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Emergency sanitation: developing criteria for pit latrine lining

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Pit latrine linings for emergency sanitation facilities require different performance criteria from those for pits used in longer-term development work. Various international initiatives are currently under way to develop new methods of supporting the pits used for latrines in emergencies, but before a solution can be found, the problem needs to be defined. Current field guidance lacks the level of detail required by humanitarian workers to construct durable pits in a timely manner. Consultations with international humanitarian field staff and UK-based geotechnical engineers were used in this research project to identify design, construction, and operational requirements of emergency pit-lining systems. However, rather than closely defined performance requirements, the study identified a wide range of criteria that need to be considered and clear distinctions between emergency and longer-term solutions. Latrines constructed in the initial stages of emergencies are likely to be communal, with long rectangular pits that require frequent emptying. Current knowledge of suitable pit support methods is sufficient to provide a limited range of standard designs that could be selected to meet local requirements.

Keywords: emergency, sanitation, latrine

In 2013, disasters affected over 95 million people (CRED, 2014). Immediate assistance can stabilize the situation and enhance recovery, so humanitarian organizations prepare by stockpiling supplies for rapid deployment. Using standardized equipment, staff can be trained in advance and implement relief with familiar materials. Items such as blankets or water taps are

well tested, readily available, and suitable for a range of locations. Also needed are bespoke articles such as health education posters that fit the context in terms of language and culture. Certain aspects of relief are well resourced, but sanitation provision has been neglected, leading to poor standards of design and construction. While sanitation can often be provided using local materials, standard sets of supplies speed up procurement and ensure quality. Several projects are addressing this issue (e.g. S(P)EEDKITS, Humanitarian Innovation Fund, and Emergency Sanitation Project; see 'Websites').

Sanitation is the safe separation of people and excreta to ensure health and dignity, with two main aspects: the 'hardware' (a latrine) and 'software' (education and management procedures to ensure effective use). A widespread method of sanitation is a pit latrine (Figure 1). The hardware consists of a pedestal or squatting slab, a pit or vault to store and perhaps treat the excreta and a superstructure to provide shelter, privacy, and security. The hardware and software are linked, as people can only maintain toilets if the toilets can be cleaned; a latrine with no light, a rough floor, and a badly designed squatting slab will be easily soiled.

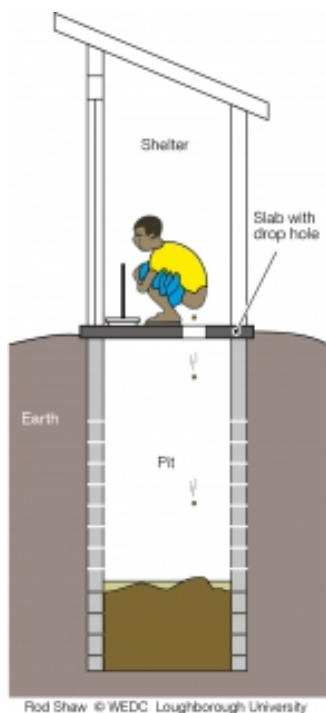


Figure 1 A basic pit latrine

Source: WEDC

1 Background

The inspiration for this research was the USAID-funded Emergency Sanitation Project being carried out by the International Federation of Red Cross and Red Crescent Societies (IFRC), WASTE, and Oxfam Great Britain (see website). This project is examining a range of innovative technical solutions relating to sanitation provision, from superstructures to emptying pits, using design competitions, consultations with manufacturers, studies, and a brainstorming workshop

(Blunt, 2013). It was at this workshop that latrine pit-lining design criteria were examined (see Table 1).

Table 1 Design criteria: an all-in-one kit for supporting pit latrine pits in poor soil conditions

Criteria	Notes
Soil types	Pit latrines are only used above the water table. For design purposes, a sandy soil can be assumed.
Depth of lining	The lining may either support the top 500 mm of the pit, or extend to the full depth, typically 2–3 m. Ideally, the solution will be usable in either configuration and adaptable in depth.
Strength	For a lightweight lining to be strong enough to line the pit, it is likely to need bracing. These should be lightweight and easy to handle.
Durability	Pit latrines are a very aggressive environment. The solution should last for at least 2 years, although ideally longer. It will be single use only and will not be used in more than one pit.
Excavation size and shape	Solutions are needed to accommodate both individual pit latrines and blocks of latrines which may share the same pit. For individual pits a circular excavation is structurally superior, but may be more difficult to pack for shipping.
Connection with slab and superstructure	The standard plastic slab that Oxfam currently uses is rectangular measuring 1,200 mm x 800 mm. The excavation will allow slabs of this size to be installed on top.
Size and weight	The solution should be as small and light as possible for air freight, and the solution should ideally fit on a EUR-pallet ... On arrival in the country, the solution will need to be man-handleable.
Construction method	The solution should be easy to use. Pit latrines are normally dug using spades and pickaxes.
Local materials	The solution should be a complete kit, not requiring any materials to be sourced in-country.
Cost	There is no fixed price which will be paid for this. As a guide, solutions costing more than £50/unit are unlikely to be considered.

Source: Emergency Sanitation Project website

A well-defined problem is a step towards a solution. Design criteria guide innovators and provide a means of assessing solutions. Having (unnecessarily) specific criteria can inhibit creativity but wide criteria may result in a one-size-fits-all solution that may be sub-optimal. Some aspects of pit-lining are essential (such as preventing collapse, see Figure 2) while some are desirable (e.g. a wide range of dimensions to choose from). This may be subjective; for instance Zakiria et al. (2015) considered immediate deployment (perhaps an *essential* emergency characteristic) as equal to re-use of the excreta (perhaps only *desirable*). Criteria

may interact: for example a cheap temporary solution requiring replacement may be comparable to a more expensive but longer-lasting solution if whole-life costs are considered rather than capital costs. 'Input' criteria (what the solution should contain) can be constraining so 'output' or 'outcome' criteria (how the solution performs) are preferable. Performance criteria describe the conditions of the humanitarian context, such as lack of electricity or transport.



Figure 2 Trench latrine under construction; this collapsed later

Source: V. Hammond

2 Researching pit-lining criteria

This research started out as a civil engineering undergraduate project to scope the range of performance characteristics that a pit-lining system should meet, building on the Emergency Sanitation Project. The student provided a fresh perspective and critically assessed current advice, being representative of an inexperienced field worker. This aspect of the research consisted of:

1. collating existing knowledge;
2. gathering opinions on design criteria from sector experts;
3. working with sector practitioners to check the criteria against a series of potential lining options; and
4. analysing these opinions to develop final criteria.

The process was to create a long list of possible issues (stage 1 and 2), reduce this list (stage 2 again and 3) using different perspectives to provide triangulation, to produce a final set of criteria (stage 4). The short exercise was to identify broad areas for further investigation rather than provide a complete solution.

2.1.1 Reviewing existing knowledge

Existing knowledge was reviewed in practitioner and academic literature, identified through literature searches and a series of unstructured interviews with six key informants (a mixture of academics and NGO technical managers). A challenge was finding knowledge that related to:

- the humanitarian context;
- low-cost sanitation; and
- excavations (Figure 3).

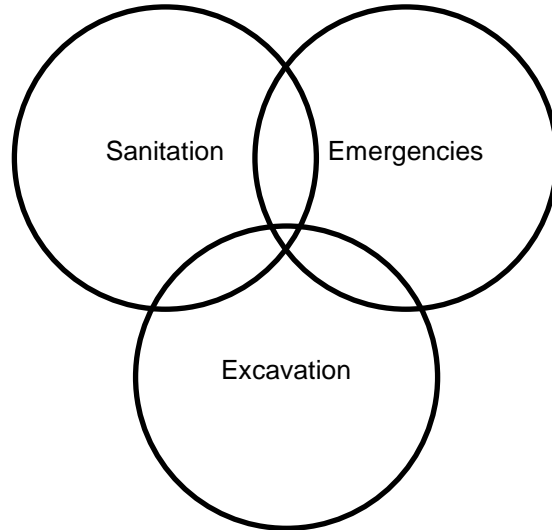


Figure 3 Expertise required

As the number of publications with this mix is limited, knowledge was drawn from the separate areas and mapped onto the problem, so 'excavation' encompassed areas similar to latrines, such as wells, pipe trenches, open channels, and tunnels.

2.1.2 Checking design criteria

The next stage checked the relevance of each criterion, using 7 semi-structured interviews with field practitioners in relief (from an INGO) and excavation (from a UK-based contractor). The discussions were based on a series of scenarios, each using a different lining technique. These vignettes allowed the interviewees to discuss how each option would perform in practice, with the researcher noting criteria used to evaluate the performance. The discussion of lining options was not designed to select a product, but check the relevance of each criterion.

2.1.3 Analysing the criteria

A 'perfect' solution would not exist as many lining systems only meet some criteria or are suitable for specific locations. Essential criteria (such as structural strength; see Figure 4) need to be tightly defined; desirable criteria with a lower priority can have a wider range of acceptability. A product that partially meets all criteria may be preferable to a product that has good performance on only certain aspects. This was in contrast to Zakiria et al. (2015) who used a grading system based on scoring options 0–5. Their arithmetic approach allowed options rated '0' for some criteria (such as product life span) to be balanced by a high score for, say,

use of local material. The Emergency Sanitation Project (see website) gave a low rating for using local material, so this aspect is subjective.



Figure 4 Latrine collapsing before completion

Source: V. Hammond

2.1.4 Reflecting on the results

Both Zakiria et al. (2015) and the Emergency Sanitation Project (website) developed criteria that appeared restrictive. The interviews resulted in some core criteria, but often issues were context-specific or contradictory. For example, both local procurement and international shipping have positive and negative aspects, often depending on the context. The emerging criteria were not as definitive as hoped. Discussions within the team drew out some lessons, providing some clear recommendations.

2.2 (Emergency) sanitation

There are few books on emergency sanitation (Harvey, 2007; Harvey et al., 2002). Various compendia of emergency WASH infrastructure (Davis and Lambert, 2002; Semiond and Gonzales, 2005; van den Noortgate and Maes, 2010; Wisner and Adams, 2002) mostly draw on earlier publications on general low-cost sanitation. This lack of emergency sanitation literature means that longer-term 'development' literature is often used, even though the context

(especially for usage rates and life cycles) is different (e.g. Franceys et al., 1992; Pickford, 1995; Brandberg, 1997). Both emergency and development literature on sanitation lack construction details.

Social context is important; in development, sanitation is a household responsibility, being 'private' rather than 'public' infrastructure as households provide a proportion of the resources required. In contrast, water supply infrastructure is a communal asset partly due to the scale of the facilities. Five hundred people may share a water supply, but a hundred separate latrines might be needed. In a relief setting, public provision of both water supplies and communal latrines is required initially to ensure a rapid, basic level of service. The public provision impacts on aspects such as 'ownership' (see Figure 5).



Figure 5 Theft of sandbags from communal latrine surrounds resulting in erosion

Source: V. Hammond

2.2.1 An overview of latrine pits

Excreta is stored in a pit; liquids percolate into the soil while the solids settle and degrade, reducing in volume. Other items (e.g. menstrual hygiene products, anal cleansing materials, 'private' waste such as medicine bottles) often get disposed of in the pit. The pit will fill up, depending on the amount of excreta (and other materials) being disposed of in relation to the rate of decomposition. This may take many years for lightly used, deep pits, but once the pit fills it has to be emptied or replaced. Deeper pits last longer, as excreta has more time to degrade.

Franceys et al. (1992) suggest a maximum sludge accumulation rate of 90 L per person per year (equivalent to 0.25 L/day including non-biodegradable anal cleansing materials). Harvey et al. (2002) suggest increasing this by 50 per cent for latrines that are heavily used, as the faeces has less time to degrade before the pit is full. Semiond and Gonzalez (2005) recommend doubling the rate if the pit has an anticipated life of less than a year. Fast filling means the pit must be designed for emptying unless land is available for new pits. The change

in loading and variation in moisture levels in the pit and surrounding soil has implications for any lining, even if the ground is stable when originally excavated. The removal of sludge could include some of the surrounding ground, so any pit to be emptied should be lined (Bastable and Ferron, 2000).

Role of pit-lining. Pit-lining is required to support the sides of the excavation (Figure 6) at four stages, during:

- construction – workers need to be safe;
- normal use – users need to be confident that the latrine will not collapse;
- maintenance activities – such as emptying; and
- decommissioning – if required.

Ground may be unconsolidated (such as sand), which crumbles into the pit, or be a weak but consolidated material (such as clay), which slowly deforms and slumps into the pit. Rock may not need much support but any saving in lining can be offset by the difficulty in excavation. Locations of latrines balance social and technical conditions, with convenience, security of users, and risk to groundwater having to be considered alongside excavation.



Figure 6 Trench latrine under construction

Source: V. Hammond

Pits have vertical sides to minimize the span of the covering slab. The lining may have to provide a foundation for this slab and perhaps the superstructure, so could carry various vertical and horizontal loads. Even if full linings are not geotechnically required, the top 500 mm may be lined to provide a stable interface and exclude surface water. A separate ground beam may be required to support the slab. The shape of the pit has an influence; circular pits are more stable than rectangular pits and require less lining material for a given pit volume (Figure 7) so may be better for single stance latrines. Rectangular pits however can be easier to dig mechanically and single-spanning slabs can be used to create multiple stances over long narrow pits, although a pit with several stances has routes for air to flow down and up the drop-holes, which is disconcerting to users and creates odour problems.

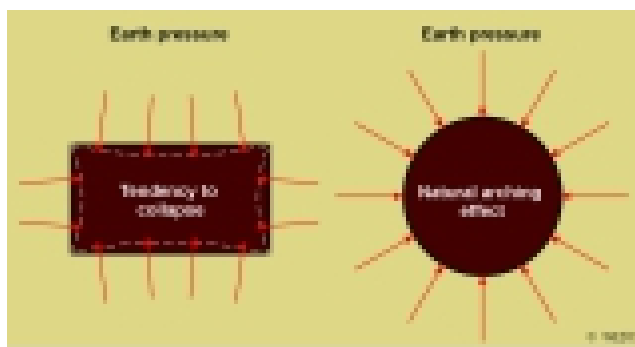


Photo: © WEDC Loughborough University

Figure 7 Influence of pit shape

Source: WEDC

Types of pit-lining. The pit-lining should allow moisture to flow in and out of the pit; urine and water from anal cleansing needs to dissipate into the soil. A fully sealed pit would result in a cess pit, with frequent emptying of fresh excreta. Cess pits may be required where groundwater needs to be protected. Pits are not normally excavated down to the water table, to separate the excreta and any aquifer, but water tables fluctuate and surface water may locally raise soil moisture levels, so water may flow into the pit to reduce soil pressures and prevent flotation of the pit-lining.

There are various linings:

- concrete, ferrocement, or mortar applied to the walls of a pit;
- metal or plastic sheets, timber, bamboo, bricks, blocks (Carroll and Ashall, 1989), masonry, tyres (Figure 8) or sandbags (Barasa, 2000) used to assemble a lining within a pit, perhaps with bracing across the pit;
- preformed units, such as precast concrete rings, trench boxes (metal or plastic sheets with fixed bracing) , wooden baskets (Cole et al., 2013) or old oil drums, inserted into an excavated pit; and
- sheet piles or precast concrete rings driven into the ground before excavation or used as a caisson.



Figure 8 Recycling car tyres and using sandbags

Source: V. Hammond

The ground conditions and the lining determine the construction method. Pits in unstable soils are either:

- over-excavated, with the slopes of the hole battered to form a stable slope – the lining is then installed and the surplus hole backfilled; or
- cased, with a (preformed) lining installed as the hole is dug.

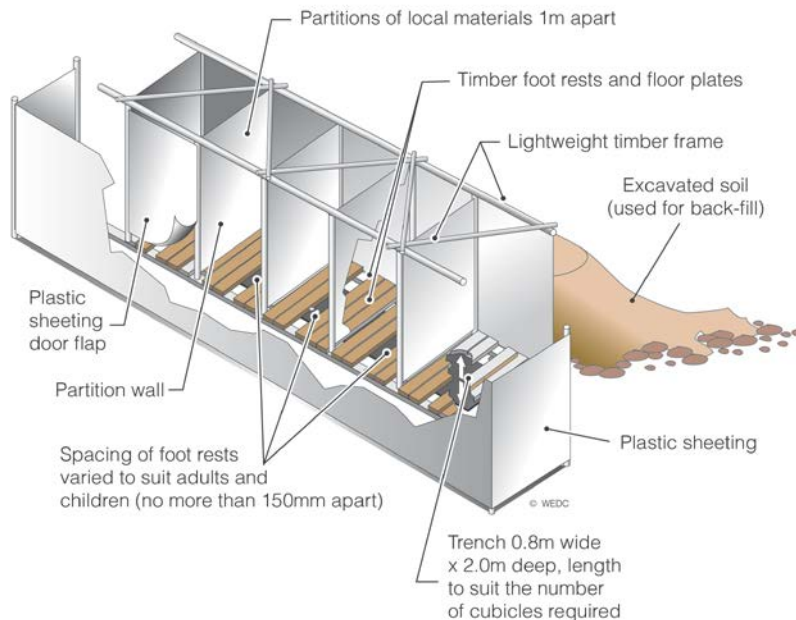
Stable soils can either be partially or completely excavated before the lining is installed.

2.2.2 An overview of emergency sanitation

Sanitation is required when existing facilities are destroyed (e.g. due to earthquake or war) or people have to leave their homes (e.g. due to flooding or famine). Various stages of emergency response are recognized (Harvey et al., 2002) but for sanitation, there are three stages.

1. In the immediate aftermath, there are few or no facilities, so people may resort to open defecation or use bags to wrap excreta, disposing it as solid waste. This can be improved by designating areas for open defecation, to contain faeces in one space. Shallow trenches can be rapidly dug to enable the faeces to be buried and the area screened to provide some level of privacy (Harvey, 2007). This stage should be short, as good levels of dignity and health are not possible.

- The next 'short-term' stage is communal latrines (Figure 9), with 1 stance per 20 to 50 people (Sphere Project, 2011). These often consist of a long, 2–3 m deep trench with a number of cubicles placed directly over the pit. An alternative are clusters of portable toilets, if available, grouped together for maintenance.



Ken Chatterton © WEDC Loughborough University

Figure 9 A communal trench latrine

Source: WEDC

- The final stage is the gradual provision of neighbourhood and household latrines, so the number of people using communal facilities reduces as individual facilities are built. There are various definitions of shared latrines (Mazeau et al., 2014), but once the immediate need is met, the trend moves from institutionally managed facilities to those built and/or managed by community groups, neighbours, or a household.

2.2.3 Existing knowledge in other sectors

Reviewing published literature showed information on lining is limited, with statements such as 'choose a site with stable soil' (van den Noortgate and Maes, 2010). Given this lack of detail, the review examined allied topics, such as well linings and supports for trenches, especially older publications, as simpler, less advanced technologies can be appropriate with limited resources.

Wells. There are parallels between wells and household latrine pits in terms of structural performance and permeability (Watt and Wood, 2007). The life expectancy of a well is longer than a latrine and excavation goes below the water table but durability is comparable. However

there is a socio-economic difference, as the community investment in a single well lasting a lifetime, serving several hundred people, with a clear willingness to pay, is in contrast to the hundreds of household latrines that last a few years. The review did show that the level of instruction required by builders for a standardized well system exceeded any advice for latrine construction; the *Instruction manual for the Well Digging Pack* (Oxfam, 1998) gives step-by-step guidance.

Pipe trenches. The detail provided for trenches used for laying pipes is extensive (e.g. Irvine and Smith, 1992; Illingworth, 1987). The focus is often on staff safety, often missing from sanitation guidance. The temporary nature of trench supports, with material often being re-used, is not directly comparable to a semi-permanent latrine pit where the lining would be contaminated, but the geotechnical advice is pertinent. The cost (including transport) of some of the proprietary systems, especially those involving piling, would be significant. This sector provided the best guidance on structural design, though how these supports would respond to latrine emptying is less clear.

Open channels. Internal propping may impede emptying and fouling of struts may lead to odour and fly problems so water channel lining was investigated (Sally, 1965). While providing a good detail, the linings tend to be impermeable and use battered sides to reduce loading, so are not very transferable.

Tunnelling. Sprayed concrete was considered a potential trench lining technique, so tunnelling literature was reviewed (e.g. Mason and Mason, 1982) but this showed that expertise and equipment would not be easy to transfer to an emergency setting.

Geotechnical engineering. Most of the literature review focused on practical guidance, but geotechnical theory was reviewed (e.g. Budhu, 2008; Barnes, 2010). The categorization of rigid/gravity and flexible/embedded retaining walls provides a firm foundation for assessing innovative pit-lining systems. The review demonstrated a gap between well-founded theory and guidance given in sanitation publications.

3 Issues arising from expert interviews

The literature review highlighted the lack of practical detail in published pit latrine advice. To supplement publications, a series of unstructured interviews with experienced academic and field staff identified additional issues and a range of lining materials, for example:

- bored piles (unlikely but used to test criteria);
- sheet piles;
- precast concrete rings;
- preformed plastic (e.g. manholes);
- corrugated steel roofing sheets;

- timber;
- oil drums;
- baskets (sticks or bamboo);
- in situ concrete (perhaps with a reusable formwork);
- masonry;
- sand bags/polythene tubes (perhaps with cement in the filling);
- recycling (car doors, old tyres, plastic bottles);
- plastic soakaway crates;
- geotextile; and
- gabions.

Reviewing the disaster cycle. Ideally sanitation follows a progression from controlled open defecation, through communal latrines to household options (Harvey, 2007). Actual progress can be less smooth. Emergency sanitation can get 'stuck' for various reasons. Longer-term household solutions can be resisted by displaced people who want to return home in the near future. In urban areas, permanent facilities may rely on repairs to water and sewerage systems. The host community may restrict construction (Osuolale, 2010). The transition often involves households building all or part of their own latrine. Dependency culture, lack of household resources, limited space, or competing priorities may slow progress. Communal latrines are used for longer than intended, requiring emptying. Emptying needs to be designed in, as desludging could damage the liner, which would have to be durable, to cope with climate, erosion, and corrosion.

Speed is important for the early stages, with pressure to get something done. This covers the whole supply chain, including permissions, international and local transport, excavation, and construction. The environmental legacy needs to be balanced against initial pressing concerns.

Complexity. People responsible for sanitation may not have engineering backgrounds and even if they do, may not have geotechnical knowledge. Contractors may understand excavations but perhaps not the details required for sanitation. Any solution must be understood by a competent person as mistakes endanger lives and waste resources, though 'replicability' could be better than 'simplicity'. Solutions need minimal maintenance and should be easy to operate.

A 'perfect' solution is not possible, so a number of solutions will be needed to match context (especially soil conditions). Rigid boundaries for criteria may not be appropriate and social conditions, including local decision-making, need to be considered. However having too many options may make choice difficult and result in inappropriate selections.

Current problems. The junction between the pit-lining and slab is a common problem. Despite advice in textbooks, surface water ingress and erosion (Figure 10), poor structural support, and air tightness are issues.

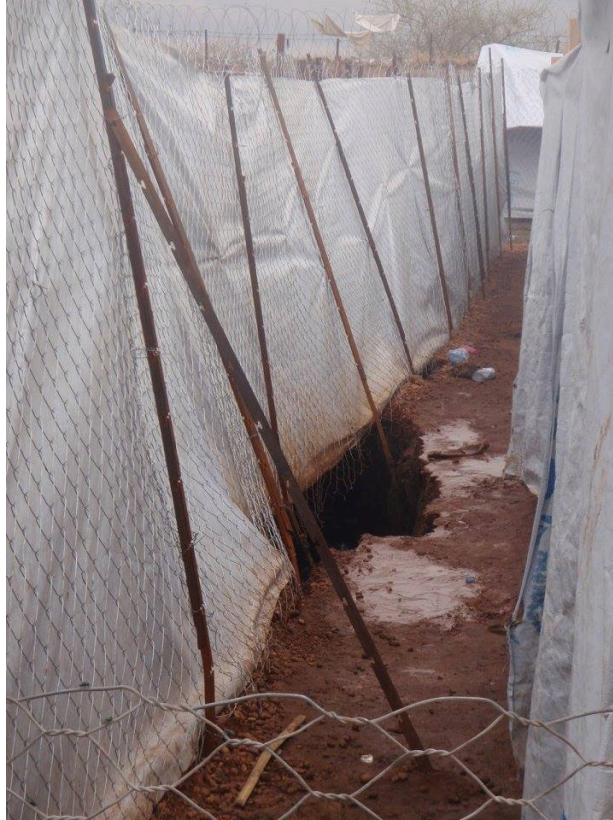


Figure 10 Collapse due to surface water erosion

Source: V. Hammond

Structural collapses (Figure 11) can be due to poor design (e.g. no cross-bracing or linings not toed-in at their base), or changes in soil pressures and strength resulting from fluctuations in groundwater levels or heavy rain. Impermeable linings led to flotation of sealed pits.



Figure 11 Collapsed latrine trenches

Source: V. Hammond

Costs need to consider the whole life (including emptying) of the facility and any equipment, tools, and labour required for construction and operation.

4 Developing and testing criteria

While improvements can be made at all stages of emergency sanitation response, for example better use of plastic bags in the first stage or a faster transition to household latrines, this research focused on the 'short-term' stage, as moving to household facilities is often dependent on factors outside the control of the sanitation engineer. The research resulted in a set of conditions:

- Communal latrines provide a quick, basic level of service.
- The pits are long and narrow, so are 'trenches' rather than circular holes. Cover slabs span in a single direction, so the width of the trench is limited but infiltration area maximized. Rectangular linings can be flat-packed.
- The trenches may not be deep as the need to prevent open defecation is pressing and construction may rely on hand tools, so 2 m is a typical depth (Davis and Lambert, 2002). Mechanical excavation (if possible) will be limited to about 4 m, depending on the machine.
- The trenches need to operate for months, so require emptying at intervals and be durable. Emptying should be assumed rather than expecting pits to be decommissioned in the short-term. Degradation and consolidation will be minimal over these short time periods.

- Components will need to be on site within several days so need to be available locally or be easy to store and transport.
- Detailed ground conditions may not be known but overdesign to cope with all conditions can be wasteful, so a balance is needed between 'one size fits all' and a bespoke solution.

The draft criteria were discussed in two sets of semi-structured focus groups with UK-based site foremen and overseas-based humanitarian workers providing different perspectives. Each group looked at a series of outline designs for pit-linings, using different materials. For each vignette, they discussed the suitability of the lining, noting critical factors. Ranking each option against various criteria helped facilitate the discussion. The UK site foremen focused on construction issues, while the humanitarian workers had a broader view, including operational and social aspects.

4.1 Construction

The criteria broadened when construction was discussed, as tools and equipment were integral, ruling out options such as bored piles and shotcrete. The excavation of the pit in 'difficult' ground conditions (e.g. hard rock, loose sand, black cotton soils, high water table) was important. 'Ease of construction' was difficult to define; skill levels related to the rapid development of a skilled team to ensure replication and sustainability. The number of workers required to excavate and install the lining was another criterion.

Solutions described by fieldworkers were often ad hoc, adapting local materials (Figure 12), often in response to a problem (such as surface water). Combinations of materials were often used, such as timber reinforcement with corrugated roof sheets or plastic sheeting.



Figure 12 Shipping container being used as a latrine pit

Source: V. Hammond

4.1.1 Operation, maintenance, and decommissioning

Surface water erosion was common, affecting the structural stability of the whole latrine (superstructure and slab as well as trench). Frequent emptying of trenches had benefits in that the sludge was less consolidated and did not stick much to the liner. Where the ratio of people to pits is high (e.g. in urban areas with limited space), the pit may effectively function more as a cess pit than a soakaway. Some sites had to be restored after use, with all materials removed. The possible benefits of recycling all or part of any lining system needed to be balanced with the costs of dismantling, cleaning, checking and transporting the materials, accounting for health risks to the workforce.

4.2 Design criteria

Table 2 summarizes the main design criteria, but some aspects had several interdependent dimensions as criteria were often linked; cheap lining might not be very durable, prefabricated units could be problematic to store and transport. A preference for sourcing material either locally or internationally was not apparent, as local context (e.g. materials available, transport links) was a determining factor.

Table 2 Possible design criteria

Category	Criterion	Notes
Costings	Initial cost	Percentage of the total latrine cost including:

		<ul style="list-style-type: none"> • procurement • storage • transport and • construction
	Operation/Maintenance Durability Whole life cost	Ideally minimal but needs to factor in emptying Design life and performance under emptying Bringing all cost aspects together but balancing speed with durability
Design	Ground conditions	Probably three ranges <ul style="list-style-type: none"> • sands, silts, soft clay • firm clay • incompetent rock (Irvine and Smith, 1992)
	Depth of pit	Saturated soils have to be assumed Probably two options to allow for deeper (longer lasting pits) and shallower (faster to excavate) options
Social factors	Interaction with other aspects of latrine design Construction constraints Local ownership	Slab foundations, superstructure arrangement, and number of stances influence lining choice Includes restrictions on excavation or infiltration Relates to both the construction and maintenance process
Logistics	Social acceptability Component weight	Wide range of social factors The maximum weight of any of the individual components
	Size of the components	The maximum size of any of the individual components
	Ease of transport	How easy is it to transport the components, both air and vehicle freight
Construction	Ease of construction	How easy is it to construct, including assembly, skill required and lifting/installation
	Replicability	Ease of repeating the construction, including required skills and training
	Time taken	The time taken to get pit operational; including transport and construction
	Labour required	Number of people required to do the job
	Equipment/plant required	Amount/type of manual equipment required
	Excavation method	If pits have to be over-excavated to install liner
	Safety	Safety of employees and users
Operation	Able to be emptied	Performance under de-sludging
	Environmental legacy	The risks and costs associated with leaving the lining in place when no longer required

The criteria differed from the Emergency Sanitation Project list (Table 1) in several aspects.

- A wider range of soil conditions needed to be considered, partially in conjunction with excavation method. Saturated soils had to be assumed.
- Trenches should be fully lined as emptying should be assumed. They should allow for percolation (Figure 13) but expect minimal degradation and consolidation due to short residence times.
- Bracing is not the only method of support, other options should be considered.
- Durability should also relate to emptying.
- For an immediate response, communal rectangular trenches should be assumed.
- Logistics/local procurement need to be considered together, with two scenarios:
 - international air freight where onward transport is available; or

- local procurement.
- Ease of construction should assume trained teams, rather than unskilled labour.
- Procurement costs should be in proportion to whole life costs.



Figure 13 Impermeable liners result in rapid filling of trenches

Source: V. Hammond

Agreeing boundaries between fully/partially/not acceptable performance criteria was not always possible, as local context dominated the discussions. However, descriptive guidance was needed to illustrate good and poor performance and distinguish between essential and desirable qualities.

5 Reflection on the problem

The research aim was a clearer definition of emergency pit latrine lining; while a comprehensive list of design criteria was produced, this was not felt to be definitive. Local context is important, but needs balancing with clear simple advice, so the fieldworker, who may not be an engineer, does not have to create bespoke designs for each pit based on local soil testing and collecting other data. A limited suite of pre-designed solutions for a range of contexts is therefore

preferable to a single solution or a multitude of choice. Focusing on one aspect, such as linings, may neglect related issues.

Any innovative system should be better than existing options. Reviewing field experiences, current best practice in supporting trenches (based on pipe-laying practice) does not seem to be implemented. Developing new approaches does not seem valid when current solutions do not appear to be disseminated, practised, or tested.

5.1 Potential future advances

Two options were worth investigating. The ideal of a flat-packed, preformed, adaptable liner for all types of latrines was still seen as a solution by interviewees, but without many suggestions of how this might be developed. The most promising area is adapting existing pipe trench lining techniques. Another option was the use of geotextiles to reinforce soils. This has the advantage of being easy to transport, but increases the excavation volume. Reinforcing strips or sheets need to extend about 0.7 times the depth of the pit (Barnes, 2010), so a 3 m deep pit may require an additional 2 m of excavation each side of the trench.

5.1.1 Lack of guidance

The process of research highlighted the lack of practical advice available. Emergency sanitation guidance is weak for the early stages of an emergency. Overall design and generic issues were discussed, but these lacked detail or only considered one possible solution. Design for emptying was not covered, partly due to lack of space in the manuals, with so many issues to consider. Multidisciplinary approaches are vital, but this should not be at the expense of specialist inputs. Emergency sanitation literature refers to the same few sources and misses out on advice from other sectors. This is illustrated by the level of information available on excavating and supporting pipe trenches, which could be adapted for trench latrines.

Surface water management is clearly stated in all the main publications, yet this is a common problem. Producing more guidance may not be enough to affect practice. Rather than focusing on one aspect of emergency sanitation, the resources, budgeting, and support should be reviewed, as the barriers to adequate provision are not just technical.

6 Conclusions

The aim of providing clear design criteria struggled to balance generic recommendations with local context, but some clear lessons were identified.

- The main option for immediate response sanitation is communal trench latrines.
- These need to be fully lined as emptying and prolonged use should be assumed.
- Existing guidance mainly focuses on later stages of emergency response, with household level solutions.
- Existing guidance lacks practical detail.

- Solutions need to consider excavation in sandy, clay, and rocky conditions.
- Solutions already exist in other sectors, such as pipe trenching, but may need adaptation.
- Field workers need prepared solutions based on a limited range of options with clear selection criteria.

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