

Greywater use for food security in refugee camps: A guidance note for risk management

Key messages

- Irrigating vegetables with greywater can support balanced diets and improve nutrition in refugee camps. It is an important adaptation strategy to water scarcity and helps to prioritize the use of limited freshwater resources.
- Minimizing risk from water reuse for human and environmental health is mandatory where population densities and risks of epidemics are high, such as in the humanitarian aid context.
- There are low-space options for irrigated gardening and different levels of risk reduction, both applicable to refugee camps.
- This review suggests a decision tree for guiding greywater (or wastewater) use while emphasizing that risk assessment and mitigation opportunities will vary between locations and types of camps.
- For the adoption of water reuse options, a high level of stakeholder involvement is needed from the start, where women will play a crucial role from crop selection to risk reduction.

Context

Where freshwater supply is limited, alternative water sources are in high demand for potable and non-potable purposes. Greywater constitutes an important option for non-potable water needs, especially in drier climates where rainwater harvesting is only feasible on a seasonal basis. Although the quality of greywater is clearly lower than that of potable water, it is generally higher than the quality of wastewater that contains black (toilet) water (Al-Gheethi et al. 2016; UNHCR 2024). However, greywater can still contain pathogens and contaminate irrigated crops unless it is well treated and/or other risk reduction measures are in place (WHO 2006a).

Since refugee camps are meant to be temporary and setting them up usually requires urgency, the choice of appropriate physical locations is often influenced by factors other than the availability of adequate water supply in terms of quality and quantity. Many camps hosting internally displaced persons (IDPs) thus suffer from water scarcity, soils unsuitable for pit latrines or gardening, and even seasonal flooding (Zakaria et al. 2015; Calderón-Villarreal et al. 2022), while humanitarian organizations struggle to provide food and the minimum water, sanitation and hygiene (WASH) services. Water-related challenges in these contexts also concern the provision of drainage systems for greywater and stormwater, as well as wastewater treatment and disposal facilities—the lack of which can pose potential health risks due to waterborne or water-related diseases (Ajibade et al. 2016).



(Photo: A.Adam-Bradford)

Greywater as a resource

When greywater is captured for safe reuse, it can constitute a valuable alternative water source for irrigated crop production (Al-Gheethi et al. 2016). The UNHCR (2020) WASH manual and the Sphere Association (2018) guidelines for humanitarian response encourage seeking “**opportunities to reuse water, such as for vegetable gardens...or irrigation**”.

A key advantage of local food production is the nutritional benefit for vulnerable groups through diversifying their diets with vitamin-rich crops, such as fruits and local vegetables, to reduce the risk of acute malnutrition, diseases and mortality. The complementarity of (internal) food production and (external) food supply for refugees has been described by Adam-Bradford and van Veenhuizen (2015).

Aside from crop irrigation, water recycling can:

- conserve freshwater that is currently used for potable or non-potable uses inside the camps, helping to address water scarcity and supporting climate change adaptation,
- provide significant amounts of crop nutrients,
- support the living conditions in the camp by watering trees and hedgerows used as windbreaks or for shade, fruits, seeds, fodder for livestock, medical purposes, etc., and
- enhance social, therapeutic and psychological (mental) well-being for the gardeners and gardening communities (Millican et al. 2019).

Although wastewater treatment for reuse can be environmentally, economically and socially advantageous (Anwar et al. 2021), beneficiaries’ interest in agricultural activities may only evolve over time as their immediate needs start to be met. Some may also not wish to start growing crops, as this might create the impression that they have to settle at that location for an extended period of time. Thus, during the first period of emergency relief, agricultural production might be unlikely, but future gardening strategies and the planning of possible production sites and water reuse systems should be taken into account by camp administrations (Adam-Bradford and van Veenhuizen 2015; Pincus et al. 2024).

Health risks

Greywater is commonly defined as wastewater from the kitchen, bath and/or laundry, which does not contain toilet water or any significant concentrations of excreta. Therefore, a collection system is required to keep greywater separate from other wastewater streams, such as black water deriving from toilets.

Although greywater typically has a fecal load 100–1,000 times lower than wastewater that contains black water (WHO 2006a), risk assessments for greywater reuse systems continue to focus on pathogenic microorganisms, as cross-contamination with fecal material can occur in different ways, enabling the transmission of

diseases. Greywater can potentially contain microbial contaminants from sick people, for example, through the washing of fecally contaminated laundry (including textile diapers) or washing hands without soap after contact with potentially contaminated surfaces, persons or objects (Ottoson and Stenström 2003). Health risks from household-generated chemicals, such as soap, shampoo or laundry detergents, on the other hand, could be more detrimental to soil health and crops than humans. However, greywater can also contain significant amounts of nutrients, particularly nitrogen and phosphorus, which can be beneficial for growing plants (WHO 2006b; Eriksson and Donner 2009).

It is important to note that most studies on greywater quality have been conducted in the global North and are only applicable to IDPs within certain limits because hygiene practices and the availability of resources—such as cleansing agents and laundry detergents—can vary significantly.

To assess the **actual risk**, the comparison of local water or crop contamination data with agreed-upon thresholds is the most common approach (Al-Gheethi et al. 2016; Boano et al. 2020; Lazarova and Koo-Oshima 2023). These threshold values operate on the precautionary principle, which demands high water quality through wastewater treatment. The postulated thresholds for maximally allowed pathogen concentrations can vary between countries and also between international guidelines¹ and seldom differentiate between greywater and wastewater (Al-Gheethi et al. 2016). While there are strict regulations in developed countries, including parts of the Middle East and North Africa, most developing countries lack the technologies to meet the required quality, resources for regular testing, and/or the power to enforce regulations (Al-Gheethi et al. 2016).

However, even in such situations, some level of health protection can still be achieved through alternative (on- and off-farm) pathogen barriers (WHO 2006a). These barriers may be a combination of crop restrictions and safer irrigation practices, irrigation withholding periods to allow pathogen die-off between the last watering and crop harvest, appropriate food preparation, food disinfection, and (food) hygiene education in general (FAO and WHO 2021). These alternatives can be within the reach of low-income countries, but they require a high level of pathogenic risk awareness in the population for successful implementation (Drechsel et al. 2022). This awareness is essential to prevent safety practices being adjusted and compromised for convenience without understanding the potential implications. In the IDP context, the multiple risk barrier approach, as promoted by the World Health Organization (WHO), will require additional training and monitoring in support of the required education and risk awareness. This should include the co-development of safe practices with gardeners, ensuring alignment with their ideas and requirements. This close collaboration is also important in view of the ownership and handover of any infrastructure.

¹ International standards can help with developing national guidelines, but they may also have limitations. For instance, the health-based targets for microbial contamination set by both WHO (2006a) and the stricter U.S. EPA benchmarks were established for assessing the safety of drinking water. However, both standards are considered too conservative for assessing the risks of non-potable water use (Mara et al. 2010a; Mara et al. 2010b; Shi et al. 2018).

Variation of risk mitigation opportunities by camp type

Risk mitigation opportunities for greywater management vary significantly depending on the type of housing in IDP camps. For example, the opportunities and constraints for household-based greywater treatment differ between refugees living in tents and those living in concrete buildings. Thus, guidance notes should fit the type of housing in IDP camps. It should also be kept in mind that the reality of wastewater management in camps can vary significantly between the extremes of black water dumping without treatment in camp vicinity to well-designed wastewater treatment plants (Ajibade et al. 2016; Anwar et al. 2021; Wardeh and Marques 2023), often resulting in risks unknown to host communities (Box 1).

Box 1. Health concerns of IDP camps require special care.

IDP camps present a higher potential exposure of people to disease vectors than typical settlements due to factors such as overcrowding, poor sanitation, limited water supply for basic hygiene, inadequate healthcare and environmental conditions (Desai et al. 2020; Ekezie et al. 2021). Many of the most common diseases causing mortality and/or morbidity in displacement camps (e.g., cholera, diarrhea, worm infections, viral hepatitis, chicken pox, typhoid, malaria, dysentery, skin and eye irritation, among others) have a strong correlation with the state of sanitation provision and stormwater and wastewater management in the camps, making IDPs more susceptible to outbreaks or epidemics than ordinary rural or urban communities. Strong compounding factors are food insecurity and undernutrition. As a result, the breeding of disease vectors and the outbreak of water-related diseases in camps around the globe are common features and have alerted authorities to invest in safe water management systems that ensure all wastewater is properly collected, treated and disposed of unless there are safe reuse opportunities, such as in vegetable gardening to enhance the nutritional status of the population (Ajibade et al. 2016; Sphere Association 2018).

While for emergency response, WASH guidelines are well defined and aligned with the recommendations of the Sphere Association (2018), the situation becomes different in the often protracted nature of forcible displacement, which prevents proper planning but may last for decades (UNHCR 2024). This challenge also extends to the monitoring of Sustainable Development Goal 6, where refugees and displaced people are frequently overlooked.

Greywater treatment and reuse options

A range of low-cost technologies have been proposed for greywater (and wastewater) collection and treatment (WHO 2006b; Boano et al. 2020; Morel and Diener 2006; Katukiza et al. 2012). These technologies are designed for, or at least adaptable to, low-space housing such as urban slums and refugee camps. These technologies are generally based on primary diversion of black water and greywater, followed by natural processes (i.e., nature-based solutions) such as sedimentation, filtration through gravel and sand layers, surface absorption, biological degradation, etc., which can accommodate varying risks of the water to be reused.

The choice of a locally selected system depends on the availability of space and materials, which will vary between locations, types of housing, etc., as well as the household's willingness and capacity to operate and maintain the facilities. Where possible, different treatment options can be combined (Morel and Diener 2006) to meet the chosen standards (Boano et al. 2020; Ho et al. 2024). Options might start with traps for grease, fat and oil, typically generated in kitchens, which, if not properly managed, can block treatment systems and inhibit biological processes. The grease traps can be combined with planted or unplanted gravel beds (Figure 1). In Figure 1, greywater enters the trench at the back, from where it moves slowly through gravel and sand layers towards the container at the front. Plastic sheets placed at the bottom and top of the bed prevent water loss. Where evapotranspiration can be accepted, such beds can be transformed into planted wetland units. Caution is recommended in households with low water consumption or with greywater potentially contaminated by pathogens. High pathogen loads may be attributed to an acute illness of one or several household members.

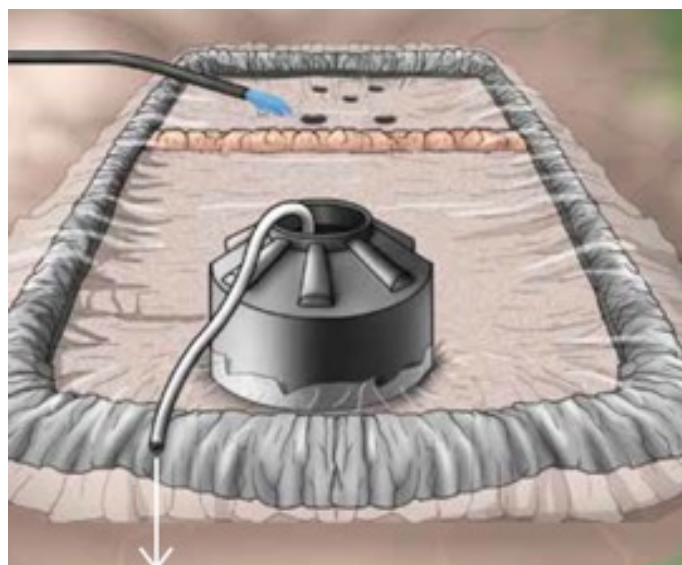


Figure 1. Gravel bed in Jerash camp, Jordan.

Source: Keraita et al. (2014)

Despite treatment, some pathogenic bacteria can survive, at least to some extent and time, within the most common treatment processes available in technology-challenged environments. Another challenge is treatment system maintenance. Slow sand filters, for example, require regular cleaning and replacement of the top layer of media (Al-Gheethi et al. 2016; Shi et al. 2018).

However, remaining bacteria do not automatically imply an obstacle for water reuse in **gardening** if other safety practices are followed, from crop selection to safe irrigation and post-harvest washing (WHO 2006a; Barker and O'Toole 2019). Epidemiological studies in Israel and Australia, for example, showed virtually no difference in the prevalence of water-related diseases between households using greywater and those using potable water, despite the different pathogen levels (Busgang et al. 2015).

Water disinfection methods common for drinking water, such as chlorination, might render the water saline and unfit for soils and crops (Al-Gheethi et al. 2016) and should be limited to effluent from camp hospitals or be used for vegetable disinfection (e.g., using chlorine tablets) before consumption (WHO 2006a; WHO 2022).

Low-space gardening

As greywater does have the potential to transmit disease, **direct contact with greywater and irrigating the edible portion of crops should be minimized or best avoided**. For households with gardens or some land, crops can be irrigated in beds or trenches with water being applied as close to the roots as possible. One example used by the Catholic Relief Services, UNHCR and the Danish Refugee Council is keyhole gardens (Figure 2, Box 2). The gardens are fertilized with kitchen scraps and watered through a central, typically woven, basket (CRS 2008).

Where space is limited, vertical farming options can offer practical solutions. In greywater towers, for instance, vegetable plants are stacked in layers using locally available materials. An example is the use of empty rice bags (Figure 3), such as those from food aid programs (Kulabako et al. 2009; Andres 2016).



Figure 2. A keyhole garden as seen in a resettlement village in Rwanda, which is also to be found in refugee camps in western Tanzania and other locations. *Source:* Esther Havens

Box 2. Importance of vegetable gardens: An example from refugee camps in Tanzania.

In Tanzania's refugee camps, 1,300 families are involved in a vegetable production project aimed at diversifying diets and improving household nutrition. The project, jointly run by UNHCR, the UN Refugee Agency, and the Danish Refugee Council, is helping families to establish so-called 'keyhole gardens' (Figure 2), providing them with vegetable seeds, tools and training on good farming practices.

Keyhole gardens are small, circular raised beds made with locally available low-cost materials. They are space-efficient and have a keyhole-shaped entrance on one side to allow gardeners to water the bed through a central basket and also easily harvest crops growing in the center (Figure 2). Compared to traditional vegetable gardens, they require less labor and water and no costly fertilizers. Keyhole gardening is especially effective in areas where good soil and water are scarce.

"The mini gardens can produce food all year round, even under harsh temperatures, and support the production of at least five varieties of vegetables at a time," said the Area Manager for the Danish Refugee Council in Tanzania. "This is key in supporting dietary diversity. It is also so prolific that its produce is more than enough to feed a family of eight persons. Moreover, such gardens also contribute to the restoration of human dignity," said UNHCR's Tanzania Representative.

Source: Ogolla and John (2020).

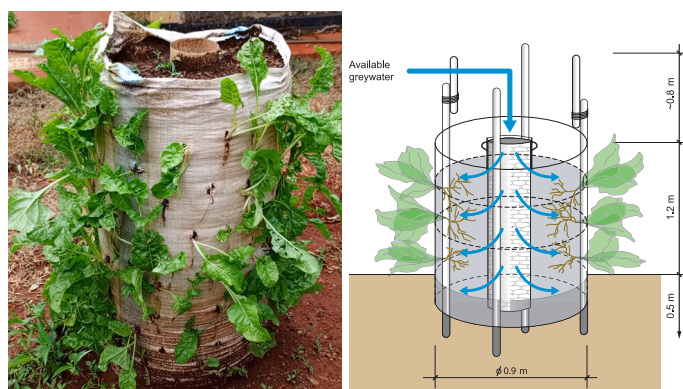


Figure 3. Vertical vegetable planting in sacks in Kenya and a sketch showing greywater entering through the vertical pipe without getting in contact with the edible parts of the crops. *Sources:* IWMI (left); Morel and Diener (2006) (right)

In each hole in the sack, a vegetable can be planted. Construction is quick, using recycled jute or poly sacks with a vertical pipe (or combined water bottles opened at both ends) in the center. The pipe is filled with gravel and has holes all along it to release the percolating greywater into the sack. Soil, compost, sawdust, ash,

biochar, straw, etc., can all be mixed and used as filling material. Depending on its nutrient content, the materials can last for several growing seasons.

Such systems, which are already being used in camps across South Asia and East Africa (Jinapala and Ariyaratne 2009; Adam-Bradford and van Veenhuizen 2015; Andres 2016), offer several advantages:

- They do not take up a large space, and they are moveable.
- Water requirements are low because water trickles through the central irrigation pipe (or bottles) from top to bottom.
- The labor requirements for maintaining the bags are minimal.
- They can be replanted until the sacks deteriorate (1–2 years).
- The greywater does not come into contact with the leaves to be eaten.

Recommendations

a) Approving greywater use

- Despite the complexity of health risk assessment, a decision tree (Figure 4) could be a starting point (Lazarova and Koo-Oshima 2023). Since opportunities, as well as constraints, related to treatment, gardening, risks and risk mitigation vary significantly between locations—including housing types and gardening options—any further development of the tree and related guidance should be camp-specific when it comes to greywater use in the IDP context.
- Residential greywater is generated by people who already live and eat together. Unless home-irrigated crops are shared between households, potential health risks remain confined. Thus, during any epidemic, such as an outbreak of waterborne diseases, formal and informal markets or trade of greywater-irrigated crops should be discontinued, and sharing of such crops across households should be discouraged.
- WHO (2006a; 2006b) proposed greywater quality thresholds for different irrigation scenarios. The required log reduction value (LRV) to meet the E. coli indicator threshold (Table 1) can be achieved by keeping greywater and black water separated, followed by subsurface irrigation or secondary treatment systems such as constructed wetlands. There are also several related options that can be combined (Table 2) and applied to the use of greywater as well as wastewater in general.

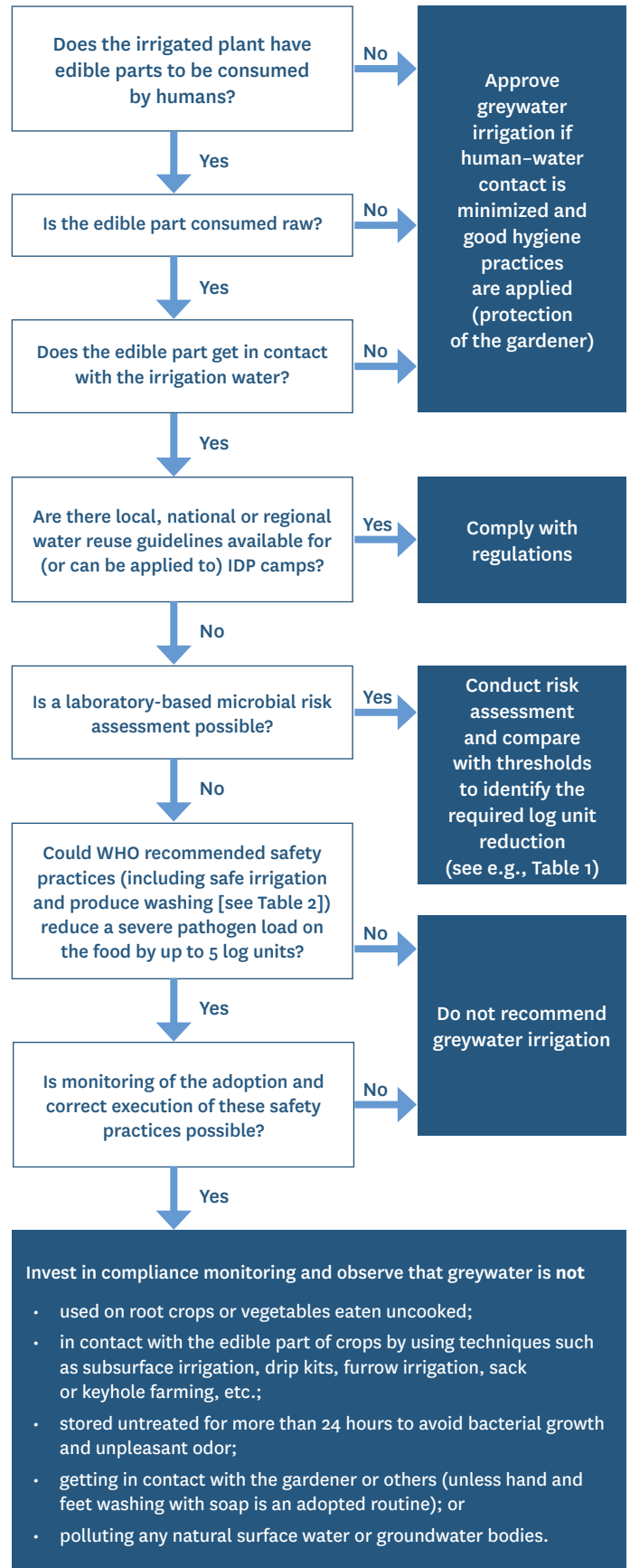


Figure 4. Decision tree for safe greywater use in IDP contexts.

Source: Based on WHO (2006a); Mara et al. (2010a); FAO and WHO (2019); UNHCR (2020); WHO (2022)

Notes: IDP - internally displaced persons; WHO - World Health Organization.

Table 1. Required log reductions through water treatment or best practices from farm to fork to reach the permitted thresholds for reuse under two irrigation scenarios assuming highly contaminated greywater.

Indicator	Restricted irrigation limited to ornamental plants, fruit trees and certain food crops	Unrestricted irrigation also of crops such as vegetables likely to be eaten uncooked	Sources
	Farmers are mostly at risk	Farmer and consumer are both at risk	
High pollution scenario E. coli (log units per 100ml)	7-8		WHO 2006a
Allowed upper threshold E. coli (log units per 100ml)*	≤ 4 (high exposure) ≤ 5-6 (low exposure)	≤ 3 for root crops ≤ 4 for leaf crops	Mara and Cairncross 1989; WHO 2006a
Required E. coli log reduction in water or on crops to reach the threshold**	3-4	4-5	WHO 2006a; WHO 2022

Notes:
 * A higher (more relaxed) log number is possible where human/crop/water contact is limited.
 ** Mara et al. (2010a) argued that two log units less would be safe enough for wastewater irrigation. WHO (2006a, p.65) adds that at least for greywater or urine reuse a 2-log reduction will normally suffice.

- Untreated wastewater can show 10 to 100 helminth eggs per liter. To achieve the common threshold of less than 1 viable egg per liter, the use of shoes or boots is recommended for farm workers, and produce washing and deworming pills for crop consumers (WHO 2006a).

b) Stakeholder buy-in

- For any gardening and/or water reuse project, a high level of stakeholder involvement is needed to understand people’s considerations and perceptions, especially regarding greywater application, and to incorporate their concerns into the design phase (Pincus et al. 2024).
- Ideally, the project should build on indigenous or favored practices and design options suggested by the IDP community to get greywater use accepted. The same applies to any other inputs such as seeds, soil nutrients or tools to be used.
- Where the refugee population is predominantly composed of women and children, it is imperative that all interventions are carried out within a gender-sensitive framework (Mendum et al. 2022). Women will play a key role, for example, in determining the crops to use and the implementation of safety measures for risk reduction in the garden and kitchen. However, women may need their husbands’ support to maintain a garden.
- Community-based facilitators can help address social acceptance issues. Peer-to-peer support through mentoring and demonstrations could help promote innovative home gardening technologies and greywater irrigation solutions.

- For the sustainable adoption of any suggested treatment technology, it is important to build on the technical know-how available within the camp and the surrounding markets. Often even simple farming inputs or tools may be hard for project participants to access (Pincus et al. 2024). The same can apply to market access if income generation through vegetable sales is envisioned.

c) Environmental vs. human health concerns

- Irrigation water chlorination (as a means to reduce human health risks) can be unsuitable for crops sensitive to chlorine or salinity. Similarly, seedlings or young plants might struggle with greywater containing high levels of detergents, such as bleach. On the other hand, plants that thrive only in acidic soils may not benefit from the typically alkaline greywater.
- Boiling vegetables would eliminate pathogenic risks, but the need for fuel should not lead to land degradation. Where firewood is the only fuel source, significant investments in reforestation are needed.
- Stagnant greywater bodies must be avoided as they can act as breeding grounds for disease vectors. *Anopheles* mosquito (malaria) eggs can hatch within 24 hours; eggs from the dengue parasites *Aedes* might need 24-48 hours. This situation requires attention to drainage, unless those pools can be dried up, for example, through planting grass or firewood species on such low-lying sites, especially if no other reuse option is permitted.

Table 2. Health-protection control measures and associated pathogen log reductions.

Control measure	Possible <i>E. coli</i> reduction (in log units)	Notes on log reduction value (LRV)
A. Wastewater treatment		
Primary treatment process	0–1	Sedimentation
Secondary treatment process	1–2	Activated sludge, trickling filters, aerated lagoon
Tertiary treatment Process	0–3	Coagulation, sand, granular or dual media filtration
	2– >6	Membrane filtration, disinfection (chlorination, ozonation)
Constructed wetlands	0.5–3	Key factors are retention time, plant type, oxygen, etc.
Waste stabilization ponds	1–6	Effectiveness depends on retention time, pH, sunlight and number of ponds. <i>Note of caution:</i> Care is required where ponds can be breeding sites for mosquito vectors.
B. On-farm options		
Crop restriction (i.e., no food crops eaten uncooked)	6–7	Depends on (a) the effectiveness of local enforcement of the restrictions and (b) the comparative profit margin of the alternative crop(s).
On-farm treatment:		
(a) Three-tank system	1–2	One pond is being filled by the farmer, one is settling and the settled water from the third is being used for irrigation. Very effective against helminth eggs but can create a vector breeding ground if not constantly used (dengue, malaria).
(b) Simple on-farm sedimentation ponds	0.5–1	Sedimentation for ~18 hours required. Effective also for helminth eggs but ensure that water fetching will not stir up sediment and settled eggs.
(c) Simple sand filtration	1–2	Value depends on the filtration system used. Log reduction also applies to helminth eggs.
Method of wastewater application:		
(a) Furrow irrigation	1–2	Crop density and yield may be reduced.
(b) Low-cost drip irrigation (on soil surface)	2–4	Reduction of 2 log units for low-growing crops and reduction of 4 log units for high-growing crops
(c) Subsurface irrigation	4	Via buried drip tubes passing the root zone. Risk of clogging.
(d) Reduction of splashing during irrigation	1–2	Splashing when using watering cans adds contaminated soil particles onto crop surfaces.
Pathogen die-off (through days of no watering till harvest)	0.5–2 per day	Natural die-off between last irrigation and harvest (value depends on sunlight, humidity, temperature, crop type and length of cessation)

(continued...)

Table 2. Health-protection control measures and associated pathogen log reductions. (cont.)

Control measure	Possible <i>E. coli</i> reduction (in log units)	Notes on log reduction value (LRV)
C. Post-harvest options during transport and at local markets		
Overnight storage in baskets (natural die off)	0.5-1	Selling produce after overnight storage in breathable baskets (rather than using sealed bags or selling fresh produce without overnight storage)
Avoidance of post-harvest contamination through good (food) hygiene practices	Mandatory	Post-harvest contamination from warm and moist storage of leafy vegetables (bacterial regrowth), unsafe refreshing or washing water for food display, cross contamination, human contact, etc., can be more harmful for consumers than the original irrigation water.
Produce preparation prior to sale	1-2	(a) Washing salad crops, vegetables and fruits with clean water
	2-3	(b) Washing salad crops, vegetables and fruits with running tap water
	1-3	(c) Removing the outer leaves on cabbages, lettuce, etc.
D. In-kitchen produce preparation options		
Produce washing	1-1.5	With clean water for 2 minutes using running tap water, which also helps with removing helminth eggs compared to using a bowl. Adding salt or washing-up liquid (against sticky helminth eggs) helps.
Produce disinfection	2-3	Using a disinfectant solution in a bowl and rinsing with clean water. Good results with potassium permanganate or chlorine (tablets, liquid). Vinegar is also effective but only at high (possibly taste-affecting) concentrations.
Produce peeling	2	Fruits and root crops
Produce cooking	5-7	Immersion in (close to) boiling water until the food is cooked ensures pathogen destruction. Option depends on crop, local diet and preference for cooked food.

Source: Vymazal (2005); WHO (2006a); WHO (2006c); Ilic et al. (2010); Mara et al. (2010a); WHO (2022)



Greywater use in Burkina Faso gives hope to cultivate soils where fresh water is scarce (photo: IWMI).

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Disclaimer

The scientific evidence related to studies on the benefits and risks of greywater use for food production in humanitarian aid situations is limited. More data is required for an official guidance document. This publication incorporated feedback from external experts but did not undergo an independent peer-review. The opinions expressed and responsibility for any possible errors lie with the author and not the funders or institutions involved.

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