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ECOLOGICAL SANITATION WITH REUSE IN CAMPS & SETTLEMENTS

A guide to closing the sanitation loop in refugee and IDP camps and settlements: How to safely use the products of ecological sanitation for growing crops, ecosystem restoration and ecosystem services.

Written by **Mary Mellett**
Illustrated by **Tanya Haldipur**
Edited by **Richard Luff**
Designed by **James Atherton**

Background

About Re-Alliance

Re-Alliance promotes a regenerative vision for the humanitarian and development sectors where the health of the environment is improved together with the health of people, understanding that the two are intrinsically linked. We are an international coalition of local organisations who use ecological and nature-based solutions (NBS) in our work. From Permaculture in refugee settlements to eco-building in disaster prone regions, our members show how we can create stability, resilience and abundance, even in times of crisis.

What is the aim of this booklet?

We feel passionate about the ecological treatment and reuse of human faeces and urine and the aim of this guide is to encourage decision makers **to be bolder in adopting it as their first choice.** Natural resources in camps and settlements are often scarce and depleted, while funding per displaced person is falling and reduces over time. In this environment of scarcity, we cannot afford to waste resources on burdensome faecal waste management and must make best use of any resources generated. While providing toilets that are safe and dignified, we can use natural processes to treat wastes and reuse the resources created to build back beneficial ecosystem services. Using the products derived from treated wastes, we can grow trees and crops, restore depleted soils and create fuels for cooking to limit deforestation. Our ultimate goal is for camps and settlements to have integrated solutions which create places which regenerate the land and the lives of the people who live on it. By connecting sanitation with reforestation, crop growing or fuel production projects we can create multiple gains as part of resilient, integrated systems within healthy environments. As the Sphere handbook states “The environment in which people live and work is essential for their health, well-being and recovery from crisis.”

This booklet is part of a series

This booklet forms part of our Regenerative Camps and Settlements programme. The programme piloted regenerative responses in refugee and IDP settlements. The learnings from the projects informed our research into regenerative responses to disaster and displacement.

From this research we have created a series of booklets on community-led regenerative interventions in settlements, aimed at influencing implementing agencies and staff. Our other booklets include: Water Harvesting and Greywater Reuse; Rooftop Gardening; Community Composting; Trauma Healing; Wicking beds for Irrigation.

Who this is for?

Maybe you are working or living in a camp now, or you are on the plane to your next deployment, or perhaps you are researching options to integrate into advocacy, policy or strategies. In all cases, we realise there are complex limiting factors influencing your work: time-pressures, sudden influxes of people, shortages of funds, difficulties sourcing materials. In all cases we hope there are still options within this booklet that you can easily integrate into projects and links to supporting resources you can use to complete designs. **Sometimes just a tweak in an existing design can give options for resource reuse and added benefits.**

Where it focuses

This guide focuses on sanitation provision for displaced communities living within emergency settlements. It covers the four major types of settlements as defined by the 🔗UNHCR:

1. Individual accommodation in communities - people living in individual housing or with host families in cities, towns or villages.
2. Formal settlements - planned settlements where land is allocated for asylum seekers, refugees or IDPs. The settlements are purpose-built, with access to facilities and services. An official management entity is assigned. Camps are a type of formal settlement.
3. Informal settlements - asylum-seekers, refugees or IDPs choose to settle in self-identified spontaneous sites.
4. Collective Centres - asylum-seekers, refugees and IDPs accommodated in pre-existing buildings such as community centres, town halls, schools. Collective centres are intended to be temporary short-term accommodation.

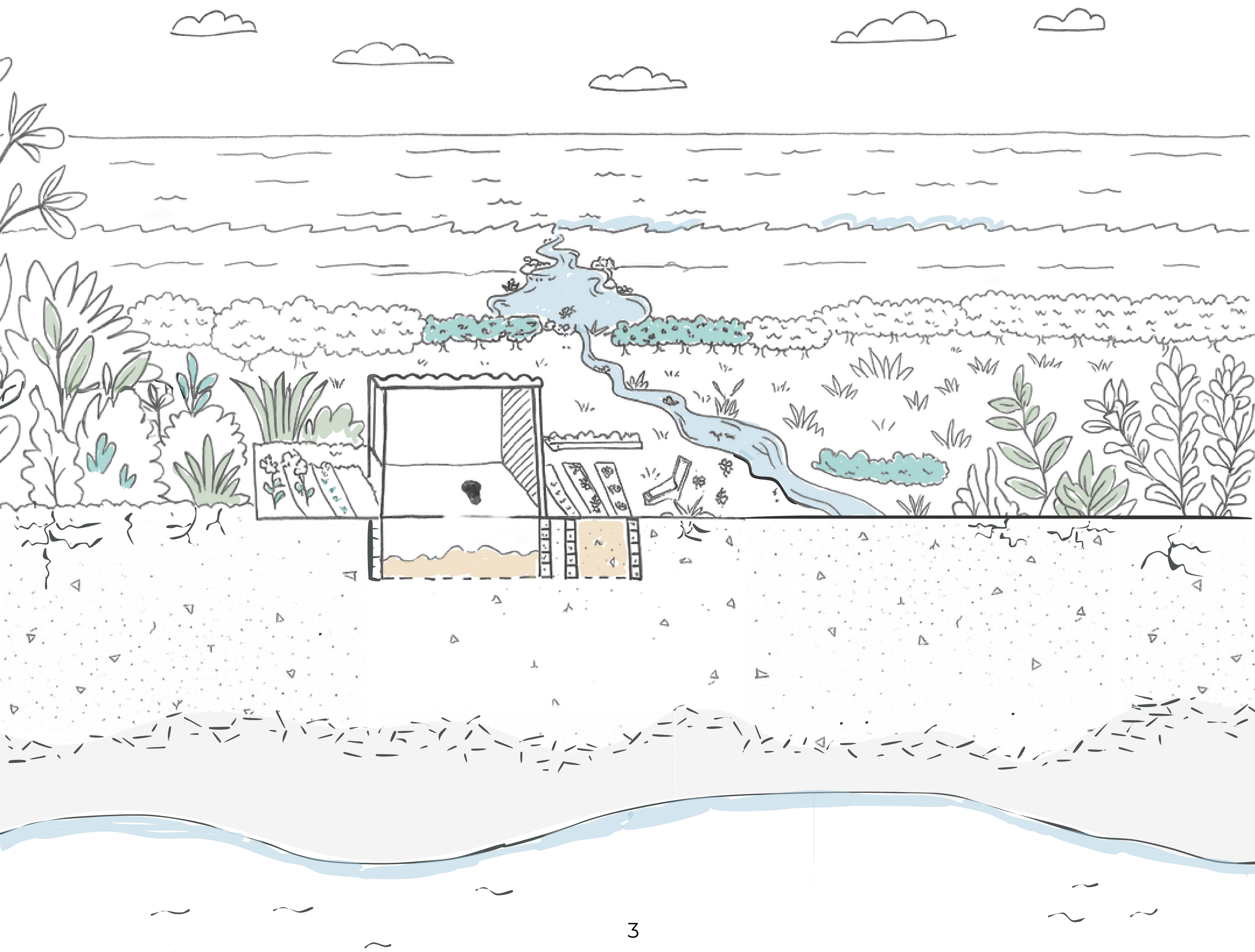
What it covers

This booklet will explain what ecological sanitation is and why resource reuse is needed in the context of settlements for displaced communities. It will put forward the guiding principles by which successful treatment and reuse projects have worked and presents the major technologies that can be used. It will look at safe ways to reuse products and then put these ideas into context by re-imagining responses in two existing refugee camps to show how things could have been done differently with the benefit of hindsight. It finishes with resources, case studies and references to guide your project to completion.

How to Navigate this document

- Use the linked navigation bar at the top of every page to switch between sections;
- Use internal links in **bold green** to navigate within the text;
- Follow **external links** in blue to recommended resources

- Boxes like this have case studies and links to major online resources.



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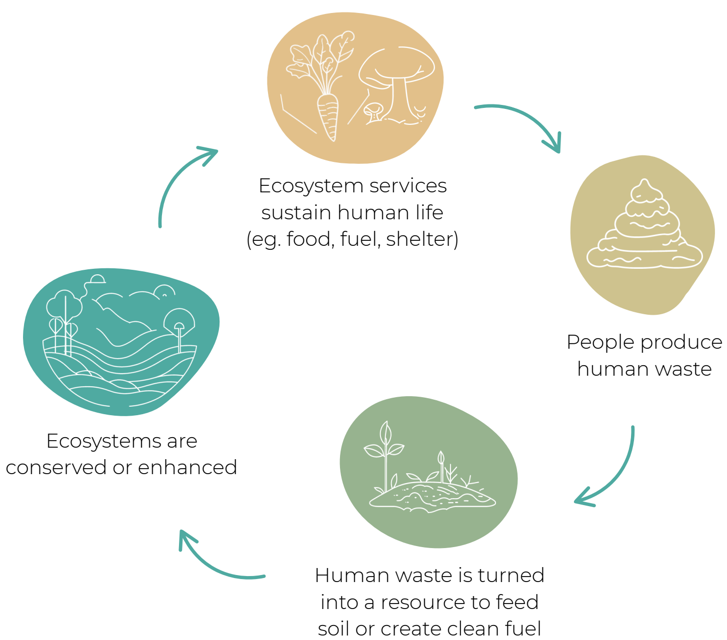
1 What is ecological sanitation and why reuse in displacement contexts?

Ecological sanitation is a fast-growing field, advocated for by **UNEP**, **UN-Water**, **UN-Habitat**, the **World Health Organisation** and the **Sustainable Sanitation Alliance,** adopted at country levels by governments such as **South Africa** and **Sweden**, and implemented in camps and settlements by INGOs such as **Oxfam**, **Wateraid** and the **Norwegian Refugee Council (NRC)**.

In camps and settlements, when ecological sanitation is chosen, there is often little **reuse** of products created because of the negative perception of the risk management needed and a lack of coordination between sectors. This guide aims to change that by promoting approaches which allow for the **simplest and safest** forms of reuse and reaffirming the value of reuse products.

Ecological sanitation uses **passive**, **natural processes** to break down human wastes into beneficial products. Wastes can be reused as part of the nutrient cycle to **feed the soil**. Enriched soils can hold more water and grow trees and crops. Another way to close the loop, is to transform wastes into **fuels**, such as biogas, to give a safe source of cooking fuel and reduce deforestation.



Conventional practices cannot be sustained

Current systems are often polluting, wasteful and dangerous. Making use of wastes rather than exporting them as faecal sludge prevents the wider pollution of waterways and food systems, reduces the need for ongoing faecal sludge management and reduces the costs and carbon footprint of ongoing maintenance and management. Treating faecal sludge often involves transporting sludge to centralised facilities with the eventual effluent discharged into waterways being of varying quality, or often faecal sludge is combined with wastewater and left untreated. The 2017 UN World Water Development Report, Wastewater: The Untapped Resource, stated that globally, **80 percent of waste water goes untreated.** Combining waste water and flush water with faeces and urine increases the volume of wastes to be contained, transported and treated and often pollutes waterways. Where possible, keeping faeces and urine separate from waste water reduces the volume of wastes to be processed and limits pollution of waterways. If reuse of treated wastes feels risky then this should be considered against the knowledge that the 2023 UN Habitat Global Report on Sanitation and Wastewater Management in Cities and Human Settlements states that *"It has been estimated that the use of untreated wastewater for urban and peri-urban agriculture accounts for about 11 per cent of all irrigated croplands (Theboet al, 2017)."*

People are already eating food grown with untreated wastewater, reuse should be planned for and managed, not ignored and incidentally undertaken several steps along the chain.

We cannot afford to waste resources

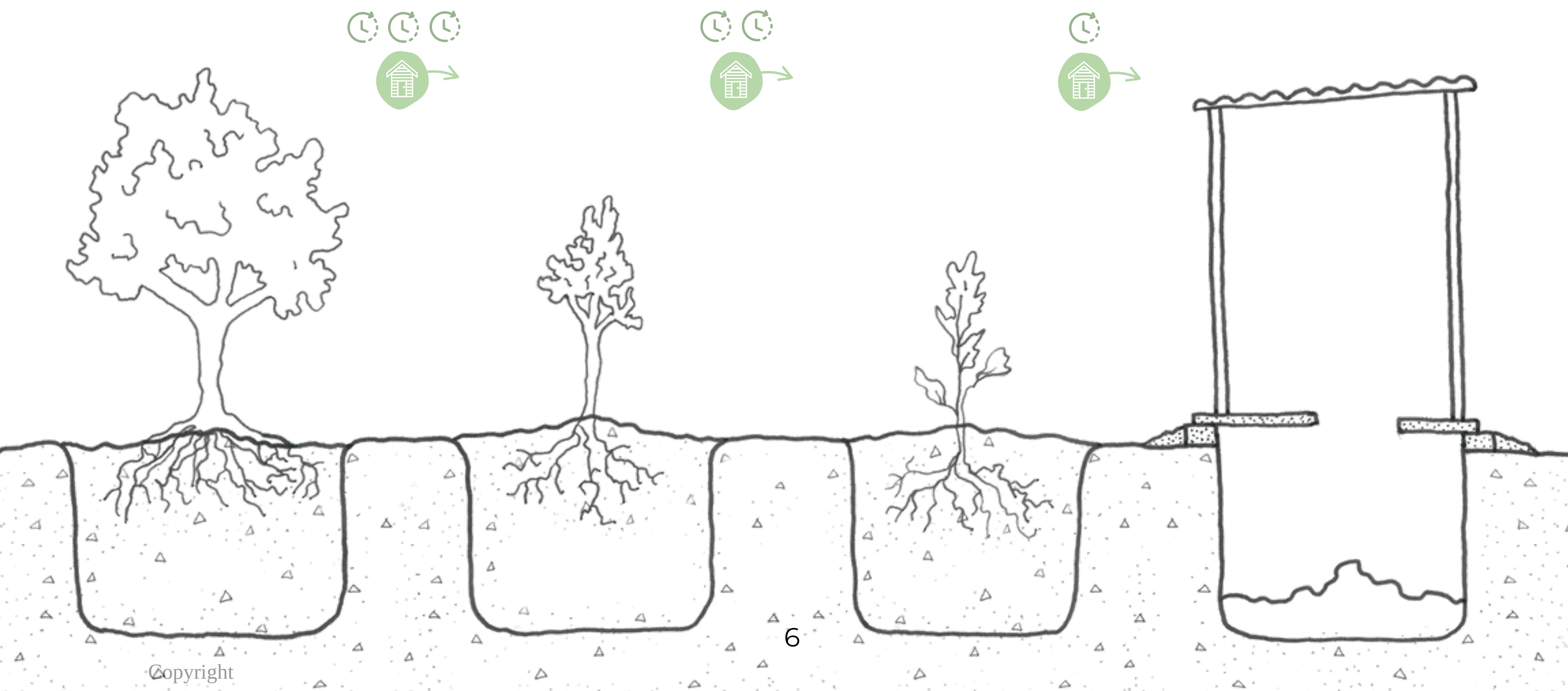
With increasing protracted crises and reduced funding per displaced person, resource production and use has to become a part of a sustainable response to protracted displacement to help provide resource security and resilience. In its 2024 report *Taking from the hungry to feed the starving,* World Vision argues *"An urgent, holistic, and united approach is imperative to break the cycle of food crises, transform food systems and put the world back on track to end hunger and all forms of* *malnutrition. Immediate humanitarian actions must be balanced with reliable funds for longer-term system change and development to strengthen health, food and social protections systems to save lives, build resilience and change the future".* Soil health and healthy ecosystems are the foundations of sustainable environments and products from human waste can and should be used to support them. Human waste can be used to improve soils to grow productive trees and plants and create fuels for cooking. This opportunity cannot be wasted, while the alternative systems of exporting faecal sludge cannot be afforded over longer timescales.

Why reuse ecological sanitation products in camps and settlements

Restoring ecosystems through nutrient recycling saves lives. In their Unpacked Guide to Nature Based Solutions, Sphere has made the case for restoring ecosystems as part of the humanitarian response. Ecological sanitation is a nature-based solution (NbS) which uses natural processes to manage human waste by recycling nutrients back into the environment. Further degrading landscapes through extractive processes puts people living in settlements at greater risk of future disasters like flooding, landslides and extreme heat and fires. The Sphere Unpacked Guide highlights how environmental degradation can drive up disaster risks and overwhelm the humanitarian sector's capacity to respond effectively.

The guide shows that by integrating NbS into humanitarian action, like reforesting degraded landscapes or restoring soil health, it's possible to enhance resilience while addressing immediate humanitarian needs. This link between degraded ecosystems and frequent emergencies is a crucial consideration in developing sustainable, long-term strategies for disaster risk reduction and response. Ecological sanitation is a NbS that should be used to build soils, grow trees, reduce deforestation and add to other ecosystem services while providing safe, dignified sanitation to people. Communities are more likely to engage and manage systems if they benefit from reuse.

If reuse is perceived to benefit the community, they are incentivised to engage with management and maintenance. In contrast, externally managed systems can face challenges in long-term maintenance, especially after the withdrawal of aid agencies. Community-led initiatives can ensure that infrastructure is cared for by those who use it daily, increasing the system's durability. When CRS promoted the installation of over 53,000 compost toilets with integrated tree planting (Arborloos) in East Africa their evaluation sited *"In Ethiopia, the large number of Arborloos constructed by households from 2005 to 2009 was nearly ten times the number of conventional latrines built between 1995 and 2004"* the *"potential for fruit or other crop production from the compost pit"* was *among the top reasons for wanting an Arborloo.* Rapid Assessment of CRS Experience with Arborloos in East Africa



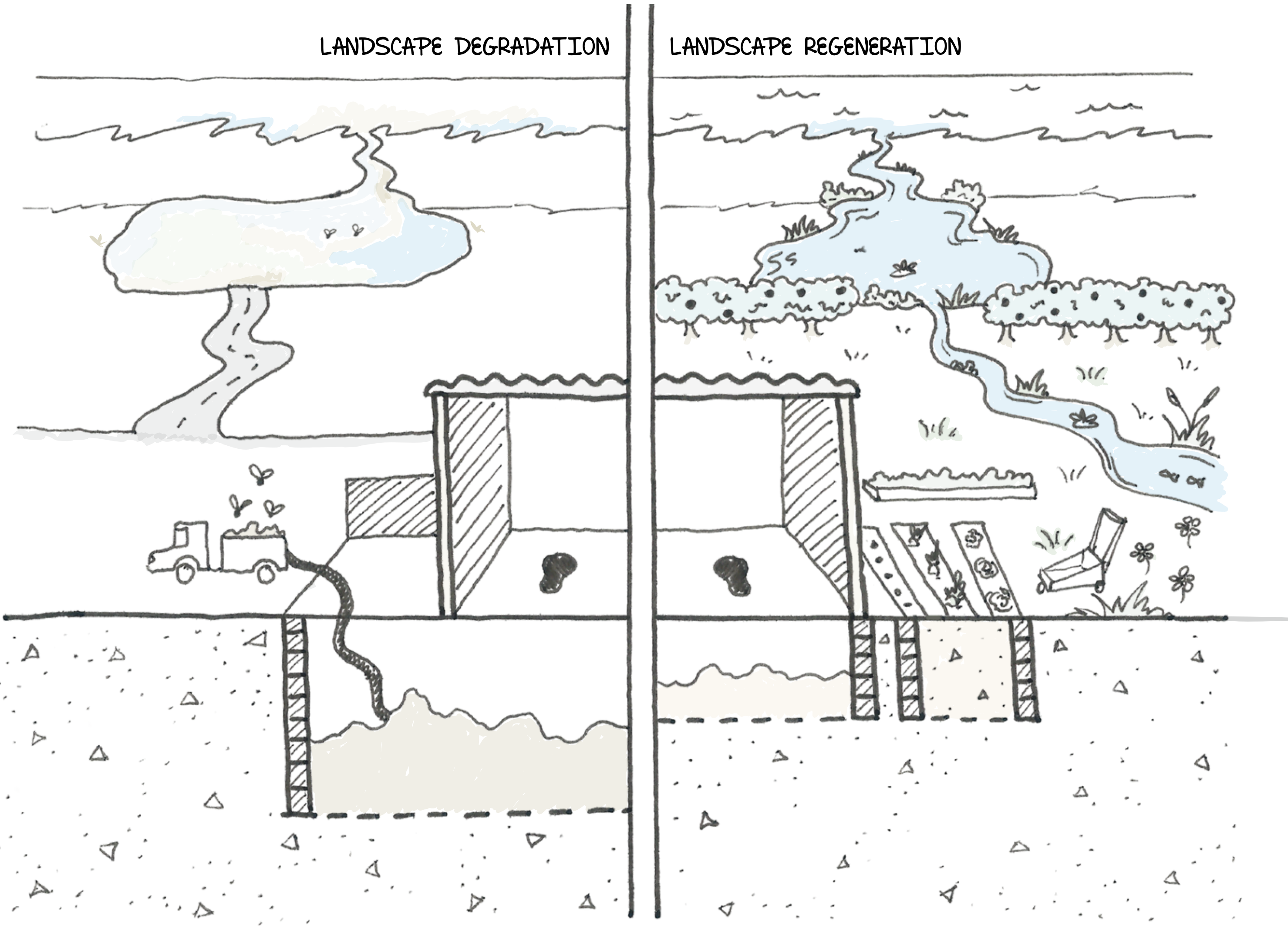
The problems with combining waste water with human excreta and desludging

In systems that combine waste water from flushing, washing and laundry with human waste to produce black water it is commonly estimated that at least 95% is water, representing a 20 fold increase in the volume of polluted wastes to be treated. By keeping waste-water separate from faeces and urine it can undergo simple treatment, such as sand filtration, and be reused for irrigation. This document argues for dry sanitation systems to be the first choice where possible.

In densely populated areas where flush water is available, a gravity-fed piped transport system of wastes to centralised ecological treatment plants such as waste stabilisation ponds can be the most cost-effective and environmentally sustainable response. In Cox's Bazar it has been shown that piped gravity-fed systems are more cost effective over time than tankering, despite the higher CapEx costs.

The increase in protracted crises and reduction in funding per person is making ongoing desludging of flush latrines increasingly unsustainable. The UNHCR Global trends report stated that in mid-2021 26.4 million refugees were displaced for over five years, representing about 70% of the total refugee population. This is in a context of reduced funding where UNHCR budgets have dropped from $110 per displaced person in 2015 to $96 pp in 2024. Over time desludging becomes increasingly less cost effective with ever increasing O&M costs negating any savings on CapEx at the start of projects. Trucks also compact the soil and create dust, further degrading the environment.

Seasonal rainfall and increased extreme weather events often prevent or delay desludging where wet seasons can increase the volume of sludge generated by about 26% (Arup & Oxfam) while dry seasons can make sludge too thick to pump out. Desludging with trucks or manually has associated health risks for secondary handling, greater carbon emissions and the potential to export pollution and disease to the wider population.

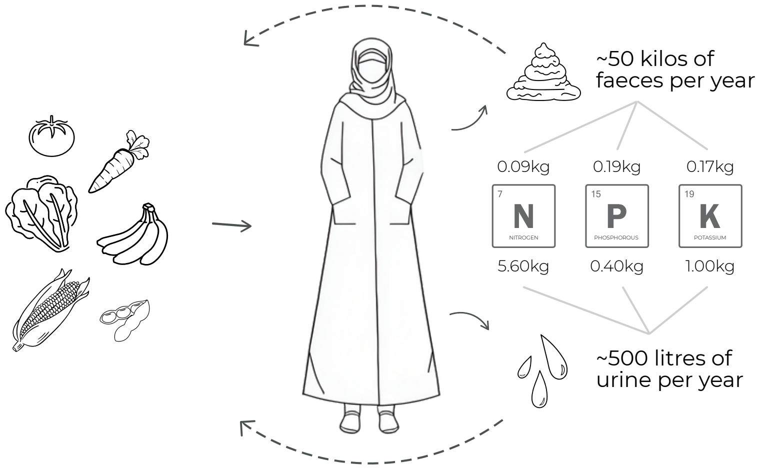


How valuable are the resources from human waste?

Humans have been using their urine and excreta to boost soil fertility in agriculture for millennia. The use of 'night soil' was widespread in agriculture in many regions until colonisation introduced sewered drains that removed nutrients rather than recycling them, and the demand for nutrient recovery reduced with the introduction of industrial fertilisers.

The average adult produces enough nutrients in one year to produce around 250 kg of cereal crops. The majority of the nutrients (phosphorus, nitrogen and potassium) are held within the urine. The faeces contains organic matter which can act to improve soils and increase water retention.

In contrast, synthetic fertilisers are increasingly **expensive** and **over time degrade soils and reduce their ability to hold water** and nutrients. They must be imported and if supply is stopped, or people cannot afford to continue buying them, there are no lasting nutrients or improvements to soil quality to enable continued food growing.



Estimations on nutrient contents of faeces and urine are proportional to the amount of protein eaten. A global average of diets estimates that there is enough nutrients in one person's waste to fertilise 250 kg of cereal.

Adapted from: **UD Toilets and Composting Toilets in Emergency Settings, Oxfam**

	Litres/kg per year	Potassium Content	Nitrogen Content	Phosphorus content
Average annual faeces production for one adult	50 kg	0.17 kg	0.09 kg	0.19kg
Average annual urine production for one adult	500 ltrs	1.0 kg	5.6 kg	0.4 kg
Total	550 lts	1.17 kg	5.69	0.59
Amount needed for 250 kg cereal	-	1.2kg	5.6kg	0.7kg

From Sustainable Sanitation Practice - Issue 3 sustainable 'Use of Urine'.
There is an approximate balance between nutrients in and out of adults

The following studies show the benefits of using human wastes as a resource and support the safety of reuse following adequate treatment:

Recycling Fertilizers from human excreta exhibit high nitrogen fertilizer value and result in low uptake of pharmaceutical compounds Hafner et al 2023

Human Waste Substitute Strategies Enhanced Crop Yield, Crop Quality and Soil Fertility in Vegetable Cultivation Soils in North China Liu et al 2021

Effect of Human Urine as a Fertilizer for Vegetable Growing in Kitemu Zone, Wakiso District, Uganda, Mbowa & Siraje 2020

2 Guiding Principles

Ecological sanitation should not compromise safety and dignity

First and foremost, sanitation should provide safety and dignity to users and promote their health and wellbeing. To understand if a design is appropriate, the community must be involved in the design of systems and their needs reflected in the choice of technologies. Particularly pertinent to ecological sanitation systems are:

- **The needs and roles of women.** Unpaid household labour such as collecting water and firewood, laundry and cooking is often primarily done by women. In on-site household sanitation systems it is probable that the work of cleaning and maintaining toilets and emptying pits would also fall to women who may already have an unsustainable burden of chores. Ensuring that there is organised community support for the maintenance of systems and budgeting for paid maintenance may be necessary. Mothers will often be the primary educators of children who will use the systems, so their involvement to help train children is pivotal. Women's menstrual hygiene practices must be understood and decisions made on how best to cater for them within designs.

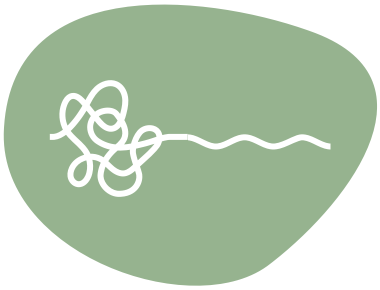
- **The needs of people with disabilities.** Designs which include steps, such as most urine diversion dry toilets and raised composting toilets will not be accessible to everyone, especially people with physical disabilities. Alternative designs may be needed to ensure access.

- **Designs must accommodate the use of anal cleansing water** if this is the common practice. It is not acceptable to expect people to change their personal hygiene customs. Designs may need to be adapted to channel anal cleansing water into soak-aways, or to integrate it into composting toilets (depending on the amounts of water used).

- Some **cultural and religious views** may prevent people from using products derived from human waste. While some concerns can be overcome with education, some deeply-held beliefs cannot be changed and in these cases changes will need to be made to the proposed system.

Three guiding principles

In addition to always ensuring that systems meet the health and dignity needs of users, there are three guiding principles that we argue for in this guide: **Keep it simple, keep it going and keep it growing.** These principles try to ensure that systems can be sustainably maintained by users, over longer periods of time to build and preserve natural resources.



Keep it simple

Keep it going

Keep it growing

Keep it simple

The more complex a system, the more vulnerable it is to failure.
Simple systems:

- Treat wastes on site wherever possible
- Where possible keep wastes dry and do not opt for systems that use flush water.
- Create products that can be reused locally, with minimum processing or transport requirements. These are primarily **compost** and **soil improvers, urine fertilisers**, and **biogas.**
- Use simple passive systems that can be easily understood and maintained. Storage over time is the simplest and most robust form of passive treatment. Wherever possible, design systems that allow for the minimum storage times set out by WHO (see **minimum storage times** section for more). For centralised treatment, passive, systems such as waste stabilisation ponds can create sources of irrigation water.

Keep it going

Build resilient future-proofed solutions

- Build systems that can be maintained by local people - allow for safe non-mechanised emptying and local processing in case funding is cut and external expertise are withdrawn.
- Build systems that have the potential to last years - displacement is increasingly protracted: 70% of the current refugee population is displaced for over 5 years.
- Design for climate change and increased extreme weather events; many contexts need designs that are resilient to drought, flood and extreme heat. E.g Urine Diversion Dry Toilets are a good solution for areas prone to flooding and dry toilets do not need flush water to maintain service.

Keep it growing

Use products to grow useful plants and trees for ecosystem restoration or crops and preserve existing trees by creating fuels for cooking.

- Identify early on what form of plant growth or fuel creation is valuable and possible in each context and integrate it into the project from the start. This may be:
    - Reforestation and afforestation
    - Slope stabilisation
    - Planting for flood prevention
    - Plants for animal fodder or green manures
    - Food growing in communal gardens or larger plots
    - Household kitchen gardens
    - Fertilising existing bushes and trees in the area and increasing areas of biodiversity
    - Linking with local agriculture for commercial crop growing
    - Biogas for schools, places of worship or community groups to reduce the deforestation caused by fuel-wood collection.

3 Major Technologies

We have selected 4 major technology types that aligning with our **guiding principles** and have established records on use and performance in displacement settings and a wealth of evidence to support them. These are:

1. **Decentralised Dry Toilets** with onsite treatment including **pit compost toilets** such as the fossa alterna and the arborloo and **Urine Diversion Dry Toilets**. These can produce compost, urine fertiliser and soil improvers.

2. **Conntainer-based sanitation** with community-scale or centralised treatment, provided it creates a reuse product, usually compost or biogas.

3. For **decentralised toilets flushed with water** we suggest **anaerobic digestion** with **biogas** production and **vermicompost toilets** (also known as tiger worm toilets).

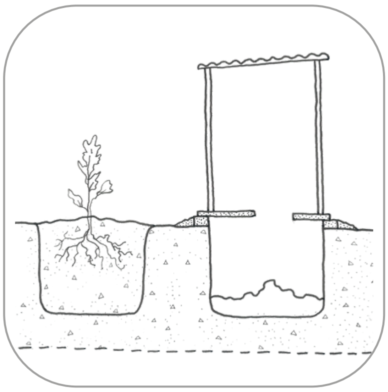
4. For larger scale centralised treatment with available land and water, we recommend **piped transfer** to **waste stabilisation ponds** where the anaerobic pond can produce **biogas** in a covered lagoon and the final effluent from aerobic ponds can be used for **irrigation**.

All the technologies listed are included in the:

'Compendium of Sanitation Technologies in Emergencies' and the associated online tool **The Emergency WASH Knowledge Portal** (Eawag et al)

Our recommendations for reuse are in line with: **Guide to Sanitation Resource Recovery Products & Technologies** (Swedish University of Agricultural Sciences (SLU)

and the **Guidelines for the safe use of wastewater, excreta and greywater** (World Health Organization)

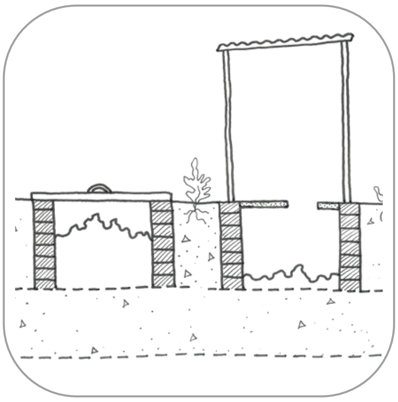


Arborloo

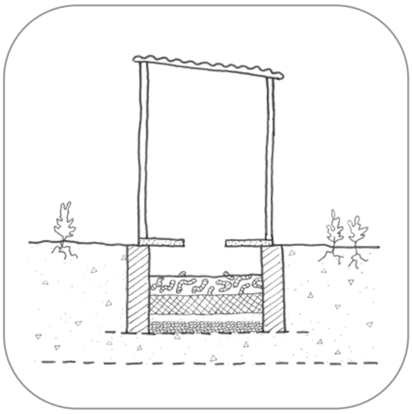
Urine Diversion Dry Toilet

Decentralised Dry Toilets

Container Based Sanitation



Twin pit composting toilet, aka 'Fossa Alterna'

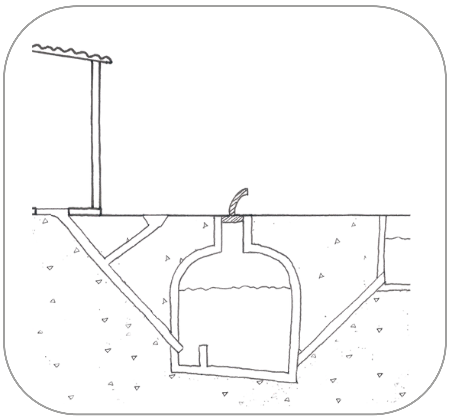


Vermicompost Toilets aka Tiger Worm Toilets

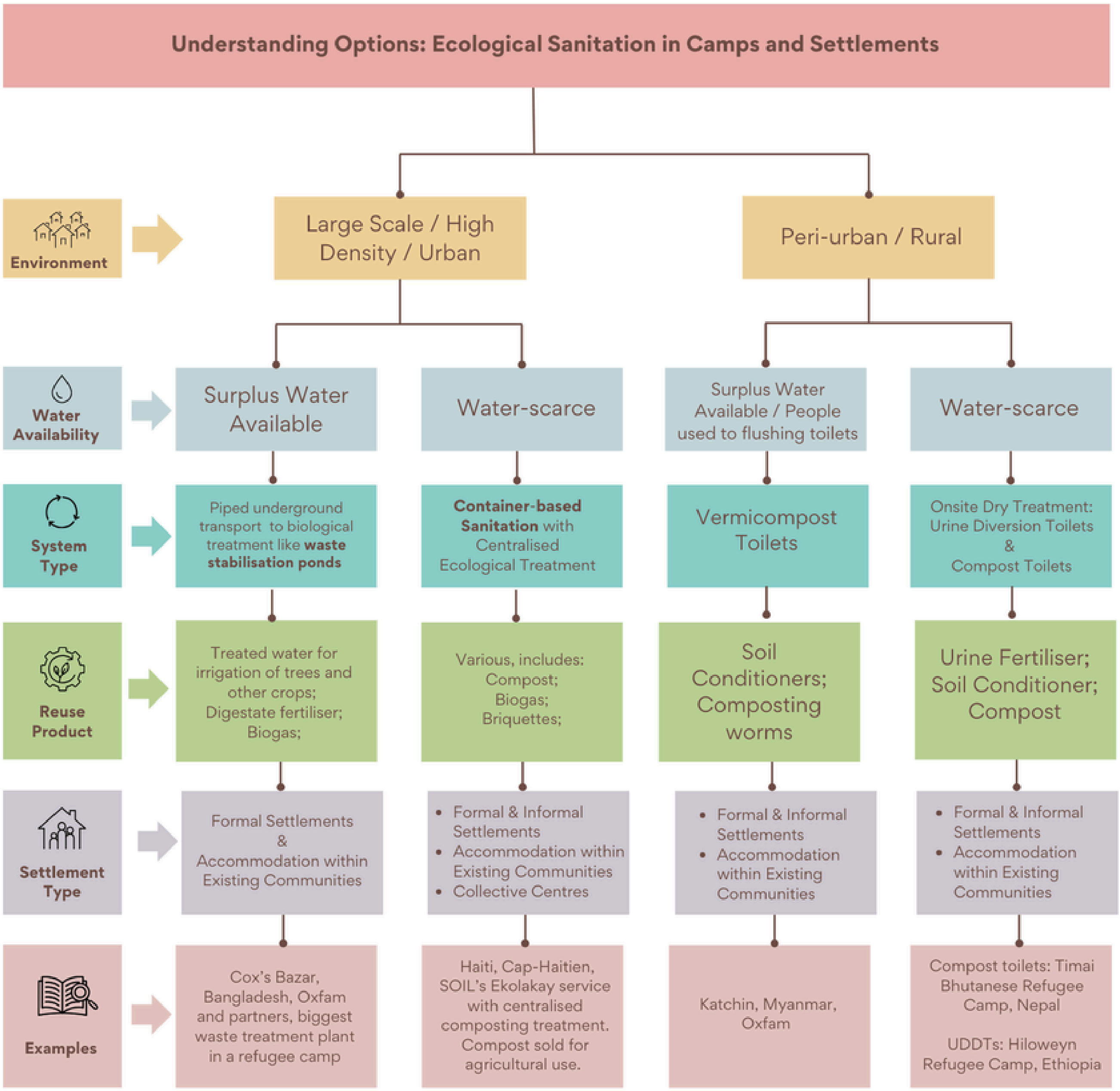
Piped Transfer to Centalised Treatment

Decentralised Flushed Toilets

Waste Stabilisation Ponds



Biogas Toilets



Emerging Technologies and innovation:

There are some emerging technologies that have shown great potential but need further research and development before being implemented at scale. **Direct application Urine Diversion Toilets** and **Treebogs** can both fertilise trees directly without the need to move wastes to make reuse easy to manage. **Terra Preta** composting toilets have the potential to create super fertile soil, inspired by the ancient Amazonian practice of creating "black earth".. Finally, methods of **transporting biogas** are also emerging which involve purifying and bottling or piping gas for greater distribution options. See the **emerging technologies** page for more.

Tweaking existing systems: Options for trench latrines, pit latrines and faecal sludge management

In addition to the technologies above, reuse can be integrated into the most common technologies of pit latrines and trenches. Faecal sludge can be placed in **deep row entrenchments** for reforestation projects and trees can be planted by or on top of decommissioned pit latrines and trench latrines. See the **Reuse Options** section for more. Urinals can be added to existing facilities to harvest urine as a fertiliser and with the addition of a carbon material like soil, ash or leaves, shallow pit latrines can be used as **compost toilets.**

Major Technologies in detail

We do not replicate the wealth of technical details and guidance already available online. For detailed descriptions for each system covered, you can refer to the following resources for technical guidance, to ensure the design you choose will not be polluting and is built in a suitable context.

It is vital to ensure that ground and surface waters are not polluted **by following Sphere standards** as well as any national legislation. Also consider that extreme whether events such as flooding and drought will become more frequent as climate change progresses.

Key online resources for technical and safety guidance

Sustainable Sanitation and Water Management Toolbox
The SSWM Toolbox is an extensive collection of knowledge around sustainable sanitation and water management. Use its search tool to find descriptions of each technology and links to technical drawings, research and case studies

Sanitation Technologies in Emergencies eCompendium
The eCompendium is a comprehensive online capacity development and decision support tool that allows filtering and configuration of entire sanitation service chain solutions in emergency settings. It includes guidance on the application of reuse products.

OCTOPUS
Focusing on faecal sludge management in emergencies OCTOPUS facilitates knowledge sharing through case studies and guides the development of projects and decision-making. It also includes free training courses on key technologies such as biogas.

Sustainable Sanitation Alliance (SuSanA)
The SuSanA website – with its library, project database and discussion forum – is an important resource for anyone wanting to explore the possibilities of sustainable sanitation.

The Sphere Handbook
Outlines minimum standards in humanitarian response. See the Excreta Management section for specific guidance on sanitation, including maximum numbers of people per toilet and minimum distances between toilets and water sources.

Decentralised Dry Toilets

Pit compost toilets

We cover two main types of pit compost toilets here - **Twin pit Fossa Alternas** and **Arborloos,** but all pit and trench toilets, including the Ventilated Improved Pit Latrine (VIP) can be composting toilets if:

- Enough carbon materials are present by adding soil, ash or leaves
- The pit is unlined so excess liquid can drain into permeable soil.
- The pit is not too deep, so that oxygen is available (ideal depth 1.5 m or less, but can be up to 2 m deep)
- Only a little or no water is added (limited amounts of wash water is ok)
- Pits are given time to compost - usually by alternating between two pits

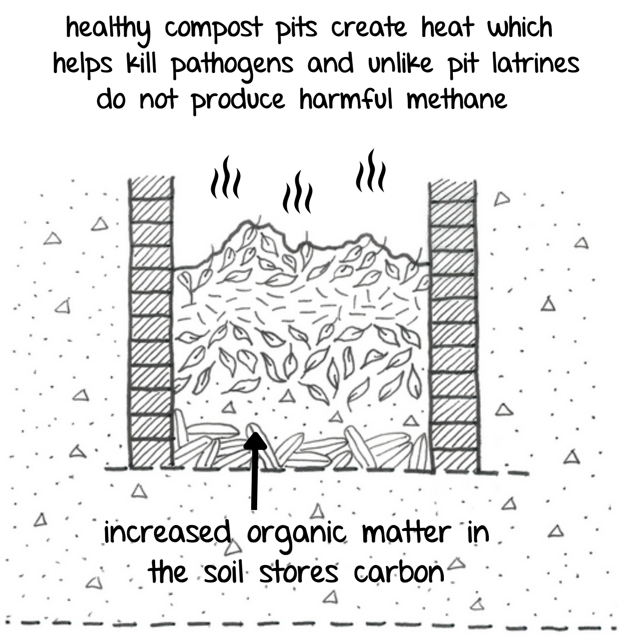
As with all pit and trench latrines, there is a risk of contaminating groundwater and these toilets are not resilient to flooding (although adaptions can be made to make them so). They are most suitable for rural or peri-urban camps with available land for reuse and enough space to dig two pits for every one toilet. There is also the option to dig a single pit which is emptied when full, but this requires a separate composting site and management of the associated transport handling and processing. Moderate soil permeability is ideal for these toilets with slow permeability risking wet, anaerobic conditions and flooded pits and fast infiltration a risk to ground water pollution.

The advantages of running pit and trench toilets as composting toilets are:

- Shallow pits can easily be emptied manually with a spade
- Shallow pits are easier to dig by hand and do not need the same stabilisation as deeper pits; depending on the soil type they may not need their sides lined with bricks.
- The contents will smell far less because it is covered with soil, ash or leaves and because it is aerobic.
- The contents is dryer so can be dug out more easily and pleasantly and will not be a breeding site for disease vectors like mosquitoes.

Composting

- Composting creates heat which kills pathogens including Ascaris, which is often resilient to other treatments.
- Shallow pits are less likely to pollute groundwater (although high groundwater levels preclude their use)
- The toilets can often be built and maintained by the community using them
- The compost can be used to plant trees, grow crops and improve the soil's capacity to hold water (provided reuse is properly managed, see how to reuse safely section for more).



Compost should be stored in the vault or in secondary composting areas for a minimum of one year before use in agriculture. See the E-Compendium's **Application of pit humus and compost** for guidance on how to safely use compost for growing crops and the **planning for safe reuse** section below.

Secondary composting can be by adding to a household compost pile, or centralised co-composting with organic solid waste. Centralised composting, usually managed in windrows, can be controlled to ensure thermophilic conditions, reducing the time in which treatment is completed. Careful monitoring and management of this process is needed.

Faecal Sludge and Septic Treatment: a guide for low and middle income countries, by Kevin Taylor has charts showing recommended treatment times and target temperatures of thermophilic composting as well as numerous case studies.

SOILs Haiti have produced a blog **Windrow Composting: What We've Learned from the Pilot Research and Where We're Going** which explains their windrow process.

Twin-pit composting toilet (Fossa Alterna)

The Fossa Alterna is a waterless double pit technology that is designed to make a compost that can be used as a nutrient-rich soil conditioner. The Fossa Alterna is dug to a maximum depth of 1.5 m and needs a constant supply of cover material such as soil, wood ash, and/or leaves.

Reuse guidance

Compost should be stored for a minimum of one year before use in agriculture. See the E-Compendium's **Application of pit humus and compost** for guidance on how to safely use compost for growing crops.

Case study, Twin-pit Composting Toilets used in the Timai Bhutanese Refugee Camps in Nepal

A 'Ventilated Improved Double Pit Latrine', a system that works in the same way as a fossa alterna, was used in the refugee camps for Bhutanese refugees in Nepal for **86,000 people**.

In **Water Supply and Sanitation: A Case Study of Timai Bhutanese Refugee Camp in Nepal,** they describe that:

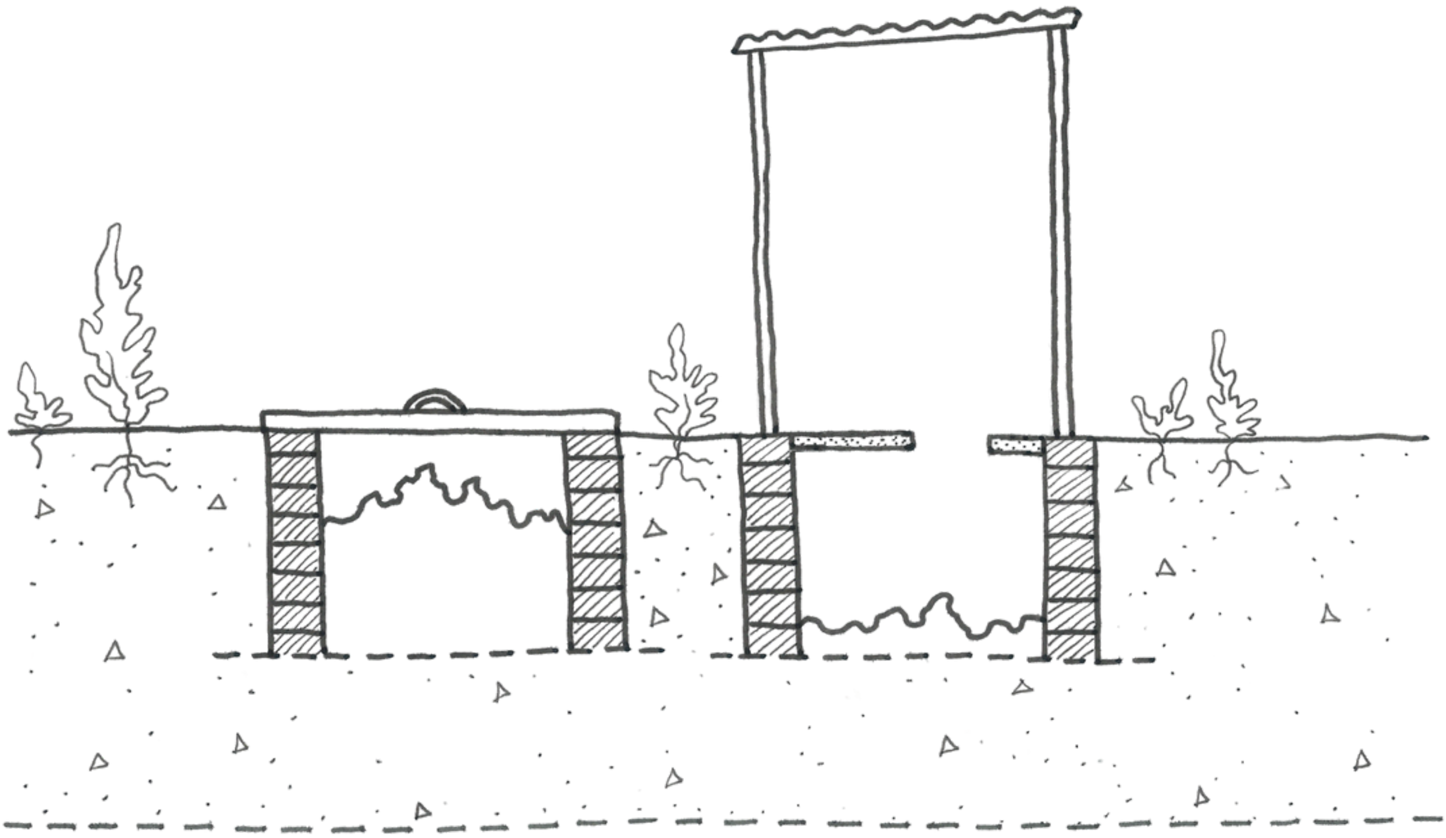
"The VIDP latrine has two pits of 1.2 m diameter and 1.2 m depth.... the twin pits are used alternately. It is reported to take about 8 - l0 months for the pits to fill up in high water table areas with clayey soil, but in sandy soil in the case of Timai camp, the actual changing of pits was reported only after one and a half to two years....The excreta filled pit is then covered with soil and left to decompose. Generally it has been observed that it takes 6 or 7 months for the contents to decompose and become nonpathogenic before the pit can be emptied of its contents.....Presently most people use the decomposed night soil for vegetable gardening after further keeping it covered in a manure pit for over six months."

Technical guidance on Fossa Alterna / Twin pit composting toilet

SSWM Fossa Alterna for an overview

E-Compendium Twin-pit-dry system for emergency contexts

Fossa alterna for household sanitation Arba Minch, Ethiopia - Case study of sustainable sanitation projects (SuSanA) Includes materials lists and indicative costs



Arborloos

The Arborloo is a shallow pit toilet that is filled with excreta and covered with soil, ash and/or leaves. Once full a tree is planted on top of the nutrient-rich pit. The pit is between 1 - 1.5 m deep and the toilet superstructure, consisting of a ring beam, slab and structure, is moved from one site to the next when needed, usually between 6 and 12 months. Space is needed for the subsequent pits to be dug, so the options for this technology within densely populated camps is limited, but it could be well suited on the growing plots for refugees in Ugandan and Kenyan camps and within community gardens. The simple design is relatively low in cost to build and maintain. From 2005 to 2009 in Ethiopia, **53,840** households in 7 regions installed Arborloos with the help of CRS. CRS reported that user satisfaction for Arboloos was high and that all the people surveyed planned to continue using them and to plant something on the filled pits.

Trees can give shade, stabilise soils, provide food, mulch materials and timber, cool the environment and encourage rainfall. Care should be given to the provision of sapling trees. It may be a tree nursery is needed to provide saplings and guidance should be given on how to care for and water trees. See the box to the right for details of a tree nursery training guide.

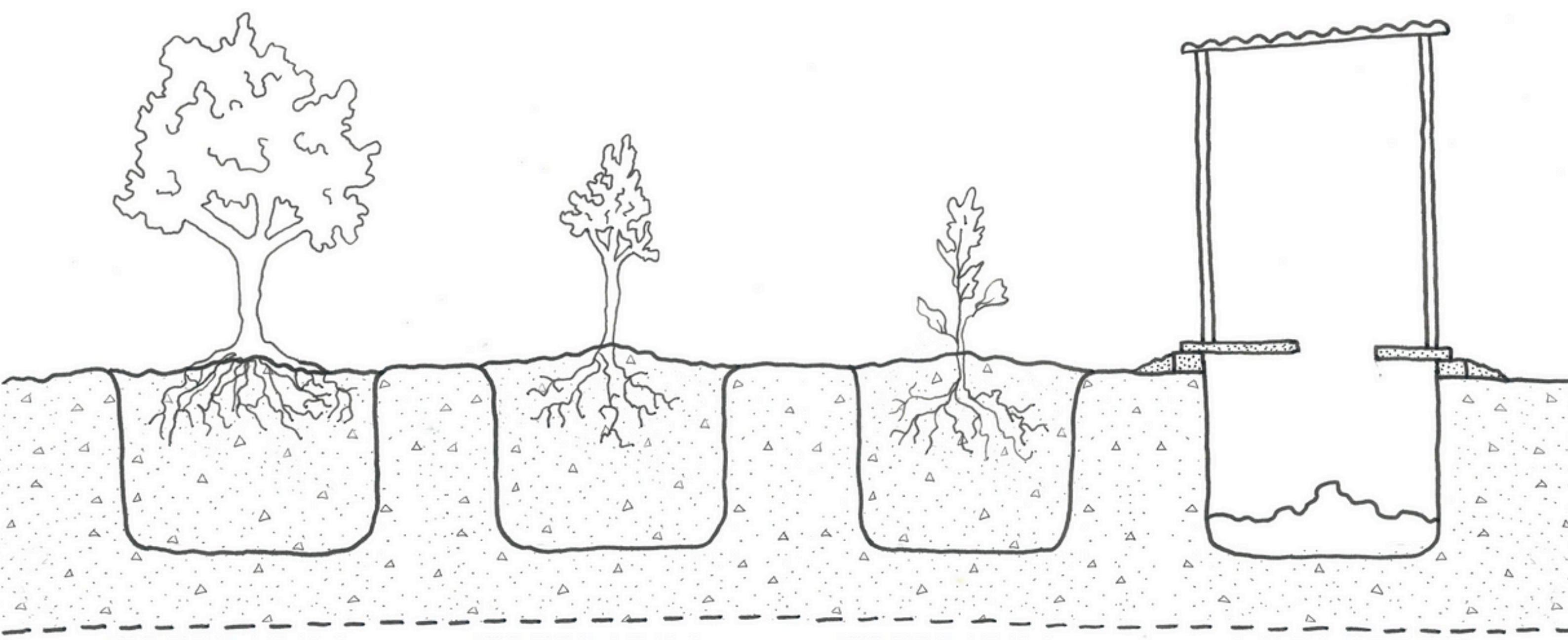
Hand washing points can be placed by trees, to allow the grey water to irrigate them. Trees can also be planted beside the Arborloo when it is first built, allowing the roots to tap into the compost pile as it grow. This has the advantage of including tree planting in the initial phase, to ensure it is not overlooked.

In How to ... build an Arborloo and a Fossa Alterna?" they state:

"Good trees for this Arborloo pit are mulberry, guava, mango, paw paw and banana. But we can plant many other trees. Plant the young tree in the soil above the compost. The young trees must be cared for. They must be protected from animals and must be watered often. In time the tree will grow big and provide many fruits. Once the tree is established we can fertilise the tree with a mix of urine (2 litres) mixed with water (10 litres) and a mug full of wood ash every month to help it grow more."

Technical guidance on Arboloos and planting trees

- SSWM Arborloo an overview of the technology
- E-Compendium Arboloos: arboloos in emergencies
- Rapid assessment of CRS experience with Arborloos in East Africa, Herbert P, 2010:
- 'Tree Nursery Establishment, a training guide' by ICRAF.
- How to build an Arborloo and Fossa Alterna, IRC

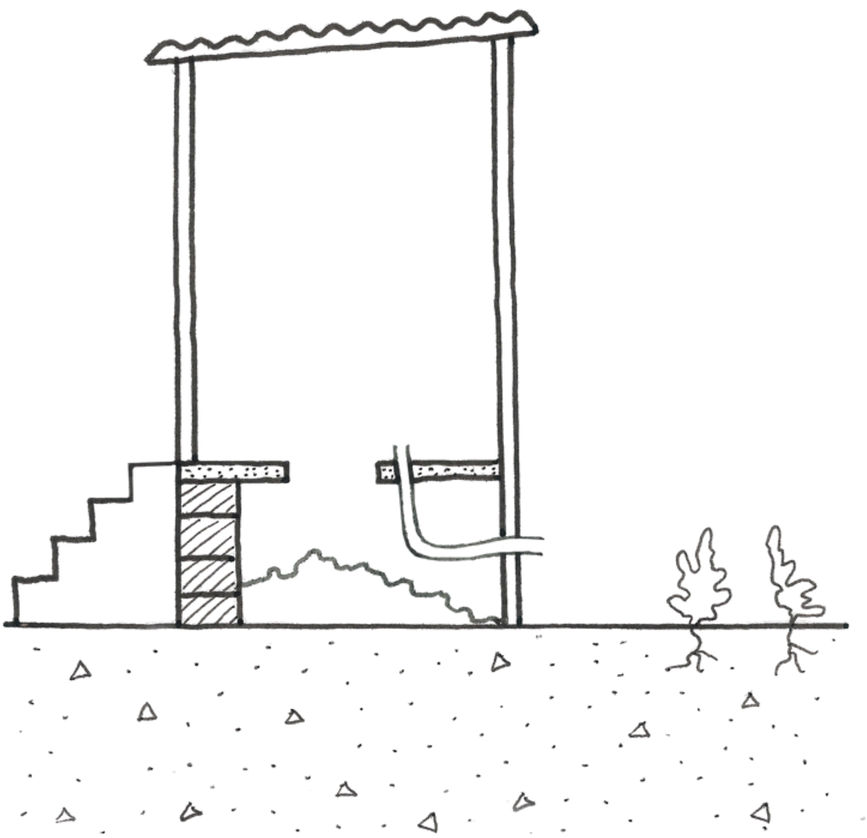


Urine Diversion Dry Toilet

Urine Diversion Dry Toilets (UDDTs) are an onsite dry system which separate urine from faeces with a specially designed toilet bowl. This separation allows for the storage and reuse of **urine** as a **fertiliser** and the storage treatment of solid wastes. Urine can be directed into a container, for reuse as a fertiliser, or a soak-away, while faeces are collected in chamber where they are covered with dry material, like ash, sawdust, or dry soil, after each use. UDDTs produce less odour than pit latrines because of the urine separation and covering of faeces. The above-ground design means they can be used in places with rocky soils or areas that flood. They have been built following disasters in Haiti, Bangladesh, Chad, and El Salvador and in Hiloweyn and Dollo Ado refugee camps in Ethiopia.

The design is limiting for some people with disabilities because it includes steps and it also requires changes in user behaviour, so community consultations and training is needed. UDDTs drastically reduce the amount of solid waste, so there is also the potential to convert existing pit latrines to include urine diversion to reduce the frequency needed for emptying. To maximise the fertility of the products, **Terra Preta Sanitation** methods can be undertaken to create rich, fertile compost. See the innovations section below for more.

Reuse guidance
Stored urine is a liquid fertiliser. See Re-use of Urine section for more. *Dehydrated faeces* is relatively low in nutrients and Ascaris eggs can remain alive in it for long periods. However, it can be used to line a pit for tree planting or incorporated into a secondary composting system.



Case study: Oxfam's Development of the UDDTs

Oxfam has been instrumental in the testing and development of UDDTs. They stated that:

"We now have confirmation, validated by UNHCR Waste to Value Sanitation programme, that the urine diversion dry toilets which Oxam's been trialling since 2012 should be considered as a standard solution for areas of refugee camps with difficult ground conditions - especially in protracted crises....The overall lifespan of these toilets is an estimated 10 years, - over three times that of a typical pit latrine - and in Ethiopia they cost $500 where a normal pit latrine lasting only two-three years would cost $325."

Oxfam also engaged the Center for disease control in the US to test the stored vault contents for pathogens and found:

"In Hiloweyn camp, Dollo Ado, Ethiopia that , overall, UDDTs there were successful in microbial inactivation over a 12-month storage period"

However, tests found the dried faeces in 3 out of 10 vaults did still contain ascaris eggs - so hazard *control measures are still needed in reuse.*

Technical guidance for UDDTs

🔗 SSWM UDDTs
🔗 E-Compendium Double Vault UDDT
🔗 Oxfam UDDT standard operating procedures for camps. This webpage contains links to several reports including: 🔗 Alternative Sanitation in Protracted Emergencies: Final Report, Center for Disease Control and 🔗 Technology Review of Urine-diverting dry toilets (UDDTs)

Container-based Sanitation

Container-Based Sanitation (CBS) has been used to provide sanitation in areas where infrastructure is either non-existent or impractical, such as in **urban slums** or **emergency settings.** Because the units can be used in-home, they are good options for people with disabilities and because they can be carried by hand, they are also good for places inaccessible to trucks and tankers. CBS has shown its potential as an inclusive, resilient, affordable approach that can be **rapidly deployed** in **high density environments** and in **areas with water scarcity**, **high water table** or **places prone to flooding.** There is a variety of treatment options of wastes from CBS units, but the technology is only truly ecological if passive treatments create products that are reused. The major drawbacks to CBS is the need for a regular collection and emptying service and the associated transport to treatment facilities.

1. **Toilet Provision:** households have an affordable, transportable dry toilet that can be placed in homes or in structures adjoining homes . The seated toilets can contain a separate compartment for urine diversion if needed.
2. **Container Collection:** Waste is collected in sealed containers that sit inside the toilet. Household toilets usually need weekly or biweekly collection, meaning a well managed collection service is needed. Alternatively, households can be responsible for taking their full containers to collection depots and receiving fresh containers.
3. **Safe Waste Transport:** Containers are transported to a centralised treatment facility.
4. **Treatment and Resource Recovery** Treatment can be varied depending on the reuse material wanted.

The most ecological treatment and viable reuse options are **thermophilic composting** to create **compost** and **anaerobic digestion** to produce **biogas** and **soil conditioners.**

The UN Habitat 2023 [Global Report on Sanitation and Wastewater Management in Cities and Human Settlements] highlights CBS as an important and innovative approach to addressing high density sanitation challenges:

"Container-based sanitation has potential as part of a mix of services in climate-vulnerable contexts, including as a waterless option in areas with water scarcity. Additionally, CBS is well suited to densely populated low income settlements, because of the lack of capital infrastructure requirements at the containment level."

Case studies: CBS following an earth quake

SOIL, an organisation in Haiti, operates a CBS system that was able to offer a strong response following the devastating 2010 earthquake and produces sanitised compost that is sold for agricultural use.

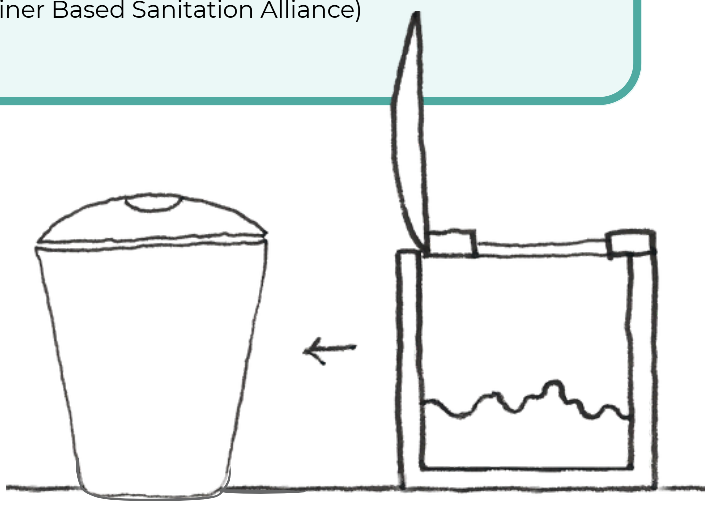
Research has proven the safety of SOIL's treatment with the CDC finding pathogen levels below detection. See [Thermophilic composting of human wastes in uncertain urban environments: a case study from Haiti"]

Key resources for CBS

[SOIL Haiti]: A leading organisation offering CBS with thermophilic composting creating sanitised compost for agriculture.

[The Humanure Handbook,] Jo Jenkins:
This seminal book and associated resources outlines the process of creating a home, or community-based composting system using CBS units.

[Container Based Sanitation Implementation Guide]
(Container Based Sanitation Alliance)



Liquid wastes: Black water and faecal sludge

In cases where the addition of water to human wastes, via flush water and wash water, is preferred, we promote **biogas systems** and **vermicomposting** toilets (also called Tiger Worm toilets) as both offer reuse options as part of onsite ecological treatment.

When dealing with high volumes of faecal sludge in densely populated environments, **piped supply networks and large centralised ecological treatment plants have been shown to be the most cost-effective option over time, have the lowest carbon footprint and produce the most consistent treatment outcomes.** However, they do come with higher capital expenditure costs.

Oxfam has opened the largest human waste treatment plant ever built in a refugee camp, in Cox's Bazar, Bangladesh, which pipes wastes for ecological treatment in treatment ponds and wetlands, including a covered lagoon which captures biogas. The key difference from conventional waste treatment plants that we argue for is that treatment should be **ecological and passive,** be **simple to maintain,** and that systems **should be be designed to allow products to be reused to increase energy and ecosystem services within the local environment.**

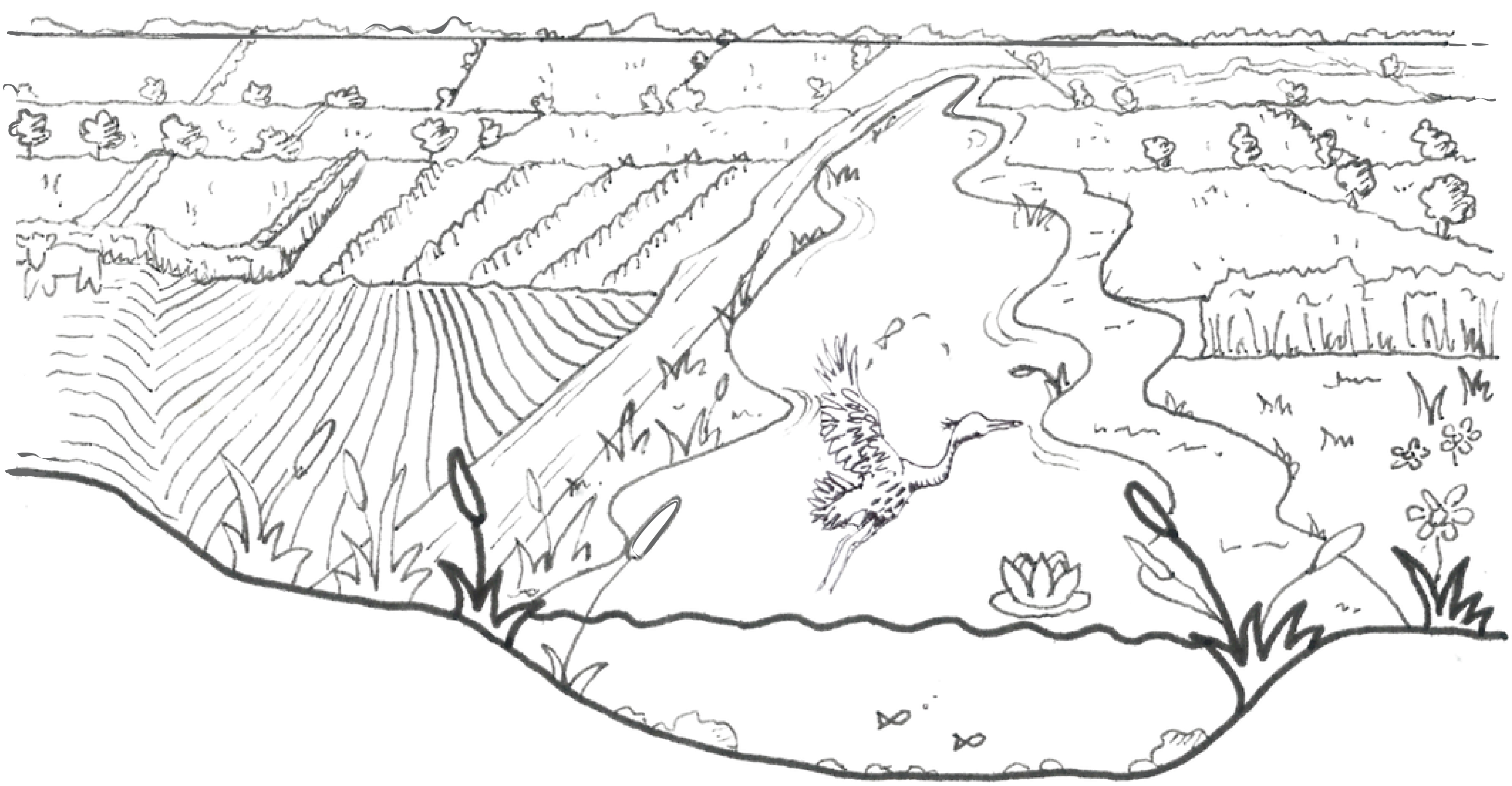
Waste stabilisation ponds with covered anaerobic lagoons can produce biogas for energy or cooking and water for irrigation, all using passive biological treatment. **Constructed wetlands** can be used in the final 'polishing' pond to further purify water and to increase biodiversity.

Choosing the best technologies for black water and faecal sludge management - Oxfam's technology reviews

For comparisons of faecal sludge treatment technologies, Oxfam has commissioned two reports from Arup, reviewing the multiple technologies used in Rohingha refugee camps:

Faecal Sludge Management for Disaster Relief: Technology Comparison Study, Arup & Oxfam
The report concluded that **Anaerobic Lagoons** (as part of a series of waste stabilistation ponds) are suitable for centralised treatment in areas with enough space, offering simplicity in operation and maintenance, water for irrigation and biogas production if lagoons are covered. **Upflow Filters** are recommended for decentralized, long-term use where space is limited.

Technical Assessment of Faecal sludge management in the Rohingya Response, Arup & Oxfam This report showed that centralised treatment using piped networks offered the best value for money over time and gave the most consistent treatment results.



Biogas Systems

Biogas systems use anaerobic digestion to convert faecal sludge (and other organic wastes) into biogas. The remaining residues after digestion need further treatment such as **composting**, storage, or deep row entrenchment to be used as **soil improvers** and **fertilisers.** Water is needed for anaerobic digestion, making it less appropriate in areas of water scarcity. The distribution of biogas is a limiting factor, with most examples using the gas as a cooking fuel in modified gas burners close to where it is produced. If only human wastes are used in the digester, the waste from 6 people can produce enough cooking fuel for one person. As well as a cooking fuel, biogas can be used for powering vehicles, lighting, heating, refrigeration and electricity generation.

At the community level, biogas systems can be installed as part of an integrated system of **toilets**, **wash rooms** and **laundry facilities** and create cooking **gas for community kitchens.**

High-volume, centralised anaerobic systems have been shown to be the most cost effective and ecologically sustainable option where large volumes of biogas are produced and the biogas can be converted to electricity using biogas engines. However arguably the greatest benefits of biogas in displacement context are from providing a cooking fuel. In centralised systems this means purifying the biogas so that it can be bottled to reach the households who need it. This has successfully been accomplished by the Indian Institute of Technology's Biogas Development and Training Centre. See the **Innovation** section for more.

Co-digestion biogas systems process organic solid waste, such as kitchen scraps, together with faecal sludge and animal dung as part of an integrated solution to solid waste management which creates bigger yields of biogas.

The three most commonly used digester types that can produce biogas are:

- Fixed dome digesters
- Floating dome digesters
- balloon digesters (including covered lagoons)

Where space is limited, fixed and floating dome digesters make use of vertical and sub-surface space. For large-scale centralised treatment where there is available land, covered anaerobic lagoons can form part of a series of waste stabilisation ponds, producing biogas, fertilisers and irrigation water.

Advantages of using biogas for cooking:

- Reduces deforestation caused by the collection of firewood for cooking
- Increases safety for women and children who are vulnerable when collecting firewood
- Improves air quality within shelters and reduces the respiratory diseases caused by smoke from firewood
- Reduces greenhouse gas emissions by converting the methane in faecal sludge to CO^2
- Gives a constant, renewable fuel source and reduces spending on fuels like propane.

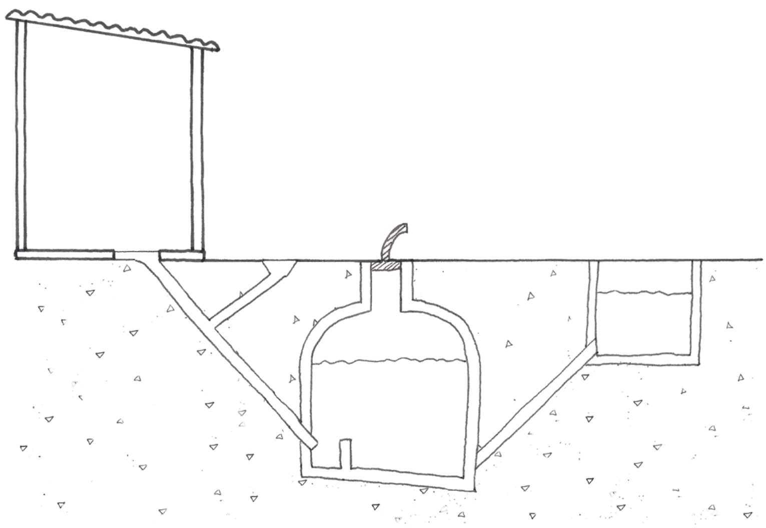
Key resources for biogas

SSWM Biogas
OCTOPUS Training course in Biogas

Biogas in refugee camps

The world's biggest waste treatment plant in a refugee camp, designed by BORDA for Oxfam in Cox's Bazar Bangladesh, uses treatment ponds and wetlands to treat wastes and produce biogas. The challenge remains getting the biogas to the people who need it for cooking.

The Circular waste management in Zaatari refugee camp, Lebanon, uses sludge from the adjacent wastewater treatment plant and organic waste to produce biogas which generates electricity at a capacity of 50 kWh / day.



Vermicompost Toilets (also known as tiger worm toilets)

These permeable pit toilets use worms to reduce the volume of matter and produce vermicompost which, after secondary treatment, such as storage, can be applied as a soil conditioner. All types of composting worms can be used in these toilets.

Worms need water to survive so this is only suitable in places with a constant supply of water for flushing. Pit latrines can be upgraded to become vermicompost toilets, which can reduce emptying frequency and smells. Major limiting factors are the availability of worms in sufficient quantities (although wormaries can be set up) and worm death due to lack of water, flooding or excessive heat.

Vermicompost toilets still need emptying and must be integrated with a secondary treatment such as storage or thermophilic composting before the compost can be reused in agriculture. Alternatively, vermicompost can be buried and a tree planted above. Oxfam suggests covering with 30 cm of soil.

Oxfam is A leader in Tiger Worm Toilets and states: *"over 1200 TWT's have been built and trialled across six countries by Oxfam in a range of settings including urban, peri-urban and refugee camps. Trials have also been run by other organisations as well as installations by the private sector. They have been proven to work in both individual household and shared communal camp settings."*

The toilets have been shown to work best for communities with a history of using flush toilets and for household, rather than communal use. In communal settings more frequent emptying is often needed.

Where space is limited, fixed and floating dome digesters are best as they make use of vertical and sub-surface space. For large-scale centralised treatment where there is available land, covered anaerobic lagoons can form part of a series of waste stabilisation ponds, producing biogas, fertilisers and irrigation water.

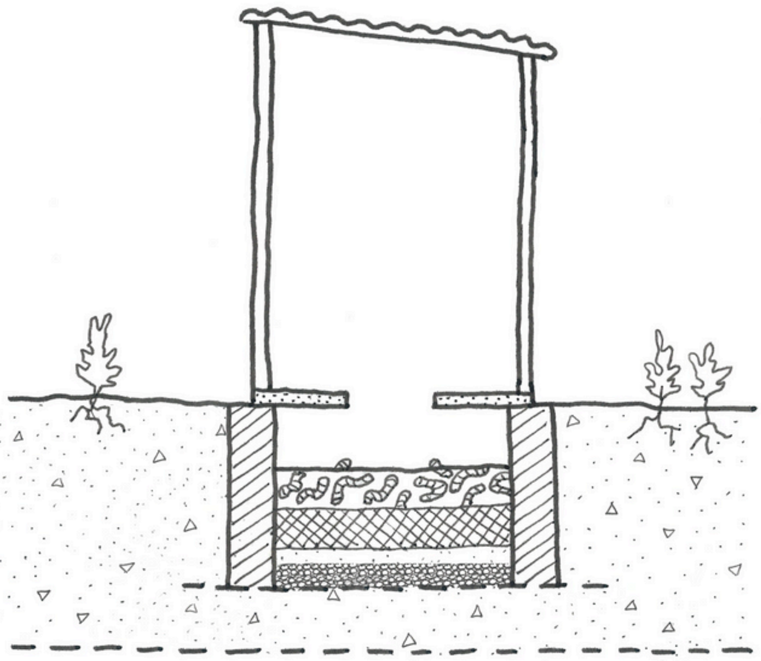
Reuse guidance

Vermicompost should be stored for a minimum of one year before use in agriculture. See the E-Compendium's 🔗 **Application of pit humus and compost** for guidance on how to safely use compost and **planning for safe** reuse section below.

Key resources for vermicompost toilets

🔗 **Oxfam's Tiger Worm Toilet guide:** guidance on Design, operation, setting up a wormary, infiltration tests and monitoring. Unfortunately Oxfam do not suggest any form of reuse, but instead suggest burying under 30 cm of soil.

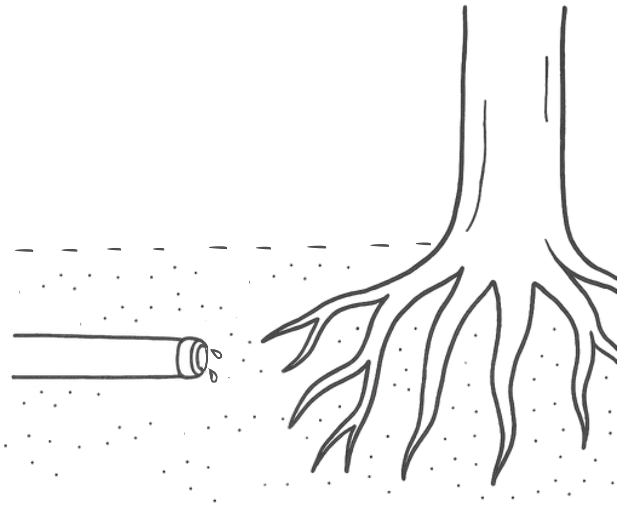
A review of Oxfam's experience can be seen in: 🔗 **Learning from Oxfam's Tiger Worm Toilets projects, C. Furlong, J. Lamb & A. Bastable.**



Emerging technologies and innovations

Using wastes in-situ

Because of the associated risks of handling, it is of course preferable to reuse products in-situ, rather than moving them. Other than the Arborloo, there is a lack of technologies that offer this. We have identified two that offer potential, but need further piloting to prove their safety and effectiveness:



1. **In-situ Urine Diversion with tree growth**

In UDDTs and urinals, urine is commonly diverted to a soakaway. Soakaways channel waste 'away' rather than for productive use. A system where water and urine are channelled directly to the roots of trees or bushes is possible, but little research is available.

Permaculture systems already exist for channelling grey water direct to trees, such as 🔗 Art Ludwig's Branched Drain Greywater System but no examples of use integrating urine reuse.

Biologist Chris Casaday has installed four 🔗 urine diverting 'aborloos' in Ecuador, where urine is piped sub-surface directly to productive trees using hose and bamboo.

2. **The Treebog**

Another innovative design which integrates tree planting is the 'Treebog' which is a twin chamber composting toilet built above the ground, with beneficial trees planted around. See the Re-Alliance resources for our 🔗 Treebog Innovations and Explorations guide for more.

Boosting Soil Fertility with Terra Preta Sanitation

Terra Preta Sanitation is a dry sanitation approach that turns human waste and food waste into **fertile, nutrient-rich compost**, inspired by the ancient Terra Preta ("black earth") soils of the Amazon. Urine diversion is needed so it can be used with Urine Diversion Dry Toilets and Container Based Sanitation where urine is diverted.

Solid wastes first undergo lactic acid fermentation (or lacto-fermentation), followed by a second step of vermicomposting. Charcoal can be added either before or after the lacto-fermentation process.

🔗 SSWM Terra Preta Sanitation Factsheet

Drip irrigation of urine for fertilising crops

Drip irrigation offers an application option with low exposure and handling of urine, which may be more acceptable to certain cultures. There have been successful trials of drip irrigation using urine:

🔗 Trial of Human-Urine-Derived Fertilizer on New Crops, Rich Earth Institute. This project included trials of drip line irrigation of urine. It concluded that urine can be delivered through drip irrigation equipment when the irrigation water is as hard as 255 ppm, (and potentially higher,) provided that the urine and water are pumped into the irrigation system in an alternating sequence.

🔗 Risk of clogging of drip-line emitters during urine fertilization through drip irrigation equipment

This report concluded that allowing the urine / water mix to settle in the tank for 45 minutes before application does not lead to more work for the farmer in terms of inspecting and unblocking the emitters in the drip lines than using only water.

Biogas bottling:

A major limitation of biogas is getting it from where it is produced, to the people who need it for cooking with.

🔗 The Biogas Development & Training Centre at the Indian Institute of Technology, Delhi, is installing biogas enrichment and bottling systems in sites across Jaipur, Jodhpur, Bikaner, and Bhilwada. After biogas is captured, carbon dioxide, hydrogen sulphide and water vapour are removed using pressurised water. The enriched biogas is then compressed and stored in cylinders.

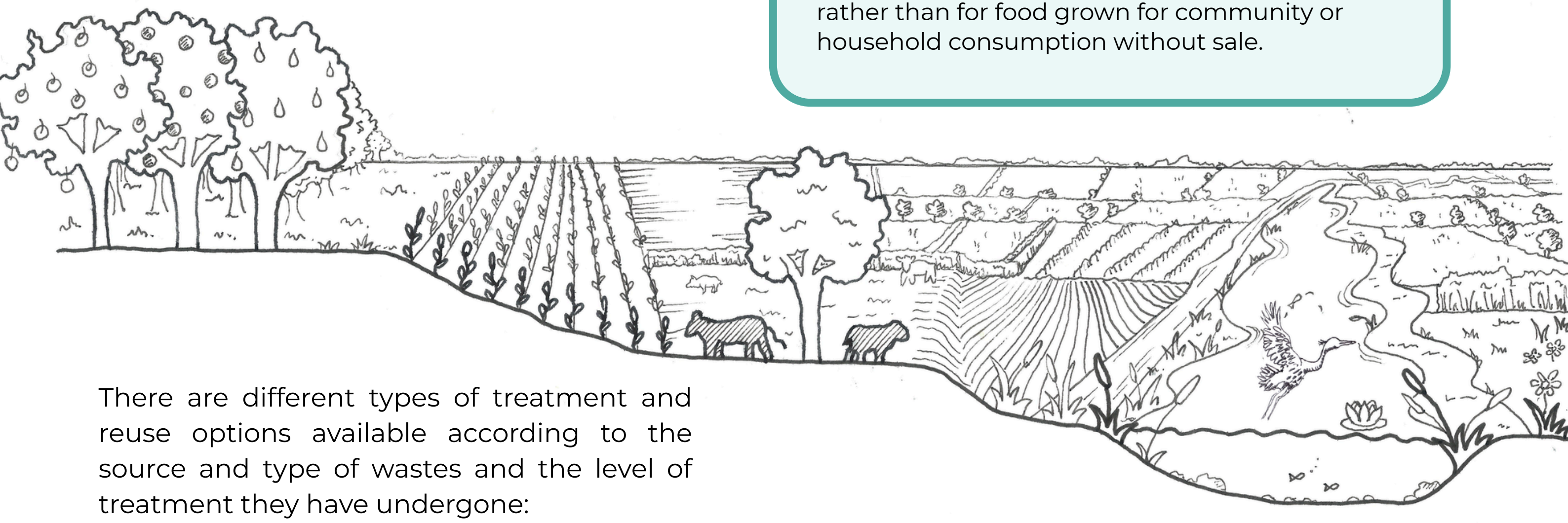
3 Reuse options

Nearly all sanitation technologies have options for the recycling of nutrients to **build up ecosystem services, enrich soils and increase biodiversity.** Not to recycle nutrients is wasteful in the resource-scarce environments of many camps and settlements so it should be planned for from the start, as standard, as part of an integrated response.

Primary guidelines managing growing crops using reuse products

WHO Guidelines for the safe use of wastewater, excreta and greywater - Volume 4 provides guidance on the assessment and management of risks associated with using excreta and greywater in agricultural settings. This is supported by their Sanitation Safety Planning Manual For Safe Use And Disposal Of Wastewater, Greywater and Excreta

Nation states may have their own regulations concerning agricultural crops grown using human waste which require adherence. Often regulations apply to crops grown commercially rather than for food grown for community or household consumption without sale.



There are different types of treatment and reuse options available according to the source and type of wastes and the level of treatment they have undergone:

Collective processing from multiple toilets

1. offsite deep row entrenchment for tree planting, afforestation and reforestation
2. Biogas production at source
3. Reuse of urine **only** (provided it is stored for sufficient time) - larger scale collection and reuse if links can be formed with agriculture or forestry.
4. Piped transport to ecological treatment with production of biogas, fertilisers and water for irrigation
5. Thermophilic and co-composting for creation of compost for agriculture.

Onsite treatment at household scale

1. Tree planting for household using compost, dried faeces, urine, vermicompost and digestate.
2. Using compost and soil improvers for growing crops for households or for feeding animals
3. Crop growing with urine

Crop selection to minimise risks

Products from human waste can be used to feed all types of plants and improve soils. Although the highest food-security, health, nutrition and educational benefits are gained through food growing, it is also the option which requires the most intensive risk management.

There is a wide variety of non-edible plants which can be grown to increase ecosystem services, including trees for shade, timber and firewood, which require less risk management.

Below is a table showing the many beneficial plants that can be grown, from lowest to highest risk, giving options to suit different circumstances. As well as crop selection, it is also important to consider the related risks of placement and any associated transport and handling.

Beneficial Plants that can be grown using products derived from human waste and their level of risk to human health			
Risk Level	**Category**	**Example Crops**	**Context**
Lowest Non-edible Crops	Trees for shade, timber, coppicing, firewood, beauty, increased biodiversity, erosion control, water regulation, climate regulation and soil fertility	Culturally appropriate native trees including: Sal, Neem, Bamboo, Cajuput, Rose, willow, eucaliptus	Good for wastes from multiple sources and on a larger scale. Risks related to handling and transport of wastes, and placement, planting and harvesting of crops must all still be considered and controlled.
	Plants grown as fertilisers	Comfrey, Nettle, Borage, Vetch, Alfalfa	
	Plants grown to feed animals	Alfalfa, Clover, Corn	
	Plants and trees for slope stabilisation	Bamboo and Bermudagrass, Acacia, Neem, Gliricidia	
	Plants for flood protection	Reeds, Switchgrass, Cattails, bullrushes, papyrus	
Minimum Edible Above-Ground Perennials	Tree crops	Banana, Mango, Papaya, Jackfruit, Cashew, Citrus	Good for community use, but not always suitable for commercial sale (depending on national regulations). It is highly unusual for biological pathogens to be up-taken from soil into fruits, contamination is possible directly via cuts in the skin of fruit.
	Shrubs, bushes, grasses, and vines	Blueberry, Gooseberry, Mulberry, Bamboo, Rooibos, Grapes	
Low-Medium Above Ground Annual crops cooked before eating	Grains	Sorghum, Millet, Maize, Teff	Good for community use, but not always suitable for commercial sale (depending on national regulations)
	Legumes	Common Bean, Soybean, Chickpea, Lentils	
	Vegetables	Aubergine, Okra	
Medium Risk	Above Ground Annuals sometimes eaten raw	Tomatoes, Peppers, Chili, Melon,	Best for household consumption from household latrines.
Medium and Higher Risk	Above Ground Annuals in some contact with the soil	Spinach, Cabbage, Pumpkins, Courgette	
Highest Risk Edible annual Crops - Grown in the Soil or Eaten Raw	Salad Crops	Lettuce, Rocket, Cucumber	Do not recommend growing using products derived from faeces or urine in displacement settings at this point.
	Herbs	Thyme, Basil, oregano	
	Root Crops	Potato, Yam, Cassava	
	Ground-level fruit	Strawberries	

Linking forestry projects with sanitation

Ecological sanitation projects can be linked to tree planting projects, providing a low-risk reuse option with multiple benefits. Methods can include **deep row entrenchment** of faecal sludge and partially treated products such as digestate from anaerobic digesters, directing effluent water from waste stabilisation ponds to water trees and collecting and applying urine to fertilise trees.

The UNHCR's **Managing Forests In Displacement Settings** guide stresses: *"The potential for establishing tree plantations in or near displacement settings should be assessed at an early stage to identify the specific needs and threats and current and future pressures on natural resources."* Neethling and Still (2022) found that the *"volume of timber in plots with sludge application showed increases of approximately 30% within the first 3 years of growth when compared to plots without sludge."*

Tree planting projects depend upon tree nurseries for a supply of sapling trees. See the **'Tree Nursery Establishment, a training guide'** by ICRAF for guidance on how to establish a tree nursery.

Many nations, including Ethiopia, Senegal and Pakistan, have ambitious reforestation goals and there have been successful tree planting projects in refugee camps. In Minawao Refugee Camp, Cameroon, 50,000 trees, including neem, acacia, moringa and leucaena, have been planted as part of the Great Green Wall initiative aimed at combating desertification. In Nyarugusu Refugee Camp, Tanzania, The Danish Refugee Council has planted over 2 million trees in the camp and surrounding areas since 2021. The project aims to restore forest cover lost to firewood, while improving soil moisture, agricultural productivity, and providing sustainable fuel sources. See the **Re-Imagining responses** section to see how sanitation could have been integrated into the project in Cameroon.

Tree planting with deep row entrenchment

Deep row entrenchment (DRE) can safely dispose of faecal sludge (and other partially treated other products like compost) by burying it in trenches, where it can provide nutrients for trees or bamboo planted above. DRE helps recycle nutrients back into the soil while minimising the risk of contamination but needs available land with appropriate conditions and saplings for planting.

.The online training tool Octopus covers DRE in its Sludge and Biosolid Management module and describes the site requirements as:

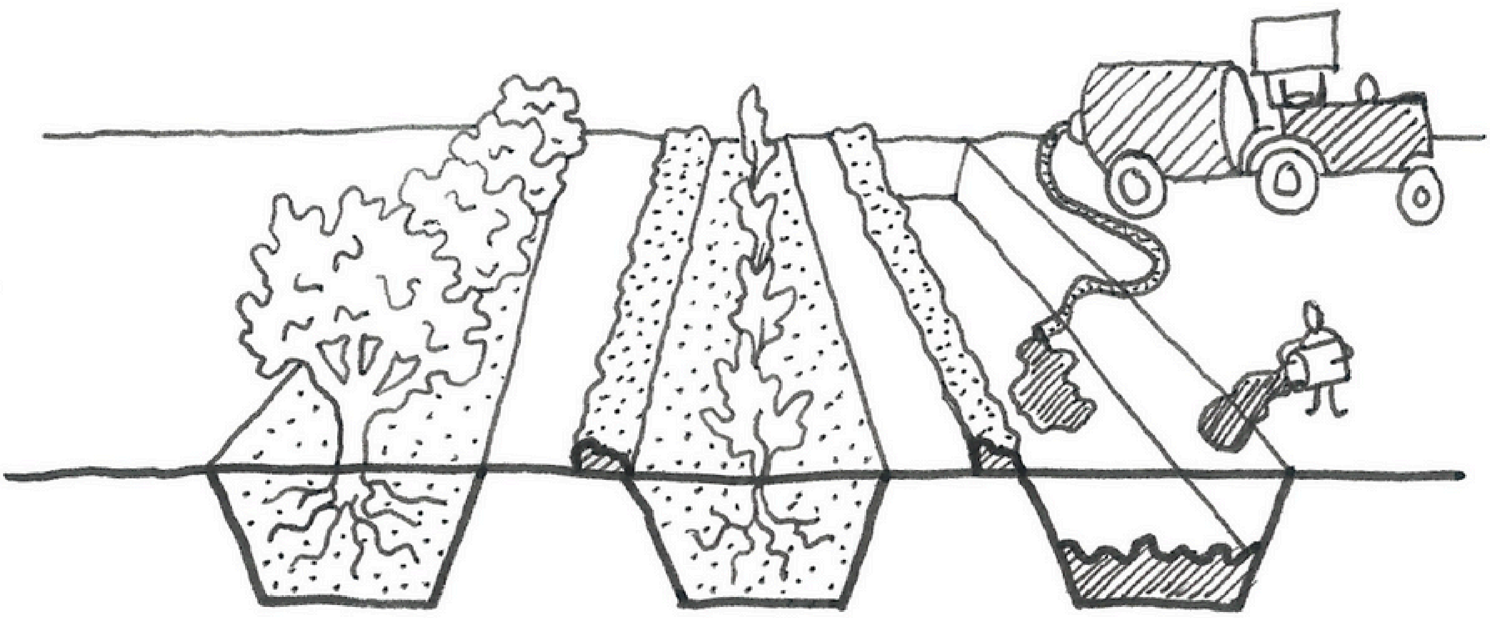
- Trenches between 1 and 2 metres deep
- Trenches located more than 50 metres from surface water bodies and at least 200 metres from human habitation
- Highest groundwater table at least 5-10 metres below the bottom of the trench
- Placed only in areas with good soil permeability and infiltration capacity, avoiding regions prone to heavy rainfall, high groundwater levels, or flooding.

In its Guidelines for Deep Row Entrenchment the South African Water Research Commission describes the methods and benefits of using faecal sludge in trenches to grow trees. For tree planting it recommends:

- Trenches can be backfilled with soil at the time of planting,
- trees can be planted using standard forestry practices
- Do not plough the soil prior to planting.

It describes how keeping entrenchment sites as small, decentralised close to the source of sludge as possible has the following advantages:

- Operations can be handled by a small business or local community
- Lower transport costs
- Minimal overheads and infrastructure needed (trenches can be dug by hand rather than with diggers)
- Minimal skills required for daily operation (no complex processes or machinery to manage)
- Timber or fruit can be grown to benefit the local community



Larger scale reuse products from centralised treatment

When there is centralised waste treatment, there can be multiple products, such as treated wastewater, biogas and compost, which can be integrated into reforestation and agricultural activities. Often this is a multi-agency approach bringing together diverse partners from INGOs, local and national governments and private sector involvement.

Circular waste management in Zaatari refugee camp, **Jordan,** integrates solid waste management, wastewater treatment, sanitation, food and tree growing, biogas and job creation. Sewage, along with organic solid waste from food waste is used to create biogas and make compost which is used with treated wastewater to grow crops including trees and food. The project was implemented by FAO, Ministry of Agriculture in Jordan, Syrian Refugee Affairs Directorate, UNHCR, Jordanian National Agriculture Research Center (NARC), Jordanian Energy Research Center (NERC), Oxfam and GIZ.

This holistic, integrated approach yields the most cross-cutting benefits, but requires centralised management and continued investments of finance, knowledge and skills.

You can read more from the FAO guides:

Improving Rural Livelihoods and the environment through the integral utilization of residues of treated waste water and organic solid waste for the production of renewable energy and compost in Mafraq Governorate of Jordan

Liquid sludge was added to organic waste as part of the composting process (also called co-composting), the results are reported on in Compost from organic bio solids, Production, socioeconomics and impact on the soil productivity Final report' from the FAO.

The compost was found to be safe to handle and the report states *"It was possible to produce quality compost from the organic solid wastes and liquid sludge generated at Zaatari. The quality of produced compost, in terms of the biological and chemical permissible limits, was within the range of the Jordanian standards of 2016."*

Unfortunately, a major limitation was that local Jordanian farmers use synthetic fertilisers and so do not want to buy the organic compost produced by the project.

Centralised Thermophilic composting in Port-au-prince

Thermophilic composting of human waste for the creation of sanitised **compost** for use in **commercial agriculture** is successfully undertaken in Haiti by SOILS as part of their container based sanitation service. Their **centralised composting** process treats the wastes of around 20,000 people in Port-au-Prince. Their website contains a wealth of resources, including their Sanitation Safety Plan, which applies the WHO safety methodologies to their operations.

See SOIL's website here
See the SOIL sanitation safety plan here

Growing crops within camps and settlements for the displaced community: Composts, soil conditioners and fertilisers

Growing food has arguably the highest benefit to a community of all the reuse options. As well as promoting food security and supporting health and nutrition it can give people a sense of dignity, purpose and self-respect. Non-edible crops can also be grown and are still beneficial.

The meaningful activity of crop cultivation can support mental health, physical fitness and gives people contact with nature to help heal from trauma. See Gardening in Displacement: The Benefits of Cultivating in Crisis, for more.

However, growing food with products derived from excreta has health risks which must be managed.

To minimise risks we recommend you follow the steps in the planning for safe reuse section.

For composts and soil conditioners the simplest ecological treatment is storage over time.

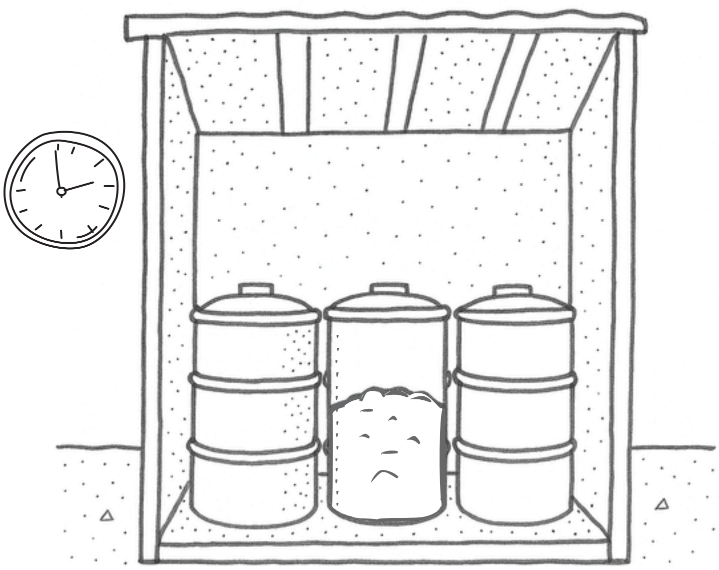
Given enough time, all pathogens will die provided no new material is added.

Ecological treatments include **thermophilic composting**, **anaerobic digestion**, raising the pH, desiccating (drying) and bacterial competition (by adding soil for example) and UV treatment (from the sun). Each of these treatment options can speed up the rate at which pathogens die.

However, maintaining optimum conditions for these natural processes needs a thorough understanding and control of the variables which influence them, such as temperature, moisture levels and availability of oxygen.

For this reason, we suggest that wherever possible, wastes containing faeces are stored for the **WHO recommended time** for storage treatment **of over one year** for hot climates and **1.5 - 2 years** for cooler climates before any reuse for food growing is undertaken. See the **planning for safe reuse** for more.

If products cannot be stored for the recommended time, consider **deep row entrenchment** with tree planting as an alternative. Trees can have edible fruits or nuts for community or household use. Alternatively, consider **Arborloos** or **Treebogs** where productive fruit trees are planted in-situ.



Reuse of Urine as a fertiliser

Urine is the most nutrient rich of all the reuse products and can be used as a highly effective fertiliser. Stored urine can be applied to the soil around crops neat after rainfall or before watering, or diluted as part of watering. Urine contains far fewer pathogens than faeces, but it has the potential to carry harmful microorganisms either directly from the urine or, more commonly, from accidental contamination with faeces. Urine from urine diversion dry toilets is more likely to be contaminated with faeces than urine from urinals. See the **planning for safe reuse** section to manage risks.

A first step in urine reuse could be the addition of urinals to a community garden or household garden plots, where it is then stored to sanitise it and then applied to the soil to fertilise crops. Urine is heavy so it is best collected close to the site of reuse. It is important that urine is stored undiluted and urine should never be mixed with wash (anal cleansing) water for storage and reuse.

Urine Fertilisers for wicking beds and container gardens

Urine can be used to fertilise container-based gardens such as Wicking Beds, a low-water food growing system. Growing crops in containers limits the incidental contact that can occur when people walk or children play on the ground around crops. See the Re-alliance guides on **Roof Top Gardening** and **Wicking Beds**, both of which show methods of container gardening.

Nutrient content of Urine

The amount of urine to apply is determined by the crop type and the soil fertility. The nitrogen requirement for each plant type should be taken as the primary guide for application. The quantity of nitrogen per litre of urine is dependent on the diet the people producing the urine, but the following table can be used as a rough guide:

Characteristics of urine	
Nutrient	**Average Value**
Nitrogen	6 grams per litre
Phosphorus	0.8 grams per litre
Potasium	0.9 grams per litre
Sodium	3.1 grams per litre
Magnesium	20 milligrams per litre
Calcium	36 milligrams per litre
PH	8.8

Adapted from Opening minds and closing loops – productive sanitation initiatives in Burkina Faso and Niger, Sustainable Sanitation Practice, Use of urine

Easy ways to reuse Urine - overcoming barriers

Despite the established benefits of using urine as a fertiliser, Oxfam still commented of its UDDTs in Ethiopia: "*The urine is disposed of into a soakaway as the alternative, collection and reuse, requires intensive management.*"

In the pressurised environment of camps and settlements, management of reuse systems at scale may be a restrictive factor. To reduce the issues of management, we would suggest the following approaches:

- Undertake urine reuse as a second-stage 'tweaking' programme, once toilets are established. This could be done when maintenance for toilets is due and urine can be diverted into storage rather than soak aways at this point.
- Plant trees in decommissioned soak-away pits as part of maintenance, with a new soakaways placed to the side.
- Consider piloting a system where urine and grey water is piped directly to trees or fruit bushes, this could be sub surface to a mulch pit around the tree - see the **emerging technologies** section for more.
- Consider the addition of urinals at existing crop growing sites. This could be at community gardens or household plots. Urinals can be mounted on existing trees and the urine directed by pipe directly to tree roots or to storage.

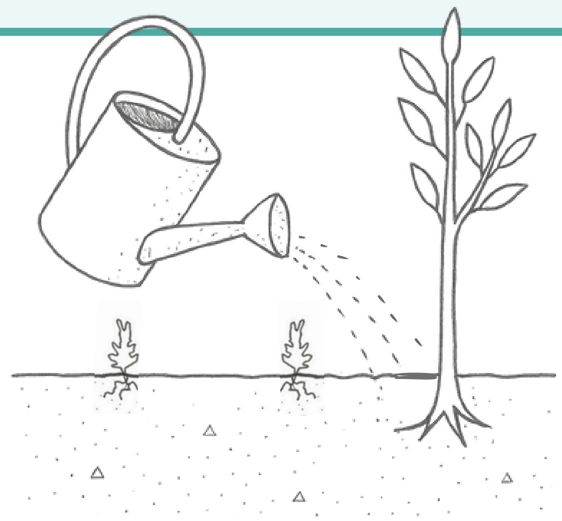
Urine Reuse guidance

See the E-compendium's **Application of Urine** pages for technical guidance for emergency sanitation contexts

Use of Urine, by the Sustainable Sanitation Alliance gives practical lessons from diverse field research

The Rich Earth Institute's **Farmer Guide to Fertilizing with Urine** is US centred, but its illustrated accessible content can be helpful to farmers in other contexts

Urine as liquid fertiliser in agricultural production in the Philippines is a practical field guide by R Gensch and others from 2011.



4

Planning for safe Reuse in agriculture

When putting together a plan to manage the risks associated with reuse in agriculture, the primary sources of guidance are the 2006 WHO Guidelines for Safe Use of Wastewater Excreta, and Greywater in Agriculture and Aquaculture and **adherence to the legislation and regulations for the relevant territory.** For guidelines aimed at protecting sanitation workers, the United States' Centre For Disease Control have clear guidance on their website for handling biowastes. The sections below go into further detail on these guidelines.

We have combined these resources into a **4 part risk management approach:**

1. **Adhere to minimum WHO Storage Treatment Times**
2. **Ensure a Multi-barrier approach: reduce risks at each stage of exposure in line with WHO recommendations**
3. **Follow the Centre For Disease Control Guidance for handling Type B Biosolids**
4. **For larger scale projects, use the WHO Sanitation Safety Planning Manual to create a Safety plan**

When Reuse in Agriculture is not appropriate

Because of the increased risks of transmissible diseases, reuse in agriculture is generally not appropriate with wastes from health care facilities, including hospitals, clinics and community health centres. There may be scope for reuse as biogas, provided no additional handling is required within the system.

There may be times when outbreaks of transmissible diseases, such as cholera, greatly increase the risks associated with reuse. In these cases reuse should be paused until risks are normalised.

Key resources:

2006 WHO Guidelines for Safe Use of Wastewater Excreta, and Greywater in Agriculture and Aquaculture.
Makes recommendations on the minimum storage treatment times and outines the multi-barrier risk reduction approach.

Center for Disease Control's Guidance for Workers Exposed to Class B Biosolids During and After Field Application gives guidance on the safe handling of partially treated waste products

The WHO's Sanitation Safety Planning Manual For Safe Use And Disposal Of Wastewater, Greywater and Excreta provides practical step-by-step guidance to assist in the implementation of the 2006 guidelines through the creation of a sanitation safety plan.

1. WHO Minimum Storage times

The following tables show the minimum time requirements for storage treatment for dry excreta and faecal sludge and urine adapted from the WHO 2006 Guidelines. Storage can be integrated into the system, such as in **Fossa Alternas,** or used as a secondary treatment after, for example, anaerobic digestion. There are methods, such as thermophilic composting, which speed up treatment, but these processes are subject to variables that can be hard to control, so it is safest to keep to the minimum storage times unless testing consistently shows safety at shorter treatment times.

WHO Recommendations for storage treatment of dry excreta and faecal sludge before use at household and municipal levels (adapted from WHO 2006)

Treatment	Criteria	Comment
Storage, with no new material added; ambient temperature 2-20°C	1.5 - 2 years	Will eliminate bacterial pathogens; regrowth of E.Coli and Salmonella may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage, with no new material added; ambient temperature >20-35°C	>1 year	Substantial inactivation of viruses, bacteria, and protozoa; inactivation of schistosome eggs (<1 month); hookworm (Ancylostoma/Necator) and whipworm (Trichuris); survival of certain percentage (10-30%) of Ascaris eggs (≥4 months), whereas a more or less complete inactivation of Ascaris eggs will occur within 1 year.

Storage does not guarantee safety

Storage for the WHO recommended time does not guarantee safety. Oxfam had the contents of its UDDTs faeces vaults tested after 1 year and 3 months of storage. Of the 10 chambers, 7 held compost within the WHO safe limits and 3 held compost that was outside the safe limits.

See **Alternative Sanitation in Protracted Emergencies,** National Foundation for the Centers for Disease Control and Prevention

Recommendations for storage treatment of urine (adapted from WHO 2006)

Source of urine	Temperature	Storage Time	Crop Type	Extra Information
Individual households eating their own crops	N/A	No storage required	All crops	Family's daily exposure to pathogens is higher than from fresh urine.
Household, crops cooked or processed	20°C or higher	1 month	Cooked crops e.g. cereals	For crops that are cooked or processed before consumption.
Household, crops consumed raw	20°C or higher	6 months	Raw crops e.g. vegetables	Reduces pathogen risk for crops consumed raw.
Household, all crops	4°C	6 months	All crops	Extended storage for pathogen reduction at cooler temperatures.
Household, general storage	20°C or higher	1-6 months	All crops	General recommendation for stored household urine.
Public toilets/schools, crops cooked or processed	20°C or higher	1-6 months	Cooked crops or non-contact crops	For crops not in direct contact with urine (e.g., cereals, fruit trees).
Public toilets/schools	20°C or higher	6 months	All crops	Requires longer storage or additional treatment. Additional risk management like dilution, pH adjustment may be required.

The table shows how **urine source, temperature** and **crop type** influence the length of storage recommended. Storage should be in **sealed airtight containers**. **Do not use metal containers** for storing urine and **do not dilute urine** before storage.

Because storage cannot guarantee safety, it is safer for all products, such as compost, fertilisers and soil improvers, derived from faeces and urine are considered as potentially hazardous and handled as a partially treated 'type B biosolid' unless laboratory testing shows otherwise. **See steps 2 and 3** for more.

2. Multi-barrier approach: reducing risk at each stage of exposure

Putting in measures to minimise risk at each stage of the chain, from the toilet through to eating crops, risks can be managed in a multi-barrier approach. This will include training and outreach of all the groups exposed, which can include sanitation workers, farmers and householders.

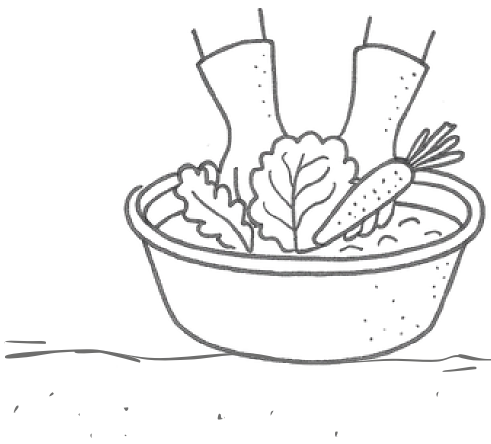
The WHO outlines six main phases in the reuse of urine and faeces and safety measures can be introduced to reduce the associated risks at each stage. The table shows the phases, who is at risk and suggests effective mitigation measures. Risks must be managed to make each stage of exposure safer.

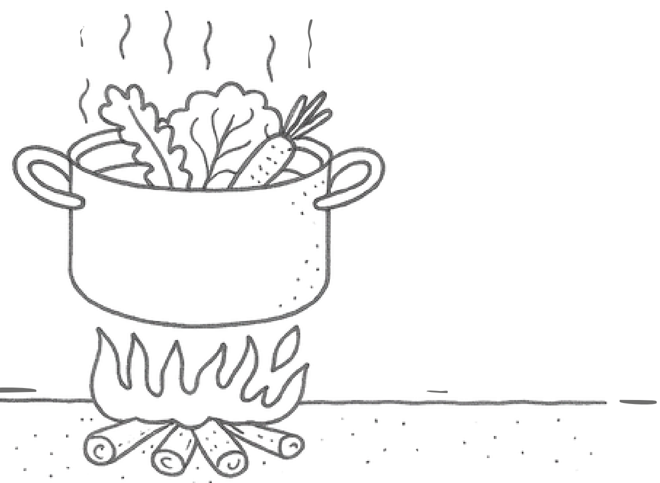
Key resource:

2006 WHO Guidelines for Safe Use of Wastewater Excreta, and Greywater in Agriculture and Aquaculture.

Major Exposure Points When Reusing Excreta
(Adapted from WHO, 2006)

Risk Activity	Exposure Route	Groups at Risk	Mitigation Examples
1. Emptying collection chamber	Contact Vectors Inhalation	Sanitation workers, Household or Local community	Adequate treatment; Protective Clothing and PPE; Training; Avoiding spillage; Suitable tools and equipment; Reducing vector propagation
2. Transport	Contact Spread through equipment	Workers, Local community	Clean equipment before using it on other material; Avoid spillage;
3. Secondary (off-site) treatment	Contact Vectors	Workers, Nearby community	Efficient treatment, Protective clothing, Restrict access, Reduce vector propagation
4. Application	Contact Inhalation	Householders, Farmers, Local community	Apply in trenches or work material into soil, Restrict access to field, Protective clothing for farmers, plant crops after application
5. Crops, harvest, processing and sale	Consumption Handling	Consumers, Workers, Vendors	Allow one month between application and harvest, select appropriate crops, provide protective clothing, provide water for cleaning
6. Consumption	Consumption	Consumers	Practising good hygiene, Cooking thoroughly before eating





3. Centre for Disease Control Guidance - consider wastes as 'partially treated' unless testing shows otherwise

Even after adhering to the minimum storage times, without lab testing it is prudent to assume that waste products contain some pathogens.

The Centre for Disease Control defined the contents of the Oxfam UDDT vaults in Ethiopia as **Class B biowaste.** The CDC defines class B as biosolids that have **undergone treatment that has reduced but not eliminated pathogens.** They set out guidelines for handling this biowaste on their website as follows.

CDC Handling recommendations for workers exposed to class B biowastes are as follows:

- Wash hands thoroughly with soap and water after contact with biosolids.
- Avoid touching face, mouth, eyes, nose, genitalia, or open sores and cuts while working with biosolids.
- Wash your hands before you eat, drink, or smoke and before and after using the bathroom.
- Eat in designated areas away from biosolids-handling activities.
- Do not smoke or chew tobacco or gum while working with biosolids.
- Use barriers between skin and surfaces exposed to biosolids.
- Remove excess biosolids from footgear prior to entering a vehicle or a building.
- Keep wounds covered with clean, dry bandages.
- Thoroughly but gently flush eyes with water if biosolids contact eyes.
- Change into clean work clothing on a daily basis and reserve footgear for use at worksite or during biosolids transport.
- Do not wear work clothes home or outside the work environment.
- Use gloves to prevent skin abrasion.

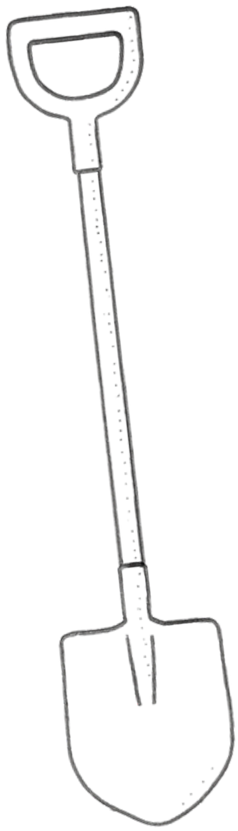
They also list PPE that can be selected from to protect workers. From their list, the items which best protect when handling solid waste products derived from faeces include:

- Strong waterproof gloves
- Boots
- A face mask for emptying vaults if the contents is dusty
- Overalls / coveralls

Long-handled shovels should be provided as part of the tools to empty vaults and appropriate storage containers, such as waterproof fertiliser bags.

Key resource

🔗 [Center for Disease Control's Guidance for Workers Exposed to Class B Biosolids During and After Field Application]



4. Creating a Sanitation Safety Plan

The WHO Sanitation Safety Planning Manual can be used to produce a safety plan for reuse. This is most appropriate for organisations operating at a larger scale and would be overly complex for self-built household toilets where reuse is kept within the household.

The manual takes you through 6 modules. Below is a table summarising the modules with suggested outputs.

Key resources:

The WHO's 🔗 **Sanitation Safety Planning Manual For Safe Use And Disposal Of Wastewater, Greywater and Excreta**

To see a worked example see the 🔗 **SOIL Sanitation Safety Plan** detailing the processes of thermophilic composting of wastes from Container Based Sanitation which is sold as compost for agriculture in Haiti.

Step	Outputs
1: Prepare	• Agree the priority areas, purpose, scope, boundaries and leadership for the Sanitation Safety Plan (SSP) • Form a multidisciplinary team representing stakeholders in the sanitation chain for development and implementation of SSP
2: Describe the Sanitation System	• Create a validated map and description of the system • Identify potential exposure groups. • Identify likely waste stream constituents and waste related health hazardsCompile the relevant technical, legal and regulatory information • Validate the system description
3: Identify Hazards, Assess Controls, and Risk	• Risk assessment table summarising hazards, events, exposure groups, and controls. • Prioritised list of hazardous events to guide system improvements.
4. Develop and Implement an Improvement Plan	• Incremental improvement plan implemented.
5. Monitor Control Measures and Verify Performance	• Operational monitoring plan. Verification of monitoring plan.
6. Develop Supporting Programmes and Review Plans	• Identify and implement supporting programmes and management procedures • Reviewed and updated SSP outputs

4

Re-imagining Responses

Here we re-imagining responses in two existing refugee camps to show how things could have been done differently with the benefit of hindsight to make better use of the resources generated from human waste.

Sahrawi refugee camp, Algeria

The Sahrawi refugee camps are a collection of refugee camps in the Tindouf Province, Algeria formed in 1975–76 for Sahrawi refugees fleeing from Morocco. At around half a century old, the situation is one of the world's most protracted examples of displacement. The UN estimates that 173,600 people live within five camps. With extreme temperatures reaching up to 50°C and low rainfall, the area is a hot, barren desert with a sandy soil low in fertility and little capacity to hold water. Despite human activity bringing water, organic matter and human bio waste into the environment, the place remains as barren as it was 50 years ago. From satellite images it appears that not one teaspoon of healthy soil has been made. Although there is little rainfall, occasional flash flooding has destroyed homes and infrastructure and further eroded the landscape.

Technology suggestion:
Twin pit composting toilets, on elevated mounds (to protect from flooding) with ash and soil/sand added as cover material. The Chamber closed for over 1 year before emptying. Contents can be further sanitised by spreading on the ground and covering with clear plastic, where UV and high temperatures will further kill pathogens.

If twin pit compost toilets had been installed from the start:

In *The Humanure Handbook* Jo Jenkins states that a family of 4 produces between 1-2 Cubic metres of compost per year. If we take an average household size of 5 (a necessary assumption) and an average compost output per household as 1.5 cubic metres (another assumption):

The population of 173,600 would represent 34,600 households who's waste would create 51,900 cubic metres of compost per year. **Over the last 50 years that would represent 2,600 cubic kilometres of compost.**

Reuse proposal:
Growing plants in wicking beds irrigated by grey water from bathing and laundry and the creation of rain gardens around the camp to reduce flood risks.

Because of the limited water, growing plants is extremely challenging in this environment. However, the following examples will make best use of limited water.

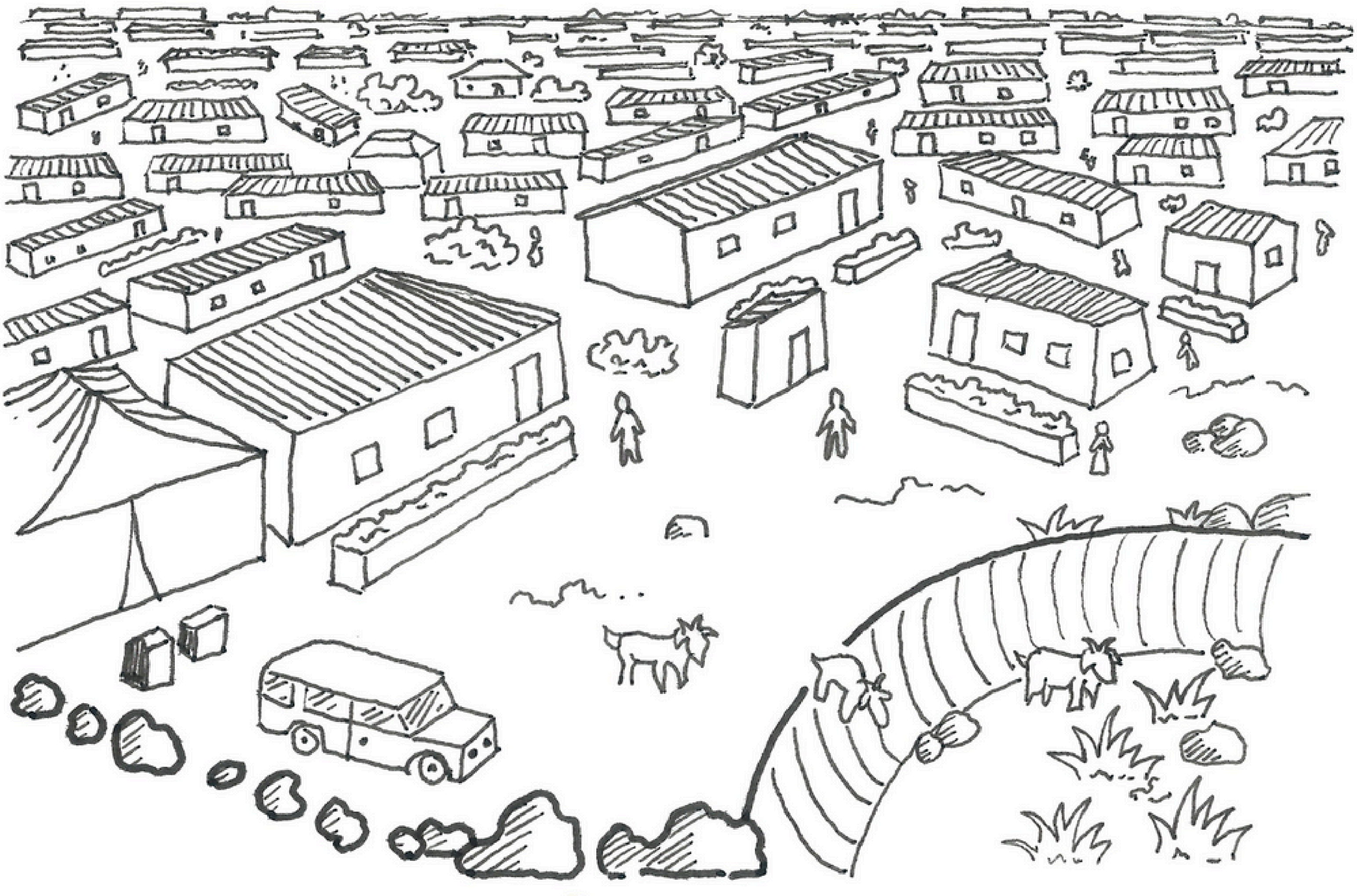
Create containers using plastic bottles or tetrapaks filled with sand to form a trough and then line with plastic to create planters, or preferably, wicking beds. Fill with a mix of compost and sand / soil. Place wicking beds directly outside households or laundry facilities and use grey water from washing the body and clothes to water it. (houses have already been built using sand-filled plastic bottles). The wicking beds could be used to grow animal fodder to feed the goats that many families own, or medicinal aloe vera plants, or above ground crops like lemon trees or legumes.

For compost not integrated into wicking beds and container gardening, larger scale rain gardens could be dug in areas around the camp. In rain gardens, depressions are dug and compost applied to their base. The pits will harvest rainfall, when it occurs, and grey water from laundry and bath houses could also be directed into the basins. During cooler months, fodder crops could be planted within the basins for feeding to the many goats kept by families.

Over time the pits may develop enough water holding capacity to plant trees and shrubs. Successive pits would need to be dug over time, and the compost from the toilets could be added to from compost made from organic waste. Sandbags and rocks could be used to stabilise the sides of the depressions and to hold the shape of the gardens. Rocks could be used to create channels to further direct rain water into the gardens. Over time the camp could be surrounded by these depressions, helping to protect against the flooding that has occurred over the past 50 plus years.

Benefits of system:

- Increasing the water-holding capacity of the land
- Building healthy soil
- Crop production
- Cooling effect of vegetation
- Greener environment
- Meaningful activity
- improved nutrition
- Educational potential of building and maintaining wicking beds for children and adults
- Capturing and using the limited water resources
- Reduced impact of flooding



Minawao Refugee Camp, Cameroon

Minawao Refugee Camp, in the Far North Region of Cameroon near the Nigerian border, shelters over 60,000 refugees who have fled the Boko Haram insurgency in northeastern Nigeria. Established in 2013, the camp faces food insecurity, and water shortages and extreme heat. A reforestation project by UNHCR has seen the establishment of tree nurseries within the camp.

In a recent report detailing sanitation in the camp, 57% of latrines were identified as 'self built' by refugees for household use out of the total 2, 222 latrines onsite, meaning that 1266 were self built.

Proposal:
Support the construction of self-build Arborloos with subsequent tree planting and irrigation with grey water.

This would enable each family to have a tree (usually acacia or moringa), giving shade over their settlement and plus eventually food and medicine. By feeding the trees with the contents of the Arborloos, trees will grow 30 per cent bigger than without fertiliser and stand a better chance of survival (Neething et al). Bringing trees within the site helps retain moisture in the soil and also encourages rain.

The CRS report shows that Arborloos are a simple design that can be built by communities. There is already an available supply of tree saplings from nurseries. Hand washing tipi taps could be placed next to trees / attached to trees for irrigation with grey water. Once available space has been filled with trees, toilets can be used as a fosse-alterna, with compost used offsite for reforestation projects.

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