GUIDANCE NOTE 11

Climate-Resilient Faecal Sludge Management

Guidance for Humanitarian Practitioners

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Abbreviations

CAPEX	Capital Expenditure
CGI	Corrugated Galvanised Iron
DEWATS	Decentralised Wastewater Treatment Systems
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
IFSTN	Intermediate Faecal Sludge Transfer Networks
ISTS	Intermediate Sludge Transfer System
O&M	Operation and Maintenance
OPEX	Operating Expenditure
PPE	Personal Protective Equipment
RC	Reinforced Concrete
UDDT	Urine-Diverting Dry Toilet
WWTP	Wastewater Treatment Plant

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Editing: Peta Sandison

Design: Ibex Ideas

Cover Image: Faecal sludge treatment plant 600m^3 polishing pond, Rohingya Camps. Oxfam.

1 Introduction

Climate adaptation is essential for faecal sludge management (FSM) in emergencies. Changing rainfall patterns, extreme floods, and prolonged droughts directly affect sanitation infrastructure, access, and safe disposal options. By integrating climate adaptation measures, FSM can maintain resilience, reduce public health risks, and provide service continuity under climate-induced stress.

This guidance highlights the impact of climate change on each stage of the FSM chain in humanitarian settings. It suggests solutions for each of the main contexts: Latrines for high water tables and flood-prone areas, Latrines in water-scarce areas, Latrines in cyclones and high wind environments and Climate change and the Sani Tweaks approach. The solutions are all field-tested, real-world examples from around the globe; many are from the Rohingya response in Bangladesh, because more innovative climate-adaptive work has been done there throughout the FSM chain than in any other response.

1.1 Impact of climate change on the FSM chain

Climate change has a significant and far-reaching impact on each stage of the faecal sludge management chain, from collection and transfer/transport, to treatment, reuse, and disposal. Rising temperatures, unpredictable rainfall patterns, and extreme weather events increasingly undermine the effectiveness and sustainability of FSM systems, particularly in low and middle-income countries. During heavy rains and floods, faecal sludge containment structures (such as pit latrines and septic tanks) are prone to overflow or structural failure, leading to widespread environmental contamination and public health risks. Floodwater can also infiltrate these systems, diluting the sludge and making it more difficult and expensive to manage. Conversely, prolonged drought reduces the availability of water for flushing toilets, increasing people's reliance on dry sanitation systems and altering the characteristics of the sludge. This, in turn, affects treatment methods.

The transport of faecal sludge is equally vulnerable, as roads and infrastructure may be damaged or made inaccessible by storms, floods, or landslides, hindering timely collection and increasing operational costs. Treatment processes are also sensitive to climate-induced changes. High temperatures may enhance pathogen die-off, but can accelerate decomposition, resulting in increased odour and toxic gas emissions. Conversely, colder temperatures can slow down biological treatment processes, lowering efficiency.

Excessive rainfall can overwhelm treatment facilities, dilute incoming waste, and trigger bypass events where untreated sludge is released into the environment.

The reuse of treated sludge, such as in agriculture, is impacted by shifting weather patterns. Drought increases the need for biosolids (the treated organic byproduct of wastewater treatment) because biosolids improve water retention, provide nutrients, and enhance long-term soil resilience, all critical under water-limited conditions. Alternatively, excessive rain can wash away applied sludge and spread pathogens. Energy recovery systems, such as those producing biogas, are also affected by changes in sludge composition and temperature fluctuations.

To address these challenges, FSM systems must be designed with climate resilience in mind. This includes constructing flood-resistant containment units, decentralising treatment facilities to minimise transport risks and integrating early warning systems for disaster preparedness and response. Adopting circular economy approaches, such as the reuse of treated sludge and the recovery of energy, can also enhance system sustainability.

In the face of flooding, droughts, rising temperatures, and sea-level rise, climate-resilient FSM systems in developing countries must be:

Low-cost (be aware that high Capital Expenditure (CAPEX) can lead to a lower Operating Expenditure (OPEX)

Resilient to climate shocks

Adaptable (as conditions change over time)

Safe, sustainable, and locally maintainable

This guidance addresses these system needs and covers the key design features of:

- Initial assessment
- Climate-resistant toilets
- Climate-resistant desludging and transfer systems
- Climate-resistant faecal sludge treatment plants or final deposit sites

2 Initial Assessment

2.1 Understand the local context[1]

By following the points below, gaps in provision can be identified and appropriate interventions can target the most vulnerable areas and people:

- Map the FSM infrastructure (containment systems, collection routes, treatment plants, disposal/reuse sites)
- Engage local stakeholders, such as local authorities, community leaders, service providers, NGOs, and residents, to share their knowledge of past disruptions and local adaptation strategies
- Understand current practices and service delivery models (formal/informal, centralised/decentralised)
- Understand both local cultural norms and national (country) policies
- Identify vulnerable populations (e.g., informal settlements, flood-prone areas)
- Assess how some groups (e.g., women, children, the elderly, disabled and marginalised communities) may be disproportionately affected by FSM disruptions and climate impacts. This helps ensure that resilience planning is inclusive and equitable
- Understand the local funding environment

2.2 Identify relevant climate hazards

Historical data and relevant climate predictions about the area will inform the scale of the adaptation of facilities required, e.g., how high to raise the latrines.

Identify:

- Historical and projected frequency, intensity, and location of climate events like floods, droughts, sea-level rise, extreme temperatures, and cyclones
- Seasonal variations that may influence service delivery or infrastructure stability
- Local knowledge of hazard-prone locations

For further information, see *Guidance Note 7, Climate Data for WASH Programming.* Additionally, access climate risk screening tools and local climate models and projections from national meteorological services or regional climate centres.

2.3 Assess the vulnerability of FSM components

Analyse each stage of the FSM chain for its exposure and sensitivity to climate shocks. Account for the high probability that future climate events will exceed historical precedents. For example, a standard design benchmark may use a 1 in 30-year flood level. A climate-resilient design is likely to be designed for a 1 in 100-year flood level:

- **Containment:** are the pit latrines or septic tanks likely to flood or collapse? Are they in low-lying or waterlogged areas?
- **Emptying and Transport:** will trucks or other means of transport be able to access households during heavy rains or floods? Are roads or bridges vulnerable?
- **Treatment:** can the treatment facility handle increased volumes from stormwater infiltration? Is it at risk of flood damage?
- **Reuse and Disposal:** will treated sludge be safe and usable during droughts or heavy rain? Are disposal sites secure from erosion or landslides?

Use field assessments, stakeholder interviews, and geospatial tools to support this analysis. See Annexe 1: Impact of climate change on elements of the sanitation chain.

2.4 Conduct a risk assessment

Combine the climate hazard data (Section 2.2) with FSM system vulnerabilities (Section 2.3) to estimate the:

- Likelihood of impact (e.g., how often floods may disrupt services)
- Severity of impact (e.g., how many people could lose access to safe sanitation, or how much untreated sludge might enter the environment?)

- Cascading effects of the impact (e.g., health risks, groundwater contamination, economic losses)

A simple risk matrix of risk versus mitigation or adaptation options can help to prioritise risks. See *Guidance Note 1: Climate Change Adaptations for WASH* for additional guidance on risk assessment.

2.5 Recommend adaptation and mitigation measures

Based on the assessment, propose context-specific interventions such as:

- Upgrading containment systems to be flood resistant
- Using mobile/decentralised treatment units
- Creating alternative access routes for sludge collection
- Strengthening governance, funding, and early warning systems for FSM during disasters
- Creating contingency plans for the failure of mitigation measures

Once the hazards and vulnerabilities have been assessed, validate the recommendations with the relevant stakeholders in the community and local authorities. Decisions can then be made about the siting, type and construction of the latrine system. See also Annexe 1: Impact of climate change on elements of the sanitation chain.

3 Climate-resistant Toilets

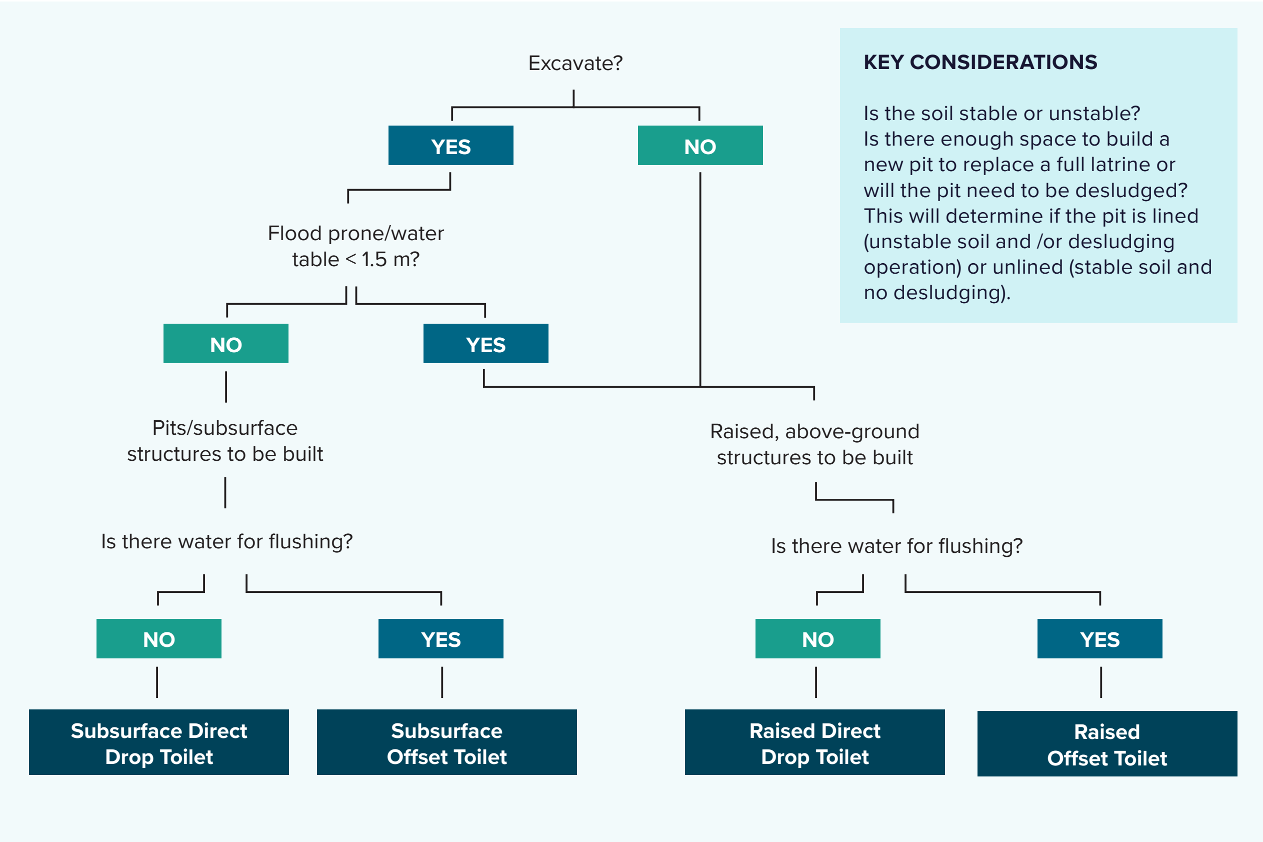
Several factors influence the type and location of a climate-resilient latrine, such as the soil type, position of the water table, and cultural appropriateness. In addition, the ongoing operation, management and cost considerations must also be addressed. For example, how will desludging be carried out - will there be access for desludging vehicles? Would access be affected by flooding (making on-site treatment, such as a septic tank system, Urine-Diverting Dry Toilets (UDDT) or Tiger Worm toilets, more appropriate)? This section supports **decision making for latrine selection** with key design considerations for different hazards and contexts.

3.1 Site selection

- Avoid flood-prone areas where possible
- Ensure a safe distance from water sources: position latrines at least 30 metres from wells, boreholes, or rivers. If unlined, the pits should be 1.5 m above the water table (Sphere, 2018). Use the worst-case scenario for groundwater levels to account for likely increases in fluctuations due to climate change
- Select elevated ground: choose higher or well-drained ground to minimise flood risk, whilst avoiding steep slopes, the risk of land slips and issues with access
- Understand the soil type to establish the permeability and types of soil (e.g., slumping clay requires substantially stronger lining materials)
- Ensure access for desludging is addressed in both the design and location, even in flood periods (wherever possible)
- Ensure there are no physical or social reasons which would limit access to certain groups at a particular location, including during floods

The most appropriate type of toilet for a site will depend on the excavation requirements, water table level, water and space availability. Figure 1 illustrates a decision-making process that uses site selection information to determine the design of the latrine. For example, in flood-prone areas, if it is impossible to find higher ground for excavation, elevated latrines would have to be considered as a design option.

Figure 1: Decision tree for selecting latrine options. Source: Excreta Disposal Manual. Oxfam



3.2 Latrines for high water tables and flood-prone areas[2]

The key design considerations for latrines in flood-prone and high water table areas are:

Limiting the contamination risk. Flooding or high groundwater can cause faecal matter to leach into water sources or spread pathogens.

Structural Stability. Flooding can collapse poorly constructed pits. Lining with bricks, stones, concrete rings, sandbags, or locally available materials (such as termite-resistant timber, bamboo, bamboo matting or cane) helps maintain the latrine's structural integrity.

Location and Siting. Latrines should be sited above the flood line and at least 30 m away from wells, boreholes, or surface water sources. Pits must be sited 1.5 m above the water table (Sphere 2018).

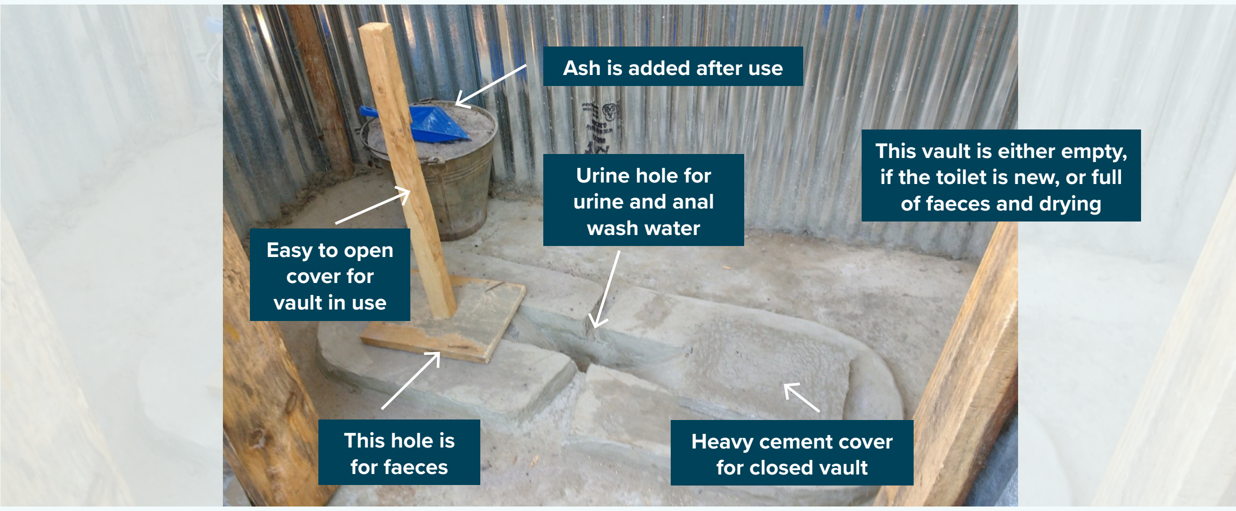
Maintenance and Access. Ensure latrines remain usable during rainy seasons: paths, platforms, and access must stay safe and dry. Sludge management must be designed for waterlogged conditions; sealed or lined pits facilitate safe emptying.

Community and Cost Considerations. Solutions must be affordable, locally appropriate, and acceptable to users. Designs should use locally available materials and align with cultural practices. Table 1 is a summary of potential solutions in high water table/flood-prone areas.

Table 1: Technical options for latrines or a septic tank in high water table and flood-prone areas

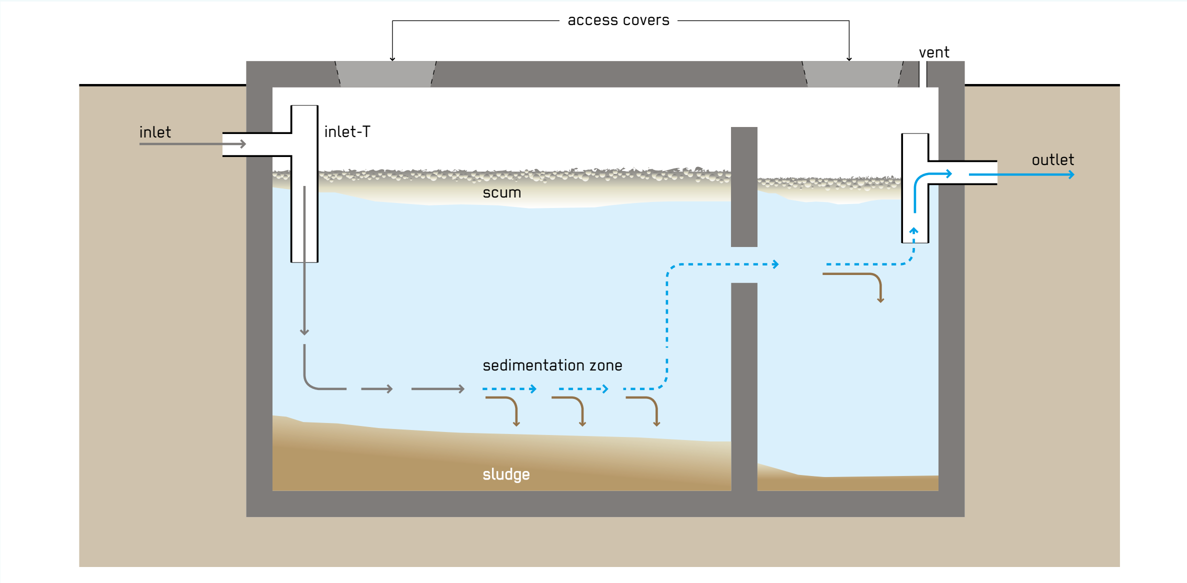
Latrine type: Eco-San/UDDT raised double vault Latrine

Appropriate for Floods?	Yes, as it is raised.
Cost	Initial cost higher than a pit latrine but savings on desludging over time.
Advantages	The urine is an asset for the community to use as a plant nutrient and compost fertiliser. Less smell than pit latrines.
Disadvantages	Moderately accepted, needs a lot of promotion for proper use and emptying. The steps are a potential barrier for elderly and disabled people.



Latrine type: Septic Tank

Appropriate for Floods?	✓	Yes, as it can be raised, or an anti-floatation rim can be added to the design.
Cost	$	CAPEX is high, but it has a low desludging frequency, saving money on long-term desludging costs.
Advantages	👍	Well accepted, little Operation and Maintenance (O&M) required & infrequent desludging.
Disadvantages	👎	Although the desludging is infrequent (every 3-5 years), it is much more costly.

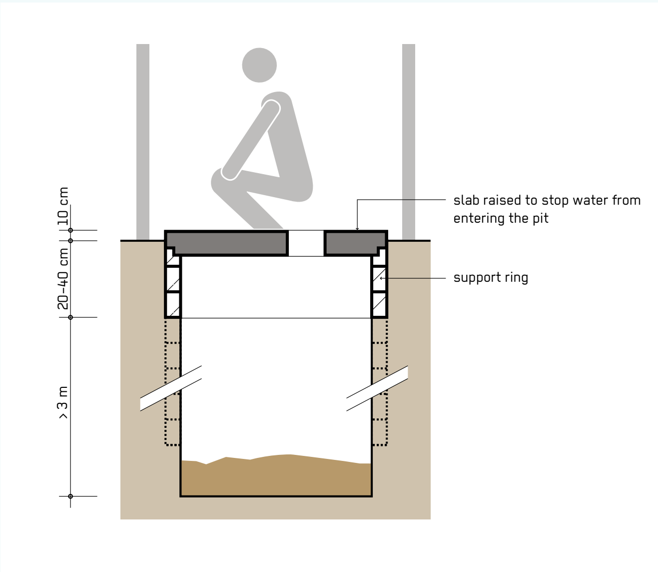


Effluent still contains contaminants and must be discharged either through a sewer or a percolation field. Consider how much space is available and whether the users want to reuse the effluent for irrigation (which would require an additional step for effluent treatment to reduce contamination risks, or for the idea to be discouraged).

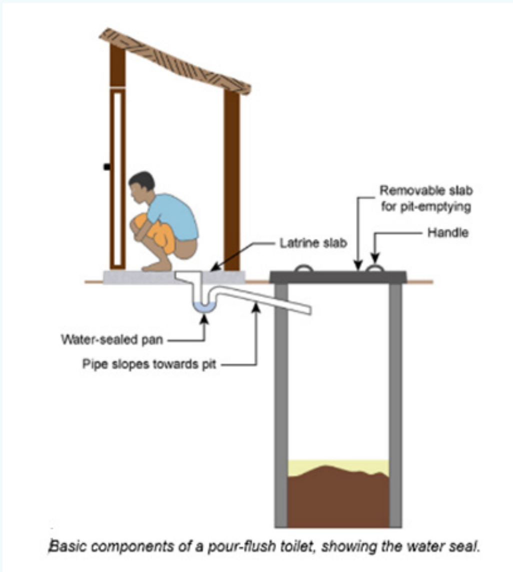
Reference: Compendium of Sanitation Technologies in Emergencies

Latrine type: Lined pit latrine (direct and off-set)

Appropriate for Floods?	More appropriate for high water tables than floods as it is not raised.
Cost	Moderate. Extra costs for lining
Advantages	Well accepted – lining protects walls during desludging & flooding events.
Disadvantages	Frequent desludging required depending on number of users & infiltration capacity.



Source: The Emergency WASH Knowledge Portal. Single Pit Latrine.



Source: [Adapted from Latrine Slabs. An Engineers Guide]

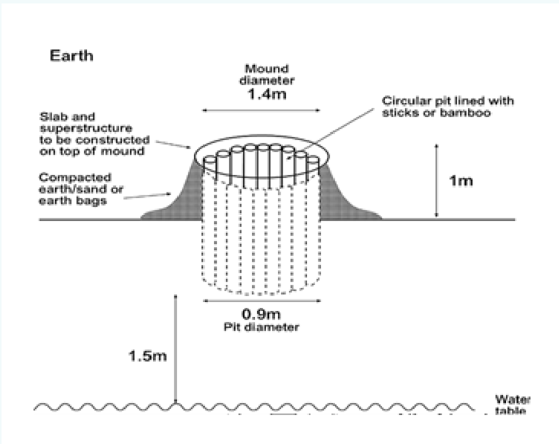
Latrine type: Earth-raised single pit latrine

Appropriate for Floods?	Yes, if the platform is protected.
Cost	Not significantly higher than a pit latrine.
Advantages	Accepted as a one family latrine.
Disadvantages	Small volume – not suitable for a communal latrine. Difficult for the less mobile.

Source: Oxfam Bangladesh

Source: Oxfam Bangladesh

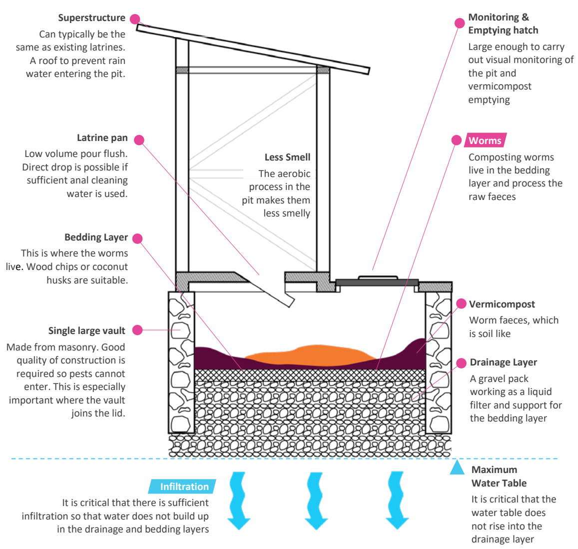
Source: Andy Bastable, Oxfam



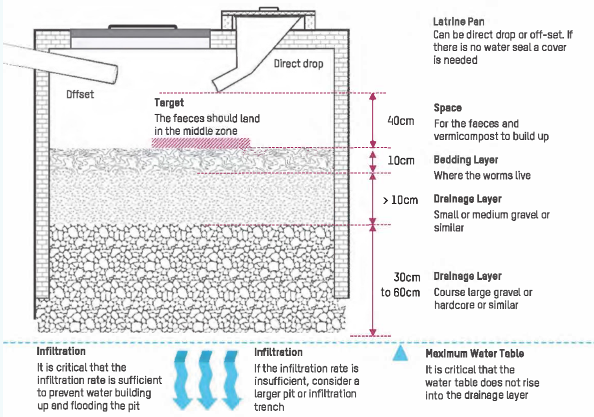
Source: 2004 version of Oxfam's Excreta Disposal Manual

Latrine type: Raised Tiger Worm Toilets

Appropriate for Floods?	Yes, as the digester can be raised.
Cost	High, similar to a septic tank.
Advantages	Savings on long-term desludging costs as it can easily last 5 years without desludging. Lack of smell is attractive to users.
Disadvantages	Family/users need to follow cleaning instructions. Only to be installed where there is a constant number of users. Not suitable in camp settings as the required constancy of users is difficult to regulate.



TWTs can be built from locally available materials. The specific design of TWTs varies based on the local context and application.



Source: Oxfam Tiger Worm Toilet Manual

Latrine type: Raised Latrines

Appropriate for Floods?	Yes, as it is raised. Less appropriate in the long term due to limitations in the size of the containment tank.
Cost	High, due to its raised design and need for frequent desludging of the containment tank.
Advantages	May be the only option in some flooded areas.
Disadvantages	The standard raised tank is only 1 m^3, requiring frequent desludging. Less well accepted due to its height and smell. Difficult for less able people.

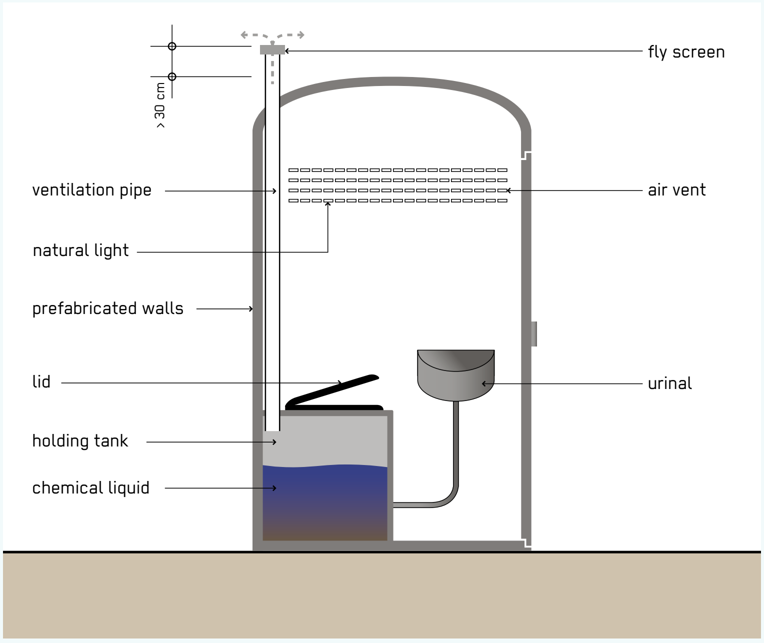
Raised toilets, Haiti 2010, Oxfam



Tayer Island, Ganyel, South Sudan, Oxfam

Latrine type: Portable Toilets

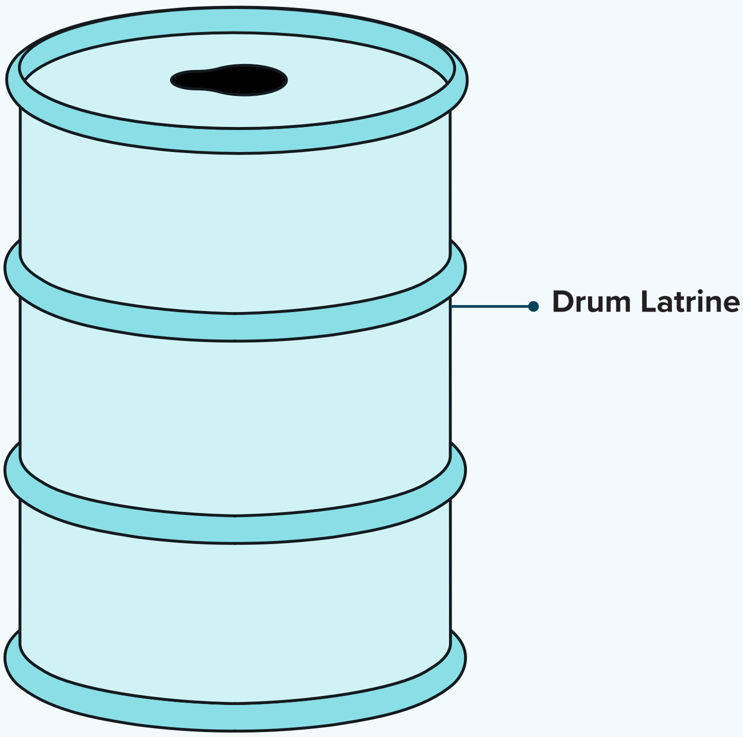
Appropriate for Floods?	✓	**Yes,** as can be easily located above the flood area. Only used as a short-term measure.
Cost	$	High, as they are normally rented from a provider, including a service agreement.
Advantages	👍	Easy to rapidly install. Offers more privacy than many emergency latrines.
Disadvantages	👎	High ongoing rental costs. Need good access for desludging/cleaning on alternate days (depending on user levels).



Source: [Compendium of Sanitation Technologies in Emergencies]

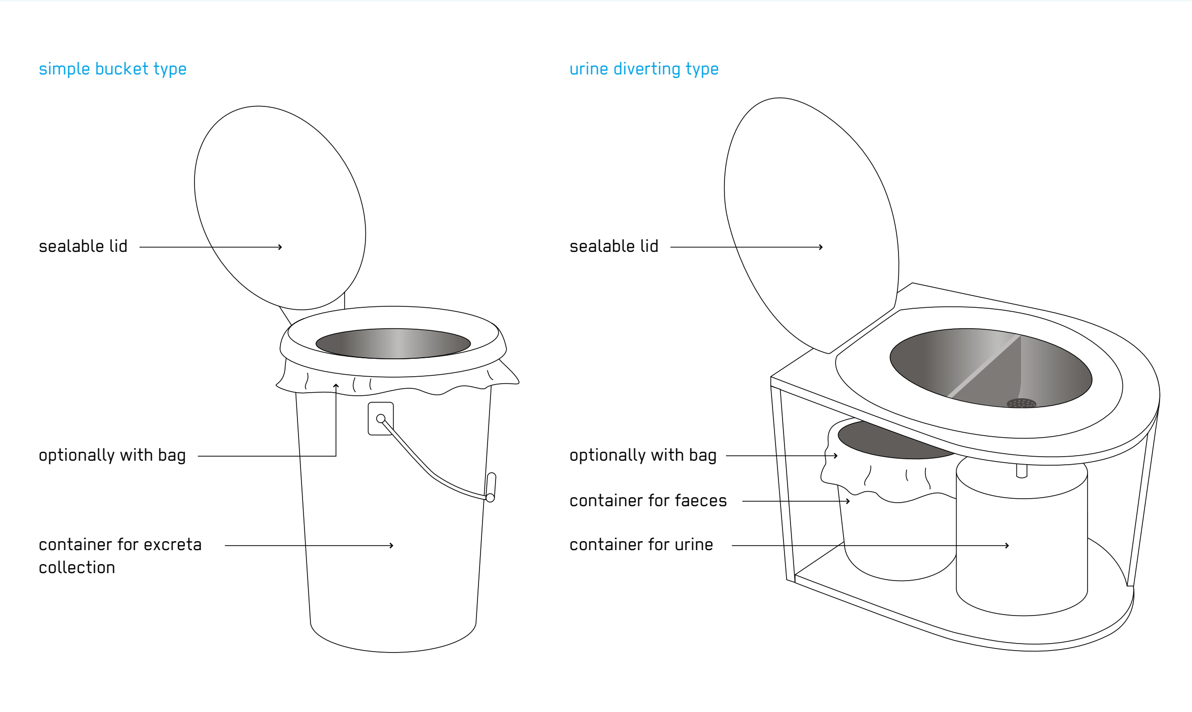
Latrine type: Drum Latrine

Appropriate for Floods?	More appropriate for a high water table than a flood zone.
Cost	Low CAPEX but high OPEX due to small containment volume, needing desludging or relocation.
Advantages	Quick and easy to install in unconsolidated soils.
Disadvantages	Not well accepted due to splashback issues. Pit fills up in 10-15 days and needs desludging at least once a week.



Source: © Ibex Ideas for Oxfam GB. Climate-Resilient Faecal Sludge Management. Oxfam. Oxford (2025)

Latrine type: Containerised toilets/bucket or UDDT version		
Appropriate for Floods?	✓	Yes, but mostly for flood responses as they are easily moved.
Cost	$	Same, or lower than a pit, but high management costs.
Advantages		Provides a solution for people with disabilities, or where access for desludging is very difficult.
Disadvantages		Less acceptable due to privacy issues and the emptying/management regime.



Consult with users to ensure there is an appropriate system to collect, transport and safely disposal of bag for clean containers.

Source: [Compendium of Sanitation Technologies in Emergencies]

Latrine type: Floating Toilet/UDDT in floating barrels – solids/liquids stored in different barrels.

Appropriate for Floods?	✓	Good for areas with prolonged periods of annual flooding.
Cost	$	Medium/high cost to build, but high costs of desludging the barrels.
Advantages	👍	Accepted in flood-prone communities, as they can use urine as a plant nutrient.
Disadvantages	👎	Desludging requires pumping out into mobile tankers.

Figure 2: Floating latrines, Bangladesh

Figure 3: Floating latrines, Cambodia

Design specifications for these latrines are available[3].

3.2.1 Drainage and sealing

The purpose of ensuring good drainage around the latrine and sealing the pit is to prevent rainwater or floodwater from entering the pit. The following actions are good practice for flood-prone areas:

- **Drainage channels:** install surface drainage around the latrine to divert rainwater. Ensure the channels are safe for children and for users at night, and have sufficient crossing points, especially for less mobile people. A simple trench or bund is sufficient for individual latrines.

Figure 4: Drainage channel. Rohingya Camps, Cox's Bazar, Bangladesh. Oxfam

- Make sure the **roof has an overhang** so rainwater is not directed down the walls, undermining the slab.
- **Seal the pit collar:** using concrete or cement, seal the gap between the pit lining and the pit cover/desludging lid to prevent surface water inflow.

- **Make a protective apron at the base of the latrine walls:** the triangular wedge at the base of a latrine is commonly called a 'drainage apron' or 'splash guard'. Its purpose is to direct rainwater away from the latrine pit to prevent pit flooding and protect the latrine's foundation from erosion, which helps to maintain the structure's stability. Common materials for the apron are:
    - **Cement:** a concrete apron is the most durable and effective solution. It provides a solid, impermeable barrier that can be sloped perfectly to direct water away from the foundations
    - **Compacted soil:** a compacted earth berm can be shaped around the base and offers a simple, low-cost solution. While less durable than cement, it is effective provided it is maintained
    - **Plastic sheeting:** can be used as a waterproof layer underneath a layer of soil or gravel to provide additional protection against water seeping into the ground near the pit
- **Preventing backflow:** for all off-set latrines in flood-prone areas, a non-return valve can be installed in a chamber above the flood level to prevent flooded pits or tanks from backing up into the latrine. However, in typical humanitarian situations, it is easier to ensure the squat hole is above the projected flood level. Sato pans[4] can prevent backflowing in direct drop latrines. Another low-cost idea, in the author's experience, is to use a floating ball which fits into an adapted inlet, blocking it off once the liquid contents rise.

Figure 5: Emergency latrine in Cox's Bazar, Bangladesh showing a large overhang. Solidarités International

3.2.2 Pit lining materials

In areas of very stable soil or where there is good soil infiltration capacity, pits can be unlined, constructed with a honeycomb structure to allow infiltration of the liquids, or only lined for the first 1 m of the pit, where the soil is more unstable. If the pit is designed to be desludged, it is always advisable to line it.

In flood-prone areas, it is strongly recommended to line the pit to:

- **Prevent pit Collapse:** especially in areas with slumping clay or black cotton soil, or in dry, sandy, unstable soil conditions.
- **Enable desludging:** pits without a lining should not be pumped out, as the soil from the walls will also be sucked in, leading to collapse.
- **Limit Contamination:** proper lining helps reduce the seepage of waste into the surrounding soil and groundwater, protecting nearby water sources. It also reduces floodwater entering the pit.
- **Pest and Vector Control:** reduces burrowing animals and insects: lining can prevent pests like flies, mosquitoes, and rats from accessing the waste.

Options for low-cost linings for flood-prone areas:

Table 2: Latrine pit lining options

Lining material	Advantages	Disadvantages
Precast Reinforced Concrete (RC) rings	High strength, good circular load distribution, durable, fast to install, widely referenced in standards, can be jointed/water-tight.	Heavy to transport/handle, higher upfront cost, needs crane/chain block, joints can leak if poorly sealed.
Cast-in-place RC (monolithic)	Excellent durability, fewer joints, therefore better leak resistance.	Requires skilled labour/ formwork (moulds), slower, cement-intensive, difficult in high groundwater without dewatering.

Lining material	Advantages	Disadvantages
Ferrocement rings/panels	Lighter and cheaper than RC for same capacity, uses less cement/ steel, can be site-fabricated, relatively crack-resistant if well-cured.	Quality control can be variable, corrosion risk if cover is thin, still needs anchoring, less understood commercially.
Brick masonry with cement mortar	Materials widely available, adaptable to irregular pits, moderate cost, easy repairs.	Weak under scour/ saturation, mortar joints leak, prone to collapse in prolonged flooding, slow to build.
Stone masonry in cement mortar	Strong in compression, good durability, local stone often cheap, tolerates abrasion.	Heavy, needs skilled masons, irregular geometry complicates sealing.
PVC/HDPE plastic rings	Lightweight, fast installation, corrosion-proof, smooth interior, fewer joints if using long sections.	Easily buoyant due to hydrostatic pressure in high water tables - must be anchored, often has to be imported, cost can be high, limited choice of diameters locally.
Corrugated galvanised steel sections	High ring stiffness, quick modular assembly, large diameters possible.	Corrodes in aggressive soils/floodwater, needs coatings, joints can leak, sharp edges, safety considerations.
Fibreglass rings/liners	Very light, corrosion-resistant, can be factory water-tight, quick to install.	High buoyancy (anchoring essential), costly, impact damage risk, limited local availability/repair skills.
200 L barrels (can be joined end-to-end)	Can be cheap in some areas.	Small pit volume, rusts in water, difficult to connect barrels with a watertight seal. Not readily acceptable due to splashback problems when using.

Lining material	Advantages	Disadvantages
Gabion cage (wire mesh with stone infill)	Excellent against scour/erosion, permeable - reduces pore pressure, robust if founded/ anchored. Easy to transport to site, then infilled locally.	Needs quality wire (galvanised/PVC-coated), bulky, difficult to make water-tight, corrosion over time, higher material handling.
Sandbags/ geotextile bags (stacked)	Very rapidly installed emergency works, adaptable to wet placement, good initial scour protection.	Short-term only, settlement and piping, bags degrade, poor structural integrity for long-term lining.
Old tyre rings filled with gravel	Readily available, good energy absorption, permeable - relieves hydrostatic pressure.	Hygiene/odour issues, hard to seal, harbours vectors, community acceptance problems, variable quality.
Timber planks/ post-and-plank	Materials/skills often available, quick, can be replaced later.	Rot/termites, joint gaps, low resistance to saturation/ scour, generally temporary.
Bamboo lining (woven mats with posts)	Very low cost, rapid community construction, good for temporary/ emergency use, biodegradable.	Short lifespan (rot/insect attack), loses strength when wet, high collapse risk in floods unless heavily braced, not watertight.
Stabilised soil blocks/ compressed earth blocks	Very low cost/embodied energy, local production.	Poor flood/saturation resistance even when stabilised, high failure risk without robust plastering and apron, generally not advised in flood zones.

3.3 Latrines in water-scarce areas

The climate predictions for the future are typically for more frequent extreme rainfall events leading to floods, and the increased occurrence and duration of droughts. In low-income countries where water is scarce, excreta disposal must be managed in a way that minimises water use for flushing while ensuring health and environmental safety. Water for anal cleansing is, however, an essential requirement.

Where off-set pit latrines are commonly used, such as in Asia and much of the Middle East, water is required to flush the excreta through the U-bend or pipe connecting to the pit. Sewered connections are uncommon in humanitarian situations; they require substantially more water for conveyance. Disease risks are exacerbated by water scarcity due to a lack of water for hand washing after latrine use. Many of the dry sanitation options may face resistance due to social taboos.

Excreta disposal options in water-scarce, low-income humanitarian settings:

Table 3: Latrine options in water-scarce settings

Latrine Type	Appropriate for water-scarce settings	Cost	Advantages	Disadvantages
Simple Direct Drop Pit Latrine	Yes: no flushing water required. Good for Camps Rural/ peri-urban with space.	Low	Simple to build, low cost.	Risk of groundwater pollution; pit must be relocated or emptied. If soil infiltration is good, can be too solid to empty by pump.

Latrine Type	Appropriate for water-scarce settings	Cost	Advantages	Disadvantages
Twin-Pit Latrine	Flushing required but water use is low when using a reduced-diameter U-bend & pipes. Rural, semi-arid areas with some space.	Low - Moderate	Alternating pits allow safe reuse of decomposed sludge.	Requires user understanding, as when the 1st pit is full, the inlet must be switched to the 2nd pit. Could use grey water for flushing.
Urine-Diverting Dry Toilet	No flushing required. Good for very dry regions and fertiliser reuse settings.	Moderate	No water needed, allows safe reuse of urine and composted faeces.	Requires user behaviour change and regular maintenance.
Container-Based Sanitation	No flushing required. Good for urban slums.	Moderate (low for users)	Very low water use, avoids pits, can be hygienic and compact.	Needs reliable frequent collection service, may face social resistance.
Pour-Flush Latrine (Twin-Pit or Sealed Tank)	Low (1-2 L/ flush). Good for semi-arid areas with some water or greywater available.	Moderate	More hygienic, familiar to users, adaptable to twin-pit design.	Needs some water; not suited for extreme drought without backup water.

3.4 Latrines in cyclones and high wind environments

Climate change is leading to an increase in severe weather events, such as cyclones and hurricanes. There have been several Asian cyclone events which have led to latrine superstructures being blown away. Latrines constructed in cyclone/hurricane-prone or high-wind areas must be built to withstand high winds. Recommended actions for wind-proofing latrines are:

1. Site the latrines near natural barriers (trees, shrubs, hedges, hillsides, walls) or create wind barriers.
2. Use robust foundations, such as wooden or metal posts buried at least 0.5-1.0 m into the ground and tamped with stones or stabilised soil. In a very high-wind area, use concrete or stone footings.
3. Anchor the superstructure with guy ropes, with rope bracing tied to buried stones or stakes.
4. Use heavier building materials, such as sand cement blocks or bricks, where possible. Cross-bracing with wood or metal in an ’X’ shape adds rigidity.
5. Ensure the roof is robust and firmly anchored to the walls, and the overhang is ≤ 30 cm to reduce uplift forces. The roof can be tied to the frame using low-cost perforated straps or flattened scrap metal.

3.5 Climate change and the Sani Tweaks approach

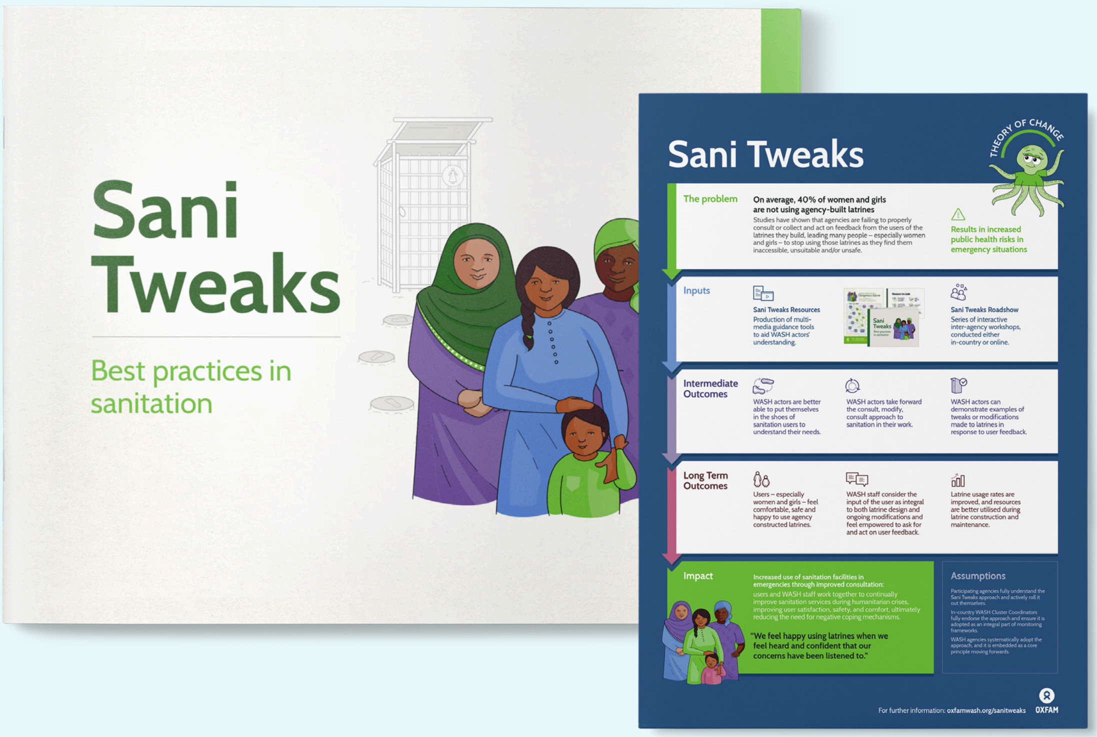
More severe weather events caused by climate change will increase the existing challenges faced in providing sustainable latrines in humanitarian contexts. Floods, cyclones, and extreme heat events can cause a rapid deterioration of first-phase plastic sheeting emergency superstructures, as well as increased warping of wooden structures so that doors no longer shut properly, making it more difficult to provide a secure, private and ’comfortable’ latrine space.

Therefore, it is more important than ever to use the Sani Tweaks approach encapsulated by *Consult - Modify - Consult* to ensure that the community or latrine-user groups are consulted about how to address these additional challenges, that users are listened to, and their feedback is seen to result in actions; or if not, explanations of why it is not possible. In this way, by consistently involving the users in design and maintenance considerations and enabling them to do simple repairs themselves, some of the extra challenges posed by increased extreme weather events can be mitigated.

During the Heat Spots in South Sudan in 2024, when many schools were closed due to extreme heat, people said it was too hot to go into the latrines. This was because the latrine superstructures were made of Corrugated Galvanised Iron (CGI) sheeting and lacked ventilation. A ‘tweak’ can adapt to the new situation. Even if replacing the superstructure is too difficult, creating extra ventilation at the top and/or painting the roof white is usually possible. Generally, if an area is prone to heat spots, CGI sheeting should not be used for superstructure walls.

For more information on Sani Tweaks, go to: https://www.oxfamwash.org/wash-tweaks/

Here you will find resources in multiple formats and languages, links to training courses, research reports and more.

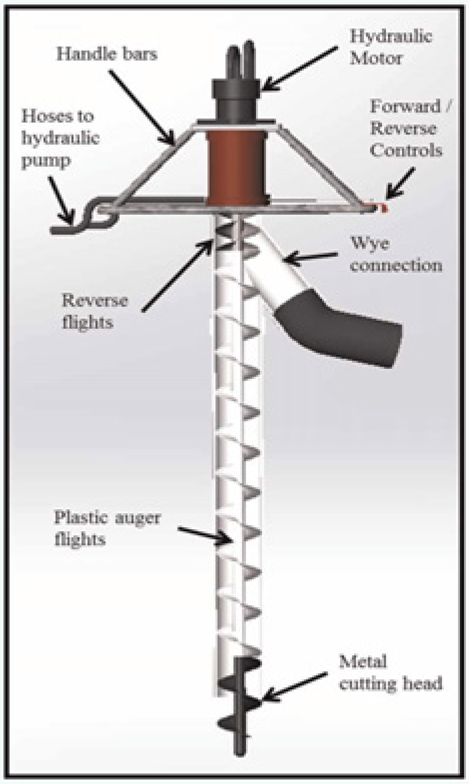


4 Climate-resistant Desludging and Transfer Systems

For **flood-prone areas,** the main climate change issue affecting desludging is maintaining access to the latrines for desludging equipment. Flooding often damages roads and bridges, making access difficult and sludge haulage costly or unreliable. Faecal sludge transfer pipelines can also be damaged in flooding events. Furthermore, too much water entering the pit can increase the quantity of sludge and the frequency of desludging required.

Flooded latrines are a major source of contamination during flood events, potentially contaminating the surrounding environment. As a mitigating preparedness measure, pit latrines in flood-prone areas can be emptied before the rainy season, when flooding is more likely to occur.

Figure 6: Motorised Pit Screw Auger for desludging compacted sludge. Image from Rogers, T. et al. 2014

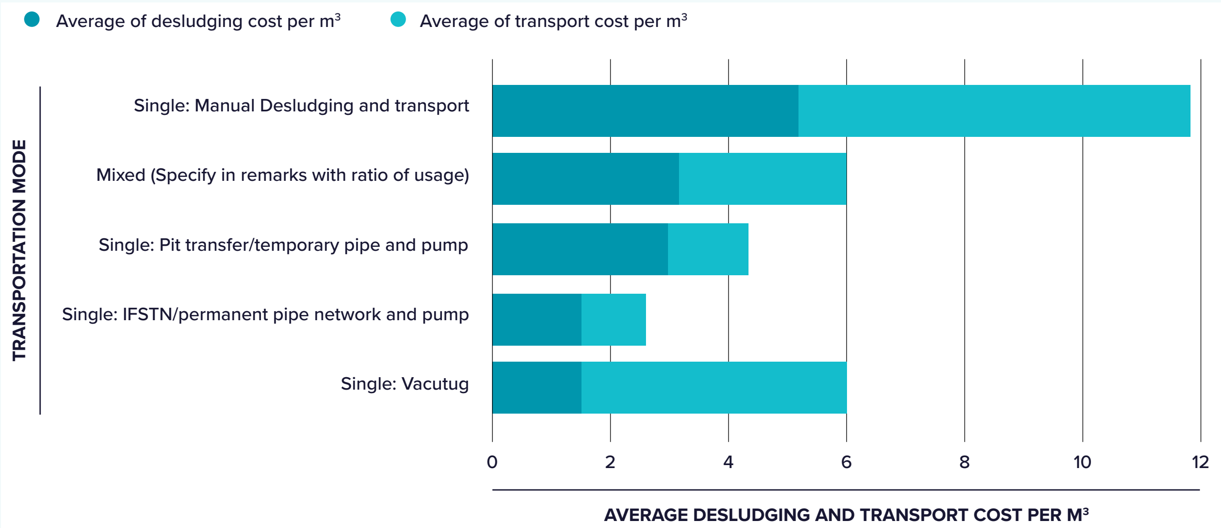


In environments **where water is scarce,** direct drop latrines, a Sato pan, or a slab with a hole cover and no U-bend are preferred to reduce water use (see Table 3). When offset latrines are used in water-scarce areas, it is good practice to use smaller-diameter U-bends and pipes to reduce the water used for flushing. Conversely, if the liquid infiltration from the pit is good and/or the desludging frequency is high, the sludge may dry out. It can then become compacted at the bottom of the pit and be difficult to desludge with a normal manual or motorised pump. In this case, augers (see Figure 6) or manual digging should be considered to excavate hardened sludge. In higher ambient temperatures, sludge decomposition is accelerated, increasing the odour and methane release during transport, potentially causing a public nuisance.

4.1 Climate adaptations for desludging systems

The most common desludging technologies are: Vacuum trucks, Pit transfer/temporary pipe and pump, Manual Desludging and Transportation, Intermediate Faecal Sludge Transfer Networks (IFSTN) or a combination of these when more than one transportation mode is used. A pipe-based system can largely avoid flood and cyclone-related issues of access, and, as Figure 7 shows, an IFSTN is the most cost-effective system.

Figure 7: Monthly desludging and transportation costs per cubic metre of sludge.



($USD/m3/month) Source: Technical assessment on FSM in the Rohingya Response, Arup 2022

The IFSTN system is more cost-effective and climate resilient because:

1. During floods, a buried pipeline is less prone to erosion or flash flood damage than the road infrastructure required for trucks to desludge and transport the waste to a treatment facility.
2. It is considerably cheaper compared to the common practice of using labour and/or sludge pumps to desludge, and tankers to transport the waste - even if additional pumping is required to transfer the sludge.
3. It reduces public health risks and environmental contamination. Due to the frequent spillage of septage (pit sludge) during normal desludging and transport, a piped transfer system substantially reduces public health risks to both the desludging staff and the population.

Box 1: An Intermediate Sludge Transfer System

Manual Stirring inside Plastic Tank While Pumping to the Next Transfer Station

An Intermediate Sludge Transfer System (ISTS) was installed by Oxfam, in collaboration with UNHCR, in the Cox's Bazar Rohingya Camps (Oxfam, 2023). It is currently one of the most cost-efficient ways of emptying and transferring the sludge in camps to the closest FSTP location, saving on transportation costs and improving safety. Several plastic tanks of different sizes are installed in different strategic locations in the camps. These tanks are connected by HDPE pipes to the nearest FSTP site (or close to an accessible roadside location), from where the sludge can be trucked to an existing centralised system. Shared or communal latrines are located within a 100-50 metre peripheral area of the tank and are desludged into that tank. In some areas, pumping is needed after each transfer tank to reach the next tank or FSTP. The ISTS eliminates the need for manual emptying and carrying of the sludge, reduces the spread of diseases and improves the public health situation by keeping the latrine facilities functional and well managed by the community.

Photos: Cox's Bazar Camp IFSTN. Oxfam

Other options, in addition to these transfer systems, are sewerage systems. They include traditional sewers, small diameter sewers and vacuum systems.

Table 4: Sewerage system options for camp environments

Transfer system Type	Low-Water Sewerage Systems or ISTS. A modified sewer system[5] that uses smaller diameter, shallow-buried pipes laid at flatter gradients.
Cost	20-50% lower CAPEX than conventional sewerage systems.
Advantages	Less excavation; easier maintenance.
Disadvantages	Requires community cooperation and regular cleaning. Needs minimal water for flow, so not fully 'dry'.
Water Use	Requires less water than conventional sewerage systems.
Best For	Designed to connect clusters of households.

Table 4 (cont.)	
Transfer system Type	Vacuum Sewer Systems. Waste is transported using air pressure rather than water. Toilets are connected to a vacuum station via sealed pipes.
Cost	High capital cost.
Advantages	Good for dense urban or flood-prone areas. Minimal leakage risk due to negative pressure.
Disadvantages	Not well understood by practitioners. Requires electricity and technical operation. More complex O&M than other systems.
Water Use	Very low - some systems use 0.5-1 litre per flush.
Best For	Ideal for flat terrain, high water tables, or rocky ground.

The selection of the most appropriate desludging methodology depends on the system's resilience to the impact of climate change. It also depends on the topography of the site, population density, materials, expertise, and the budget available. Importantly, selection must recognise that most camps for displaced people or refugees are long term, so the chosen desludging method must be sustainable and keep OPEX costs as low as possible.

5 Climate-resistant Faecal Sludge Treatment Plants or Final Deposit Sites[6]

The standard options for depositing the desludged material are landfill containment and faecal sludge treatment plants. There are multiple environmental concerns with landfill (i.e., burying the sludge), including contamination of the water table, over-topping by floods and the need for protection from animal or human contact; it should only be considered as a last resort – and even then, only with proper lining, flood, and human and animal protection measures in place.

The preferred option in developing countries is to design low-cost faecal sludge treatment plants (FSTPs) that are resilient to climate change. That means making them robust against floods, droughts, heatwaves, extreme rainfall, and rising groundwater levels.

Issues which affect FSTPs are the overloading of treatment capacity, climate-driven surges in desludging needs that overwhelm existing treatment systems (e.g., after floods), leachate and runoff risks. Extreme rainfall increases the risk of untreated sludge leaking into water bodies. The impact is often inequitable: informal settlements, flood-prone areas, and poor households face greater service disruptions and higher health risks.

Key Principles

- **Plan with future climate risks in mind,** not historical averages
- Balance **initial cost savings** with **lifecycle resilience**
- Use Geographic Information Systems **or flood-risk maps** to site FSTPs wisely
- Include **climate and disaster-risk training** in O&M manuals

Box 2: Changes in performance of FSTPs and Wastewater Treatment Plants (WWTPs) due to climate change

The characteristics of WWTP effluent (i.e., temperature and biological organic load) and FSTPs will change in response to different climate conditions (e.g., rising/falling temperatures, more or less water and dilution). The effects of these parameters on WWTPs will depend on their design (i.e., the range of biological organic loading and flows allowed), which will dictate the plant's ability to cope with such variations in characteristics.

Too much water at WWTPs (due to increased volume and frequency of rainfall, extreme weather, or sea level rise) can result in excess wastewater spilling into the environment. Wastewater treatment systems typically have buffering and bypass spill control systems in place to manage heavy rainfall events - especially for combined sewers. Prolonged wet seasons or rainfall events can cause the WWTP to operate above its design capacity, raising its operating costs. By contrast, prolonged dry periods lead to low flow and high-strength wastewater, which can contribute to increased blockages and more concentrated biological organic loads; these are harder to treat.

Temperature changes due to climate change can also impact treatment. WWTPs can be sensitive to temperatures below 4 °C, where systems physically cannot treat ammonia. This results in the release of untreated wastewater, with high levels of nitrogen, into the surrounding environment. With temperature increases, the rate of biological treatment reactions increases. However, in practice, incoming effluent temperatures above 40 °C have been observed to adversely affect membrane technology during the treatment stage. This phenomenon is not well-documented in the literature, and further investigation is needed. [Anna Grieve, Associate at Arup. 2025 personal communication.]

Recommendations for climate-proofing an FSTP, without significantly increasing costs:

1. Choose Resilient Sites and Elevations

- **Avoid low-lying, flood-prone areas**
- **Raise critical infrastructure** (inlet chamber, drying beds, composting units) on embankments or plinths, if in a flood zone
- **Design for safe overflow** in case of heavy rains; construct overflow channels to unpopulated areas
- Use **gravel sub-bases** and **drainage trenches** to manage stormwater around the plant

See Arup (2019 and 2024)[7] for more information. For an FSTP decision-making tool, see Arup (2024)[8].

2. Use Low-Energy Treatment Technologies

The systems in Table 5 are more tolerant of climate variability and operational lapses than most fabricated, decentralised treatment systems[9].

Table 5: Low-Energy Faecal Sludge Treatment Technologies

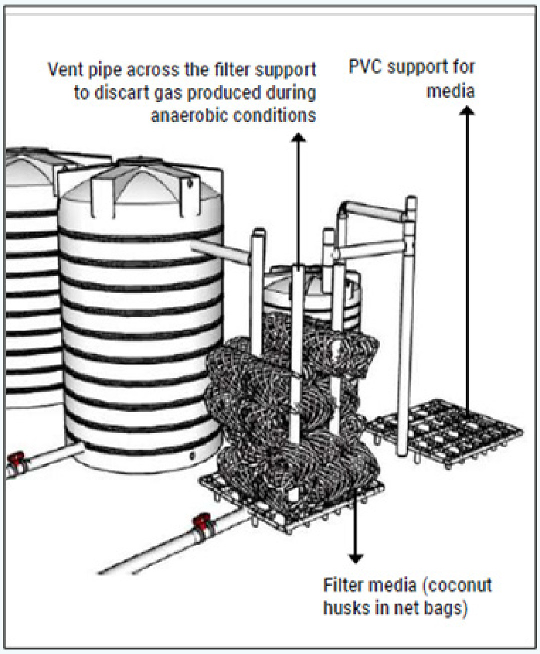
Technology	Climate Resilience Benefit	Notes
Unplanted or Planted Drying Beds	Adaptable to variable sludge volumes; passive drying.	Use greenhouse covers (i.e., a transparent or semi-transparent roof) in high-rain zones.

Technology	Climate Resilience Benefit	Notes
Composting of faecal sludge (co-composting with organics)	Pathogen destruction with proper heat; resilient in wet or dry conditions.	Add roof/cover during rain.
Constructed Wetlands	Can handle flow variability; self-recovering.	Protect from erosion during floods.
Anaerobic baffled reactors	Handles intermittent flows; low O&M.	Needs desludging every 1-3 years.
Biogas digesters	Reduces methane emissions; handles varying inputs.	Insulate in colder/ hotter climates.

3. Decentralised Systems

Decentralised FSTPs or decentralised wastewater systems (DEWATS) can serve smaller areas. They avoid loss of access for desludging caused by flood-damaged roads and reduce the cost of transport. Constructed Wetlands are an example of a low-energy, decentralised option (see Table 5). Others include decentralised chemical treatment (such as by using lime), septic tanks and Upflow Filters[10].

Figure 8: Sketch of an example Upflow Filter Plant (Arup 2019)



Constructed wetlands treat FS by separating solids/liquid by filtration through the media bed. The solids accumulate around the plant roots and are stored for long enough to achieve biochemical stabilisation and pathogen die-off. Liquids are filtered as they drain through the bed media, separating out the remaining solids.

Upflow filters are tanks where the inlet is below the outlet level, forcing upflow and anaerobic conditions. The solids/liquid separation is achieved through settlement and filtration, as well as some digestion of solids under anaerobic conditions. Solids are progressively removed by a series of filters and are disposed of from the bottom zone of the tanks. Liquids pass forward from the top of the tanks for further treatment or disposal.

4. Incorporate Modular Design

Scalable modules allow the isolation, repair, and expansion of components independently, e.g., adding multiple drying beds, adding buffer storage tanks to manage peak loads during storms, or desludging surges. An example of an adaptation of a septic tank as a long-term containment and treatment option is IOM's pilot study in Syria[11]. The project piloted a 3-chamber communal septic tank design supported by a study to investigate its efficiency and possible additional treatment steps.

Table 6: Modular design elements of an FSTP

Module	Purpose	Key options / technologies	Design Considerations	Scalability & Flexibility
1. Reception & Screening	Remove large debris, regulate inflow.	Manual/ automated screens, grit chambers.	Low-cost, easy maintenance, safe operator access.	Units can be duplicated or upgraded with automated screening.
2. Primary Treatment (Solids-Liquids Separation)	Separate solids for stabili-sation & drying.	Sedimenta-tion tanks, settling-thick-ening tanks, unplanted/ planted dry-ing beds.	Consider local material use, hydraulic loading, sludge characteristics.	Add more beds/ tanks in parallel as sludge volumes grow.
3. Sludge Stabilisation & Drying	Reduce pathogens, moisture and odours.	Drying beds, composting, co-composting, solar drying.	Land area availability, climate (sun, rain), vector control.	Additional beds or mechanised dryers can be added modularly.
4. Liquid Treatment (Effluent Management)	Treat separated liquid fraction.	Anaerobic baffled reactors, constructed wetlands, waste stabilisation ponds, filtration units.	Effluent standards, space availability, simple O&M.	Add treatment units in series or parallel; switch to higher tech if needed.

Module	Purpose	Key options / technologies	Design Considerations	Scalability & Flexibility
5. Resource Recovery & Reuse	Recover nutrients, energy, water: the circular economy.	Compost for agriculture, briquettes/ pellets, biogas, treated water reuse.	Market demand, safety standards, local regulations.	Recovery units can be plugged in as demand grows.
6. Storage & Final Disposal	Safe handling of residues.	Covered storage, landfill co-disposal, soil amendment.	Safety, transport logistics, environmental protection.	Modules can expand in response to waste generation.
7. Support Infrastructure	Ensure functional-ity & sus-tainability.	Access roads, drainage, laboratory, operator facilities.	Cost-effectiveness, staff training, local supply chain.	Designed for phased expansion.
8. Cross-cutting: monitoring & O&M	Track per-formance & ensure sustainabil-ity.	Simple test kits, logbooks, remote monitoring (if feasible).	Build operator capacity, plan preventive maintenance.	Monitoring system scaled with plant size.

5. Flood-Resistant Construction

- Use **reinforced concrete** or **masonry tanks** sealed against infiltration
- Elevate **electrical components, valves,** and **pumps** above expected flood levels
- Install **overflow bypasses** with safe drainage for beds and tanks
- Use **perforated raised drying beds** with underdrains and elevated effluent discharge points

6. **Protect from Heat and Drought**
   - **Add shading** (e.g., with simple bamboo roofs or netting over pumps, compost or biogas units). Some systems, such as waste stabilisation ponds, need ultraviolet light; they should not be shaded
   - **Reclaim treated water** for wetting compost or irrigating vegetation around the plant
   - Design for **variable inflow** - for example, allow partial-bed loading or batch-based treatment

7. **Design for Power Flexibility**
   - Use **gravity-based flows** where possible
   - Select **manual desludging tools** and **solar-powered pumps/blowers** if electricity is unreliable
   - Consider **anaerobic digesters** with biogas generation to power some operations

8. **Stormwater and Surface Water Management**
   - Include **stormwater drains, soak pits,** and **perimeter bunds**
   - Create **buffer zones** with vegetation (e.g., vetiver grass) to reduce erosion and runoff impacts

9. **Community Resilience and Operations**
   - **Train local operators** for extreme weather scenarios (emergency overflow, system shutdown)
   - Use **robust, locally sourced materials** to simplify repairs
   - Design with **O&M simplicity** in mind (e.g., easy-to-clean screens, no complex valves or controls)
   - **Support local entrepreneurs** in emptying/treatment services
   - Build climate and WASH planning into **local disaster response strategies**

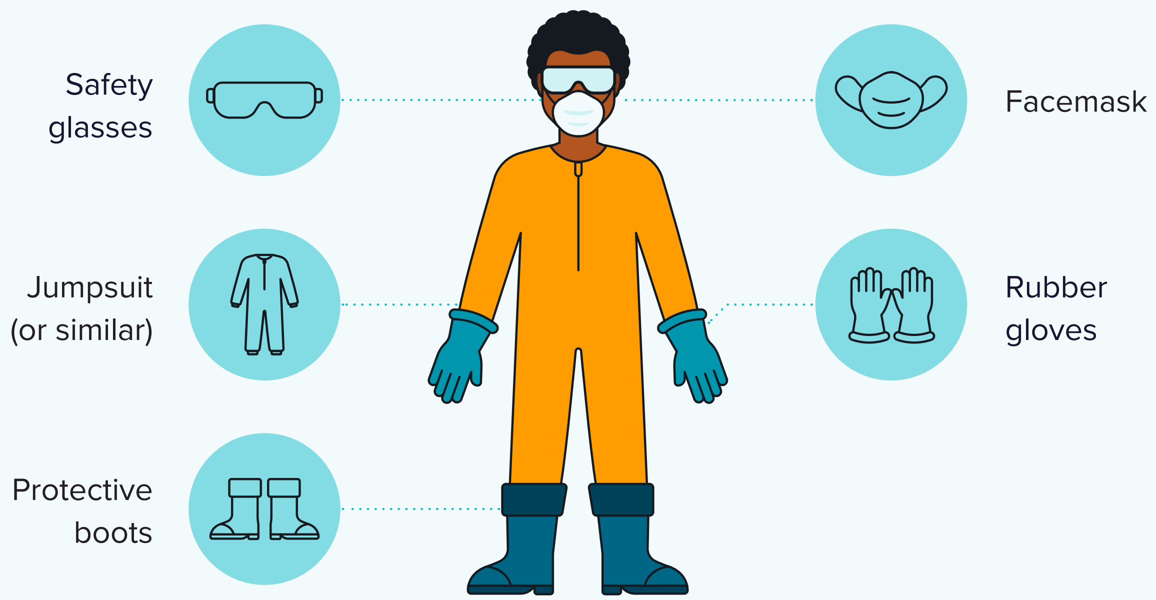
For more information and a comparison of different types of FSTPs used in emergencies, see Arup and Oxfam (2019)[12] and the Compendium of Sanitation Technologies in Emergencies (Gensch et al. 2018)[13].

6 Hygiene, Health and Safety

With a predicted increase in extreme weather events, especially very wet or flooding conditions, the risk of faecal contamination for individuals and the environment will significantly increase. Furthermore, in periods of extreme heat, the risk of heat exhaustion and dehydration will be heightened, leading to people making mistakes.

Due to accelerated decomposition, the release of harmful gases, such as methane, hydrogen sulphide, and ammonia, will also increase. Warm conditions can boost pathogen proliferation, increasing the risk of infection through skin contact or inhalation. These risks can become deadly. Therefore, it is more important than ever to observe existing safety protocols and to add further protection against extreme heat for the staff (such as extra hydration, shade), Personal Protective Equipment (PPE), and medical support, including vaccination against Tetanus and Hepatitis.

Every desludging worker should receive training on hygiene and standard operating procedures for desludging. This should cover the principles of transmission and prevention of faecal-related diseases. Table 7 includes examples of good practice in operating FSM from a hygiene, health and safety perspective.



Source: © Ibex Ideas for Oxfam GB. Climate-Resilient Faecal Sludge Management. Oxfam. Oxford (2025)

Table 7: Health and Safety considerations for FSM staff to protect against the increased risks due to climate change

FSM workers wear PPE	FSM workers have access to hygiene items	There are standard operating procedures and regular monitoring
Examples of PPE for FSM workers: • Adequate footwear, such as gumboots • Rubber Gloves (covering the wrists) • Facemask • Safety glasses • Clothes dedicated only to FSM work (jumpsuit covering all skin)	Examples of hygiene items that should be accessible to FSM workers: • Soap • Laundry soap • Dettol • Chlorine solution • Hand sanitiser • Rehydration • Shade	Examples of critical actions to monitor in FSM operations include asking whether FSM workers: • Always wash their hands after finishing Faecal Sludge (FS) handling and other activities? • Wash their FSM clothes at the end of the day? • Use laundry soap and a mild chlorine solution? • Wash the bottom of their shoes, which may have trodden in FS • Adequately drain the water used for washing any FS? **In addition:** FSM workers should have access to relevant vaccinations and regular health checks.

References

- Arup and Oxfam (2019). *Faecal Sludge Management for Disaster Relief.* Technology Comparison Study. Oxfam, June 2019. Available here
- Arup (2022). *Technical Assessment of Faecal Sludge Management in the Rohingya Response. Phase 2. Final Report.* Available here
- Arup (2024). *Faecal Sludge Decision Making tool.* Sanihub, September 2024. Available here
- Emergency WASH Knowledge Portal (webpage). S.3. Single Pit Latrine. Accessed December 2025. Available here
- Gensch, R., Jennings, A., Renggli, S., Reymond, P. (2018). *Compendium of Sanitation Technologies in Emergencies*. German WASH Network. Available here
- Oxfam (2020). *Tiger Worm Toilet Manual.* Oxfam. Oxford. Available here
- Oxfam (2021). *Oxfam Excreta Disposal Manual.* Oxfam. Oxford. Available here
- Oxfam (2022). *Faecal Sludge Management in the Rohingya Response.* Oxfam. Available here (In Oxfam Excreta Disposal and Faecal Sludge Management Manual, Sanitation)
- Oxfam (2023). *Intermediate Fecal Sludge Transfer Network. An Overview & Operation Maintenance Manual.* Oxfam, June 2023. Available here
- Rogers, T. et al. (2014). *Power earth auger modification for waste extraction from pit latrines.* Journal of Water, Sanitation & Hygiene for Development. March 2014. 4(1):72. IWA Publishing. Available here
- Solidarités International Octopus Project (2023). *Piloting septic tanks as a long-term containment and treatment option.* Solidarités-Octopus platform January 2023. Available here
- The Sphere Project (2018). *Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response.* [Water Supply, Sanitation and Hygiene Promotion chapter]. Sphere. 2018. Available here
- UN Environment Programme/OCHA Joint Environment Unit (2020). *The Nexus Environmental Assessment Tool (NEAT+) Process Guidance: Integrating environmental risks and opportunities into the Humanitarian Programme Cycle.* Available here
- WASH Sector, Cox's Bazar (2023). *Fecal Sludge Management (FSM) Strategy for Rohingya Response.* WASH Sector Bangladesh. August 2023. Available here
- WEDC, Loughborough University, (2012). *Latrine Slabs. An Engineers Guide.* Guide 5. WEDC Publications 2012. Available here
- World Bank (2024). *Urban sanitation in the times of climate change.* Washington (DC): World Bank Group; 2024 (Background Paper by Arup and WSUP Advisory). [Unpublished background study funded by the World Bank].

End notes

1. See https://www.oxfamwash.org/sanitation-the-sani-tweaks-green-card/ & https://www.oxfamwash.org/checklist-for-rapid-assessment-in-emergencies/ and Guidance Note 1: Climate Change Adaptations for WASH. See also the NEAT + Tool at https://reliefweb.int/report/world/nexus-environmental-assessment-tool-neat-enesfr
2. For more information on all the following options, see https://www.oxfamwash.org/excreta-disposal-manual/ & https://www.washnet.de/wp-content/uploads/emergency-sanitation-compendium.pdf
3. Design specifications for these latrines can be found at https://www.oxfamwash.org/oxfam_category/sanitation/
4. Sato pan: https://sato.lixil.com/product/sato-101/
5. https://assets.publishing.service.gov.uk/media/57a08d4ee5274a31e00017aa/R7535-simplified_sewerage_manual_full.pdf
6. https://rohingyaresponse.org/wp-content/uploads/2023/08/FSM-strategy-Final-Version-CXB-August-2023.pdf
7. https://www.oxfamwash.org/wp-content/uploads/FSM-CXB-Phase-2-Final-Report-2022.pdf and https://www.oxfamwash.org/wp-content/uploads/oxfam-arup-fsm-report.pdf
8. https://sanihub.info/resource/decision-tool-for-faecal-sludge-treatment-plants-fstps/
9. See https://www.washnet.de/wp-content/uploads/emergency-sanitation-compendium.pdf for more information on these technologies
10. https://www.oxfamwash.org/wp-content/uploads/oxfam-arup-fsm-report.pdf
11. https://octopus.solidarites.org/2023-02-piloting-septic-tanks-long-term-containment-and-treatment-option
12. https://www.oxfamwash.org/wp-content/uploads/oxfam-arup-fsm-report.pdf
13. https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/schwerpunkte/sesp/WASH_Humanitarian_Context/compendium_emergencies.pdf

Annexe 1: Impact of climate change on elements of the sanitation chain

The following tables from the WSUP-Arup *Study on Urban sanitation in times of climate change (unpublished)* describes responses of infrastructure and services to failures on the sanitation service chain caused by climate change.

Element of Sanitation Chain	Containment				
Potential Impacts of Climate Change	**Technical Responses**				
Pits and tanks overflowing due to surface flooding.	Raising latrines and tanks to avoid overflow and avoid flotation of underground structures.	●		●	
Pits and tanks experiencing flotation from rising groundwater due to sea-level rise or increased rainfall.	Enhancing the construction of containment infrastructure through pit, and cylinder and related reinforcement, with concrete rings as one way to combating groundwater intrusion for some structure.	●		●	
Toilets being badly damaged or eroding during flood events and rendered inaccessible.	Construction of more robust latrines that withstand extreme weather conditions. Elevating latrines to prevent overflow from pits and tanks. Employing flotation resistant design for underground structures, to prevent displacement during floods. This will ensure their functionality is maintained even under inundation.	●		●	
Pits and tanks experiencing flotation from rising groundwater due to sea-level rise or increased rainfall.	Enhancing the construction of containment infrastructure through pit, and cylinder and related reinforcement, with concrete rings as one way to combating groundwater intrusion for some structure.	●		●	

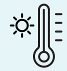
Element of Sanitation Chain	Containment				
Potential Impacts of Climate Change	**Technical Responses**				
Toilets being badly damaged or eroding during flood events and rendered inaccessible.	Construction of more robust latrines that withstand extreme weather conditions. Elevating latrines to prevent overflow from pits and tanks. Employing flotation resistant design for underground structures, to prevent displacement during floods. This will ensure their functionality is maintained even under inundation.	●		●	
Abandonment of toilets is linked to dry periods and higher temperatures causing toilets blockages and unhygienic conditions.	Construction of more robust latrines that withstand extreme weather conditions. Elevating latrines to prevent overflow from pits and tanks. Employing flotation resistant design for underground structures, to prevent displacement during floods. This will ensure their functionality is maintained even under inundation.		●		●
Humidity, heat and increased salinity accelerate the rate of corrosion of containment structures.	Regular maintenance and anti-corrosion lining of containment materials to be utilized.		●	●	●
Higher rates of GHG emissions (i.e. CH4) during heavy rainfall and untreated effluent being released into surrounding environment.	Ensuring better and more efficient collection and containment practices and services. Promote community engagement regarding the impacts of illegal emptying.	●		●	

Element of Sanitation Chain	Wastewater conveyance				
Potential Impacts of Climate Change	**Technical Responses**				
Pipe damage through ground movement and settlement due to variations in rainfall frequency, groundwater levels and/or fluctuating temperatures.	Thus far, no literature that responds to such practice other than conventional pipe design and maintenance.	●	●	●	●
Sewer overflow/flooding due to insufficient network capacity and high volumes of incoming stormwater, when mixed with wastewater in combined sewer networks. Increased CSO discharge events release harmful pathogens, organic material and nutrients into the environment.	Further treatment measures provided via retrofitting with added treatment layers like constructed wetlands. Increased sewer capacity adds storage and better conveys CSO flows. Improved stormwater management and reduced flows within the network to reduce sewer capacity constraints. This includes rainwater harvesting, infiltration practices (i.e. permeable paving), and green infrastructure (i.e. green roofs).	●			
Raised groundwater levels from increased rainfall can lead to infiltration into sewerage networks and contribute to sewer overflows.	Improved seals of networks and inspection facilities, such as manholes, and monitoring and evaluation to identify needed maintenance through inspection of infiltration defects and lining of sewers and inspection facilities with watertight liners.	●			
Lower flows in the network due to dry periods and higher temperatures can trigger increased anaerobic decomposition and higher pollutant concentrations. This puts pressure on the WWTPs.	Use of sewers systems that require less water to operate in water-scarce areas, including vacuum sewer systems which allow for low-flush toilets and separates greywater and blackwater.	●		●	

Element of Sanitation Chain	Wastewater conveyance				
Potential Impacts of Climate Change	**Technical Responses**				
Reduced wastewater flows from prolonged dry weather can also cause blockages caused by sedimentation of solids in reticulation pipes.	Use of sewer systems that require less water to operate in water-scarce areas. These include gravity driven simplified sewers with smaller diameter sewer networks, removing the need for pumping and is suitable for high density areas.	●		●	
Reduced flows can also lead to accelerated sewer corrosion due to increase in H2S production, driven by higher temperatures and more concentrated organic matter.	Fitting sewers with anti-corrosion materials such as PVC, HDPE and FRP. Alternatively, epoxy and polymer modified coatings can be applied to damaged steelwork to prevent further corrosion.	●		●	
Intense storm events can import natural and manmade debris, clogging the sewers.	Active maintenance of sewers to prevent and repair failures associated with blockages, such as performing preventative maintenance by cleaning sediments from the sewer system. Cleaning of sewers will enhance their resilience during extreme weather events. This should be paired with awareness campaigns to avoid contributing factors that cause man-made blockages.	●			
Sea level rise or storm surges risk saltwater ingress into WWTP outfall pipes.	Incorporate design features to avoid sewer backflow from sea level rise or storm surges.			●	
Increased salinity from sea level rise, storm surge or increased salinity in groundwater, accelerate the rate of corrosion of sewers through network defects and saltwater infiltration.	Sewers that can withstand corrosion due to seawater infiltration. This includes selective pipe materials that are more resistant to corrosion. In existing networks, corrosion protection can be applied where pipes are not replaced.			●	

Element of Sanitation Chain	Emptying and Transport of Sludge				
Potential Impacts of Climate Change	**Technical Responses**				
Disruption of emptying services due to damage or inaccessibility of roads.	Alternative emptying technology options include portable vacuum/pump systems for lined pits and septic tanks (e.g. ‘gulping’ technology) and compressor operated emptying units for pits.	●	●	●	●
Pit and tanks emptied illegally before and during floods and emitting higher levels of NCH4.	Regular and preventative emptying of pits and tanks to avoid overflows or illegal excreta/faecal waste dumping.	●			
Element of Sanitation Chain	Faecal Sludge/Septage Treatment I and Wastewater Treatment				
Potential Impacts of Climate Change	**Technical Responses**				
Extreme weather events are capable of causing physical damage to the WWTP assets, which in turn can cause untreated sewage overflow and mechanical and hydraulic system failure. This includes flooding out WWTP-FSTP treatment units and washing their contents into the environment.	Incorporate flood defences, such as gates or barriers, to prevent inundation. Effective surface water management around treatment facilities prevents equipment damage, waterlogging, and erosion. Sealing or waterproofing electrical equipment and pumps ensures continuous functionality. Use balancing tanks to manage peak flows, reducing overflow occurrences and sewer spills. Design treatment processes with built-in buffering capacity for flow and load variations, including water stabilization ponds and constructed wetlands.	●		●	

Element of Sanitation Chain | Faecal Sludge/Septage Treatment | and Wastewater Treatment

Potential Impacts of Climate Change	Technical Responses				
Dry weather low flow and high-strength wastewater loads occur which can cause problems for WWTPs, leading to an increase in concentration of organic and solid matter. Depending on the type of treatment works, this can lead to the discharge of partially treated wastewater with higher pollutant concentrations into the receiving water.	Employing recycled wastewater streams within WWTPs to dilute incoming effluent. Using modular plants can provide the ability to disconnect parallel settling tanks and biological treatment units during low flow. Real time monitoring systems of treatment inflows and quality can support operators in adjusting treatment regimes in real time. Extensive wastewater systems (i.e. waste stabilization ponds and constructed wetlands) being used where possible, due to better resilience against fluctuation of inflows and organic loadings.				●
Dry weather patterns can lead to increased corrosion rates and to blockages due to insufficient wastewater flows to transport sediments within the sewers.	Using more corrosion resistant materials, such as sulphur-resistant cement or anti-corrosion coatings against harmful by-products. Strong community outreach programs to minimize misuse of sewers through discharge of inappropriate materials, such as solid waste.				●
During prolonged wet seasons or rainfall events, incoming effluent to the WWTP from combines stormwater/ wastewater sewers is diluted, thus affecting treatment effectiveness and raising costs of pumping required.	The use of balance/buffer tanks/units can better manage increased wastewater flows and could potentially also save energy costs by adjusting the treatment regimens through storing the daytime flow of wastewater and treating it at night when energy costs are lower.	●		●	

Element of Sanitation Chain	Faecal Sludge/Septage Treatment I and Wastewater Treatment				
Potential Impacts of Climate Change	**Technical Responses**				
Fluctuation in organic load due to dilution of faecal waste from containment sites affects efficiency of biological FSTPs.	Extensive wastewater/faecal sludge treatment systems (i.e. waste stabilization ponds, constructed wetlands, drying beds, etc.) being used where possible, due to their better resilience against fluctuation of inflows.	●		●	
Soil-based treatment can be limited or unusable due to soil saturation from raised groundwater levels from increased rainfall, or rising sea level and tidal fluctuations. This results in overflow of lagoons and sludge landfills.	No literature available.	●		●	
Saltwater intrusion can reduce the effectiveness of biological treatment processes and result in poor biological treatment.	Monitoring and identification of saltwater infiltration in the network followed by adjustments to treatment processes and upgrades to pipework and units within WWTP, such as appropriate anti-corrosion linings. The incorporation of flood defences or anti-flooding measures near the treatment plant, such as gates or barriers, can prevent saltwater ingress and/or flood inundation.			●	
Storm surges during extreme weather events can affect coastal wastewater assets, causing system overflow and/ or mechanical failure.	Increased resilience through sealing or waterproofing of mechanical and electrical equipment and including pumps.	●		●	

Element of Sanitation Chain	Faecal Sludge/Septage Treatment I and Wastewater Treatment				
Potential Impacts of Climate Change	**Technical Responses**				
Wastewater treatment plants have great difficulty in removing nitrogen at low temperatures (below 4°C) and consequently large amounts of nitrogen are released in WWTP effluent in such situations.	Separating urine from wastewater at the household level prevents 80%-90% of human-generated nitrogen from entering sewer systems, easing treatment challenges. Pilot osf urine-diverting toilets are underway worldwide, including a new development in Paris for 600 households, to prevent excess nitrogen discharge into the River Seine and to monitor for future scale-up.				●
High temperatures (above 40°C) affect water temperatures, and can cause failures of membrane treatment technologies as well as their air blowers needed for forced aeration in many WTTPs.	Use extensive WTTP designs, such as water stabilization ponds and constructed wetlands, that do not rely on forced aeration systems.	●		●	
Electricity failures of containment and leading to problems with sewerage collection (wet toilets), pumping stations and/or at the treatment plant.	Back-up power systems using alternative power sources, including biogas generation, solar PV systems and diesel generators to power pumping stations and WWTP electro-mechanical units; locating these back-up systems and their batteries above floodwater levels to ensure flood resilience. Diesel generator backup can offer a reliable power supply during emergencies.				●

Element of Sanitation Chain	Faecal Sludge/Septage Treatment I and Wastewater Treatment				
Potential Impacts of Climate Change	**Technical Responses**				
Higher GHG emissions from higher pumping rates during heavy rainfall or higher temperatures, therefore requiring more cooling of machinery (i.e. air blowers).	Ensuring better collection, containment and reuse systems for direct sources of GHGs and use of alternative energy sources (i.e. Solar PV) for minimizing indirect sources of GHGs. Carrying out energy audits and investing in energy efficiency measures, including SCADA systems and replacing aging equipment.	●	●		●
Element of Sanitation Chain	General				
Potential Impacts of Climate Change	**Technical Responses**				
Disruption of service due to heat stress of workers.	Ensuring shaded environments, providing drinking water dispensers, outlining regular break periods and avoiding working near live active machinery.				●

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