (roundworm) eggs are the most persistent pathogen to die off [6].

Any leachate safely permeates into the surrounding soil and pathogens contained in the liquid are filtered out, adsorbed onto particles, or die off during their slow travel through soil [2, 3].

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

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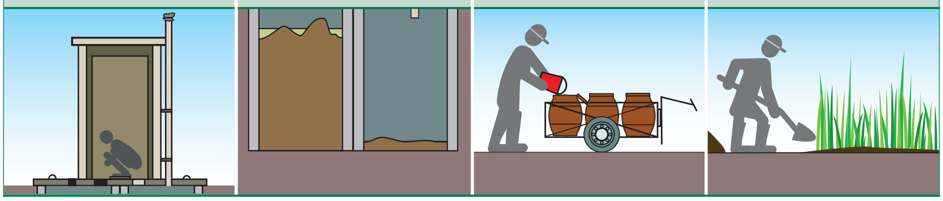
Fact sheet 2

Dry toilet or urine-diverting dry toilet (UDDT) with onsite treatment in alternating pits or compost chamber

Toilet	Containment	Conveyance	End use / disposal
Dry toilet or urine diverting dry toilet	Fossa alterna, double VIP or compost chamber	Manual emptying and transport	Pit humus or compost used as a soil conditioner



Summary

This system is designed to produce a solid, earthlike material by using alternating pits or a composting chamber. Inputs to the system can include urine, faeces, organics, cleansing water, and dry cleansing materials. There is no use of flushwater.

A dry toilet is the recommended toilet for this system, although a urine-diverting dry toilet (UDDT) or a urinal could also be used if the urine is highly valued for application. A dry toilet does not require water to function and in fact, water should not be put into this system; cleansing water should be kept at a minimum or even excluded if possible.

The dry toilet is directly connected to a double ventilated improved pit (double VIP), fossa alterna or a composting chamber for containment. Two alternating containers, as in the double VIP or fossa alterna, give the material an opportunity to drain, degrade, and transform into pit humus (sometimes also called ecohumus), a nutrient-rich, hygienically improved, humic material which is safe to excavate.

When the first pit is full, it is covered and temporarily taken out of service. While the other pit is filling with excreta (and potentially organics), the content of the first pit is allowed to rest and degrade for at least two years before use. Only when both pits are full is the first pit emptied and put back into service. This cycle can be indefinitely repeated.

A composting container can also have alternating chambers and, if properly operated, produces safe, useable compost. For these reasons it is included in this fact sheet.

This system is different from the system shown in Fact sheet 5 regarding the treatment product generated at the containment step. In the other system, the sludge requires further treatment before it can be used, whereas the pit humus or compost produced in this containment technology is ready for end use and/or disposal.

Applicability

Suitability: Because the system is permanent and can be indefinitely used (as opposed to the single pits in Fact sheet 1, which are backfilled and covered), it can be used where space is limited.

Additionally, because the treatment product must be manually removed, this system is suitable for dense areas that cannot be served by trucks for motorized emptying. This system is especially appropriate for water-scarce areas and where there is an opportunity to use the compost or humic product as soil conditioner.

Cost: For the user, this system is one of the least expensive in terms of capital cost. The only maintenance costs will be for cleaning of the toilet, upkeep of the superstructure and arranging for periodic emptying of containers [2,3]; and it produces an end product that the user may be able to use or sell.

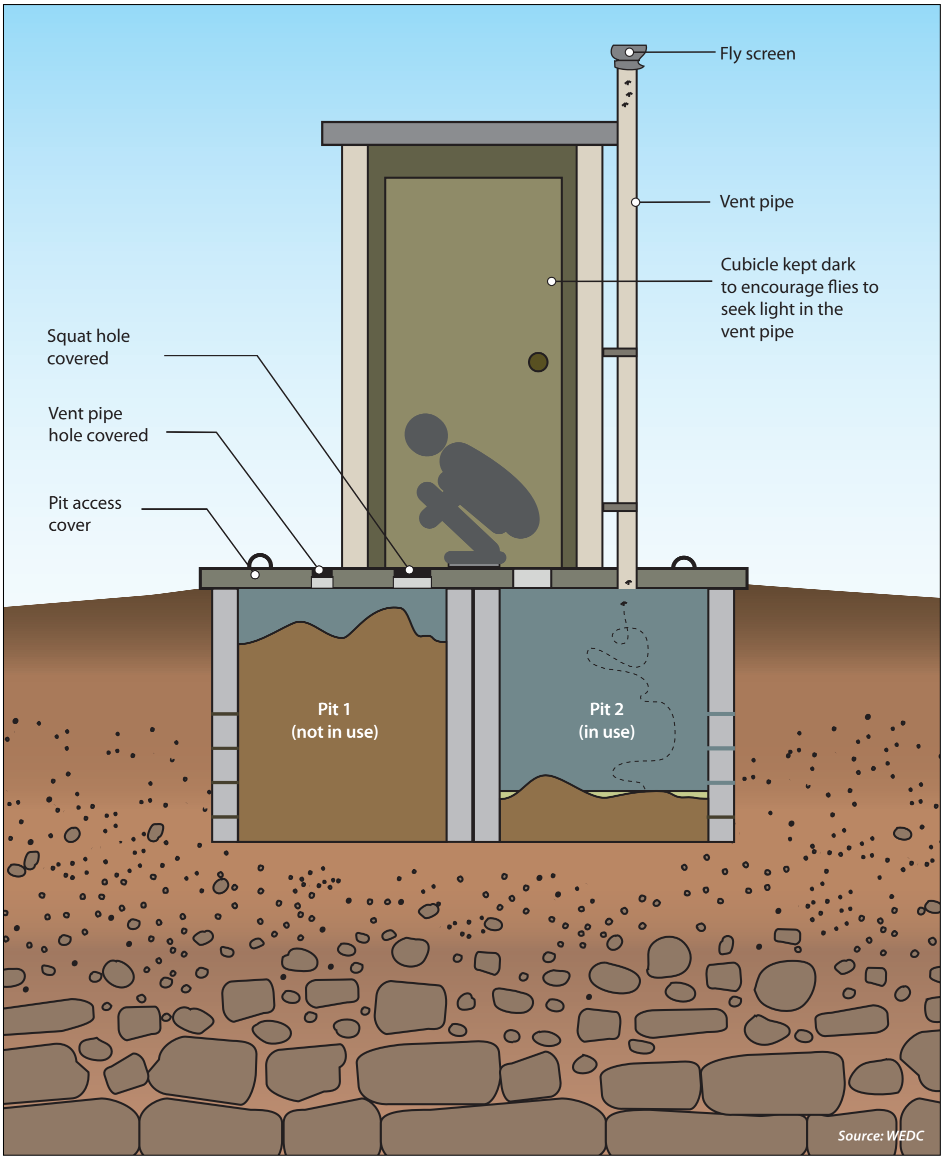


Figure 1. A twin-pit latrine (fossa alterna)

Design considerations

Toilet: The toilet should be made from concrete, fibre-glass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the container [2, 3].

Containment: For the pit-based technologies, the water table level and groundwater use should be taken into consideration in order to avoid contaminating drinking water. If groundwater is not used for drinking or alternative cost effective sources can be used, then these options should be explored before assuming that groundwater contamination by pit latrines is a problem. Where groundwater is used for drinking and to prevent its contamination, the bottom of the pit should be at least 1.5m above the water table [3]. In addition, the pit should be installed in areas located down gradient of drinking water sources, and at a minimum horizontal distance of 15m [4].

Excreta, cleansing water and dry cleansing materials can usually be collected in the pit or chamber, especially if they are carbon-rich (e.g., toilet paper, newsprint, corncobs, etc.) as this may help degradation and airflow. Other inputs such as menstrual hygiene products and other solid wastes are common and may contribute significantly to the contents. Where they cause the container to fill up more rapidly and make it more difficult to empty, an appropriate container for disposal of these wastes should be provided in the toilet cubicle.

Greywater must be collected and treated separately. Too much moisture in the container will fill the air voids and deprive the microorganisms of oxygen, which may impair the degradation process.

End use/disposal: As the excreta in the resting container is draining and degrading for at least two years, the resulting pit humus or compost needs to be manually removed using shovels (the material is too dry for motorized emptying) and can be used in agriculture as a soil conditioner [5].

Operation and maintenance considerations

Toilet and containment: The user is commonly responsible for the construction of the toilet and container, although they may pay a mason to carry out the work. The user will be responsible for cleaning of the toilet and are most likely to be responsible for removing the pit humus or compost, although they may pay a labourer or service provider to do this.

At shared facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified.

The success of this system depends on proper operation and an extended storage period. If a suitable and continuous source of soil, ash or organics (leaves, grass clippings, coconut or rice husks, woodchips, etc.) is available, the decomposition process is enhanced and the storage period can be reduced. The required storage time can be minimized if the material remains well aerated and not too moist.

End use/disposal: The material removed from the container or compost chamber should be in a safe, useable form, although workers must wear appropriate personal protection during removal, transport and end use.

Mechanisms for protecting public health

Toilet and containment: The toilet separates users from excreta and the container isolates the excreta and pathogens within from physical human contact.

The main mechanism for pathogen reduction is through long storage time. The conditions in the pit are not favourable for pathogens survival, which die off over time. In the pit, any leachate permeates into the surrounding soil and pathogens contained in the liquid are filtered out, adsorbed onto particles, or die off during their slow travel through soil [2, 3].

During rains, the slab and the pit or composting chamber contain the fresh excreta and prevent it from being washed away into surface water bodies, while squathole covers or lids can reduce disease transmission by preventing disease carrying vectors from entering and leaving the pit [2, 3].

Conveyance: Any non-degradable solid waste removed from the container needs to be disposed of properly, for example through a regulated solid waste management service or, where this is not available, through burial.

End use/disposal: Since it has undergone significant degradation, the pit humus or compost is quite safe to handle and use as a soil conditioner in agriculture. If there are concerns about the pathogen level or quality of the pit humus or compost, it can be further composted in a dedicated composting facility before it is used. If there is no end use for the treatment product, it can be permanently disposed of.

References

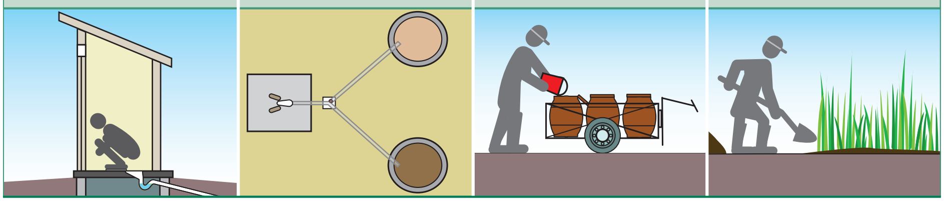
The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).
2. Brikké F, and Bredero M (2003). *Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. A reference document for planners and project staff.* Geneva, Switzerland.
3. Reed R A, Scott R E, and Shaw R J (2014). *WEDC Guide No. 25: Simple Pit Latrines.* WEDC, Loughborough University, UK.
4. Graham J, and Polizzotto M (2013). *Pit latrines and their impacts on groundwater quality: A systematic review.* Environmental Health Perspectives.
5. Strande L (2017). *Introduction to Faecal Sludge Management.* Online Course available at: www.sandec.ch/fsm_tools (accessed March 2017). Sandec: Department of Sanitation, Water and Solid Waste for Development Eawag: Swiss Federal Institute of Aquatic Science and Technology.

Fact sheet 3

Flush toilet with onsite treatment in twin pits

Toilet	Containment	Conveyance	End use / disposal
Pour flush toilet (squat pan or pedestal)	Twin pits for pour flush	Manual emptying and transport	Pit humus or compost used as a soil conditioner. No effluent product.



Summary

This is a water-based system utilizing the pour flush toilet (squat pan or pedestal) and twin pits to produce a partially digested, humus-like product, that can be used as a soil conditioner.

Inputs to the system can include faeces, urine, flush-water, cleansing water, dry cleansing materials and greywater. The toilet technology for this system is a pour flush toilet. A urinal could additionally be used. The blackwater output from the pour flush toilet (and possibly greywater) is discharged into twin pits for containment.

The twin pits are lined with a porous material, allowing the liquid to infiltrate into the ground while solids accumulate and degrade at the bottom of the pit. While one pit is filling with blackwater, the other pit remains out of service. When the first pit is full, it is covered and temporarily taken out of service. It should take a minimum of two years to fill a pit. When the second pit is full, the first pit is re-opened and emptied.

After a resting time of at least two years, the content is transformed into pit humus (sometimes also called ecohumus), a nutrient-rich, safer, humic material which is safe to excavate for end use as a soil conditioner, or disposal. The emptied pit is then put back into operation. This cycle can be indefinitely repeated.

Applicability

Suitability: This system is suited to rural and peri-urban areas with appropriate soil that can continually and adequately absorb the leachate. It is not appropriate for areas with clayey or densely packed soil. This system is well-suited for cleansing with water. If possible, dry cleansing materials should be collected and disposed of separately because they may clog the pipe fittings and prevent the liquid inside the pit from infiltrating into the soil.

Cost: For the user, this system is one of the least expensive in terms of capital cost. The only maintenance costs will be for cleaning of the toilet, upkeep of the superstructure and arranging for periodic emptying of containers [2, 3]; and it produces an end product that the user may be able to use or sell.

Design considerations

Toilet: The squat pan or pedestal should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the pit [2, 3].

Containment: As leachate from twin pits directly infiltrates the surrounding soil, this system should only be installed where there is a low groundwater table. If there is frequent flooding or the groundwater table is too high and enters the twin pits, the dewatering process, particularly in the resting pit, will be hindered.

Greywater can be co-managed along with the blackwater in the twin pits, especially if the greywater quantities are relatively small, and no other management system is in place to control it.

However, the water table level and groundwater use should be taken into consideration in order to avoid contaminating drinking water. If groundwater is not used for drinking or alternative cost effective sources can be used, then these options should be explored before assuming that groundwater contamination by pit latrines is a problem. Where groundwater is used for

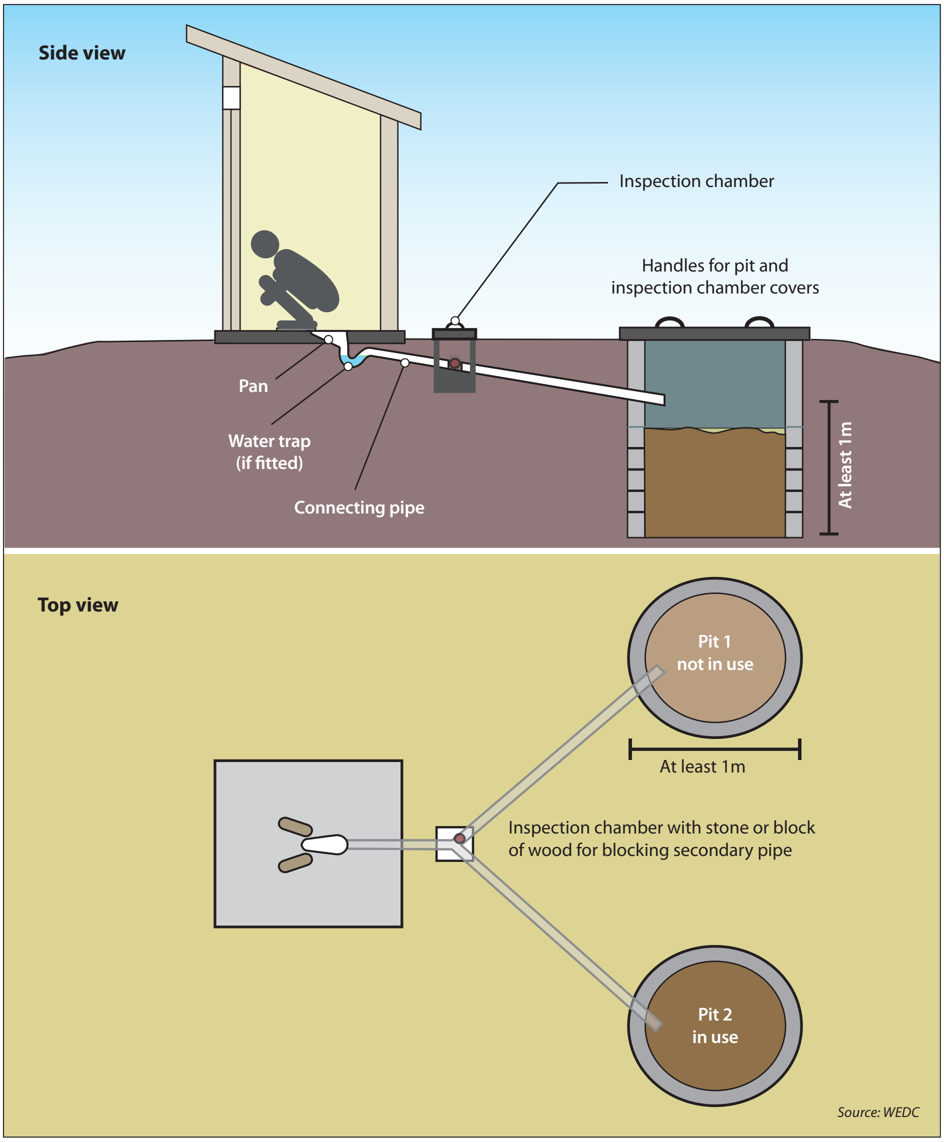


Figure 1. A twin-pit, pour flush latrine

drinking and to prevent its contamination, the bottom of the pit should be at least 1.5m [3] above the water table.

In addition, the pit should be installed in areas located down gradient of drinking water sources, and at a minimum horizontal distance of 15m [4].

End use/disposal: Any non-degradable solid waste removed from the pit, needs to be disposed of properly, for example through a regulated solid waste management service or, where this is not available, through burial.

Operation and maintenance considerations

Toilet and containment: The user is commonly responsible for the construction of the toilet and pit, although they may pay a mason to carry out the work.

The user will be responsible for cleaning of the toilet and are most likely to be responsible for removing the pit humus, although they may pay a labourer or service provider to do this [2].

At shared facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified.

End use/disposal: As the excreta in the resting pit is draining and degrading for at least two years, the resulting pit humus needs to be manually removed using shovels – vacuum truck access to the pits is not necessary.

The pit humus removed should be in a safe, useable form, although workers must wear appropriate personal protection during removal, transport and end use.

Mechanisms for protecting public health

Toilet and containment: The toilet separates users from excreta and the pit isolates the excreta and pathogens within it from physical human contact.

The main mechanism for pathogen reduction is through long storage time. The conditions in the pit are not favourable for pathogen survival, which die off over time. Leachate permeates from the pit into the surrounding soil and pathogens contained in the liquid are filtered out, adsorbed onto particles, or die off during their slow travel through soil.

During rains, the toilet and the pit contain fresh excreta and prevent it from being washed away into surface water bodies, while squat-hole covers or lids can reduce disease transmission by preventing disease carrying vectors from entering and leaving the pit [2,3].

Treatment: Since it has undergone significant dewatering and degradation, pit humus is much safer than raw, undigested sludge. Therefore, it does not require further treatment in an offsite treatment facility. If there are concerns about the pathogen level or quality of the pit humus, it can be further composted in a dedicated composting facility before it is used (see Fact sheet 5).

End use/disposal: Pit humus has good soil conditioning properties and can be applied in agriculture [5]. If there is no end use for the product, it can be permanently disposed of.

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

2. Brikké F, and Bredero M (2003). *Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. A reference document for planners and project staff.* Geneva, Switzerland.

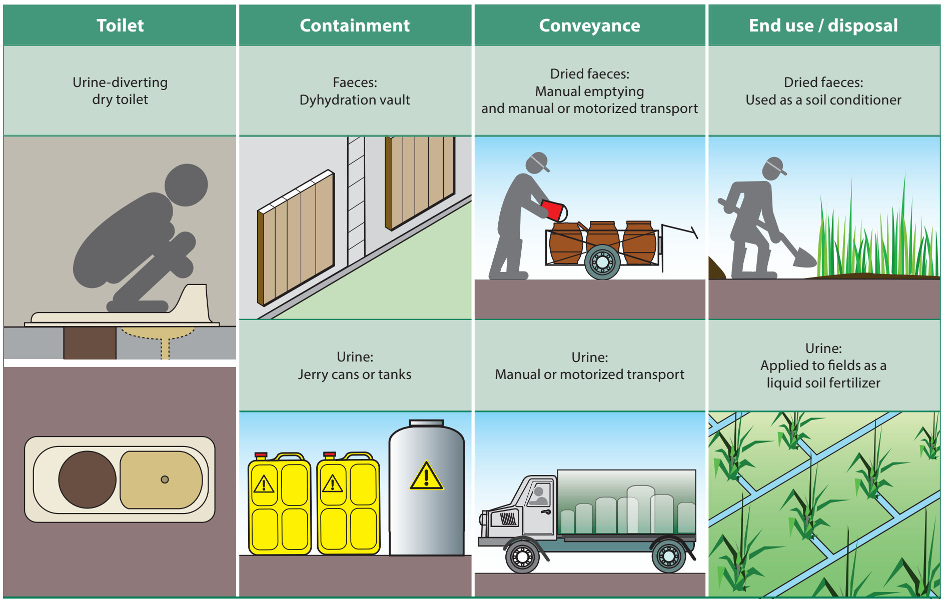
3. Reed R A, Scott R E, and Shaw R J (2014). *WEDC Guide No. 25: Simple Pit Latrines.* WEDC, Loughborough University, UK.

4. Graham J, and Polizzotto M (2013). *Pit latrines and their impacts on groundwater quality: A systematic review.* Environmental Health Perspectives.

5. Strande L (2017). *Introduction to Faecal Sludge Management.* Online Course available at: www.sandec.ch/fsm_tools (accessed March 2017). Sandec: Department of Sanitation, Water and Solid Waste for Development Eawag: Swiss Federal Institute of Aquatic Science and Technology.

Fact sheet 4

Urine-diverting dry toilet (UDDT) with onsite treatment in dehydration vault



Summary

This system is designed to separate urine and faeces to allow the faeces to dehydrate and/or recover the urine for beneficial use. Inputs to the system can include faeces, urine, cleansing water and dry cleansing materials.

The main toilet technology for this system is a urine-diverting dry toilet (UDDT), which allows urine and faeces to be separately stored. A urinal can additionally be installed for the effective storage of urine. UDDT designs vary and include adaptations for different preferences, for instance with a third diversion for cleansing water management.

Dehydration vaults are used for the containment of faeces. They should be kept as dry as possible to encourage dehydration and pathogen reduction. After each use, the faeces are covered with ash, lime, soil, or sawdust, which helps to absorb humidity, minimize odours and provide a barrier between the faeces and potential disease carrying vectors. The vaults should be watertight and care should be taken to ensure that no water is introduced – cleansing water should never be put into dehydration vaults.

Using two dehydration vaults, and alternating their use, allows for an extended dehydration period so that when they are removed the dried faeces contain zero, or very low, pathogen levels and pose little human health risk. A minimum storage time of six months is recommended when ash or lime are used as cover material, after which the dried faeces can be applied as soil conditioner [2].

The urine can be stored in either jerrycans or a tank for application in agriculture. With its high nutrient content it can be used as a good liquid soil fertilizer and can be easily handled and poses little risk because it is nearly sterile. Stored urine can be transported using manual or motorized transport technologies. Alternatively, the urine can be diverted directly to the ground for infiltration through a soak pit.

Applicability

Suitability: This system can be used anywhere, but is especially appropriate for rocky areas where digging is difficult, where there is a high groundwater table,

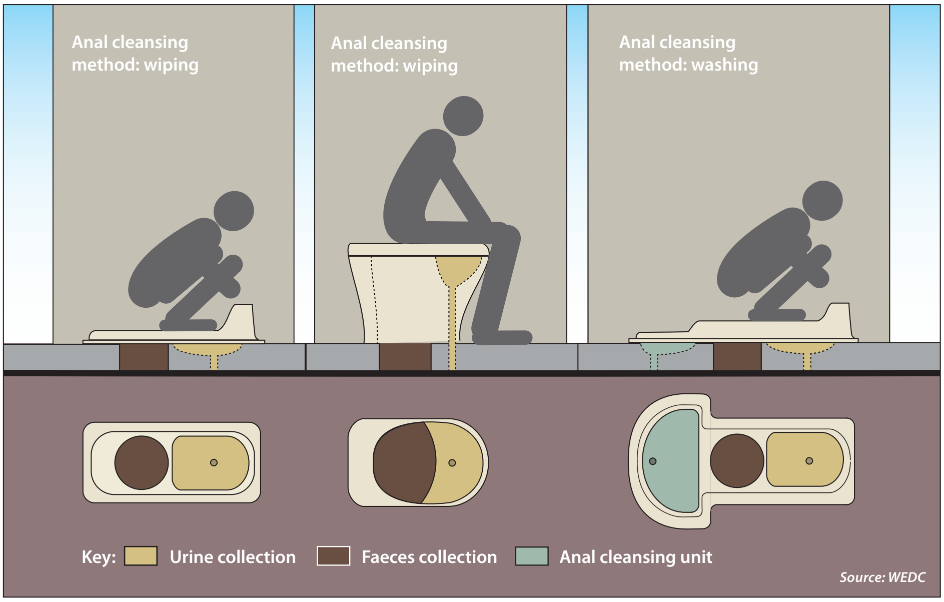


Figure 1. Urine diversion systems

or in water-scarce regions. A dry, hot climate can also considerably contribute to the rapid dehydration of the faeces.

If there is no agricultural need and/or no acceptance of using the urine, it can be directly infiltrated into the soil or into a soak pit.

Cost: For the user, this system is one of the least expensive in terms of capital cost and produces end products that the user may be able to use or sell. As the containment technology does not include a pit or underground tank, there is no excavation cost, however, this saving may be offset by the cost of constructing the above ground tank or vault and urine separation arrangement, which will also require a reasonable level of technical expertise.

The only maintenance costs will include cleaning of the toilet, upkeep of the superstructure and arranging for periodic emptying of the vaults and urine containers (if any).

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the vaults. Where there are no suppliers of prefabricated UDDT pedestals or slabs, they can be locally manufactured using available materials.

Containment: The dehydration vaults should be watertight and fitted with a vent pipe to reduce nuisance from smells and preventing access to disease carrying vectors. Any urine tanks should also be watertight and sealed to reduce nuisance from smells.

All types of dry cleansing materials can be used, although it is best to collect them separately as they will not decompose in the vaults and use up space. Cleansing water must be separated from the faeces, but it can be mixed with the urine if it is transferred to a soak pit. If urine is used in agriculture, cleansing water should be kept separate and infiltrated locally or treated along with greywater. A separate greywater system is required since it should not be introduced into the dehydration vaults.

Conveyance: Manual emptying equipment is required for the removal of the dried faeces generated from the dehydration vaults (the material is too dry for motorized emptying), which can then be transported using manual or motorized transport, and used in agriculture as a soil conditioner.

Operation and maintenance considerations

Toilet / containment: The user is commonly responsible for the construction of the UDDT, dehydration vaults and providing the urine tanks (if any), although they may pay a mason to carry out the work. The user will be responsible for cleaning of the UDDT and are most likely to be responsible for removing the dried faeces, although they may pay a labourer or service provider to do this.

At shared facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified.

The success of this system depends on the efficient separation of urine and faeces, as well as the use of a suitable cover material. Therefore, the urine separation plumbing must be kept free of blockages to prevent urine from backing up and overflowing into the dehydration vaults, and there should be a constant supply of ash, lime, soil, or sawdust available to cover the faeces.

End use/disposal: The dried faeces removed from the container should be in a safe, useable form with a zero to very low pathogen content, although workers would be advised to wear appropriate personal protection during removal, transport and end use.

Mechanisms for protecting public health

The toilet separates users from excreta and the dehydration vault isolates the excreta and pathogens within from physical human contact.

The main mechanism for pathogen reduction in the vaults is through long storage time. The dehydrated conditions in the vault are not favourable for pathogen survival, which die off over time. If ash or lime is used as a cover material, the related pH increase also helps to kill pathogens. The urine poses little health risk as it is nearly sterile, and storage before use in sealed containers or disposal to the ground via a soak pit will protect public health. However, in areas in which schistosomiasis is endemic, urine should not be used in water-based agriculture, such as rice paddies.

During rains, the slab and vaults contain the fresh excreta and prevent it from being washed away into surface water bodies, while squat-hole covers or lids and a screened vent pipe can reduce disease transmission by preventing disease carrying vectors from entering and leaving the vaults.

Any non-degradable solid waste removed from the vaults needs to be disposed of properly, for example through a regulated solid waste management service or, where this is not available, through burial.

Since it has undergone significant degradation, the dried faeces should be safe for end use as a soil conditioner in agriculture. If there are concerns about the pathogen level or quality of the dried faeces, they can be further composted in a dedicated composting facility before it is used.

References

The text for this fact sheet is based on Tilley, et al. [1]

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

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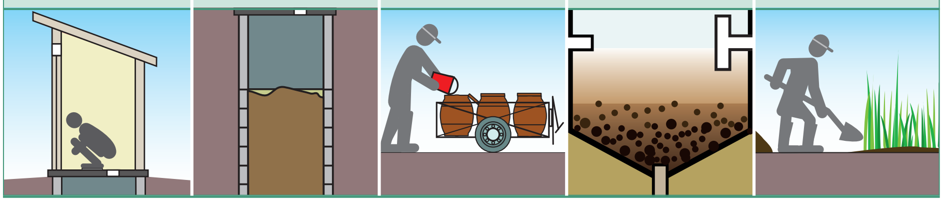
Annex 1

Fact sheet 5

Dry or flush toilet with pit, effluent infiltration and offsite treatment of faecal sludge

Toilet	Containment	Conveyance	Treatment	End use / disposal
Dry or pour flush	Single pit or single VIP	Manual emptying and transport	Faecal sludge treatment plant for sludge and effluent	Soil conditioner; solid fuel; building materials; irrigation; surface water recharge*



* Sludge: treated and used as soil conditioner, solid fuel or building materials. Effluent: treated and used for irrigation or surface water recharge.

Summary

This system is similar to the system described in Fact sheet 1 with the use of a single pit technology to collect and store excreta. The system can be used with or without flushwater, depending on the toilet. Inputs to the system can include urine, faeces, cleansing water, flushwater and dry cleansing materials. The use of flushwater and/or cleansing water will depend on water availability and local habit.

The toilet for this system can either be a dry toilet or a pour flush toilet. A urinal could additionally be used. The toilet is directly connected to a single pit or a single ventilated improved pit (VIP). As the pit fills up, leachate permeates from the pit into the surrounding soil.

When the pit is full the faecal sludge needs to be emptied and transported for treatment. The treatment products can then be used (e.g. effluent used in irrigation), converted into end use products (e.g. faecal sludge converted to soil conditioner or solid fuels) or disposed of.

Applicability

Suitability: This system should be chosen only when there is an appropriate way to empty, transport, treat and use or dispose of the faecal sludge. For instance, in dense urban settlements, narrow roads may make it difficult for vehicles with emptying equipment to gain access to pits.

It is suited to areas where the soil is appropriate for digging pits and absorbing the leachate; where hard, rocky ground is found, or where groundwater level is high or the soil is saturated, conditions are not suitable. It is also not suited to areas that are prone to heavy rains or flooding, which may cause pits to overflow into users' houses or to the local community [2,3].

When it is not possible to dig a deep pit or the groundwater level is too high, a raised pit can be a viable alternative: the shallow pit can be extended by building the pit upwards with the use of concrete rings or blocks. A raised pit can also be constructed in an area where flooding is frequent in order to keep water from flowing into the pit during heavy rain.

Cost: For the user, this system is one of the least expensive in terms of capital cost. However, the maintenance costs may be considerable, depending on the frequency and method of pit emptying [2,3].

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the pit [2,3].

Containment: On average, solids accumulate at a rate of 40 to 60L per person/year and up to 90L per person/year if dry cleansing materials such as leaves or paper are used. In many emergency situations, toilets with infiltrating pits are subjected to heavy use, consequently

Annex 1

excreta and anal-cleansing materials are added much faster than the decomposition rate, therefore the 'normal' accumulation rates can increase by 50 percent [9].

The volume of the pit should be designed to contain at least 1,000L. Typically, the pit is at least 3m deep and around 1m in diameter. If the pit diameter exceeds 1.5m, there is an increased risk of collapse. Depending on usage and how deep they are dug, some pits may last 20 or more years without emptying, but shallow pits that are used by many people every day may require emptying once or twice a year. As a general rule, a pit 3m deep and 1.5m wide that is used by a family of six, will require emptying after about 15 years [3].

As the pit will be reused, it should be lined. Pit lining materials can include brick, rot-resistant timber, concrete, stones, or mortar plastered onto the soil. If the soil is stable (i.e., no presence of sand or gravel deposits or loose organic materials), the whole pit need not be lined. The bottom of the pit should remain unlined to allow for the infiltration of liquids out of the pit.

The water table level and groundwater use should be taken into consideration in order to avoid contaminating drinking water. If groundwater is not used for drinking or alternative cost effective sources can be used, then these options should be explored before assuming that groundwater contamination by pit latrines is a problem.

Where groundwater is used for drinking and to prevent its contamination, the bottom of the pit should be at least 1.5m above the water table [3]. In addition, the pit should be installed in areas located down gradient of drinking water sources, and at a minimum horizontal distance of 15m [4].

Excreta, cleansing water, flushwater and dry cleansing materials should be the only inputs to this system; other inputs such as menstrual hygiene products and other solid wastes are common and may contribute significantly to pit contents. As this will result in pits filling up more rapidly and make it more difficult to empty, an appropriate container for disposal of these wastes should be provided in the toilet cubicle. (Some greywater in the pit may help degradation, but excessive amounts of greywater may lead to quick filling of the pit and/or excessive leaching.)

Conveyance: As the untreated faecal sludge is full of pathogens, human contact and direct agricultural application should be avoided. Instead, the emptied sludge should be transported to a faecal sludge treatment facility.

The conveyance technologies that can be used include manual emptying and transport or motorized emptying and transport. However, a vacuum truck cannot be used as it can only empty liquid faecal sludge.

In the event that a treatment facility is not easily accessible, the faecal sludge can be discharged to a transfer station. From there, it can be transported to the treatment facility by a motorized transport technology.

Treatment: Treatment technologies produce both effluent and sludge, which may require further treatment prior to end use and/or disposal. For example, effluent from a faecal sludge treatment facility could be co-treated with wastewater in waste stabilization ponds or in constructed wetlands, and then used for irrigation water, fish ponds, floating plant ponds or discharged to a surface water body or to groundwater.

End use/disposal: Options for the end use of the treated sludge include use in agriculture as a soil conditioner or as a solid fuel or as an additive to construction materials [6].

Operation and maintenance considerations

Toilet and containment: The user is commonly responsible for the construction of the toilet and pit, although they may pay a mason to carry out the work. The user will be responsible for cleaning and repairs to the toilet, including the slab, seat/squat hole, drop-hole, cover/lid and superstructure. In rural areas, the user may undertake emptying but in urban locations this is more likely to be done by a service provider who charges the household for the service [2].

At shared facilities, a person (or persons) needs to be identified to clean and carry out maintenance tasks on behalf of all users.

Conveyance and treatment: The conveyance and treatment technologies are typically operated and maintained by a combination of private and public service providers working together; for example, where emptying and transport is done by private and/or public service providers who deliver faecal sludge to treatment plants operated by public service providers. All plant, tools and equipment used in the conveyance and treatment steps will require regular maintenance by the relevant service providers.

End use/disposal: Farmers and the general public will be the main users of the treatment products and will be responsible for maintenance of all tools and equipment they use [5].

Mechanisms for protecting public health

Toilet and containment: The toilet separates users from excreta while the pit isolates the excreta and pathogens within from physical human contact.

During rains, the toilet and the pit contain the fresh excreta and prevent it from being washed away into surface water bodies, while squat-hole covers or lids can reduce disease transmission by preventing disease carrying vectors from entering and leaving the pit [2, 3].

Any leachate permeates from the pit into the surrounding soil and pathogens contained in the liquid are filtered out, adsorbed onto particles, or die off during their slow travel through soil [2, 3].

Conveyance: The conveyance step removes the pathogen hazard from the neighbourhood or local community. To do this safely, emptying and transport workers require personal protective equipment as well as standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices. The emptiers should not enter a pit but use long handled shovels to remove sludge at the bottom of a pit [5].

Any non-degradable solid waste removed from the pit, needs to be disposed of properly, for example through a regulated solid waste management service or, where this is not available, through burial.

Treatment: In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site. To safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must wear appropriate protective equipment and follow standard operating procedures [5].

End use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice [8]. For example, sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying. While effluent will require stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water [6, 7].

To protect the health of themselves, colleagues and the general public, end users must wear appropriate protective equipment and follow standard operating procedures in accordance with the actual level of treatment and end use [5].

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

2. Brikké F, and Bredero M (2003). *Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. A reference document for planners and project staff.* Geneva, Switzerland.

3. Reed R A, Scott R E, and Shaw R J (2014). *WEDC Guide No. 25: Simple Pit Latrines.* WEDC, Loughborough University, UK.

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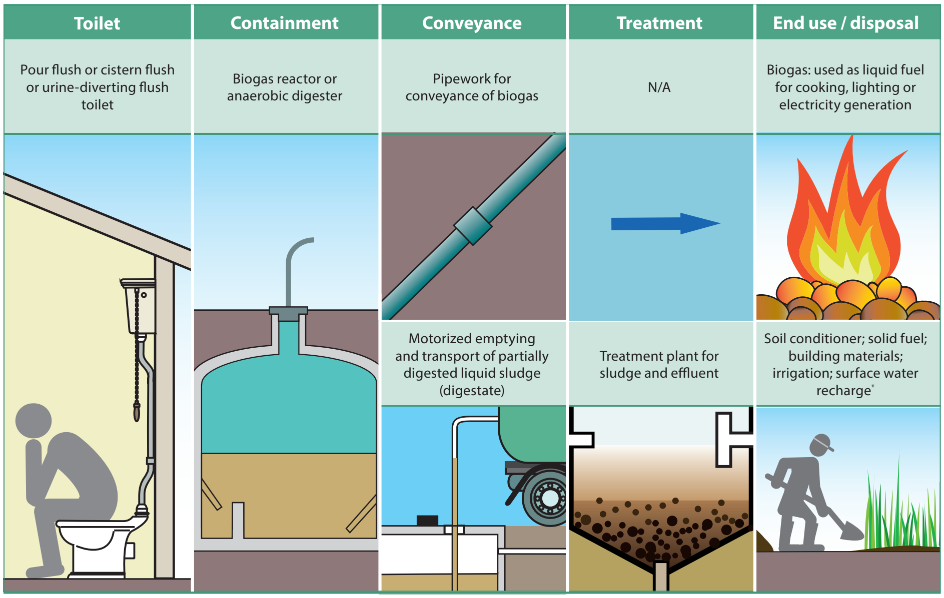
Fact sheet 6

Flush (or urine-diverting flush) toilet with biogas reactor and offsite treatment



* Sludge: treated and used as soil conditioner, solid fuel or building materials. Effluent: treated and used for irrigation or surface water recharge.

Summary

This system is based on the use of a biogas reactor to collect, store and treat the excreta. Additionally, the biogas reactor produces biogas, which can be burned for cooking, lighting or electricity generation. Inputs to the system can include urine, faeces, flushwater, cleansing water, dry cleansing materials, organics (e.g., market or kitchen waste) and, if available, animal waste.

The system requires a pour flush toilet or, if there is a demand for the urine to be used in agriculture, a urine-diverting flush toilet. A urinal could additionally be used. The toilet is directly connected to a biogas reactor, which is also known as an anaerobic digester. If a urine-diverting flush toilet is installed (and/or a urinal), it will be connected to a storage tank or jerry cans for urine storage.

Although the sludge has undergone anaerobic digestion, it is not pathogen free and must be removed with caution and transported for further treatment, where it will produce both effluent and sludge. Depending on the end use, these fractions may require further treatment prior to end use and/ or disposal.

The biogas produced must be constantly used, for example as a clean fuel for cooking or for lighting. If the gas is not burned, it will accumulate in the tank and, with increasing pressure, will push out the partially digested sludge (digestate) until the biogas escapes to the atmosphere through the digestate outlet.

A biogas reactor can work with or without urine. The advantage of diverting urine from the reactor is that it can be used separately as a concentrated nutrient source without high pathogen contamination (see Fact sheet 4 for more details).

Applicability

Suitability: This system is best suited to rural and peri-urban areas where there is appropriate space, a regular source of organic substrate for the biogas reactor and a use for the partially digested sludge (digestate) and biogas.

The reactor itself can be built underground (e.g., under agricultural land, and in some cases roads) and, there-

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fore, does not require a lot of space. Although a reactor may be feasible in a dense urban area, proper sludge management is essential as the digestate production is continuous and requires year-round emptying and transport away from the site.

Cost: For the user, the capital investment for this system is considerable (excavation and installation of a biogas tank), but several households can share the costs if the system is designed for a larger number of users. The maintenance costs may be considerable, depending on the frequency and method of biogas tank emptying [2, 3]. However, these costs are somewhat offset by the generation of a constant supply of liquid fuel.

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the biogas reactor [2, 3].

Containment: The biogas reactor can function with a large range of inputs and is especially suitable where a constant source of animal manure is available, or where market and kitchen waste is abundant [4]. On farms, for example, large quantities of biogas can be produced if animal manure is co-digested with the blackwater, whereas significant gas production would not be achieved from human excreta alone. Wood material or straw are difficult to degrade and should be avoided in the substrate. Achieving a good balance between excreta (both human and animal), organics and water can take some time, though the system is generally forgiving.

Most types of dry cleansing materials and organics can be discharged into the biogas reactor, although to accelerate digestion and ensure even reactions within the tank, large items should be broken or cut into small pieces.

However, care should be taken not to overload the system with either too many solids or too much liquid. For example, greywater should not be added into the biogas reactor as it substantially reduces the hydraulic retention time; a separate greywater system is therefore required.

Conveyance: As the digestate is not pathogen free, human contact and direct agricultural application should be avoided [4]. Instead, it should be transported to a dedicated sludge treatment facility. The conveyance technologies that can be used include both manual or motorized emptying and transport. In the event that a treatment facility is not easily accessible, the sludge can be discharged to a transfer station. From the transfer station it is then transported to the treatment facility by a motorized transport technology.

Treatment: Treatment technologies produce both effluent and sludge, which may require further treatment prior to end use and/or disposal. For example, effluent from a faecal sludge treatment facility could be co-treated with wastewater in waste stabilization ponds or in constructed wetlands.

End use/disposal: Options for the end use and/or disposal of the treated effluent include irrigation, fish ponds, floating plant ponds or discharge to a surface water body or to groundwater. Treated sludge can either be used in agriculture as a soil conditioner as a solid fuel or as an additive to construction materials [5].

Operation and maintenance considerations

Toilet and containment: The user is responsible for the construction of the toilet and the biogas reactor, but they are most likely to pay a mason to carry out the work. The user will be responsible for cleaning of the toilet and employing an emptying service provider to empty digestate from the biogas tank periodically.

At shared facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified as well as an emptying service provider.

Biogas can be safely burned for cooking, lighting or electricity generation but as it is explosive when mixed with air, precautions should be taken when a reactor is opened for cleaning, when biogas is released to repair a reactor, or when there is a gas leak in a poorly ventilated room. In such cases, sparks, smoking and open flames should be avoided.

Conveyance, treatment and end use/disposal: The digestate conveyance and treatment part of the system is typically operated and maintained by a combination of private and public service providers working together; for example, emptying and transport may be done by private and/or public service providers who deliver the digestate to treatment plants operated by public service providers.

Importantly, for this system, all machinery, tools and equipment used in the conveyance, treatment and end use/disposal steps will require regular maintenance by the service providers.

Mechanisms for protecting public health

Toilet and containment: The toilet separates users from excreta and the biogas tank isolates the brownwater and pathogens within it from physical human contact.

During rains, the slab and the impermeable biogas tank contain the fresh excreta and prevent it from being washed away into surface water bodies, while the water seal reduces disease transmission by preventing disease carrying vectors from entering and leaving the biogas tank.

Conveyance: The conveyance step removes the pathogen containing digestate from the neighbourhood or local community to a treatment plant. Motorized emptying using vacuum trucks (or similar) fitted with long-reach hoses is the preferred method, as this reduces direct contact by emptiers with the sludge. Nevertheless, emptying and transport workers must wear personal protective equipment and follow standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices. The emptiers should not enter a biogas tank but use long handled shovels to remove any hard to shift sludge at the bottom [6].

Treatment: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practise. For example, sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying. Effluent will require stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water.

In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site; to safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must wear appropriate protective equipment and follow standard procedures [6].

End use/disposal: Provided the workers responsible for operation and maintenance of the biogas reactor follow standard operating procedures, the burning of biogas presents no health risk to the consumers of end products generated using biogas [4].

References

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1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

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3. Reed R A, Scott R E, and Shaw R J (2014). *WEDC Guide No. 25: Simple Pit Latrines.* WEDC, Loughborough University, UK.

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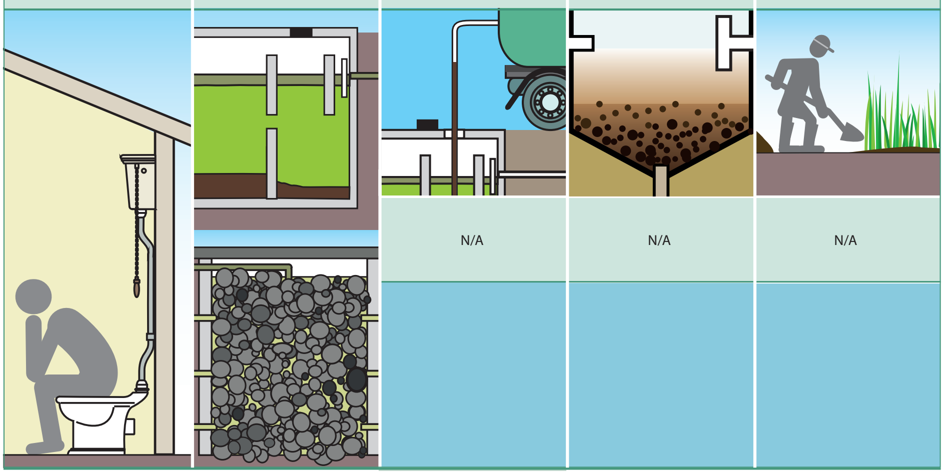
Flush toilet with septic tank and effluent infiltration, and offsite faecal sludge treatment

Toilet	Containment	Conveyance	Treatment	End use / disposal
Pour flush or cistern flush toilet	Septic tank (or anaerobic baffled reactor or anaerobic filter) connected to soak pit or leach field	Motorized emptying and transport	Faecal sludge treatment plant for sludge and effluent	Soil conditioner; solid fuel; building materials; irrigation; surface water recharge*



* Sludge: treated and used as soil conditioner, solid fuel or building materials. Effluent: treated and used for irrigation or surface water recharge.

Summary

This is a water-based system that requires a flush toilet and a containment technology that is appropriate for receiving large quantities of water. Inputs to the system can include faeces, urine, flushwater, cleansing water, dry cleansing materials and greywater.

Two toilet technologies can be used for this system: a pour flush toilet or a cistern flush toilet. A urinal could additionally be used. The toilet is directly connected to a containment technology for the blackwater generated: either a septic tank, an anaerobic baffled reactor (ABR), or an anaerobic filter may be used.

The anaerobic processes reduce the organic and pathogen load, but the effluent is still not suitable for direct use; instead, it can be directly diverted to the ground for disposal through a soak pit or a leach field.

The sludge that is generated from the containment technology is also not pathogen free and must be removed with caution and transported for further treatment, where it will produce both effluent and sludge. Depending on the end use, these fractions may require further treatment prior to end use and/or disposal.

Applicability

Suitability: This system is only appropriate in areas where desludging services are available and affordable and where there is an appropriate way to dispose of the sludge.

For the soak pit or leach field (the infiltration technologies) to work, there must be sufficient available space and the soil must have a suitable capacity to absorb the effluent. If this is not the case, refer to Fact sheet 9 (Flush toilet with septic tank, sewerage and offsite treatment of faecal sludge and effluent).

This system can be adapted for use in colder climates, even where there is ground frost.

The system requires a constant source of water for toilet flushing.

Cost: For the user, the capital investment for this system is considerable (excavation and installation of a septic tank and infiltration technology), but several households can share the costs if the system is designed for a larger number of users. The maintenance costs may be considerable, depending on the frequency and method of tank emptying [2, 3].

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Design considerations

Toilet: The toilet should be made from concrete, fibre-glass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the pit [2, 3].

Containment (septic tank and soak pit): The septic tank is sealed and impermeable but the soak pit is permeable and designed to leach effluent into the surrounding soil. Therefore, the water table level and groundwater use should be taken into consideration in order to avoid contaminating drinking water. If groundwater is not used for drinking or alternative cost-effective sources can be used, then these options should be explored before assuming that groundwater contamination by the soak pit is a problem. Where groundwater is used for drinking and to prevent its contamination, the bottom of the soak pit should be at least 1.5m above the water table [3]. In addition, the pit should be installed in areas located down gradient of drinking water sources, and at a minimum horizontal distance of 15m [4].

This water-based system is suitable for cleansing water inputs, and, since the solids are settled and digested onsite, easily degradable dry cleansing materials can also be used. However, rigid or non-degradable materials (e.g., leaves, rags) could clog the system and cause problems with emptying and, therefore, should not be used. In cases when dry cleansing materials are separately collected from the flush toilets, they should be collected with solid waste and safely disposed of, for example through burial or incineration. Greywater can be managed along with blackwater in the same containment technology; alternatively it can be managed separately.

Conveyance: As the untreated sludge is full of pathogens, human contact and direct agricultural application should be avoided. The emptied sludge should be transported to a dedicated sludge treatment facility. The conveyance technologies that can be used include both manual or motorized emptying and transport. In the event that a treatment facility is not easily accessible, the sludge can be discharged to a transfer station. From the transfer station it can then be transported to the treatment facility by a motorized transport technology.

Treatment: The treatment technologies will produce both effluent and sludge, which may require further treatment prior to end use and/or disposal. For example, effluent from a faecal sludge treatment facility could be co-treated with wastewater in waste stabilization ponds or in constructed wetlands.

End use/disposal: Options for the end use and/or disposal of the treated effluent include irrigation, fish ponds, floating plant ponds or discharge to a surface water body or to groundwater. Treated sludge can be used in agriculture as a soil conditioner, as a solid fuel or as an additive to construction materials [5].

Operation and maintenance considerations

Toilet and containment: The user is responsible for the construction of the toilet and the septic tank, but they are most likely to pay a mason to carry out the work. The user will be responsible for cleaning and repairs to the toilet, including the slab, seat/squatting plate and superstructure, and for employing an emptying service provider to empty the septic tank periodically [2].

At shared facilities, a person (or persons) to clean and carry out maintenance tasks on behalf of all users needs to be identified as well as an emptying service provider.

Conveyance and treatment: The conveyance and treatment part of the system is typically operated and maintained by a combination of private and public service providers working together; for example, emptying and transport may be done by private and/or public service providers who deliver faecal sludge to treatment plants operated by public service providers. All plant, tools and equipment used in the conveyance and treatment steps will require regular maintenance by the relevant service providers.

End use/disposal: Farmers and the general public will be the main end users of the treatment products and will be responsible for maintenance of all tools and equipment they use [6].

Mechanisms for protecting public health

Toilet and containment (septic tank and soak pit): The toilet separates users from excreta and the septic tank isolates the blackwater and pathogens within it from physical human contact.

During rains, the toilet and the impermeable septic tank contain the fresh excreta and prevent it from being washed away into surface water bodies, while squat-hole covers or lids reduce disease transmission by preventing disease carrying vectors from entering and leaving the septic tank [2, 3].

The septic tank is impermeable but the permeable soak pit allows effluent to leach into the surrounding soil. Pathogens contained in the liquid are filtered out, adsorbed onto particles, or die off during their slow travel through soil [2, 3].

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Conveyance: The conveyance step removes the pathogen hazard from the neighbourhood or local community to a treatment plant. Motorized emptying using vacuum trucks (or similar) fitted with long-reach hoses is the preferred method, as this reduces direct contact by emptiers with the sludge. Nevertheless, emptying and transport workers must wear personal protective equipment and must follow standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices. The emptiers should not enter a septic tank but use long handled shovels to remove any hard to shift sludge at the bottom [6].

Treatment: In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site. To safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must be trained in the correct use of all tools and equipment they operate, wear appropriate personal protective equipment and follow standard operating procedures [6].

End use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice. For example, sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying. Effluent will require stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water [5, 7, 8].

To protect the health of themselves, co-workers and the general public, end users must wear appropriate protective equipment and follow standard operating procedures in accordance with the actual level of treatment and end use [6].

References

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1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).
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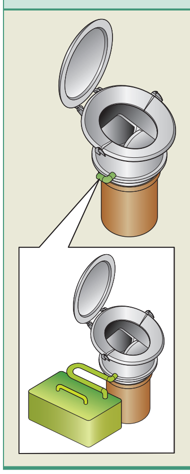
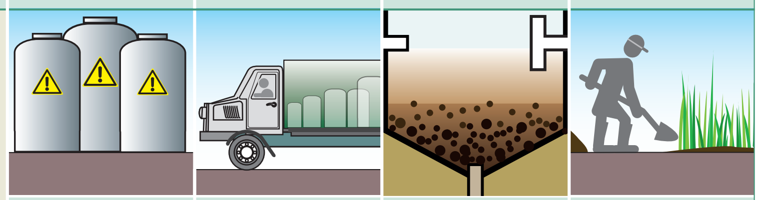
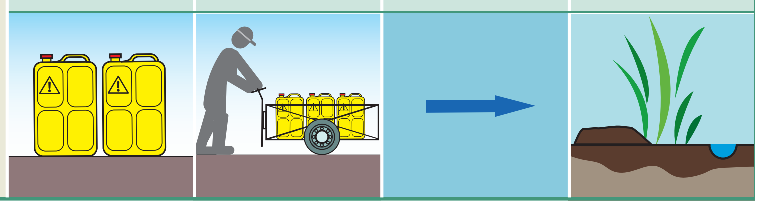
Fact sheet 8

Urine-diverting dry toilet and container-based sanitation with offsite treatment of all contents

Toilet	Containment	Conveyance	Treatment	End use / disposal
Urine-diverting dry toilet	Brownwater: Portable storage container or cartridge	Brownwater: Collection and motorized (or manual) transport of storage tanks	Brownwater treatment plant – for effluent and sludge	Soil conditioner; solid fuel; building materials; irrigation; surface water recharge*
				
	Urine: Portable storage tanks or jerry cans	Urine: Collection and motorized (or manual) transport of storage tanks	N/A	Urine: used as liquid fertilizer
				

* Sludge: treated and used as soil conditioner, solid fuel or building materials. Effluent: treated and used for irrigation or surface water recharge.

Summary

This system is designed to separate urine and faeces so that they can be managed independently. Inputs to the system can include faeces, urine, cleansing water and dry cleansing materials.

The main toilet technology for this system is a urine-diverting dry toilet (UDDT), which allows urine and faeces to be separately managed. A urinal could additionally be used. UDDT designs vary and include adaptations for different preferences, for instance with a third diversion for cleansing water management.

The UDDT configuration ensures that the faeces, cleansing water and/or dry cleansing materials, which when combined comprise a relatively thick brownwater, pass into a portable container. This is commonly referred to as a cartridge that is portable. Once a brownwater cartridge is full, it is removed/collected and transported to treatment using either motorized or manual transport. After dewatering and drying, the faeces can be used as a solid fuel or, more commonly, they are co-composted with organics and used as a soil conditioner.

Depending on the demand for urine end use and local requirements, the UDDT diverts the urine to the ground for infiltration through a soak pit. Alternatively, it can be directed into a portable container where it is stored. Stored urine can be collected and transported for use on neighbouring fields [2] using manual or motorized transport technologies, as indicated in the schematic.

Applicability

Suitability: This is a relatively new system typically implemented in dense, informal, urban locations and in emergency contexts, in particular, where there is limited space and/or soil conditions are not appropriate for the construction of underground pits and tanks; where there is a risk of surface flooding; where the water table is high; where there is no sewer network for users to connect to; or where tenants cannot afford the higher capital cost of other containment technologies.

Cost: The users often pay no capital or initial cost. Instead, they pay a weekly or monthly fee to the service provider for removal of full brownwater cartridges and urine cartridges (if any) and replacing them with clean, empty cartridges.

The treatment plant capital cost and operation and maintenance cost will depend on the technology chosen and the energy required to operate it. These costs can be significantly reduced where brownwater treatment can be combined into an existing plant; however, where a new dedicated plant is required then the costs could be considerable.

Overall, this system is most appropriate when there is a high willingness and ability to pay for the container-based service, where there is an appropriate facility for the brownwater treatment and a demand for the end use products.

Design considerations

Toilet and containment (cartridges): Container-based urine-diverting toilets are generally prefabricated, modular units that connect directly to the cartridges into which they discharge. They are often made from fibreglass or rigid plastics, which are relatively light in weight, portable, durable and easy to clean.

A separate system is required for stormwater and greywater, neither of which should enter into the cartridges. The toilets should be designed to prevent rain or stormwater from entering the cartridges.

This system is suitable for cleansing water inputs, and easily degradable dry cleansing materials can be used. However, rigid or non-degradable materials (e.g., leaves, rags) could block the system and should not be used. In cases when dry cleansing materials are separately collected from the toilets, they should be collected with solid waste and safely disposed of, for example through burial or incineration.

Conveyance: As the untreated brownwater is full of pathogens, human contact and direct agricultural application should be avoided. The (ideally) sealed containers should be transported to a dedicated treatment facility using either manual or motorized transport.

Treatment: Treatment of brownwater will produce both effluent and sludge, which may require further treatment prior to end use and/or disposal. For example, effluent produced from dewatering could be co-treated with wastewater in waste stabilization ponds or in constructed wetlands.

End use/disposal: Treated brownwater can either be used in agriculture as a soil conditioner or used as a solid fuel or as an additive to construction materials.

Operation and maintenance considerations

Toilet and containment (cartridge): The toilet, containment and conveyance steps are commonly operated by a private company (service provider) who is responsible for providing the user with a toilet, cartridge(s) and instructions on their operation and maintenance.

The user is responsible for cleaning the toilet and maintaining the toilet cubicle. At shared toilet facilities, a person (or persons) to clean the toilets and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified.

Conveyance: The provider's service will also include regular (either demand–based or fixed interval-based) replacement of a full brownwater cartridge with a clean, empty cartridge and the removal and transport of the full cartridge to treatment. Where urine is stored in a cartridge, the service may also include removal and transport of a full urine cartridge and replacement with an empty one. The service provider will be responsible for cleaning of all cartridges and maintenance of all transport equipment.

Treatment: Functioning, properly maintained treatment technologies are a key requirement. In most situations these are managed at the municipal or regional level. In the case of more local, small-scale systems, operation and maintenance of the collection and transport service and the treatment plant, is managed and organized by private service providers at the community level. All machinery, tools and equipment used in the treatment step will require regular maintenance by the relevant service provider.

End use/disposal: Farmers and the general public will be the main end users of the treatment products and will be responsible for maintenance of all tools and equipment they use [2].

Mechanisms for protecting public health

Toilet: The toilet separates the excreta from direct human contact, and squat-hole covers or lids can reduce disease transmission by preventing disease carrying vectors from entering and leaving the cartridges.

Containment (cartridges): The urine requires storage before use in sealed cartridges or direct discharge to the ground; both methods will protect public health when operated correctly [2].

The watertight cartridges isolate the brownwater from physical human contact and ensure surface waters and groundwater are not contaminated. The conveyance step then removes the pathogen containing brownwater from the neighbourhood or local community to a treatment plant.

Conveyance: To reduce the risk of exposure from spillages when moving and transporting full cartridges to treatment, all workers require personal protective equipment and must follow standard operating proce-

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dures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices [2].

Treatment: In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site, and to safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must be trained in the correct use of all tools and equipment they operate, wear appropriate personal protective equipment and follow standard operating procedures [2].

End use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the brownwater by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice. For example, the thick brownwater will require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, it will only require dewatering and drying [3, 4].

To protect the health of themselves, co-workers and the general public, end users must wear appropriate protective equipment and follow standard operating procedures in accordance with the actual level of treatment and end use [2].

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies*. *2nd Revised Edition*. Swiss Federal Institute of Aquatic Science and Technology (Eawag).

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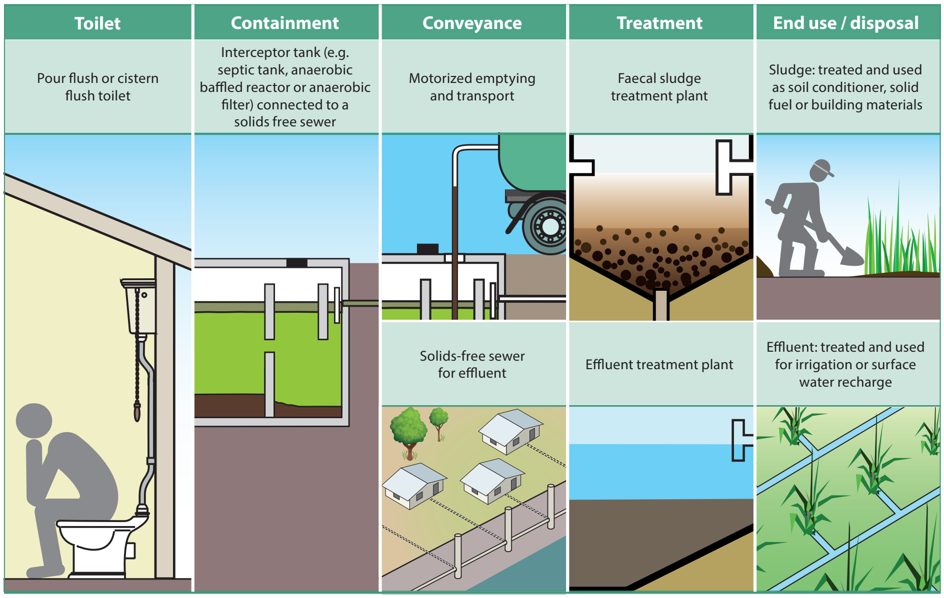
4. World Health Organization (2006). *WHO Guidelines for the safe use of wastewater, excreta and greywater. Volumes I to IV.* Geneva, Switzerland.

Fact sheet 9

Flush toilet with septic tank, sewerage and offsite treatment of faecal sludge and effluent



Summary

This system is characterized by the use of a household-level containment technology to remove and digest settleable solids from the blackwater, and a sewer system to transport the effluent to a treatment facility.

Inputs to the system can include faeces, urine, flushwater, cleansing water, dry cleansing materials and greywater.

There are two toilet technologies that can be used for this system: a pour flush toilet or a cistern flush toilet. A urinal could additionally be used. This system is comparable to Fact sheet 7 (Flush toilet with septic tank, sewerage and offsite treatment of faecal sludge and effluent) except that the management of the effluent generated during containment of the blackwater is different: the effluent from septic tanks, anaerobic baffled reactors or anaerobic filters is transported to a treatment facility via a solids-free sewer.

The containment technologies serve as "interceptor tanks" and allow for the use of small-diameter sewers, as the effluent is free from settleable solids.

The sewer system transports effluent to a treatment facility where it is treated and will produce both sludge and effluent, which may require further treatment prior to end use or disposal.

Applicability

Suitability: This system is especially appropriate for urban settlements where the soil is not suitable for the infiltration of effluent. Since the sewer network is shallow and (ideally) watertight, it is also applicable for areas with high groundwater tables. This system can be used as a way of upgrading existing, under-performing containment technologies (e.g., septic tanks) by providing improved treatment.

There must be a constant supply of water to ensure that the sewers do not become blocked.

Cost: For the user, the capital investment for this system is considerable (excavation and installation of an interceptor tank), but several households can share the costs if the system is designed for a larger number of users. The maintenance costs may be considerable, depending on the frequency and method of tank emptying.

With the sewer-based transport of effluent to a treatment facility, the capital investment is considerable. However, the design and installation of solids-free sewers will be considerably less expensive than a conventional gravity sewer network.

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Overall, this system is most appropriate when there is a high willingness and ability to pay for the capital investment and maintenance costs and where there is an appropriate treatment facility.

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the tank.

Containment: This water-based system is suitable for cleansing water inputs, and, since the solids are settled and digested onsite, easily degradable dry cleansing materials can be used. However, rigid or non-degradable materials (e.g., leaves, rags) could clog the system and cause problems with emptying and should not be used. In cases when dry cleansing materials are separately collected from the flush toilets, they should be collected with solid waste and safely disposed of, for example through burial or incineration.

End use/disposal: Options for the end use and/or disposal of the treated effluent include irrigation, fish ponds, floating plant ponds or discharge to a surface water body or to groundwater [2].

Treated sludge can be used in agriculture as soil conditioner, as a solid fuel, or as an additive to construction materials.

Operation and maintenance considerations

Toilet and containment: The user is responsible for the construction of the toilet and interceptor tank, but they are most likely to pay a mason to carry out the work. The user will be responsible for cleaning of the toilet and will most likely pay an emptying service provider to empty the interceptor tank periodically.

At shared facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified as well as an emptying service provider.

Conveyance, treatment and end use/disposal: The success of this system depends on the conveyance systems. There must be an affordable and systematic method for emptying sludge from the interceptor tanks since one user's improperly maintained tank could adversely impact the entire sewer network.

Typically, the technologies may be operated and maintained by a combination of private and public service providers working together; for example, emptying and transport may be done by private and/or public service providers who maintain the sewer network and also deliver faecal sludge to treatment plants operated by public service providers.

Functioning, properly maintained sludge and effluent treatment technologies are a key requirement. In most situations these are managed at the municipal or regional level. In the case of more local, small-scale systems, operation and maintenance of the emptying and transport service, the sewer network and the treatment plant, are managed and organized at the community level [3].

Importantly, for this system, all machinery, tools and equipment used in the conveyance, treatment and end use/disposal steps will require regular maintenance by the service providers.

Mechanisms for protecting public health

Toilet: The toilet separates users from excreta and the impermeable interceptor tank isolates the blackwater and pathogens within it from physical human contact.

During rains, the slab and the impermeable interceptor tank contain the fresh excreta and prevent it from being washed away into surface water bodies, while the water seal reduces smells, nuisance and disease transmission by preventing disease carrying vectors from entering and leaving the tank.

Conveyance: The conveyance step removes the pathogen hazard from the neighbourhood or local community to a treatment plant. The watertight sewer network isolates the blackwater from physical human contact and ensures groundwater is not contaminated.

Motorized emptying using vacuum trucks (or similar) fitted with long-reach hoses is the preferred method of removing the sludge, as this reduces direct contact by emptiers. Nevertheless, emptying and transport workers must wear personal protective equipment and follow standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices. The emptiers should not enter an interceptor tank but use long handled shovels to remove any hard to shift sludge at the bottom [4].

Treatment and end use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice. For example, sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying. Effluent will require stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water [2, 5, 6].

In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site; and to safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must wear appropriate protective equipment and follow standard operating procedures [4].

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

2. Strande L (2017). *Introduction to Faecal Sludge Management.* Online Course available at: www.sandec.ch/fsm_tools (accessed March 2017). Sandec: Department of Sanitation, Water and Solid Waste for Development Eawag: Swiss Federal Institute of Aquatic Science and Technology.

3. Brikké F, and Bredero M (2003). *Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. A reference document for planners and project staff.* Geneva, Switzerland.

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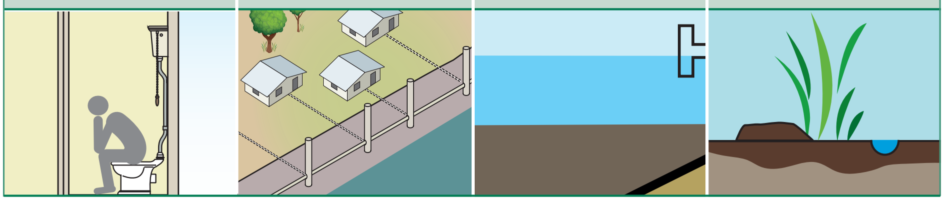
Fact sheet 10

Flush toilet with sewerage and offsite wastewater treatment

Toilet	Conveyance	Treatment	End use / disposal
Pour flush or cistern flush toilet	Simplified or conventional gravity sewer	Wastewater treatment plant – for wastewater and wastewater sludge	Soil conditioner; solid fuel; building materials; irrigation; surface water recharge *



* Sludge: treated and used as soil conditioner, solid fuel or building materials. Effluent: treated and used for irrigation or surface water recharge.

Summary

This is a water-based sewer system in which wastewater is transported to a treatment facility. Importantly, unlike the system described in Fact sheet 9, in this system there is no interceptor tank (i.e. a containment technology such as a septic tank).

Inputs to the system include faeces, urine, flushwater, cleansing water, dry cleansing materials, greywater and possibly stormwater.

There are two toilet technologies that can be used for this system: a pour flush toilet or a cistern flush toilet. A urinal could additionally be used. The blackwater that is generated at the toilet together with greywater is directly conveyed to a treatment facility through a conventional or a simplified gravity sewer network.

As there is no containment, all of the blackwater is transported to a treatment facility where a combination of technologies is used to produce treated effluent for end use and/or disposal, and wastewater sludge. This sludge must be further treated prior to end use and/or disposal.

Applicability

Suitability: This system is especially appropriate for dense, urban and peri-urban settlements where there is little or no space for onsite containment technologies or emptying. The system is not well-suited to rural areas with low housing densities.

Since the sewer network is (ideally) watertight, it is also applicable for areas with high groundwater tables.

The system requires a constant supply of water for flushing, to ensure that the sewers do not become blocked.

Cost: The capital investment for this system can be very high. Conventional gravity sewers require extensive excavation and installation that is expensive, whereas simplified sewers use smaller diameter pipes laid at a shallower depth and at a flatter gradient, so are generally less expensive.

Users may be required to pay a connection fee and regular user fees for system maintenance; the size of the fees will depend on the operation and maintenance arrangement and whether or not the local topography dictates that the blackwater requires pumping to reach the treatment plant.

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Overall, this system is most appropriate when there is a high willingness and ability to pay for the capital investment and maintenance costs and where there is an appropriate treatment facility.

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the sewer.

Conveyance: This water-based system is suitable for cleansing water inputs, and easily degradable dry cleansing materials can be used. However, rigid or non-degradable materials (e.g., leaves, rags) could block the system and should not be used. In cases when dry cleansing materials are separately collected from the flush toilets, they should be collected with solid waste and safely disposed of, for example through burial or incineration.

The inclusion of greywater in the conveyance technology helps to prevent solids from accumulating in the sewers and stormwater could also be put into the gravity sewer network. However, this would dilute the wastewater and require stormwater overflows. Local retention and infiltration of stormwater, or a separate drainage system for rain and stormwater are therefore preferred approaches.

Treatment: Typically, the wastewater treatment technology will consist of a series of ponds or wetlands, which can produce a stabilized, pathogen-free effluent, which is suitable for use as crop irrigation water. As well as effluent, the treatment technology will produce wastewater sludge, which may require further treatment prior to end use and/or disposal. For example, dewatered and dried wastewater sludge can be used as a solid fuel or as an additive to construction materials.

End use/disposal: Options for the end use and/or disposal of the treated effluent include irrigation, fish ponds, floating plant ponds or discharge to a surface water body or to groundwater [2].

Operation and maintenance considerations

Toilet: The user is responsible for the construction, maintenance and cleaning of the toilet.

At shared toilet facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified as well as an emptying service provider.

Conveyance: Depending on the sewer type and management structure (simplified vs. conventional, city-managed vs. community-operated) there will be varying degrees of operation or maintenance responsibilities for the user. Where conventional, city-managed sewerage is found, users' involvement will be limited to paying user fees and reporting problems to the service provider. In contrast, if simplified, community-operated sewerage is used, users may help the community organization inspect, repair and/or unblock the sewer line [3].

Treatment: Functioning, properly maintained wastewater and sludge treatment technologies are a key requirement. In most situations these are managed at the municipal or regional level. In the case of small-scale systems, operation and maintenance of the treatment plant is managed and organized at the community level. All machinery, tools and equipment used in the treatment step will require regular maintenance by the relevant service providers.

End use/disposal: Farmers and the general public will be the main end users of the treatment products and will be responsible for maintenance of all tools and equipment they use [4].

Mechanisms for protecting public health

Toilet: The toilet separates the excreta from direct human contact, and the water seal reduces smells, nuisance and disease transmission by preventing disease carrying vectors from entering and leaving the sewer.

Conveyance: The conveyance step removes the pathogen-containing blackwater from the neighbourhood or local community to a treatment plant. The (ideally) watertight sewer network isolates the blackwater from physical human contact and ensures groundwater is not contaminated.

As the blackwater contains pathogens, when clearing blockages or repairing sewers, all workers require personal protective equipment and must follow standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices [4].

Treatment: In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site, and to safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must be trained in the correct use of all tools and equipment they operate, wear appropriate personal protective equipment and follow standard operating procedures [4].

End use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice. For example, effluent requires stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water. While sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying [2, 5, 6].

To protect the health of themselves, co-workers and the general public, end users must wear appropriate protective equipment and follow standard operating procedures in accordance with the actual level of treatment and end use [4].

References

The text for this fact sheet is based on Tilley, et al. [1] unless otherwise stated.

1. Tilley E, Ulrich L, Lüthi C, Reymond P, Schertenleib R, and Zurbrügg C (2014). *Compendium of Sanitation Systems and Technologies. 2nd Revised Edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag).

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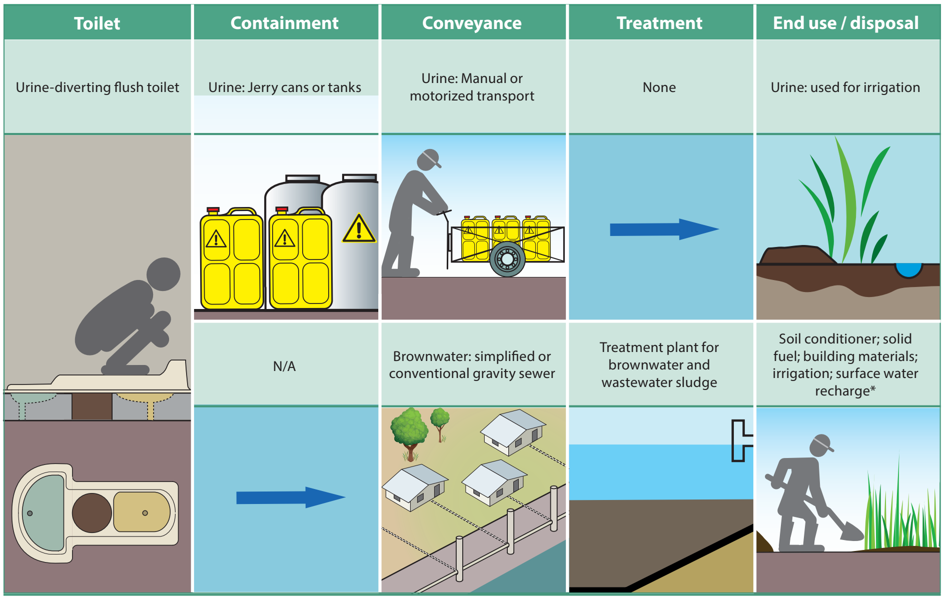
Fact sheet 11

Urine-diverting flush toilet with sewerage and offsite wastewater treatment



* Soil conditioner; solid fuel; building materials; irrigation; surface water recharge*

Summary

This is a water-based system that requires a urine-diverting flush toilet (UDFT) and a sewer. The UDFT is a special toilet that allows for the separate collection of urine without water, although it uses water to flush faeces.

Inputs to the system can include faeces, urine, flushwater, cleansing water, dry cleansing materials, greywater and possibly stormwater.

The main toilet technology for this system is the UDFT. A urinal could additionally be used. Brownwater and urine are separated at the toilet. Brownwater bypasses the urine storage tank and is conveyed to a treatment facility using a simplified or a conventional gravity sewer network.

Brownwater is treated at a treatment facility where a combination of technologies is used to produce treated effluent for end use and/or disposal, and wastewater sludge. This sludge must be further treated prior to end use and/or disposal.

Urine diverted at the toilet is collected in a storage tank. Stored urine can be handled easily and with little risk because it is nearly sterile. With its high nutrient content it can be used as a good liquid fertilizer. Stored urine can be transported using manual or motorized transport technologies. Alternatively, the urine can be diverted directly to the ground for infiltration through a soak pit.

Applicability

Suitability: This system is only appropriate when there is an end use and therefore a need for the separated urine, and/or when there is a desire to limit water consumption by using a low-flush UDFT (although the system still requires a constant source of water).

Depending on the type of sewers used, this system can be adapted for both dense urban and peri-urban areas. It is not well-suited to rural areas with low housing densities. Since the sewer network is (ideally) watertight, it is also applicable for areas with high groundwater tables.

Cost: UDFTs are not common and the capital cost for this system can be very high. This is partly due to the fact that there is limited competition in the toilet market and also because high quality workmanship is required for the dual plumbing system. Conventional gravity sewers require extensive excavation and installation, which is expensive, whereas simplified sewers are generally less expensive if the site conditions permit a condominial design.

Users may be required to pay a connection fee and regular user fees for system maintenance; this will depend on the operation and maintenance arrangement.

The capital cost of the treatment plant may also be considerable, while the treatment plant maintenance costs will depend on the technology chosen and the energy required to operate it.

Overall, this system is most appropriate when there is a high willingness and ability to pay for the capital investment and maintenance costs and where there is an appropriate treatment facility.

Design considerations

Toilet: The toilet should be made from concrete, fibreglass, porcelain or stainless steel for ease of cleaning and designed to prevent stormwater from infiltrating or entering the sewer.

This water-based system is suitable for cleansing water inputs, and easily degradable dry cleansing materials can be used. However, rigid or non-degradable materials (e.g., leaves, rags) could clog the system and cause problems and should not be used. In cases when dry cleansing materials are separately collected from the flush toilets, they should be collected with solid waste and safely disposed of, for example through burial or incineration.

Conveyance: The gravity sewer network can transport greywater to treatment, where the combined flows are treated together. Stormwater could also be put into the gravity sewer network, although this would dilute the wastewater and require stormwater overflows. Local retention and infiltration of stormwater, or a separate drainage system for rain and stormwater are therefore preferred approaches.

End use/disposal: Options for the end use and/or disposal of the treated effluent include irrigation, fish ponds, floating plant ponds or discharge to a surface water body or to groundwater [2].

Treated sludge can be used in agriculture as soil conditioner, as a solid fuel, or as an additive to construction materials [3].

Operation and maintenance considerations

Toilet: The user is responsible for the construction, maintenance and cleaning of the UDFT.

At shared toilet facilities, a person (or persons) to clean and carry out other maintenance tasks (e.g. repairs to superstructure) on behalf of all users needs to be identified, as well as a urine transport service provider.

Conveyance: Depending on the sewer type and management structure (simplified vs. conventional, city-managed vs. community-operated) there will be varying degrees of operation or maintenance responsibilities for the user [4].

Treatment and end use/disposal: Functioning, properly maintained wastewater and sludge treatment technologies are a key requirement. In most situations these are managed at the municipal or regional level. In the case of more local, small-scale systems, operation and maintenance of the urine transport service, the sewer network and the treatment plant are managed and organized at the community level [4].

Importantly, for this system, all plants, tools and equipment used in the containment, conveyance, treatment and end use/disposal steps will require regular maintenance by the service providers.

Mechanisms for protecting public health

Toilet and containment: The toilet separates the excreta from direct human contact, and the water seal reduces smells, nuisance and disease transmission by preventing disease carrying vectors from entering and leaving the sewer.

The urine poses little health risk as it is nearly sterile, and storage before use in sealed containers will protect public health [3]. In areas in which schistosomiasis is endemic, urine should not be used in water-based agriculture, such as rice paddies

Conveyance: The conveyance step removes the pathogen-laden brownwater from the neighbourhood or local community to a treatment plant. The (ideally) watertight sewer network isolates the brownwater from physical human contact and ensures groundwater is not contaminated.

When clearing blockages or repairing sewers, all workers require personal protective equipment as well as standard operating procedures. For instance, the wearing of boots, gloves, masks and clothing that cover the whole body is essential, as well as washing facilities and good hygiene practices [5].

Treatment and end use/disposal: If correctly designed, constructed and operated, treatment technologies can be combined to reduce the pathogen hazard within the effluent or sludge by removal, reduction or inactivation to a level appropriate for the intended end use and/or disposal practice. For example, effluent requires stabilization and pathogen inactivation in a series of ponds or wetlands before use as crop irrigation water. Sludges require dewatering and drying followed by co-composting with organics before use as a compost-type soil conditioner, but for use as a solid fuel or building material additive, they only require dewatering and drying [2, 3, 6].

In order to reduce the risk of exposure of the local community, all treatment plants must be securely fenced to prevent people entering the site, and to safeguard workers' health when operating the plant and carrying out maintenance to tools and equipment, all treatment plant workers must wear appropriate protective equipment and follow standard operating procedures.

References

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Annex 2

GLOSSARY

Biochemical oxygen demand (BOD)
A measure of the oxygen used by microorganisms to degrade organic matter. The oxygen demand is reduced through stabilisation, and can be achieved by aerobic or anaerobic treatment.

Biogas
Biogas is the common name for the mixture of gases released from anaerobic digestion. Biogas is comprised of methane (50 to 75%), carbon dioxide (25 to 50%) and varying quantities of nitrogen, hydrogen sulphide, water vapour and other components. Biogas can be collected and burned for fuel (like propane).

Biomass
Biomass refers to plants or animals cultivated using the water and/or nutrients flowing through a sanitation system. Biomass may include fish, insects, vegetables, fruit, forage or other beneficial crops that can be utilized for food, feed, fibre and fuel production.

Blackwater
Blackwater is the mixture of urine, faeces and flushwater along with anal cleansing water (if water is used for cleansing) and/or dry cleansing materials. Blackwater contains the pathogens of faeces and urine and the nutrients of urine that are diluted in the flushwater.

Brownwater
Brownwater is the mixture of faeces and flushwater, and does not contain urine. Urine-diverting flush toilets generate it and, therefore, the volume depends on the volume of the flushwater used. The pathogen and nutrient load of faeces is not reduced, only diluted by the flushwater. Brownwater may also include anal cleansing water (if water is used for cleansing) and/or dry cleansing materials.

By-law
A regulation made by a local authority or corporation; a rule made by a company or society to control the actions of its members.

Centralised sewer system
A system used to collect, treat, discharge, and/or reclaim wastewater from large user groups (i.e. neighbourhood to city level applications).

Cleansing water
Water used for cleansing after defecating and/or urinating; those who use water, rather than dry material, for cleansing, generate it. The volume of water used per cleaning typically ranges from 0.5– to 3 l.

Combined sewer
Sewer network where blackwater and/or stormwater runoff are carried by the same sewers.

Compost
Compost is decomposed organic matter that results from a controlled aerobic degradation process.

Containment
Containment describes the ways of collecting, storing, and sometimes treating the products generated at the toilet (or user interface). The treatment provided

by these technologies is often a function of storage and is usually passive (e.g., requiring no energy input). Thus, products that are 'treated' by these technologies often require subsequent treatment before use and/or disposal.

Container-based sanitation
A sanitation service in which excreta is captured in sealable containers that are then transported to treatment facilities.

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
Conveyance describes the 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.

Disability-adjusted Life Year (DALY)
Population metric of life years lost to disease due to both morbidity and mortality.

Downstream consumers
In this document refers to the wider general public (e.g., farmers) who use sanitation products (e.g., compost or water) or consume products (e.g., fish or crops) that are produced using sanitation products, and may be either actively or passively affected.

Dry cleansing material
Dry cleansing materials are solid materials used for cleansing after defecating and/or urinating (e.g., paper, leaves, corncobs, rags or stones).

Effluent
Effluent is the general term for a liquid that leaves a technology, typically after blackwater or faecal sludge has undergone solids separation or some other type of treatment.

End use/disposal
In this document refers to the methods by which products are ultimately returned to the environment as reduced-risk materials and/or used in resource recovery. If there is an end use for the output they can be applied or used, otherwise they should be disposed of in ways that are least harmful to the public and the environment.

Excreta
Urine and faeces.

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 or pathway
The pathway or route by which a person is exposed to a hazard.

Faecal sludge
Solid and liquid wastes removed from on-site storage containers, also called septage when removed from septic tanks

Faeces
(Semisolid) excrement that is not mixed with urine or water.

Flushwater
Flushwater is the water discharged into the user interface to transport the content and/or clean it.

Greywater
Greywater is the total volume of water generated from the household, but not from toilets.

Hazard
A biological, chemical or physical constituent that can cause harm to human health.

ID50
Dose at which 50% of subjects would become infected; or probability of infection = 0.5.

Hazardous event
Any incident or situation that

- Introduces or releases the 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.

Leachate
The liquid fraction that is separated from the solid component by gravity filtration through media (e.g., liquid that drains from drying beds).

Legislation
Laws, considered collectively, as well as the process of making or enacting laws.

Local community
In this document refers to the people who live and/or work near to, or downstream from, the sanitation system, and may be either actively or passively affected.

Log reduction
Organism reduction efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.

Low-income country
Low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of $995 or less in 2017.

Manual emptying
In this document refers to the emptying of faecal sludge from on-site sanitation technologies, where humans are required to manually lift the sludge. Manual emptying can be used with either manual or motorized transport.

Manual transport
In this document refers to the human-powered transport of faecal sludge emptied from on-site sanitation technologies. Manual transport can be used with manual or motorized emptying.

Mechanical vector transmission
The mechanical transfer of pathogens in excreta, faecal sludge or wastewater by insect (e.g. flies) or vermin (e.g. rats) to a person or food items.

Middle-income country
Lower middle-income economies are those with a GNI per capita between $996 and $3,895; upper middle-income economies are those with a GNI per capita between $3,896 and $12,055, calculated using the World Bank Atlas.

Motorized emptying
In this document refers to the use of motorized equipment for the emptying of faecal sludge from on-site sanitation technologies. Humans are required to operate the equipment and manoeuvre the hose, but the faecal sludge is not manually lifted. Motorized emptying is most commonly followed by motorized transport, but it is also used with manual transport.

Motorized transport
In this document refers to the use of motorized equipment for the transport of faecal sludge from

on-site sanitation technologies. Humans are required to operate the equipment, but the faecal sludge is not manually transported. Motorized transport can be used with either motorized or manual emptying.

Nutrient Management
Treatment objective of treatment technologies principally for management of Nitrogen, Phosphorous and Potassium.

Off-site sanitation
A sanitation system in which excreta (referred to as wastewater) is collected and transported away from the plot where they are generated. An off-site sanitation system relies on a sewer technology for transport.

On-site sanitation
A sanitation technology or system in which excreta (referred to as faecal sludge) is collected and stored and emptied from or treated on the plot where they are generated.

Open drain
Open channel used to carry greywater, surface water or stormwater.

Outlet
A pipe or hole through which wastewater is discharged or a gas may vent.

Overflow
An outlet for excess wastewater.

Pathogens
Disease-causing organisms (e.g. bacteria, helminths, protozoa or viruses).

Plan
A detailed and time-limited proposal for achieving stated objectives.

Policy
A course or principle of action adopted or proposed by an organization or individual; A plan or course of action, as of a government, political party, or business, intended to influence and determine decisions, actions, and other matters.

Public toilet
Not restricted to specific users; may be formally or informally-managed.

Regulation
The action or process of regulating or being regulated.

Regulations
Rules or directives made and maintained by an authority.

Risk
The likelihood and consequences that something with a negative impact will occur.

Sanitary inspection
A sanitary inspection is an on-site inspection and evaluation, by qualified individuals, of all conditions, devices, and practices in the sanitation system that pose an actual or potential danger to the health and well-being of the various exposure groups. It is a fact-finding activity that should identify system deficiencies - not only potential sources of hazardous events, but also inadequacies and lack of integrity in the system or that could lead to hazardous events.

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 system
A context specific series of sanitation technologies (and services) for the management of faecal sludge and/or wastewater through the stages of containment, emptying, transport, treatment and end use/disposal.

Sanitation technologies
The specific infrastructure, methods, or services designed to support the process of managing faecal sludge and/or wastewater through the stages of containment, emptying, transport, treatment, and end use/disposal.

Sanitation users
In this document refers to all people who use a toilet.

Sanitation workers
In this document refers to all people – employed or otherwise – responsible for cleaning, maintaining, operating or emptying a sanitation technology at any step of the sanitation chain.

Separate (foul) sewer
A sewer that may carry blackwater and greywater but from which stormwater is excluded.

Sewage
Wastewater that is transported through the sewer.

Sewer
An underground pipe that transports blackwater, greywater and, in some cases, stormwater (combined sewer) from individual households and other users to treatment plants, using gravity or pumps when necessary.

Sewerage
The physical sewer infrastructure for conveyance and treatment of sewage.

Shared toilet
A single toilet shared between two or more households.

Soak pit
A pit or chamber that allows effluent to soak into the surrounding ground.

Stabilization
A process achieved through the biodegradation of the more readily degradable molecules, resulting in faecal sludge with a lower oxygen demand. It is a treatment objective of treatment technologies and results in faecal sludge containing organic, carbon-based molecules that are not readily degradable, and which consists of more stable, complex molecules.

Standard
A required or agreed level of quality or attainment.

Stormwater
Stormwater is the general term for the rainfall runoff collected from roofs, roads and other surfaces before flowing towards low-lying land. It is the portion of rainfall that does not infiltrate into the soil.

Theory of Change
A comprehensive description and illustration of how and why a desired change is expected to happen in a particular context.

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 toilet, for example pour- and cistern-flush toilets, dry toilets and urine-diverting toilets.

Treatment
Process/es that changes the physical, chemical and biological characteristic or composition of faecal sludge or wastewater so that it is converted into a product that is safe for end use or disposal.

Urine
The liquid produced by the body to rid itself of urea and other waste products. In this context, the urine product refers to pure urine that is not mixed with faeces or water.

User interface
User Interface describes the type of toilet, pedestal, pan, or urinal with which the user comes in contact; it is the way by which the user accesses the sanitation system.

Wastewater
Used water from any combination of domestic (households and services) industrial, stormwater and any sewer inflow/infiltration.

Water body
Any substantial accumulation of water, both natural and manmade (i.e. surface water).

WHO Guidelines
A WHO guideline is any document containing recommendations about health interventions, whether these are clinical, public health or policy recommendations.

Notes

Notes

Safe sanitation is essential for health, from preventing infection to improving and maintaining mental and social well-being.

Developed in accordance with the processes set out in the WHO Handbook for Guideline Development, these guidelines provide comprehensive advice on maximizing the health impact of sanitation interventions. They summarize the evidence on the links between sanitation and health, provide evidence-informed recommendations, and offer guidance for international, national and local sanitation policies and programme actions. The guidelines also articulate and support the role of health authorities in sanitation policy and programming to help ensure that health risks are identified and managed effectively.

The audience for the guidelines is national and local authorities responsible for the safety of sanitation systems and services, including policy makers, planners, implementers within and outside the health sector and those responsible for the development, implementation and monitoring of sanitation standards and regulations.

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