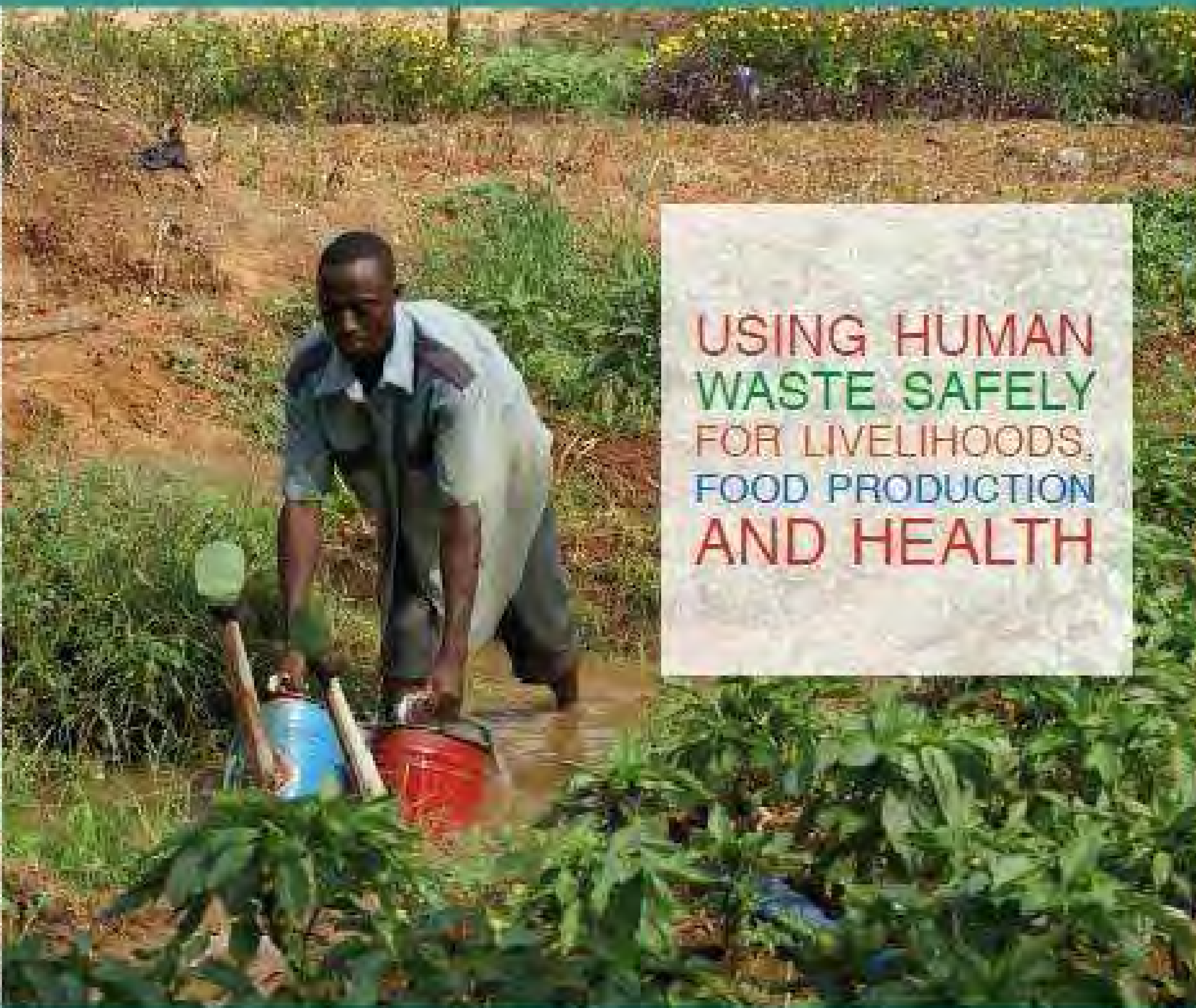
USING HUMAN WASTE SAFELY FOR LIVELIHOODS, FOOD PRODUCTION AND HEALTH



USING HUMAN WASTE SAFELY FOR LIVELIHOODS, FOOD PRODUCTION AND HEALTH

INFORMATION KIT ON THE THIRD EDITION OF THE GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER IN AGRICULTURE AND AQUACULTURE

CONTENTS

THIS INFORMATION KIT HAS BEEN PREPARED BY WHO, FAO, IDRC AND IWMI IN RESPONSE TO REQUESTS FROM THE READERSHIP OF THE GUIDELINES FOR INFORMATION ON SPECIFIC COMPONENTS OF THE INTEGRATED RISK ASSESSMENT AND INCREMENTAL RISK MANAGEMENT APPROACH PROPOSED BY THE GUIDELINES.

The first information kit on the third edition of the *Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture* was published in 2008 and contains the following materials:

- A numerical guide to Volume 2 of the Guidelines and practical advice on how to transpose them into national standards
- Key issues in the safe use of wastewater and excreta in aquaculture
- The concept of exposure reduction in the use of excreta and greywater in agriculture
- Research options and priorities
- On-going research in West-Africa and the Eastern Mediterranean
- IWMI Comprehensive Assessment Brief 11
- Water Policy Briefing Issue 17
- Food for the Cities – water use and reuse for urban agriculture
- FAO Agriculture-Wastewater Fact Sheet
- Briefing Note for WHO Country Offices
- Fact Sheet for Agricultural Policymakers
- Fact Sheet for Farmers and Agricultural Extension Workers

These materials can be accessed at and downloaded from www.who.int/water_sanitation_health/wastewater/usinghumanwaste

Third edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture

Guidance note for National Programme Managers and Engineers

OPTIONS FOR SIMPLE ON-FARM WATER TREATMENT IN DEVELOPING COUNTRIES

INTRODUCTION

The lack of wastewater treatment capacity, which is especially prominent in low-income countries, has resulted in untreated wastewater polluting streams and rivers used for crop irrigation. This situation calls for further options for health risk reduction. Hence, while source treatment of wastewater remains the priority option, implementing supplementary, or in the worst case alternative, non-conventional treatment or non-treatment measures appears, at least for the time being, crucial to reduce health risks posed by the use of untreated or only partially treated wastewater in agriculture.

This Guidance note presents some point-of-use irrigation water treatment options, which are low-cost, often build on farmers' own infrastructure and have shown potential in reducing microbiological crop contamination in smallholder farming (0.05-0.8 ha) in developing countries. The effectiveness of most systems varies with the area available and commitment of farmers to install and/or maintain them. While the area can not be changed, farmers' commitment can be supported through incentives.

Farm-based treatment is never a singular measure for risk reduction, but, depending on local conditions, it may be an important component of an incremental risk management strategy. Its value comes to expression in combination with other measures, such as safer irrigation practices and post-harvest food safety measures. The reader should thus feel encouraged to use the cases presented here as examples for local adaptation and upgrading. They address on-farm ponds, filter systems and conventional irrigation infrastructure.

1. Pond-based on-farm water treatment systems

In many countries smallholder-farmers in urban and peri-urban areas use ponds, dugouts, drums or concrete tanks for various reasons. Dugouts and ponds may collect surface flow or subsurface flow near streams (Figure 1), function as storage reservoirs for pumped drain or stream water, or simply reduce walking distances to water sources where watering cans are the means of irrigation (Figure 2). Where the slope allows, farmers may link their ponds or reservoirs via narrow trenches in a network which can further reduce manual water transport (Figure 3). These types of informal irrigation infrastructure offer obvious opportunities for pathogen reduction e.g. through sedimentation, even at small scale.

Pond systems are widely used as simple, low-cost but effective biological wastewater treatment systems in many countries, not only in low-income countries. They remove helminth eggs and protozoa cysts mainly by sedimentation, while pathogenic bacteria and viruses are removed by a combination of factors that create an unfavorable environment for their survival. As long as the required retention times can be maintained most of these processes also work in small on-farm ponds.

To facilitate water collection, especially in smaller wastewater drains or streams, farmers block the water flow with sand bags or other materials, to create deeper pools suitable for watering cans. Often it is also possible to create cascades of small dams which offers further options for sedimentation processes (http://video.google.com/videoplay?docid=-7881268516571430438&hl=en). Table 1 shows different forms of pond-based systems commonly used in developing countries, with potential to contribute to point-of-use wastewater treatment.

TABLE 1. Overview of informal pond-based water 'treatment' systems in smallholder agriculture

	On-farm sedimentation ponds	"Chinese"-3-tank system	In-stream dams
Description	Already installed small ponds, dugouts, drums or tanks (2-10 m^2 surface) used for interim wastewater storage. Usually, water is fetched from these reservoirs with watering cans while they are filled by small pumps.	To upgrade a one-pond system for an undisturbed retention time, three ponds are a preferred option: one pond is being filled by the farmer, one is settling and the settled water from the third is being used for irrigation. The pond size should exceed the daily water needs.	To ease water collection in wastewater drains and streams farmers block the water flow to create pools with sand bags or other materials. These constructions can form cascades suitable for trapping helminth eggs (see also Table 3).
Area requirement and/or size of ponds	Varies with crop water needs (i.e. crop type and climate) and the size of the cropped farm area		Varies widely but usually between 1 and 3 m^3
	In West Africa: Pond volumes vary in general between 2 and 10 m^3.	See left	
Pathogen removal	Studies in Ghana show that a two-day period of settling removed almost all helminth eggs from the water (reduced to less than 1 egg per litre) and about 2 log units for coliform bacteria. However, ponds are often used every day or every other day resulting in lower reductions, especially when their volume is small.	A one-day period of quiescent settling removes almost all helminth eggs and can achieve a 1 to 2 log unit reduction of other pathogens. The longer the water can 'rest' the better.	With more than one barrier helminth egg sedimentation can be significant. Fecal coliform reductions of 2 log units were found in Accra. If sand bags are perforated and closely packed, they can also function as sand filters.
Challenges	Stepping into ponds or touching the bottom with the watering can will stir up settled pathogens (training needed). Having alternative ponds will increase retention time (see right). Avoiding runoff of manure or contaminated water/soil into ponds.	Labour to dig more ponds than usually used. Pumps useful to fill ponds from streams. See comments for ponds left.	Sand bags might be washed away in the rainy season. Two or more barrier systems are preferred.
References	Keraita et al. (2008a, 2010); Reymond et al. (2009)	Mara et al. (1996)	IWMI (2008ab)

Figure 1: Dug-out on a vegetable farming site in Kumasi, Ghana, close to a highly polluted stream.

Figure 2: Interconnected tank system in Lomé, Togo (the water source here is shallow groundwater).

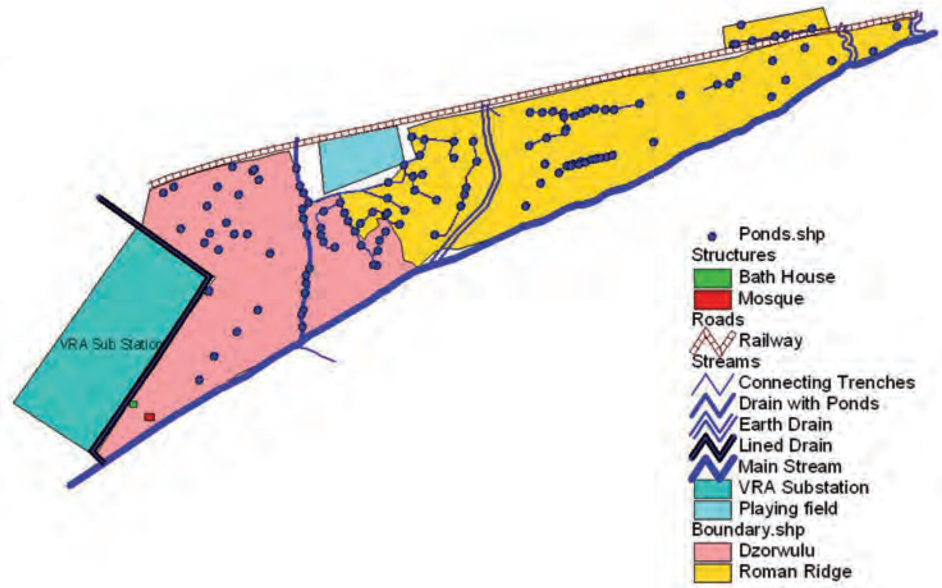


Figure 3ab: Distribution of individual and interconnected ponds and dugouts on a farming site in Accra, Ghana, drawing water via pumps from polluted streams and wastewater drains (see also Box 1).

BOX 1. Ponds as possible breeding sites for mosquito vectors

Pond-based systems are potential habitats of mosquito vectors of diseases like malaria, filariasis and different types of encephalitis or snail intermediate hosts of schistosomiasis. Contrary to the conventional wisdom that anopheline vectors of malaria only breed in rather clean water there are increasingly indications e.g. from Pakistan, Tanzania, Nigeria and Ghana, that some anopheline species also breed in polluted water sources (Mukhtar et al., 2003; Sattler et al., 2005). The actual occurrence however, can vary between seasons, from region to region and the type of wastewater (raw or diluted); therefore, programme managers or extension officers should put in place vector surveillance plans with the support of health authorities. Where schistosomiasis is endemic, water contact should be prevented and sanitation facilities improved.

In hyper-endemic malaria situations (such as those prevailing in many parts of sub-Saharan Africa) wastewater ponds might not pose a significant additional risk, but in meso-endemic areas like in Asia control measures will be important. These can be natural predators such as tadpoles which are often present even in smaller ponds. Small ponds could also be covered with netting while larger systems may need other methods of biological control e.g. larvivorous fish like Tilapia (Homski et al., 1994).

BOX 2. Improving on-farm ponds for wastewater treatment in Accra, Ghana

Location: A large vegetable farming site in Accra where polluted stream and drain water is the common irrigation water source for about 100 farmers. Individual ponds and networks of interconnected ponds are common (see Fig 3.). Networks are managed by two to over 20 farmers depending on their size. These systems enhance fecal coliform removal from 10^6-10^7 MPN/100ml by at least 2 log units from the wastewater source to the last pond. As for individual ponds, a removal of 1-1.5 log units was observed over two days. Helminth eggs were only occasionally found in the water source at this site (up to two eggs/litre) and dropped below one egg/litre in the first pond. A pilot project was initiated to upgrade an existing 5-pond network for enhanced risk control. The project was carried out in a participatory way with the farmers. Design modifications aimed at doubling the water volume and reducing "short-circuiting" (rapid flow), to increase the overall water retention time in the systems from one to two days.

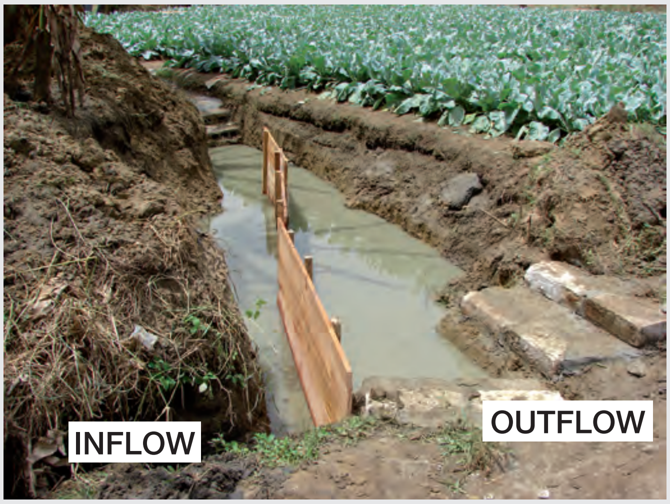


Figure 4: Interconnected pond with hardwood baffle.

Technology Description: Trenches were slightly widened and ponds were deepened and their shape regularized. Some stairs were built to facilitate water fetching without risk of re-entrainment of sediment. Simple baffles were placed in transit ponds to increase the retention time of the water (see figure 4).

Required inputs: Mostly labor for construction (two man-days) and USD50 per farmer for construction materials.

Pathogen removal: First results indicate that the retention trenches account for a quite stable permanent improvement and a flood gate (weir or pipe-elbow that can be turned) installed to stop the continuous inflow of pathogen-rich water from the main stream during the watering period prevented re-contamination.

Adoption and out-scaling potential: Pathogen reduction should ideally take place before or in the first pond to increase food safety on the whole site. Thus further 'upstream' experiments have been started. While this case does not illustrate a perfect solution, it shows that systems farmers are already implementing on their own initiative can contribute to pathogen reduction and also offer opportunities for improvements through participatory research. Important site criteria in this case were space, sufficient tenure security to allow the set-up of infrastructure and an adequate slope to allow flow by gravity for interconnected systems. Given the load of two 15 l watering cans, 50 beds per farmer and 10 watering cycles per bed over the day, every reduction in transport facilitates farmers' cooperation. The system is not suitable in areas prone to flooding.

Reference: Reymond et al. (2009).

2. Filtration systems

Table 2 shows some common filtration systems for treatment of wastewater at farm-level, using media such as sand, gravel or soil. In general, pathogen removal is achieved by a) retaining pathogens by straining and adsorption in the media and b) die-off and predation. The first two examples in Table 2 are about technologies that have been introduced, the third and fourth filtration techniques are about technologies that are already traditionally used by farmers.

Figure 5: Well next to a wastewater channel in Ouagadougou, Burkina Faso.

TABLE 2. Overview of common filtration systems for on-farm water treatment

	1. Slow sand filters	**2. Gravel sand filters for greywater treatment**	**3. Soil filter systems**	**4. Strainers**
Description	Used for example in water containers feeding *drip irrigation systems* where unfiltered wastewater tends to clog the outlets. Sand should be of correct configuration i.e. effective size of 0.15–0.40 mm and uniformity coefficient of 1.5-3.6.	Used in confined soil trenches, e.g. to treat greywater from small streams or households before irrigating crops and flowers. See Box 3 for an example.	Wells are sunk one to five metres away from wastewater streams or canals with the aim of collecting shallow groundwater as observed in Burkina Faso, Mali and Ghana. Canal water passes through the soil to the well following a hydraulic gradient and is filtered in the process (see Fig. 5).	In Togo, Ghana and Senegal, farmers use various materials like mosquito netting to prevent particles like algae, waste and organic debris from entering the watering cans while fetching water. Filtration materials are also attached to pumps.
Pathogen removal	0–3 log units for bacteria and 1–3 log units for helminthes (WHO 2006). In Ghana, 0.5–1m deep column sand filters removed about 2 log units of bacteria and 71–96% of helminthes.	Gravel under anaerobic conditions facilitates biological treatment with retention times of 2-3 days. Pathogens and total suspended solids were reduced to 50%.	Pathogen removal depends on soil properties (texture) and subsurface flow distance. Most effective for larger pathogens like protozoa and helminthes but less effective for removal of bacteria and viruses.	Positive side-effect is that pathogens adsorbed to the sieved organic matter are removed. Depending on the kind of matter and pathogen load, up to 1 log unit removal for bacteria and 12–62% for helminthes was observed with a normal nylon cloth.
Challenges	Clogging of the filtration medium (sand) makes frequent cleaning necessary.	Depending on location, cleaning to prevent odors and with time clogging of the gravel media.	Cracks in soil structure or termite tunnels can allow pathogens to pass through without being filtered.	Fine material which is most effective for egg removal without affecting water in-flow or out-flow. Continuous removal of filtered residues.
References	Metcalf and Eddy, Inc., (1995); Keraita et al., (2008b).	Bino et al., (2008) WQSD (2009).	Cornish and Lawrence (2001), IWMI (unpub.).	Keraita et al (2008b, 2010).

BOX 3. Confined trench gravel filter system for greywater treatment in Jordan

Location: The technology has been tested on different sites in Jordan, for example in Karak it has been used for over four years to water olive trees, and downstream of the Jerash refugee camp where the water is used for horticultural production for over one year.

Technology description: The system can support a large garden or horticultural enterprise. Downstream of the Jerash camp, greywater from a near-by stream is diverted when needed by a tube to the trench. In the photo, the water enters the trench in the back section where the transparent plastic sheet is perforated to allow water infiltration (Figure 6). From there the water moves slowly by gravity through gravel layers towards the container in front. The confined trench is lined with a dark impermeable plastic sheeting about 400 micron thick and is filled with gravel. In Karak there is three m3 of gravel medium 2–3 cm in diameter. The designed retention time is 2-3 days after which the filtered water enters the container through a perforated lower part. From here the water is pumped into a larger tank supporting an irrigation system. One unit can treat up to 240-300 litres a day, which is sufficient to irrigate about 20 olive trees throughout the year.

Figure 6: Treatment trench at Jerash, Jordan

Economic assessment: In Karak, the cost of one unit was estimated at USD120 for site preparation, gravel, plastic sheets and PVC pipes. The additional installation of an electric pump, electric wiring and drip irrigation would result in a total cost of USD300. This amount could be halved using a treadle pump. The average annual operation and maintenance costs were estimated to be USD39. Based on the Net Present Values and benefit-cost ratio of 2.6-2.7, which were calculated for different interest rates over 5 and 10 years, the system proved to be economically feasible.

Pathogen removal: While it was reported for the farm site near the Jerash camp that pathogens and total suspended solids were reduced to 50%, crops irrigated at Karak showed fecal coliforms within allowable limits for restricted irrigation.

Adoption and up-scaling potential: Suitable for small farms that have access to external or internal wastewater streams. Adoption could be high, especially in drier climates and in locations with strict enforcement of water quality standards. Capacity building is necessary for proper operation and maintenance. Odor from the system could pose a challenge if people live nearby.

References: WQSD (2009), Bino et al. (2008)

3. Use of irrigation infrastructure

Though not designed for pathogen removal, some components of irrigation infrastructure such as weirs (Figure 7ab) and storage tanks in irrigation schemes can significantly improve the microbiological quality of domestically polluted water. In the case of the Musi River which passes Hyderabad in India, the natural remediation efficiency of the river system, aided by the construction of irrigation infrastructure, particularly weirs, was very high. It was found to reduce fecal coliforms, helminth eggs, BOD and nitrogen at rates comparable with the treatment efficiency of a well designed waste stabilization pond system. The results showed a significant improvement in water quality over a distance of 40 km with 13 weirs, probably due to different remediation processes principally: sedimentation, dilution, aeration, natural die-off and exposure to UV-light. Weirs proved to be particularly effective traps for helminth eggs (Table 3).

Based on the large number of eggs found in the sediment of irrigation channels, it is recommended to modify the design of suction pipes on motorized water pumps to minimize the intake of sediment. An option might be U-shaped pipe ends which reduce sediment intake (Keraita et al., 2010).

Figure 7ab: Weir downstream of Hyderabad, India and in Northern Laos.

TABLE 3. Use of irrigation infrastructure for pathogen reduction

	Weirs and tanks
Description	Water reservoirs and weirs in irrigation canals can facilitate pathogen removal. • In irrigation schemes in Hyderabad, India, weirs, which are used for regulating irrigation water, act as efficient traps for helminth eggs. • The same principle can apply to dams constructed by smallholders (see Table 2).
Pathogen removal	The study along the Musi river showed that over a 40 km stretch of the river • Helminth eggs had reduced from 133 eggs/l to zero. • *E. coli* levels showed a reduction by over 4 log units from 7 log units per 100ml.
Challenges	The positive impact of natural processes for pathogen elimination and options to enhance them via standard irrigation infrastructure should be considered before investing in conventional wastewater treatment. The design and maintenance of irrigation infrastructure could benefit from consideration of its possible positive impact on pathogen levels (e.g. via sedimentation and sediment management).
Reference	Ensink et al (2010)

To take advantage of existing farm infrastructure and/or to build new ones requires full farmer participation, especially where risk awareness is low, regulations are not enforced and marketing channels (or demand) for safe produce are still lacking. Participatory on-farm research should be supported by awareness creation and the exploration of social marketing strategies and possible incentives (e.g. increased tenure security, credit) to facilitate technology adoption.

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World Health Organization

IDRC CRDI

IWMI International Water Management Institute

Third edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture

Guidance note for National Programme Managers

HEALTH-BASED TARGETS

THE PURPOSE OF HEALTH-BASED TARGETS

The establishment and enforcement of standards and best practices are fundamental components of the risk assessment and management framework used to optimize the safe use of wastewater in agriculture and aquaculture. Yet, setting health-based targets is only worth the effort and resources if done in a properly contextualized way. The local setting will determine which health issues are relevant, and which risk reduction measures are feasible. Thus, formulating health-based targets is an essential first step in the process of integrated risk assessment of wastewater use, and the incremental management of these risks.

Health-based targets are measurable health-related water quality or performance objectives. They are established based on exposure and risk assessments of water-associated health hazards. The third edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture (WHO, 2006) distinguishes four components that singularly or in combination make up health-based targets.

- Health outcome targets, expressed as loss of disability-adjusted life years (DALYs) or risk of infection averted, are set through a national policy decision based on a judgement of tolerable risk and are used to inform derivation of performance and water quality, and technology targets. They may also be determined by epidemiological studies or public health surveillance and expressed as reduction in detected disease incidence or prevalence or the absence of one or more specific diseases.
- Wastewater quality indicators, such as concentrations of viable intestinal nematode eggs and/or *E. coli*, on the level of contamination with potentially toxic chemicals.
- Performance targets, expressed as log-reductions of pathogens or percentage removal of chemicals, and based on Quantitative Microbial Risk Assessment or chemical guideline values. Performance targets can be achieved through a range of interventions, including environmental protection of water catchment areas, management and treatment of wastewater, wastewater application techniques, hygiene at market places and best practice in safe food preparation.
- Technology specifications: general descriptions of required equipment and procedures, usually underpinned by validated performance, with reference to applications in settings that will influence these specifications.

SETTING HEALTH-BASED TARGETS FOR SAFE WASTEWATER USE

Health-based targets are a common component of the widely accepted concept for water quality management, known as the Stockholm framework. The advantage of this harmonized approach to water quality management comes to expression through the combined experiences in drinking-water quality, safe use of wastewater and safe recreational waters - and it is expected that agricultural water quality will also become part of this in the near future.

While the procedures and underlying methods for these different categories of water uses largely overlap, the institutional and associated actors greatly vary from one type of use to the other.

Providing benchmarks for drinking-water quality is straightforward in that these are generally set by the water quality regulator (often Ministry of Health, or Environment/Water or equivalent) and are typically applied to water supply utilities in a standardized fashion. Wastewater use in agriculture and aquaculture, on the other hand, is, in many parts of the world, an informal sector. It is the aspect of informality, in particular, that makes setting health-based targets a greater challenge. Farmers using wastewater are at best loosely organized in associations (as, for example, in the Pikin area of Dakar, Senegal), their plots may shift frequently, often remaining outside of the jurisdiction of municipal authorities, along the chain of events a more heterogeneous group of regulators may be involved and a lot of decisions with a bearing on the safety of food preparation are made at the household level. And even where wastewater use is part of the formal agricultural production system, the links between agricultural and public health authorities tend to be less well developed than those between drinking-water regulators and public health authorities.

In this connection, setting health-based targets is usually a task of local government, involving public health authorities, water quality and food safety regulators and inspectors overseeing market-places, leaving influence over the most informal decision-making to advocacy and educators. This implies key roles for primary health care workers, agricultural extension workers and farmer field schools[1]. The use of health-based targets in the safe use of wastewater in agriculture is applicable to countries at all levels of development. Health-based targets must be based on scientific evidence, measurable and realistic and relevant in the local context of economic, social, cultural and environmental conditions[2]. They must take into account the public health status and trends, and both health hazards and opportunities, considering the contribution of wastewater use to the transmission of infectious diseases as well as their role in improving people's nutritional status as a result of the increased availability to a greater variety of food items. This is not a matter of trade-offs - health-based targets should combine maximum nutritional benefits with minimal infectious disease risks. Health-based targets should be embedded in public health policy and linked to the capacity of the local health services.

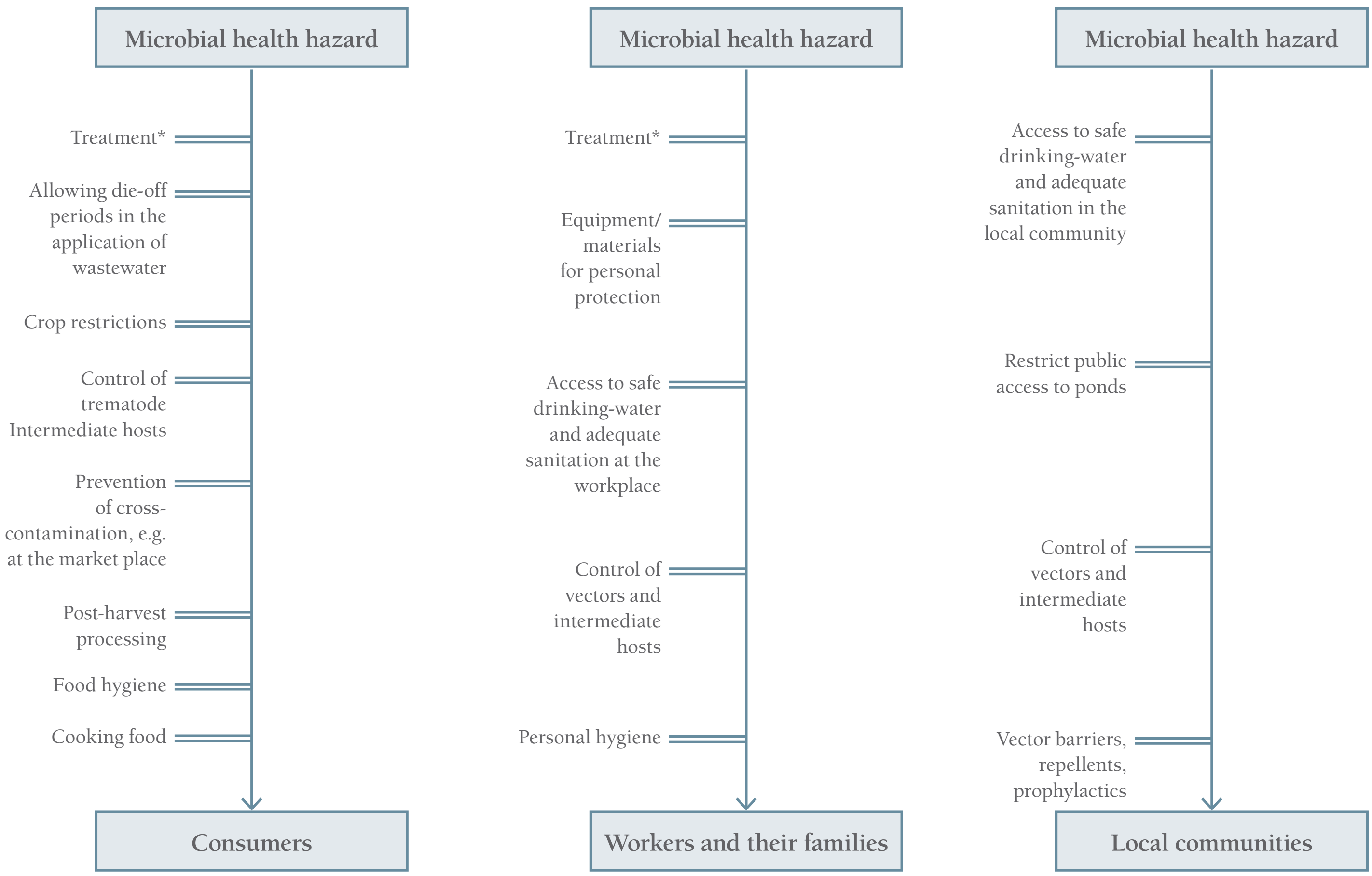
In most settings, food produced with wastewater or the handling of wastewater to produce food will not be the only source of microbial or chemical hazards. Depending on the local sanitation and hygiene conditions, attribution of a fraction of the disease burden to wastewater use in a scenario of multiple exposure routes ranges from difficult to mission impossible. As a consequence, setting strict health-based targets as a starting point for safe use of wastewater is often neither helpful nor desirable. Strict targets will call for a disproportionate allocation of resources towards achieving results under conditions of relatively high uncertainty. This does not imply that health-based targets should remain completely flexible. As more evidence becomes available they should be tightened. This may be evidence that specifies with greater certainty the fraction of the disease burden attributable to wastewater use. Alternatively, it may be evidence of the overwhelming predominance of another transmission pathway that renders the impact of wastewater use insignificant.

1 Reference is made to the *Fact Sheet for Farmers and Agricultural Extension Workers* prepared by staff of the IWMI Africa in Accra, Ghana, and contained in the first Information Kit published in 2008 – available on the web www.who.int/water_sanitation_health/wastewater.

2 Reference is made to the Guidance note for national programme managers and engineers: *Applying the Guidelines along the Sanitation Ladder* prepared by P. Drechsel and B. Keraita of IWMI, contained in the second edition of the Information Kit.

Broad public health policy provides the enabling environment for meeting health-based targets through the safe use of wastewater in agriculture. Meeting the targets can, therefore, not be considered in isolation from other efforts to improve sanitation, waste disposal, personal hygiene and people's nutritional status. Improved capacity of primary prevention by public health services, reduced pathogens loads and reduced levels of contamination of wastewater will all contribute to safe wastewater. In this context, it is crucial to ensure that health-based targets maintain their focus on vulnerable groups, i.e. farmers and their families, marketers and consumers. Examples of hazard barriers for the vulnerable groups, incrementally leading to risk reduction, are presented in Figure 1.

FIGURE 1: Examples of hazard barriers for wastewater use in agriculture, incrementally building up towards achieving health-based targets.



*Treatment intended in this context as a way to reduce community pathogen load.

TOLERABLE BURDEN OF DISEASE

The disability-adjusted life year (DALY) is a measure of community health combining the loss of healthy life years due to premature death and/or due to disability caused by disease or injury. This loss is expressed as the burden of disease, and makes it possible to attach a relative weight to different conditions of ill-health, as well as to measure the effectiveness of different intervention options. DALYs are an important tool for measuring health outcomes. They account not only for acute health effects, but also for delayed or chronic effects. The burden of disease concept places risk assessment and management in a clear health economics framework. When risk is described in terms of DALYs lost, different health outcomes can be compared and risk management decisions can be made in a way that is informed about the ratio between required resource allocation and expected effectiveness.

The WHO Guidelines for drinking-water quality (third edition, 2003) propose a tolerable burden of waterborne disease from consuming drinking-water of $\leq 10^{-6}$ DALY per person per year. This upper limit DALY is approximately equal to one excess case of cancer per 100 000 people consuming drinking-water containing a carcinogen at its guideline value concentration.[3]

The rationale for setting this global guideline value for both drinking-water and food crops irrigated with wastewater goes back to the premise that those who drink the water or eat the food expect it to be perfectly safe. Yet, exactly those conditions that challenge authorities to effectively achieve this health-based target are also the conditions under which many other risk factors contribute to high overall exposure risks and serve as important confounding factors. Meeting the global $\leq 10^{-6}$ DALY loss per person per year target is usually not feasible under these conditions, and authorities should set realistic health-based targets with the intention to move towards the global target. In other words, responsible national authorities set health-based targets that reflect a tolerable burden of disease, i.e. an upper limit of the burden of health effects associated with waterborne disease.

There are multiple benefits to setting health-based targets as the outcome of negotiations with environmental, social, cultural, economic and political dimensions. These benefits are associated with the different stages of the development and use of targets as presented in Table 1.

Developing, implementing and evaluating health-based targets for agricultural wastewater use must take the informal nature of the production system into account by including the following components:

- Development and testing of locally relevant education and training materials on health-based targets, from local authorities, leaders of communities and farmers' associations and managers of local NGOs.
- Production of information materials for consumers, in collaboration with food safety authorities and consumers associations on locally relevant good practice for safe food handling and preparation.
- Involvement of farmers in the development of health-based targets and the associated health risk management measures.
- Introducing the subject of health-based targets in environment and health curricula of secondary schools.

3 Reference is made to *The discussion paper: Options for Updating the 2006 WHO Guidelines, More appropriate tolerable additional burden of disease and other issues,* prepared by D.D. Mara (University of Leeds, UK), A. Hamilton, A. Sleigh and N Karavarsamis (University of Melbourne, Australia) for a discussion on the universal suitability of the global guideline values.

TABLE 1. Benefits of health-based targets for the safe use of wastewater in agriculture and aquaculture.

Target development stage	Benefits
Formulation	Provides insight into the health status of vulnerable groups. Reveals knowledge gaps, identifies research questions. Supports evidence-based priority setting. Allows harmonization of public health and agriculture policies. Points to both health risks and health opportunities in a context of agricultural production. Encourages involvement and participation of vulnerable groups.
Implementation	Provides a basis for targeted action by national or local authorities, farmers' associations and NGOs. Fosters stakeholder commitment. Links responsibility to accountability. Provides criteria for the rational allocation of resources. Adds a public health dimension to otherwise strictly economic decisions on crop selection and agricultural practice.
Evaluation	Provides an opportunity to take action to correct deficiencies and deviations. Identifies data discrepancies, contradictions and needs. Reveals weaknesses in the approach to risk assessment and management. Provides the basis for incremental improvements in method and procedure. Points to opportunities for improved intersectoral arrangements.

TYPES OF HEALTH-BASED TARGETS

Health outcome targets

For public health authorities, health outcomes of managing risks associated with wastewater use in agriculture are the bottom line. They point towards contributions towards the health sector's overarching goal (attainment of the highest possible level of health by the population under its jurisdiction) and towards reducing the burden of demand on health systems and services. Yet, as already pointed out, in settings with complex exposure scenarios, attribution of health outcomes is a challenge.

Under exceptional circumstances, the attribution may become tangible. The 2010 events following the earthquake in Chile are a case in point. The earthquake destroyed Chile's only chlorine production facility. The acute shortage of chlorine led to a serious outbreak of diarrhoeal disease (30 000 cases reported) in the arid North of the country, 2000 kilometres from the epicentre, where agricultural production essentially depends on the use of wastewater. Exclusive reliance on disinfecting wastewater and crops using chlorine clearly provided a risk management measure that could meet the health-based target under "normal" circumstances, but the approach lacked the robustness of the multi-barrier management system that would have the elasticity to withstand the loss of this important control measure while maintaining overall capacity to meet the target.

The Guidelines propose five essential steps towards meeting health outcome targets:

- setting a tolerable risk of infection, based on a tolerable disease risk;
- carrying out a quantitative microbial risk assessment;
- establishing the required pathogen reduction measures;
- designing the combination of risk reduction measures to achieve the required pathogen reduction level
- define the indicator values for verification monitoring.

Microbial reduction targets

With two major groups at risk of concern (i.e. farm workers and consumers) and a large range of contextual determinants of hazards and risks at play, establishing microbial reduction targets is a process whose level of complexity depends on the number of determinants at play in a local setting. The considerations for establishing the level of reduction are discussed in the document *Updating the 2006 Guidelines*, contained in this information kit, as there has been new thinking on this recently. The analysis of the risk factors along the events chain, the exposures they entail and the incremental risk management measures they allow for require a checklist approach, linked to a flowchart of logical decision-making in a systems framework.

The first choice is between restricted and unrestricted irrigation. In settings where restricted irrigation with wastewater is legally enforced, the risk group of concern is narrowed down to farm workers and their children. In this context, the level of mechanization in agriculture will be another critical determinant, as exposure levels will drop along with a reduction in labour- intensive agriculture. Access to and use of basic sanitation is another determining factor, as is the level of treatment of human waste and wastewater. Setting microbial reduction targets in such a system, thought not necessarily simple, is straightforward.

For unrestricted irrigation with wastewater the scope increases, as more risk groups than the farm workers and their children are involved, the number of exposure points multiplies and the options for risk management measures (and the interactions between them) increase in number. In generic terms, determinants of infection exposure and disease transmission include:

- the pathogen load of the populations generating the wastewater;
- position of different relevant population groups on the sanitation ladder;
- level of treatment of wastewater, if at all;
- nature of agricultural production system: labour intensive on highly mechanized as the two extremes;
- irrigation technology and practice;
- crop selection and composition;
- physical lay-out (fields vs community centres) and fencing;
- harvesting and post-harvest practice;
- produce handling and management during marketing;
- food preparation practices in restaurants, catering services, fast-food outlets and household.

Depending on the local feasibility of risk management options to deal with the specific determinants under each of the above generic items, contextual microbial reduction targets can be established[4].

Performance targets

A third option is the establishment and monitoring of performance targets which can be derived from the agreed tolerable disease burden or from quantitative microbial risk assessment, provided sufficient data are available, resources are adequate for monitoring and the risk reduction potential of individual measures has been reliably estimated.

Three types of monitoring of performance targets are proposed in the Guidelines:

- Validation - the initial testing to prove that a system as a whole and its individual components are capable of meeting the performance targets and, thus, the health-based targets. Validation is done before the operations contained in a risk management plan start. It is used to test or prove design criteria. It should also be done when equipment is upgraded or when new equipment and/or processes are added under the risk management plan. The first step in validation sets the testing requirements, based on available data. In the second step, individual components and the overall system are tested under laboratory or pilot conditions in a range of realistic scenarios. Once the system has been validated and becomes operational other forms of monitoring for performance target achievement take over. If validation shows the system is not capable of meeting the performance targets, then (1) one or more of its components will need to be upgraded, and the system re-validated, or (2) if upgrading is technically or economically not feasible, the performance targets and, as a consequence, the health-based targets will need to be adapted until such time as the upgrades are feasible.
- Operational monitoring - the routine monitoring of parameters that can be measured rapidly to inform management decisions to prevent hazardous conditions from arising. It is a planned, systematic set of actions to make observations of measures included in the risk management plan and of their expected impacts. Proper operation of each measure and combinations of measures needs to be defined by limits for normative values. An example is the establishment of limits for turbidity where this is associated with the likely presence of pathogens. There are also on/off parameters such as the presence or absence of aquatic weeds in a wastewater-fed irrigation scheme in areas where schistosomiasis is endemic. Such weeds provide a major habitat of the snail intermediate hosts of this parasitic disease.

4 Reference is made to Guidance note for national programme managers and engineers *A Numerical Guide to Volume 2 of the Guidelines and Practical Advice on how to Transpose them into National Standards*, prepared by D.D. Mara (University of Leeds, UK), for detailed guidance on calculations. This Guidance note is contained in the first Information Kit published in 2008 - available on the web www.who.int/water_sanitation_health/wastewater.

- In brief, operational monitoring should consider parameters that indicate the potential for increased risk of hazard break-through. Mostly, it is based on simple and rapid observations at adequate frequencies, providing statistically meaningful information about the status of the locally most-important hazards. Like the risk management plan itself, operational monitoring must be technically and economically feasible in order to meet its objective of adequately monitoring control measures allowing for the timely signalling and communicating potential risks, to minimize adverse public health impacts.
- Verification monitoring - a periodic exercise to demonstrate that the system is working as intended. Verification complements operational monitoring by determining if the performance of the system of risk management measures for wastewater-based agricultural production complies with the stated objectives required to meet the health-based targets. Verification monitoring may lead to the conclusion that the system needs modification and/or upgrading and revalidation. The best-known example of verification monitoring is the testing of wastewater quality after it has passed through a treatment regime.

IN CONCLUSION

The concept of health-based targets is at the core of methods and procedures proposed in the third edition of the Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Proper assessment of the local conditions in a setting where wastewater is used or is planned to be used in agriculture allows the health-based targets to be defined in a realistic way. The aim is to set targets that are achievable, with the intention to raise them, in an incremental way, to the optimal level that suits local conditions, while bearing in mind international standards for crops destined for export. Measuring the impact of risk management measures in relation to health-based targets becomes increasingly complex as the indicator is further removed from the measure in the overall chain of events. Therefore, measuring health outcome targets is a challenge because of the many confounding factors. Measuring for microbial reduction targets is often more feasible. Proper monitoring of performance targets is an essential element of any integrated risk management approach.

This guidance note has been prepared by Robert Bos, Coordinator, Water, Sanitation, Hygiene and Health, WHO Geneva, and Bruce Gordon, Technical Officer, Water, Sanitation, Hygiene and Health, WHO Geneva. The views expressed in this document represent those of the authors alone; they do not necessarily represent the decisions or stated policy of the World Health Organization, the Food and Agriculture Organization of the United Nations, the International Development Research Centre or the International Water Management Institute.

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Third edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture

Guidance note for National Programme Managers and Engineers

APPLYING THE GUIDELINES ALONG THE SANITATION LADDER

INTRODUCTION

Writing technical guidelines which consider the economic constraints and opportunities prevalent in the diversity of countries across the globe is a challenge. The resulting text may either be an over-simplification or present a level of complexity that defeats the practical implementation of the guidelines. In both cases further explanation for implementation will be required.

This Guidance Note gives examples to show how the third edition of the Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture (WHO, 2006) could be applied in countries at three different levels of economic development reflecting different positions on the sanitation ladder (Table 1):

a) Low-income countries with insufficient wastewater treatment capacities and largely uncontrolled wastewater use.

b) Middle-income countries trying to move from uncontrolled to controlled wastewater use.

c) High income countries where wastewater is treated and wastewater irrigation is a planned process.

Figure 1 outlines the principal application steps of the 2006 Guidelines, which form the structure for the application examples in Table 2.

Tables 3 and 4 complement Table 2 with further details on options for setting health-based targets and examples of common wastewater treatment technologies by scale of irrigation and level of economic development.

The Guidance Note further distinguishes between farmers' and consumers' safety showing, in simplified flow-charts, differences and commonalities for decision-makers in the three country groups (Figure 2ab).

TABLE 1. Common characteristics of wastewater use for irrigation by level of economic development

Country group	High-income countries	Middle-income countries	Low-income countries
Sanitation ladder	Upper section	Middle section	Lower Section
Wastewater use practices	Direct use of reclaimed wastewater commonplace in agriculture and industry.	Indirect use of untreated effluents still commonplace; direct use of treated effluents on the increase.	Indirect use of untreated wastewater commonplace due to widespread pollution; direct use of untreated wastewater and fecal sludge common, especially in water and nutrient short areas.
Wastewater use policy framework	Use policies established and enforced, often within an integrated water resources management framework, especially in water-scarce areas.	Emerging policies and framework; enforcement capacity a major concern	Generally non-existent or not enforced; informal (or unplanned) use predominates
Wastewater use health issues	Pathogens under control; industrial discharges under control; primarily concerned with amenity values and exotic toxic substances.	Continued concern with helminth infections and diarrhoeal diseases; Uncontrolled industrial discharges problematic in emerging economies.	High burden of helminth infections and diarrhoeal diseases (both occupational and consumer exposure); Difficult to assess impact in households due to many confounding factors.
Drivers of wastewater use in irrigation	Water scarcity or drought; resource recovery; food security.	Water pollution and scarcity; urban food demand.	Widespread water pollution from domestic sources in and around urban areas; demand for fresh vegetables from urban centers; water scarcity; nutrient value of wastewater.
Key wastewater use countries and regions (examples)	Australia, France, Greece, Israel, Italy, Japan, Portugal, Spain, USA; Bahrain, Cyprus, Kuwait, Oman, Qatar, Saudi Arabia, UAE.	Bolivia, China, Egypt, India, Iran, Jordan, Morocco, Pakistan, Sudan, Syria, Tunisia; Argentina, Chile, Colombia, Lebanon, Libya, Mexico, Peru, South Africa.	Sub-Saharan Africa except South Africa; Yemen; some Asian countries like Viet Nam.

Source: Adapted and modified from World Bank 2010

FIGURE 1: Key Steps of the Guideline Application Process

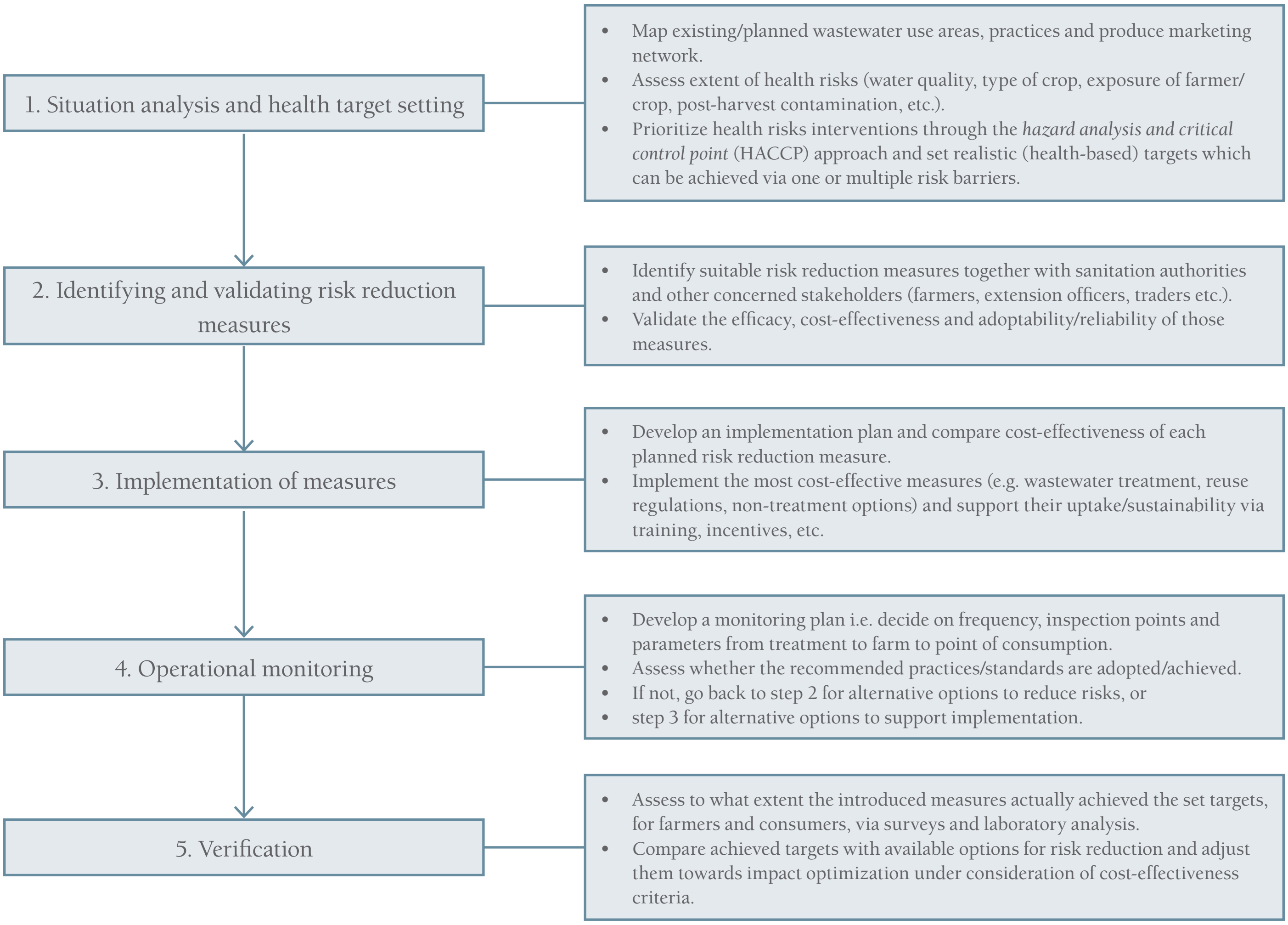


TABLE 2. Practical example of the application process (see Figure 1) in countries at different levels on the sanitation ladder

Step	Activity	Level on the sanitation ladder		
		Higher part (High-income countries)	**Middle part** (Middle-income countries)	**Lower part** (Low-income countries)
1.Situation analysis	**Mapping areas and practices**	• Planned reuse schemes to be mapped using remote sensing. • Related farmers and marketing enterprises to be identified and registered.	• Mapping of planned or existing reuse areas and irrigation practices using remote sensing, water analysis and field surveys. • Assessing related populations at risk via production figures, farm/market/retail surveys and produce analysis.	• Mapping existing areas where wastewater or polluted stream water is used and irrigation practices through field visits, water quality testing and/or expert interviews. • Assessing populations at risk via production figures and farm/market/retail surveys.
	Quantifying risks	• Water quality to be analyzed on regular time intervals using standard laboratory methods (microbial including actual pathogens, and chemical hazards). • Results to be compared with national water quality standards. Areas with contamination levels beyond tolerable levels targeted for interventions. • Quantitative Microbial Risk Assessment (QMRA) and Quantitative Chemical Risk Assessment (QCRA) can be used to model ex-ante risk scenarios for different wastewater treatment types and levels which might be adjusted for maximizing nutrient benefits for agricultural reuse.	• Irrigation water quality should be assessed using microbial and chemical indicators at point of contact (farm) in dry and wet season; data obtained should be compared with (inter)national safety standards. • Crop parts to be consumed without cooking/peeling should be analyzed for actual contamination. • Risks of already exposed farm communities can be verified via hospital data, interviews and/or epidemiological analysis (all vs. control group). QMRA could predict risks of the usually larger consumer group based on produce quality analysis at point of consumption. In the case of epidemics, microbial and epidemiological studies can be used to trace and verify the source.	• If laboratories are available at least key pathogen indicators (fecal coliforms, helminth eggs) should be analyzed in irrigation water and on irrigated crops. If not, local surveys and observations combined with local water users' and/or experts' knowledge could inform whether water is contaminated with human excreta. • Risks for farmers could be verified via interviews with farmers vs. control group; and for farmers at different locations, semi-quantified via exposure ranking. • If faecal coliforms have been analyzed, simple QMRA programs can support the risk assessment for consumers. • If water pollution from industry or mining is possible, at least those heavy metals which are little absorbed in soils and generally not phytotoxic (e.g. Cadmium) should be analyzed.

1.Situation analysis (ctnd)	**Risk prioritization and target setting**	• Based on available data, risks can be clearly assessed, contained to the water and translated into required treatment capacity targets. • If for any reason, like nutrient benefits, treatment will remain suboptimal, the remaining risk should be mitigated through non-treatment options which can be controlled using established procedures. • Risk reduction targets are defined via compliance with established standards for acceptable risk probability.	• If available microbial data exceed tolerable levels and can not be controlled prior to the farm e.g. via wastewater treatment, health-based targets for risk reduction will be set at the point of contact (farmer) and consumption (consumer) to allow for the establishment of multiple barriers along the food chain. • Targets can be set as number of diarrhoea cases or averted Disability adjusted Life Years (DALYs). • Based on the HACCP approach, hazards and control points can be ranked taking account of existing control practices. • For each control point a monitoring target should be set jointly by health officials, farmers, produce sellers etc. • Farm locations near likely chemical contamination sources should receive high attention.	• Based on available data, risks can be ranked for different exposed populations using multi-criteria analysis of their exposure level (contact, intake, frequency). This could be done with concerned stakeholders such as health officials, farmers and produce sellers and should allow for priority setting. • Intervention targets should be realistic and measurable. Simple examples are the percentage of reduced diarrhea cases, or levels of log reductions of fecal coliforms from source to level of produce consumption (assuming irrigation is not restricted and produce is eaten raw). • Farm locations near possible chemical contamination sources should receive particular attention (see below).
2. Identification and validation of risk reduction measures	**Identification of risk reduction measures**	• Wastewater treatment has proven to be very reliable and is a priority risk reduction measure. For any remaining risk, non-treatment options will be applied using the HACCP approach with agreed standards. • Measures might include: pre-farm - conventional wastewater treatment to tertiary level; at farm - use of subsurface drip irrigation systems, crop restriction, and occupational protection measures. • Post-harvest re-contamination risk is assumed to be under control and monitored by standard food safety and hygiene protocols; i.e. non-treatment interventions also apply here.	• Explore if alternative land and water resources are available for farmers concerned. • Explore with stakeholders concerned the current treatment standards upstream of farming areas, and non-treatment safety practices at pre-farm, on-farm and post-farm levels, as well as options for optimizing them in a lasting way. • Measures for risk reduction could include, at pre-farm, wastewater treatment (upgrade) to secondary level; at farms, drip irrigation and occupational safety measures; post-harvest, ensure sanitary conditions in markets and food selling points, etc. • Enforce existing food safety regulations and standards.	• Plan for appropriate wastewater treatment upstream of farming sites taking into account the absorption capacity of the receiving water body. • Explore whether alternative land and (ground) water resources are available for farmers, and if not focus on non-treatment options. • Identify realistic interventions with relevant stakeholders under consideration of available funds, reliability, cost-effectiveness, and adoption potential. For example: pre-farm - some water treatment to primary level using pond systems; at farm - using simple sedimentation ponds, drip irrigation kits; post-harvest - using more effective vegetable washing methods, which in various realistic combinations achieve the required risk reduction. • Support educational efforts on the need to minimize occupational water contact while maintaining appropriate hygiene after work.

Step	Activity	Level on the sanitation ladder		
		Higher part (High-income countries)	**Middle part (Middle-income countries)**	**Lower part (Low-income countries)**
2. Identification and validation of risk reduction measures (ctnd)	**Validation of suggested measures**	• Treatment plant effluent monitoring. • Pilot phase with accompanying research to monitor the impact of recommended farm practices. • For laboratory analysis, use specific pathogens and chemical parameters as spelled out in standards.	• If upgraded/constructed wastewater treatment facilities will geographically influence irrigation water quality, implement effluent monitoring. • Pilot phase with accompanying research to monitor the efficacy and local acceptance of recommended non-treatment options using a combination of interviews, field and laboratory testing. • For assessment, use standard parameters, both microbiological and chemical.	• If upgraded/constructed wastewater treatment facilities will geographically influence irrigation water quality, implement effluent monitoring. • Pilot phase of accompanying participatory research to mutually understand and improve the efficacy and local adoption of recommended non-treatment options. • For assessment, use social, economic, and microbiological laboratory analysis as well as qualitative methods (observations, interviews) and any means to visualize the invisible (microbial) risk.
3. Implementation of measures	**Developing plan**	• Should follow established practices and regulations involving all concerned stakeholders.	• Develop an integrated risk mitigation plan combining treatment and non-treatment options. The combined approach requires a focus on defined hydrological catchment areas where water treatment affects the water flowing to the concerned farming sites and - if possible - defined (isolated) produce marketing channels for wastewater irrigated produce. • Explore options to sustain adoption of non-treatment options via incentives, social marketing, regulations/fees etc. along the farm to fork pathway.	• Develop an integrated risk mitigation plan with all concerned stakeholders with emphasis on awareness creation, education and non-treatment options. • Extend safety measures to all irrigated crops, as for those produced with wastewater if marketing channels can not be separated for safe and unsafe produce. • Extend risk reduction measures to address food safety and hygiene in general, if risk of post-harvest contamination is high.
	Actual implementation/ dissemination	• With wastewater treatment in place, non-treatment options will be equally well regulated and monitored. • Such options should also should be incorporated into educational programmes and training curricula.	• Limit wastewater irrigation to those locations (catchments) with upstream wastewater treatment. • Limit wastewater irrigated produce to those farm-to-fork pathways where safety measures support each-other. • Involve broad range of stakeholders.	• Implement a behavior change campaign, based on incentives, social marketing (values), regulations and education to facilitate a lasting adoption of non-treatment options.

3. Implementation of measures (ctnd)	**Actual implementation/ dissemination (ctnd)**		• Use media and social marketing to support behavior change towards non-treatment options. • Regulate chemical contaminants and improve (source) treatment facilities and till then ban related wastewater use.	• Farmers in areas with high probability of chemical contamination should be supported to farm elsewhere. The sites should be closed until pollution sources have been identified and controlled.
4.Operational monitoring	**Develop plan**	• Should follow established regulations by certified institutions/governmental agencies/laboratories in the water and food sector/ industry.	• Can be adapted to local monitoring plan of ongoing programs related to food safety, public health and water pollution. • Should have inspection standards or analytical indicators to be adhered to.	• Develop monitoring plan with relevant stakeholders. • Focus on simple indicators and proxies. • Encourage local research institutions to get involved in systematic operational monitoring.
	Actual monitoring of compliance	• Follows established inspection and sampling protocols with independent control/audit. • Non-compliance should lead to legal implications and appropriate fees.	• Should be done by whichever entity that can most reliably monitor: government institutions, environmental protection agency or private sector. • Non-compliance should have legal implications and appropriate fees	• Implementers (farmers, vegetable and food sellers) should be empowered through training to do (and understand the value of) self-monitoring. • At least random inspection by authorities (risk of fraud to be addressed). • Monitoring should be based on simple and rapid observations, like physical indicators such as color, smell etc.
5.Verification	**Verify if set targets are achieved**	• Follows established protocols of microbial and chemical risk analysis.	• Should verify if the various risk barriers actually achieve the pre-defined health-based targets (e.g. reduction in diarrhoea cases or DALY in target populations).	• Should verify if combinations of the various risk barriers achieve the pre-defined (see above) health-based targets like reduction in number of diarrhoea cases.

TABLE 3A. Example of health-based targets in countries at different levels on the sanitation ladder

	Level on the sanitation ladder		
	Higher part (High-income countries)	**Middle part (Middle-income countries)**	**Lower part (Low-income countries)**
Type of target (examples per country group)	• Health outcome targets • Water and food quality targets • Technical targets	• Water and food quality targets • Performance/technical target	• Water and food quality targets • Performance targets

TABLE 3B. Characteristics of different health-based targets

	Health outcome targets	**Water and food quality targets**	**Performance/technical targets**
Nature of target	Defined tolerable burden of disease (maximum frequency of disease)	Low- or no-risk thresholds for chemicals or pathogen indicators usually based on international guidelines	Risk reduction targets per non-treatment intervention or treatment technology
Typical application	High-level policy targets e.g. for restricted and unrestricted irrigation, or type of crop; best expressed in DALY per person and year as this allows the correspondingly required risk reduction to be defined	Common monitoring guideline values. National adaptation requires quantitative risk assessment based on exposure and acceptable intake.	Based on achievable risk reduction, e.g. expressed as *E. coli* log-unit reduction, or percentage reduction of chemical indicators
Data needs and/ or complexity of monitoring	High	Medium	Low

Adapting the approach of the WHO Guidelines on Drinking-water Quality, Table 3 describes possible health-based targets: (i) measurable health objectives, (ii) water quality or food quality thresholds, (iii) intervention performance targets, and (v) technology related standards. All targets should be based on a judgment of the required safety and on risk assessment. The traditionally preferred targets are water quality threshold values, which provide a simple benchmark; however, where technical thresholds can not be achieved or maintained, or where achieving them would not change the actual risk (for example where highly treated effluent enters a larger untreated wastewater stream) they will only cost money but not safeguard public health. Targets should thus be realistic and relevant to local conditions (considering for example. the receiving water body's quality and absorption capacity) and financial, technical and institutional resources. With increasing options and resources, targets can be progressively adjusted. In many situations there are advantages to achieving the targets through different but complementary interventions along the contamination pathway (multiple barrier approach). Health-based targets should also consider the wider context of risk, especially in low-income countries, where wastewater irrigated food is only one of several risk factors. In these cases, the cost-effectiveness of different interventions addressing different risk factors should be compared.

TABLE 4. Examples of common wastewater treatment options by scale of irrigation and level of economic development[1]

Characteristics	High-income countries	Middle-income countries	Low-income countries
Scale of interventions	a) Households with garden b) Small-scale communal plots near polluted streams and drains c) Larger urban or peri-urban plots next to decentralized simplified sewerage systems d) Larger peri-urban plots with city-wide sewerage system		
Typical treatment technology options per scale (examples) [1]	Households with garden: • Sewerage • Dry toilets, urine collection, and greywater separation and treatment Communal or municipal farming areas of any size: • Conventional treatment + tertiary treatment • Membrane technologies • Soil aquifer treatment (SAT) systems where possible • Industrial source treatment	Households with garden: • Septic tanks • Imhoff tank • On-site greywater treatment Communal plots: • Primary treatment + constructed wetlands Large plots or medium-size city: • Waste stabilization pond systems • Decentralized wastewater treatment systems (DEWATS) (e.g. secondary treatment + reed bed systems) • Upflow Anaerobic Sludge Blanket (UASB) and other anaerobic systems • Wastewater Storage and Treatment Reservoirs • Chemically enhanced primary treatment Large city centralized system: • Conventional treatment + polishing ponds • SAT systems	Households with garden: • On-site latrines and alternatives • Septic tanks Communal plots: • On- or off-farm treatment via (series of) dug-out ponds • Sedimentation traps for helminth eggs • Three-tank systems • Sand filter systems Large plots or medium-size city: • Waste stabilization pond systems[2] • UASB and other anaerobic systems (able to produce biogas revenue) Larger peri-urban plots with city-wide sewerage system: • Wastewater Storage and Treatment Reservoirs [2]

Source: Adapted and modified from Word Bank (2010)

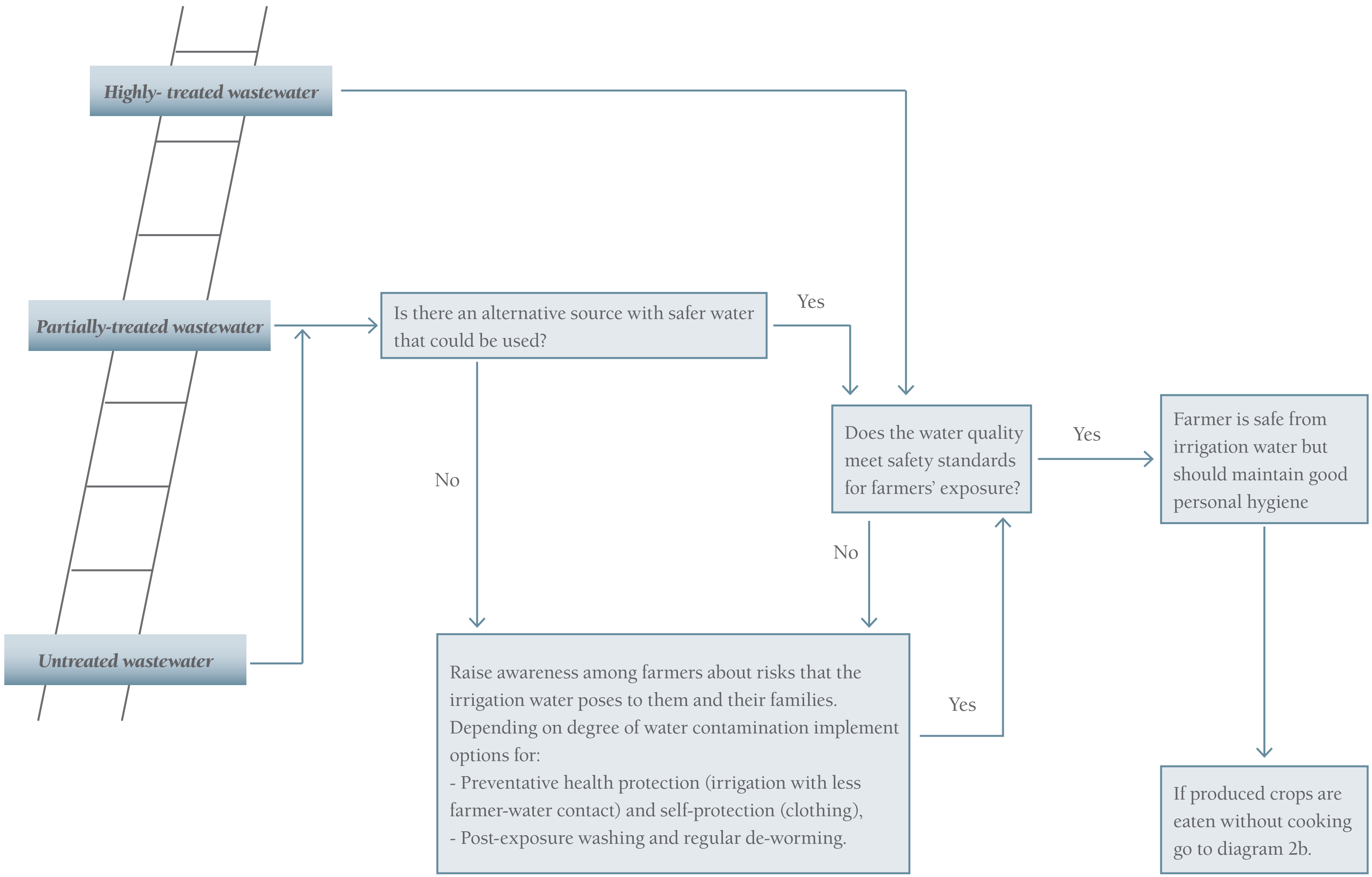
[1] The examples do not imply a necessary progression with increasing economic development. In high-income countries waste stabilization pond systems, for example, can be the most appropriate and economically preferred option for treatment as well. The target should be in any situation to find locally appropriate and if possible reuse-oriented systems where treatment levels are based on receiving water bodies' absorption capacity and the technology on locally viable options (Libhaber, 2007; Murray and Buckley, 2010).

[2] Most suitable where continuous electricity supply is a challenge, but also beyond this stage.

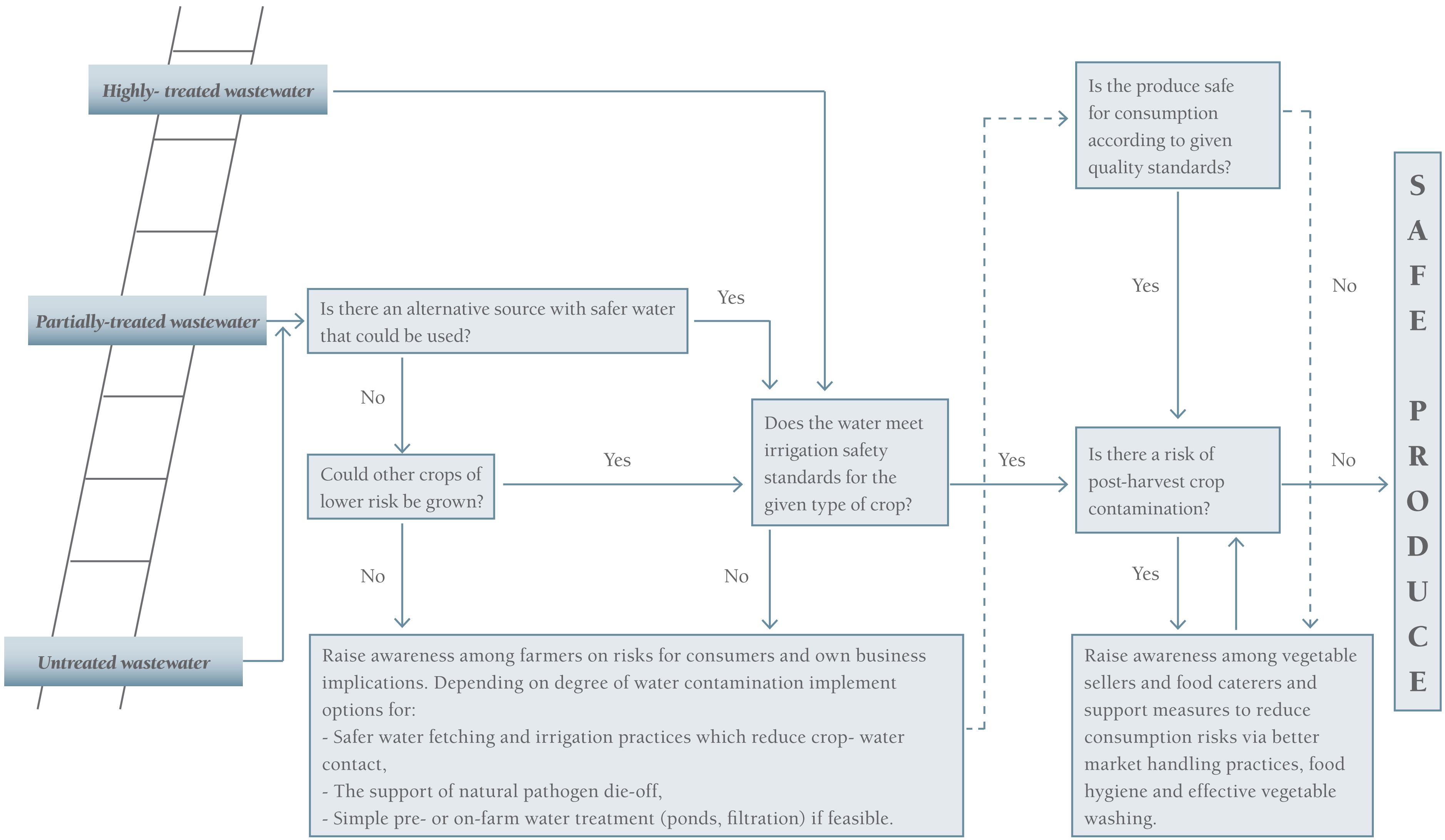
FIGURE 2: Multiple Barrier Decision Support Flow Diagrams

These simplified flow-chart shows differences and commonalities for decision-makers facing water quality conditions typical for the three stages of economic development along the sanitation ladder. They assume that overall health-based targets have been identified and/or that for each barrier operational quality standards have been set.

a. Farmer safety



b. Consumer safety



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ABBREVIATIONS USED IN THE TABLES

DALY: Disability adjusted Life Years

DEWATS: Decentralized wastewater treatment systems

USEPA: United States Environmental Protection Agency

HACCP: Hazard Analysis and Critical Control Points (approach)

QMRA: Quantitative Microbial Risk Assessment

QCRA: Quantitative Chemical Risk Assessment

SAT: Soil aquifer treatment

UASB: Upflow Anaerobic Sludge Blanket Reactor

This guidance note has been prepared by Pay Drechsel and Bernard Keraita; International Water Management Institute, Ghana and Colombo. The views expressed in this document are those of the authors alone; they do not necessarily represent the decisions or stated policy of the World Health Organization, the Food and Agriculture Organization of the United Nations, the International Development Research Centre or the International Water Management Institute.

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Guidance Note on Microbial Risk Assessment
by Duncan Mara, Andrew Hamilton and Andy Sleigh

This document is not yet released. It awaits a discussion at the WHO water quality meeting in Japan in December 2010 and will be made available after that meeting.

FAO Water Report 35

The Wealth of Waste

The economics of wastewater use in agriculture

Executive Summary

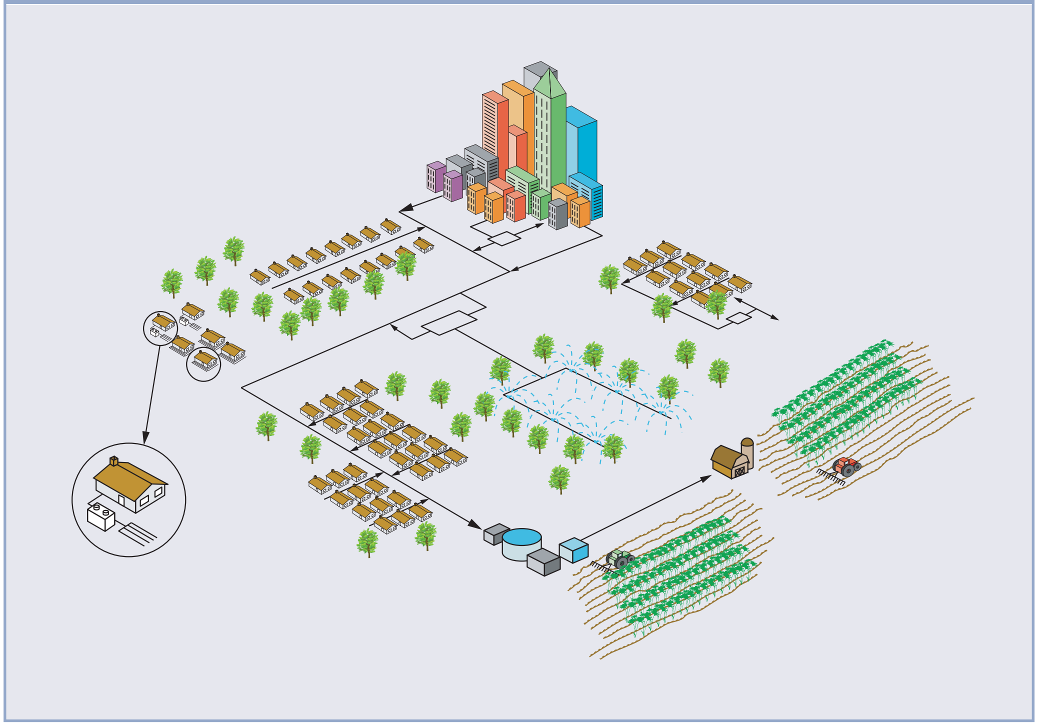
by
Winpenny, J., Heinz, I., Koo-Oshima, S.

FAOWATER

Introduction

The use of reclaimed water in agriculture is an option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations and growing demand for irrigation water. FAO Water Report 35 presents an economic framework for the assessment of the use of reclaimed water in agriculture, as part of a comprehensive planning process in water resource allocation strategies to provide for a more economically efficient and sustainable water utilization.

Different schemes of direct use of treated or untreated wastewater



Reuse as a response to water scarcity

Many regions of the world are experiencing growing water stress. This arises from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts due to climatic factors. Water stress is also caused by pollution from increasing amounts of wastewater from expanding cities, much of it only partially treated, and from the contamination of aquifers from various sources. Such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use. Water scarcity in all its aspects has serious economic, social and even political costs.

At times of serious scarcity, national authorities are inclined to divert water from farmers to cities since water has a higher economic value in urban and industrial use than for most agricultural purposes. In these circumstances, the use of reclaimed water in agriculture enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water. This exchange also has potential environmental benefits, reducing the pollution of wastewater downstream and allowing the assimilation of its nutrients into plants. Recycling water can potentially offer a “triple dividend” - to urban users, farmers and the environment.

Reclaimed water use can help to mitigate the damaging effects of local water scarcity. It is not the only option for bringing supply and demand into a better balance – and WR35 shows how different options can be analysed for comparison – but in many cases it is a cost-effective solution, as the growing number of reuse schemes in different parts of the world testify. A recent comprehensive survey found over 3,300 water reclamation facilities worldwide. Agriculture is the predominant user of reclaimed water, and its use for this purpose has been reported in around 50 countries, on 10% of all irrigated land.

Benefits of reuse

The feasibility of reuse will depend on local circumstances, which will affect the balance of costs and benefits. The major benefit in most cases is likely to be the value of the fresh water exchanged for high-value urban or industrial use. This would lessen the cost for municipal authorities of seeking their supplies through more expensive means. In addition, reuse prevents untreated wastewater discharge to coastal and groundwater systems with ecosystem and tourism benefits.

Depending on the local situation, there could also be benefits to farmers if they can avoid some of the costs of pumping groundwater, while the nutrient present in the wastewater could save some of the expense of fertilizer. There could also be benefits to the local environment from reduced flows of untreated wastewater – though the interruption in the downstream water cycle could have other, less beneficial, effects.

Costs of reuse

The costs of the reuse option could include the installation or upgrade of wastewater treatment plants (WWTPs) to produce effluent of the desired standard, any addition or modification to the infrastructure for water and reclaimed water distribution, the extra recurrent costs of treatment, and the cost of any produce restrictions imposed by the use of reclaimed water in irrigation. Where climatic and geographical features are suitable, low-cost treatment of wastewater may be an option through the use of stabilisation ponds, constructed wetlands, etc. The net cost of treatment may also be reduced through the reuse of biogas for energy and power in the intensive treatment processes, or potentially through the sale of carbon offsets.

Economic justification

The economic appraisal of the project should be from a regional basin viewpoint, comparing its economic costs and benefits. Judging by the evidence of our case studies, it is unlikely that schemes could be economically justified with reference only to agriculture. Although farmers may be net beneficiaries from using treated wastewater, compared with their previous or alternative sources of water, this depends very much on local circumstances, and in any event their net benefits are unlikely to offset the full costs of the scheme. On the other hand, the benefits to urban and industrial users could be relatively sizeable, and in most cases would be the principal justification for the project. The net impact of the project on the local and downstream environment will also be very site-specific, and there are likely to be both benefits and costs.

Financial feasibility

Once the basic economic justification of the project is established, the next step is to examine its financial feasibility. The distribution of the costs and benefits of the project between different stakeholders is crucial to its feasibility. Its impact on the finances of the various stakeholders – national government, regional water authority, farmers, municipal utility and/or other major players – should be assessed. Financial gainers and payers should be identified to gauge the incentives, or conversely the penalties, to be applied and the type of funding that would be appropriate. Water charges, taxes, subsidies, soft loans, environmental service payments, and other instruments could all form part of the financing proposals.

A planning framework

The economic framework for wastewater reuse is intended to fit within a comprehensive planning framework. A sound and methodical planning approach will assist in identifying all the relevant factors necessary for the decision to proceed with a project. WR35 presents such a planning framework, its key elements being: identification of problem and project objectives; definition of study area and background information; market assessment and market assurances; identification of project alternatives; appraisal and ranking of project alternatives; and implementation. Among the major specific technical issues to be addressed are: facilities and infrastructure, balancing supply and demand, wastewater quality, and public health risks and safeguards.

Factors essential for the success of reuse projects

The feasibility of reuse projects hinges on several key factors. The physical and geographical features of the area should be conducive to an exchange of water rights between the parties concerned. The extra costs (of treatment and infrastructure) should be affordable in relation to benefits. Farmers should be supportive, which depends on the net impact on their incomes, the status of their rights to freshwater, and what are their alternatives. Public health authorities should be satisfied that the projects pose no undue risks, after reasonable precautions have been taken. Finally, the environmental impact should be acceptable: the same impact may be acceptable or not in different circumstances, and different authorities will place a different weight on specific impacts in forming an overall judgement.[1]

A reality check – case studies from Spain and Mexico

On a global scale, only a small proportion of treated wastewater is currently used for agriculture, but the practice is growing in many countries, and in some regions a high proportion of reclaimed water is used in irrigation. The variety of case material presented from Spain and Mexico provides a good field testing of *Methodologies of Cost-Benefit and Cost-Effective Analyses*. The case study results demonstrates that the methodology presented for appraising wastewater reuse projects is viable. Although the *Cost-Benefit Analysis* analytical framework is well able to incorporate the interests

[1] Local environmental policy (pollution taxes, payments for environmental services, incentives for the recovery of heat from biogas, etc.) could tilt the balance in favour of reuse schemes.

of municipalities and farmers, there is an important third party at the table – the environment – which needs a champion and a custodian. Reflecting the needs of the environment, valuing its assets and services, and ensuring that its financing needs are met, is a challenge to analysts in this area. The case studies confirm that reuse is an area ripe for the application and refinement of the tools of environmental cost-benefit analysis.

The case material demonstrates that certain items of costs and benefits are more robust than others. On the cost side, the capital costs of treatment units, pumps and canals can be estimated with high confidence, and their operating costs (pumping, chemicals, labour, etc.) are also fairly evident. The technology of wastewater treatment and its future level of unit costs are liable to change, and future options should not be prematurely foreclosed.

Most of the case studies stress the perceived benefits to farmers from the nutrient properties of effluent, plus savings in groundwater pumping and the greater reliability of effluent compared with other sources of water in arid and semi-arid climates. While pumping costs are reasonably firm, the benefits of fertilization depend on local empirical evidence ("with and without project"). The value of *reliable* wastewater also needs to be demonstrated more convincingly, *e.g.*, by a closer study of farmers' response behaviour where water supply is erratic or scarce.

From the viewpoint of urban water demand, the case studies reflect the widespread view that water supply tariffs are too low, hence there is a pervasive underestimation of the benefits created by developing new solutions to growing demand. However, some of the cases illustrate the importance of distinguishing genuinely new benefits, on the one hand, from the avoided costs of meeting existing demand in a different way.

The analysis of the case studies has implications for policy towards the use of reclaimed water, depending on what its principal objectives are:

- *as a feasible and cost-effective means of meeting the growing demands of agriculture for water in regions of growing water scarcity and competition for its use.* This motive also applies in situations where demand is not necessarily rising, but where periodic water scarcity is a problem for farmers planning their annual crop patterns. The case studies contain evidence (*revealed preferences*) of farmers responding positively to the use of effluent in these situations, as a temporary expedient or long term solution. However, effluent reuse is one amongst a number of options at farm level to minimizing exposure to water risk. Moreover, the creation of expensive distribution and storage facilities, with a high recurrent cost, in order to furnish water for low value farm purposes, is not always warranted – unless there are benefits to other sectors.

- *as an environmental solution to the growing volume of wastewater effluent and its potential for downstream pollution.* The Mexico City-Tula case is the clearest example of the mutual benefit for the City and farmers from disposing of urban sewage and effluent to agriculture – and allowing natural processes to carry out some of the purification *en route.* Reuse schemes allow the dispersion of effluent and its assimilation across a wide area, as compared to the point source pollution from WWTPs. The reuse of effluent nutrients in crop production, rather than their removal and effective destruction during advanced processes of wastewater treatment also has a strong appeal to many Greens. The case studies confirm these environmental benefits of using reclaimed water.

- *as a "win-win" project that is a solution to urban water demand, while also delivering the agricultural and environmental benefits stated above.* The Llobregat sites and Durango City are clear-cut examples of potential win-win propositions since in both cases it is physically and geographically feasible for farmers to exchange their current entitlements to freshwater for effluent, and for the cities to gain access to the freshwater rights that are thus "released."

Whether or not "win-win" outcomes occur depends on legal and other barriers being overcome, as well as successful negotiation over the financial arrangements between the parties to the deal. It must not be assumed that farmers will readily give up their rights to freshwater, without further consideration of their operational situations. Most farmers prefer to have several water sources as insurance against drought. A cost-benefit approach helps to set the parameters for agreements between the main stakeholders, which in this report are assumed to be farmers, cities and the natural environment. It helps to define the interests of the parties in moving towards, or resisting, agreements that change the *status quo*. Where the balance between costs and benefits for one party (*e.g.* farmers) is very fine, the existence of a large potential net benefit to another (*e.g.* city or environment) can provide "headroom" for agreement by indicating the economic or financial bounty available to lubricate the deal.

The overall message the report seeks to convey is that the recycling of urban wastewater is a key link in Integrated Water Resource Management (IWRM) that can fulfil several different, but interrelated objectives. These are expressed as *win-win* propositions, delivering simultaneous benefits to farmers, cities and natural environmental systems, part of the solutions to the urgent global problems of food, clean water, the safe disposal of wastes and the protection of vital aquatic ecosystems. The traditional "linear society" is not a sustainable solution and the "circular society" has to become the new standard.

WR35 is based and contains an extensive bibliography, testimony to the large and growing interest amongst the professional and policy communities in this important topic.

FAOWATER

www.fao.org/nr/water

Lessons learned and recommendations based on pilot research in Jordan, Ghana and Senegal 2006-2010

Mark Redwood[1], Javier MateoSagasta[2] and Robert Bos[3]

In November 2006, the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO) and the International Development Research Centre (IDRC) joined forces in a research initiative entitled *non-treatment options for safe wastewater use in agriculture by low-income urban communities*. The initiative aimed to evaluate the applicability of the third edition of the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture. Through the use of specific case studies, this initiative evaluated the feasibility of the methods and procedures proposed in the guidelines. In addition, the project explored the constraints and obstacles that may be encountered in their implementation.

The flexible and contextualized nature of these new guidelines represents a significant shift in approach. Where previously measurements of health risk would be done by a single regulator, the new guidelines require the involvement of a number of stakeholders in determining both risk, and risk mitigation strategies. This new approach articulated in the guidelines should ensure meaningful use in a range of settings and at different scales, but it also implies involvement of professionals and authorities across several public sectors.

The expected deliverable at the point of departure of this project was a guidance document to assist national and municipal authorities and other users of the guidelines in their application. After four years of work, research teams have provided valuable feedback on the practicality of the WHO Guidelines.

The four case study projects are:

- Ghana/Kumasi: Evaluation of non-treatment options for maximizing public health benefits of WHO guidelines governing the use of wastewater in urban vegetable production in Ghana.
- Ghana/Tamale: Minimizing health risks from using excreta and grey water by poor urban and peri-urban farmers in the Tamale municipality, Ghana.

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- Jordan: Safe use of greywater for agriculture in Jerash Refugee Camp: focus on technical, institutional and managerial aspects of non-treatment options.
- Senegal: Proposition d'étude en vue de l'intégration et de l'application des normes de la réutilization des eaux usées et excréta dans l'agriculture (*Research project on the integration and application of standards in the use of wastewater and excreta in agriculture*).

Over the four years, field teams reviewed different methods of conducting risk assessment, risk management and the enabling environment to assess the feasibility of applying the guidelines; some policy environments favour a comprehensive wastewater related health policy more than others. The following issues were discussed in a final workshop in Amman, Jordan (7-10 March 2010):

RISK ASSESSMENT	Setting health-based targets Quantitative Microbial Rick Analysis (QMRA) and other risk assessment approaches Synthesis of risk assessment
RISK MANAGEMENT	Design of non-treatment options Effectiveness of non-treatment options Calculation of cumulative risk reduction Social acceptability and economic feasibility Criteria for selection of interventions
ENABLING ENVIRONMENT	Policy framework and regulation Conditions favouring community participation Institutional arrangements

The outcome of these discussions is presented below in the form of lessons learned. The technical terminology used is explained in the guidelines and in documents contained in this and the 1st edition of the information kit.

RISK ASSESSMENT

1. Setting Health-based Targets

This was identified early on as a potentially difficult task. None of the projects fully accomplished setting health-based targets. In all projects, however, proxies were used (e.g. indicator bacteria or disease incidence) with the objective to achieve maximum risk reduction. The fact that this was a difficult task for local researchers to complete suggests an important need to emphasize capacity building in the setting and monitoring of health-based targets. One practical option might be to set the most conservative target (e.g. a reduction of 6 logs of *e-coli*) and then aim for the best possible outcome.

Lessons Learned
No team had the core experience required to set health-based targets effectively which is a reflection of the need to build capacity to actually formulate health-based targets. Despite working in wastewater, many of the teams noted that the concept of health-based targets was new to them. A significant amount of backstopping – likely from highly resourced research institutions – would be needed to develop health-based targets unless proxies can be used as is the case with the WHO Drinking Water Guidelines.

2. QMRA and other risk assessment approaches

The research teams learned about the importance of defining systems in terms of where the problem starts, what the exposure routes are, the elements along this food chain and the boundaries of the system, and critical hazard points. Risk assessment of this kind can be challenging as it requires a deep understanding of contextual factors as well as of the variables that can influence health risks. For instance, in the case of diarrhea, the risk can come from contaminated water, food, the market etc. It is equally important to categorize types of people along the chain of risks – e.g. children (coming from schools, playing), farmers, consumers, marketers. A critical step, in order to understand the health risks faced by a population, is to ask the following five questions:

- Who is exposed?
- Where are they exposed?
- When are they exposed?
- How are they exposed?
- How often are they exposed?

The system of food production through to consumption is defined by *exposure points* – and these, in turn, is largely defined by activities of the target groups. Four different approaches of risk assessment and analysis were used:

1. Epidemiological (stool samples – applied in Tamale, Dakar).
2. QMRA (Tamale, Kumasi).
3. Recall period survey fed into EpiInfo software to correct for confounding factors (Jordan).
4. Multiple regression analysis (Tamale) which was applied to identify the share of diarrhoea cases attributable to bad hygiene and to determine what was the contribution of wastewater to latent health risks.

In the Jordanian case study, data was collected through straightforward household surveys, supported by EpiInfo software. The frequency and incidence of sickness was recorded that aided greatly in identifying hazards. It was found also that identifying hazards for farmers and their immediate households was much easier than identifying wastewater related hazards for consumers and the wider community. For example in Ghana, children playing in gutters, people swimming at a beach or family members of farmers are more difficult subjects to study as the origin of diseases can come from many different exposure points.

Lesson learned

A clear lesson from these projects suggests that the Guidelines over-emphasize QMRA while there are many other (also statistical) mainstream options available to researchers. The challenges imposed by QMRA are amplified by language limitations (i.e. most QMRA material is in English limiting its applicability in some contexts). The possibility of proxies as health indicators should not be discarded; hazard identification should be the first step to be linked to disease incidence as a proxy. To do this properly, a multidisciplinary team is required (including but not necessarily limited to microbiologists, economists, statisticians). Scoping, i.e. setting systems boundaries, for the research exercise is important to ensure that the planned risk assessment is feasible and can be pursued.

3. Synthesis of risk assessment

While each team conducted risk in a slightly different manner, each addressed two common questions: Who is most affected and to what degree are they affected? Each team assessed risk in a slightly different manner. The Kumasi proposal targeted consumers and the team therefore followed the contamination pathway that they established through a preparatory phase of interviews, combined with baseline data collection along the farm-to-fork food chain from previous research. The team then estimated the number of consumers affected. The Tamale proposal targeted farmers exposed to wastewater and the application of raw fecal sludge in agriculture.

In Dakar, because considerable work has already been conducted on wastewater use this project focused instead on and the project focussed on reducing occupational hazards as well as crop contamination. Women sellers and consumers were included in the exposed groups. The Jordan team initially looked at farmers, but after the risk assessment, identified children as a priority group at risk which has important implications for their research.

Lessons learned
It became evident that one must consider the entire system rather than targeting only one group (i.e. household, links between farmers, their families, how food is prepared, hygiene practices; the market). Systems are inherently more complex since many variables can affect risk – and this raises the question why one would not just assume maximum risk, thereby reducing the high costs associated with a full epidemiological study which is outside of the scope of capacity for many research institutions. An important conclusion is that given the high cost to eliminate risk entirely, the more accurate a risk assessment, the more likely one can identify a cost effective solutions. For example, in Jordan, knowing that children playing in street drainage systems is a source of risk would naturally lead to ways of reducing contact between children and wastewater. A compromise could be the use of rapid risk assessments advocated by some epidemiologists.

RISK MANAGEMENT

4. Design of non-treatment options

Non-treatment options are advocated in situations where wastewater treatment is not feasible or readily available. It was clear that all options for preventive measures related to critical hazard points must be identified and defined. For example, one frequently proposed approach of ceasing irrigation two to four days prior to harvest (in order to allow pathogens to die) also can imply unacceptable yield losses of around 10% or more. Such losses were observed in Ghana, rendering the method unfeasible as farmers would not accept the loss of income. Therefore, every option proposed requires thoughtful analysis to ensure that there would be no problems or resistance in implementing the solution.

If recommended measures, such as ceasing irrigation prior to harvest, are applied strictly, non-treatment options can be very effective. Monitoring, however, is critical to ensure compliance and effectiveness. For instance, an analysis on how waste is traditionally used is important to better understand the cultural context. In particular, reliance on surveys is not enough; they should be complemented by direct observations and, importantly, that within the boundaries set, appropriate sample sizes and their representativeness should be ensured. It was noted that monitoring capacity is lacking in many countries.

In the four pilot projects, intervention designs focused on different target groups with the following further specifications:

- Kumasi – the focus was on traders as this complemented previous work targeting farmers and street-food vendors, and on consumers' willingness to pay for the additional costs incurred by non-treatment options.
- Dakar – the focus was on all groups with the potential to participate in risk reduction.
- Tamale – farmers were consulted and researched in terms of their interest in and attitudes towards for example drip irrigation as a safer wastewater irrigation method.
- Jordan – a main focus was on awareness raising – for example, on changing practice in collecting olives to reduce exposure. Conventional wisdom had it that non-treatment options were not possible in Jordan, but the project tried to break down barriers to change.

Lessons learned

The evidence for non-treatment options is an important basis through which to inform policy, however, policy making is nuanced and involves a great deal more than simply good evidence. Networking of researchers working on wastewater use is an important element in placing the topic on local and regional policy agendas. Tying the theme of safe wastewater use to larger agendas of food security, poverty and environmental management will likely generate more support in the long run. It was noted that targeted observation – for instance, focusing on one group or on a specific irrigation method - helps to increase the likelihood of uptake and clarifies the evidence. Straightforward proposals are received well by decision makers under pressure to come up with easily understood solutions.

Needless to say, the generation of an evidence base on safe wastewater use is a long process in countries challenged by a lack of sanitation. For example, in the Ghana case, it took more than two years to identify people's current practices, modify these practices, study the economic implications for farmers/traders, study perceptions and to test these modified practices and verify that they did reduce risk levels. Lessons from one country could then feasibly be transferred to other countries if the right incentives and contextual similarities exist. To better assess the transfer of lessons, perception studies and deeper social and market analysis will still be required to assess if uptake of the solutions proposed by this research are realistic.

5. Effectiveness

There were two perspectives raised in the research projects related to the question of the effectiveness of risk mitigation activities. First, the effectiveness *per se* in the removal of health risks as measured in terms of proxy indicators and second, the cost-effectiveness of risk reduction measures. For instance, the use of vinegar as a kitchen practice to disinfect lettuces has proved to be effective (achieving a *4 lo*g reduction in e-coli), but can become expensive since a large amount is required. Another example is that of more expensive imported drip irrigation kits as compared to those locally produced.

Lessons learned
Economic arguments for the effectiveness of risk reduction strategies are clearly important. For instance, having a measure of the unit price per log reduction in risk is an appropriate cost-effectiveness indicator if different interventions are to be compared. Essentially, the fundamental question to answer in most research on risk reduction in wastewater irrigation is: how much does it cost a farmer or consumer household to reduce the risk?

Disability-adjusted life years (DALY`s) can be used as an indicator, a feasible approach but one that requires QMRA. Moreover, estimating the dollar value of each DALY reduction requires some basic economic analysis which can be an important measure of cost effectiveness.

6. Calculation of cumulative risk reduction

It is important to note that the multiple-barrier approach assumes that risk reduction occurs cumulatively. For instance, strategies can be employed along the food chain of risk from food production, marketing through to consumption. The research in Kumasi, Ghana explored this and focused on a multi-step process that involved: (1) identifying best practices; (2) assessing their effectiveness and then; (3) combining different options to increase log reduction in risk. In addition to the calculation of cumulative risk reduction, there also should be a disaggregation of cumulative risks for each different target groups (farmers, vendors, consumers). While this is a better way to reduce risk, it can only realistically be done under highly controlled conditions unless appropriate adoption incentives can be provided.

Lessons learned
A main lesson learned was that one cannot just add up independently measured log reductions. The pathogens filtered at one barrier might be the same removed at another and pathogenic re-growth can

occur in between barriers. Collecting the relevant information requires a larger effort in terms of combined field trials.

7. Social acceptability and economic issues

Wastewater use in agriculture is still an activity largely done by the poor and marginalized. This is particularly true when untreated wastewater is used. While recognition of wastewater use may result in some helpful policy, it often draws negative attention to farmers. Increased attention on the risks inherent in wastewater use must be accompanied by practical and acceptable solutions on how health risks can be managed.

While economic analysis was not explicitly addressed in this project, it remains an important element in understanding risk mitigation. If there are large economic trade-offs to reduce health risks, or if the trade-offs are not well understood, most people will opt for the more profitable solution. Sometimes this means taking the risk of infection from wastewater or faecal sludge application. The potential for scaling up risk management solutions is an important factor (uptake through social marketing, establishing economic incentives) and also an area for further research. It is clear that the need for better economic data is required in order to raise the prospect of uptake.

Lessons learned
The introduction of interventions of different types should be carried out incrementally, in a step-wise manner; offering whole packages of integrated interventions at once does not work and may be counterproductive.

Economic incentives would be the best way to achieve social uptake, such as increased prices for produce that is certifiably safe. But this requires risk awareness among consumers if they are to be willing to pay such prices. Where this is lacking, social marketing can support uptake of non-treatment options. Also non-monetary incentives are possible. For example given that urban farmers have a high economic return, tenure security would be an important incentive for farmers to stay in farming and adopt safe wastewater use practices.

Education and awareness creation are considered crucial as no one will change his/her behaviour unless the person knows for what reason they need to change it. The WHO guidelines under-emphasize the mechanisms by which to facilitate the adoption of safer practices and needless to say, the adoption rate matters in the overall result in terms of health impact and the cost-effectives of interventions. In each context appropriate incentives need to be identified and tested and this requires time.

8. Criteria for the selection of interventions

The following criteria had been developed and applied in the studies:

- Cost effectiveness and affordability of the interventions.
- Identification of traditional practices and capitalizing on these (Tamale – faecal sludge management).
- Ownership and adoption potential (linked to social marketing).
- Efficacy in terms of reducing health risk, at least the intervention must be an improvement over what is the current risk.

Lessons learned
The most important criterion is adoptability**.** How to support this criterion for non-treatment options is not clear in the WHO guidelines and should be further developed.

ENABLING ENVIRONMENT

9. Policy Framework and regulation

Many questions of a policy nature arose repeatedly in the implementation of these studies. Among them: Who is responsible for monitoring? Who regulates? From where should standards be referenced? Who is responsible for failures? In Jordan, for example, enforcement of wastewater use legislation is strong. The previous WHO Guidelines (1989, second edition) are still being used by many policy makers, and are considered the "current" version. It is clear that there will need to be a period of transition and the question is how to increase the uptake of the 2006 Guidelines amongst ministries of health. Standards associations are good targets for evidence since they often develop Standards based on the best evidence available. The Wastewater Safety Plan under development by the WHO could become the basis of a framework for monitoring and control.

Lessons learned
It will be difficult to translate the Guidelines into policies and strategies as long as they are hard to explain and implement. Without policy backing, they may not become institutionalized. The logical lesson is therefore: simplify the guidelines to increase their policy acceptance, or better explain them per country group along the sanitation ladder as some countries need to emphasis more non-treatment options while others can rely on treatment. Clearly, countries where the 1989 Guidelines have already been incorporated into legislation and regulation will require some innovative thinking on how to link the previous edition of the Guidelines to the current, 2006 third edition. A small learning module – as short as one or two days - would be extremely helpful. Currently, few training courses exist, despite the fact that there are a number of international institutions that might be well placed to develop training along these lines. Translation of the guidelines into multiple languages would also be helpful.

10. Conditions favouring institutional arrangements and community participation

Too often, regulatory institutions are working at cross-purposes vis a vis wastewater use. Overcoming this sectoral fragmentation is critical. Meaningful community participation to harness the energies available at the community level helps to surpass sectoral boundaries. At a local level the roles of households and individuals become more pronounced in regulating risk and how wastewater is used in agriculture. In the proposed cross-sectoral approach of integrated risk assessment and incremental risk management it became obvious in all four projects that in all settings there were a range of stakeholders (in some projects specifically addressed in stakeholder workshops) and in all settings the community involvement was a key contributing factor to a positive outcome.

Lessons learned
The essential analysis to be done addresses the question: which ministries are in charge? It is critical to minimize jurisdictional overlap in this process – something which is often a major hindrance to implementing new frameworks. Wastewater policy affects mostly Ministries of Health, Water and Agriculture. Multi-ministerial working groups and capacity development are required to bridge these entities. Capacity building needs could be reduced in low-income countries if the guidelines are easier to understand and also if they do not require advanced (QMRA) or expensive (monitoring) analytical capacities. Also in this case the premise applies: the easier the guidelines can be explained and implemented, the higher the chance of uptake and participation. The credibility of the team encouraging adoption of new practices is a key determinant of success. A community-based process building on the PHAST[4] experience should be pursued since it provides one proven approach of participatory decision-making.

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[4] PHAST – Participatory Hygiene and Sanitation Transformation, step-by-step guide published by WHO in 1998, available at www.who.int/water_sanitation_health/hygiene/envsan/phastep

While the four projects were only short-term pilots to test the implementation potential of the 2006 Guidelines, any serious follow-up will require a longer project period to address the identified technical, institutional and capacity building needs.

More on each of the individual research projects can be acquired by contacting:

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Concept Note

Sanitation Safety Plans (SSP):

A vehicle for guideline implementation

This note serves as an introduction to the concept of sanitation safety plans, which aim to facilitate the implementation of the guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture (WHO, 2006). It provides background information on the links between sanitation and human health, recent developments with respect to sanitation policies and updates on access and use of sanitation. This concept note also elaborates on the context, contents, and possible objectives and boundaries of sanitation safety plans, and highlights questions that remain unanswered and merit further discussion. The intention of this concept note is to serve as a basis for discussion among stakeholders in safe sanitation and wastewater use, scientists, managers and practitioners, in order to generate ideas and interest to contribute to the development of a Manual on Sanitation Safety Plans.

Background

Sanitation & health - the narrow picture

On July 28 2010, the UN General Assembly adopted a non-binding resolution calling on states and international organisations "*to scale up efforts to provide safe, clean, accessible and affordable drinking-water and sanitation for all*". As a result, drinking-water and sanitation are now enshrined as basic human rights. (Lancet, 2010).

Adequate sanitation is essential for the protection and promotion of individuals' and community health and enables a productive and dignified live. Access to basic sanitation, linked to proper 'use and disposal', can substantially reduce diarrhoeal disease, intestinal worm infections and vector-borne disease. The reduction in incidence of diarrhoeal infection has been estimated to be up to 32% (WHO, 2008). In contrast, lack or improper use of sanitary installations, as well as inadequate containment, treatment or handling of the resulting excreta and wastewater will impact on both human disease incidence and mortality, via multiple routes of exposure. Inadequate disposal also contributes importantly to the degradation of the environment.

Multiple human exposure pathways, the quantity of pathogens, local environmental and climate conditions, the capacity to deal with waste and the attitudes, knowledge and believes related to human waste are all closely linked to sanitary safety. The pathways include the fecal-oral pathway of infection through direct or hands-mouth contact or through foodstuffs. Other pathways involve exposure to contaminated soil: e.g. hookworm infection is spread through larval penetration of the bare skin. Unimproved latrines may serve as breeding places for certain disease vectors (mosquitoes, houseflies) (e.g. lymphatic filariasis and blinding trachoma – therefore, transmission by vectors provides yet another pathway that can be tackled by improved sanitation.

In light of the above, there is an obvious need to assess, prioritize and manage sanitation in a systematic manner both for the 2.6 billion people estimated to lack access to improved sanitation facilities (WHO/UNICEF, 2010), as well as in relation to different existing installations, treatment and disposal or reuse options. Despite its vast effects on public health and clear epidemiological evidence, political commitment for sanitation continues to be insufficient. Sanitation safety planning may function as a tool to promote and facilitate the priority setting and management of sanitation for the future.

Sanitation and health - The broad picture

Sanitation has a broader scope that goes beyond the strict disposal of human waste. Indeed, sanitation is the hygienic means of promoting health through prevention of human contact with the potential hazards posed by wastes, including either physical, microbiological, biological or chemical agents of disease. The assessment and planning from a systems perspective therefore needs to account for the risks but also for the benefits of use of wastewater, excreta and greywater (in agriculture and aquaculture), either partially or wholly treated, or the treatment and further impact for the release back into local ecosystems. Such a systems approach also accounts for further impacts on humans in the management of waste, and thus covers recreational waters and the management of solid waste, as well. The secondary effects of sanitation assessed through environmental determinants of health - traditionally addressed through environmental management- can partly be addressed within the same framework, thus also including the receptiveness of the environment to disease transmission at large.

Water safety plans (WSP) serving as a model for sanitation safety plans (SSP)

The publication of the third edition of the WHO Guidelines for Drinking-water Quality (WHO, 2004) introduced the concept of integrated, preventive risk management through water safety plans (WSPs) as a means to put in to operation the principles, standards, norms and best practice proposed by the Guidelines. Using health-based targets as a point of departure, WSPs provide a systematic approach towards assessing, managing and monitoring risks from catchment to consumer. It provides a way of structuring and applying tools, methods and procedures to replace end-of-pipe measurements of water quality by a *hazard analysis critical control points* (HACCP) approach, referring to a series of actions to be taken to ensure safety of the drinking-water supply chain at critical control points. WSPs follow the logical sequence of this chain and enable system-tailored hazard identification and risk assessment/management.

Based on an earlier edition of the WHO Guidelines for the safe use of wastewater and excreta (WHO, 1989) and as a response to the increasing use of wastewater in agriculture and the needs to account for the benefits of plant nutrients in human waste, WHO, in collaboration with UNEP and FAO, updated the Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture (WHO, 2006). This third edition of the Guidelines explains how the practice of wastewater use can be pursued in a safe way. The methods and procedures proposed followed the same principles of HACCP. It therefore follows, as a logic that mirrors the use of water safety plans to render the WHO Drinking-water Quality Guidelines operational, that the development of a concept of wastewater or sanitation safety plans is needed for a similar purpose. A technical seminar at the 2009 Stockholm World Water Week recommended the term sanitation safety plans because of the opportunity it implies to place safe use of wastewater in a broader sanitation context.

Essential actions

As with WSPs, sanitation safety plans would aim to assist in the application of the Guidelines. Sanitation Safety Plans should comprise three essential actions. Firstly, a *system and exposure assessment*, which refers to mapping the system and identifying potential risks along the sanitation chain. This involves the collection of all available and relevant data on the sanitation system in question from the users to the reuse/disposal and downstream effects. Risks that may appear in the different components of the sanitation system need to be assessed and ranked according to the measures of 'likelihood' and 'severity'. The exposure levels of different vulnerable groups need to be established. It is important to consider all routes of exposure in order to make adequate estimates, ranking and prioritization. This first action component, implemented in the context of a system assessment, provides the basis for planning and implementing a sanitation safety plan.

Secondly, *operational monitoring* is a key action component, aimed to establish control measures for previously identified and ranked hazards and exposures at critical control points in the chain, and a mechanism to ensure that a failure to control such are being detected in a timely manner. Operational monitoring mainly includes simple measures that can also be pursued in settings where training opportunities for workforce may be limited and can be carried out on a day-to-day basis. Examples are given in the guidelines and may range from the integrity, use and containment conditions of a latrine, the emptying practices, fencing around sludge collection sites, and irrigation application and crop selection in waste-water-irrigated fields. Mechanisms of operational monitoring should reflect the likelihood and the consequences of a loss of control. Operational monitoring may also function as a base for further definition of parameters and critical limits. When considering existing systems, operational monitoring serves to reveal the need for upgrading, restoring and extending the system for better performance. Verification monitoring is relevant as a back-up in already well-defined systems. Details on objectives and means of monitoring components are covered in the Guidance Note on Health-based Targets in this information kit (Gordon and Bos, 2010).

Thirdly, the actions comprise a *management* component, referring to a plan of actions and control measures for normal conditions and incident situations. It defines procedures for the normal variation in operational monitoring parameters, and management procedures for predictable incidents accounting for sudden changes as well as emergencies. With corrective actions and their execution at its centre, the management component aims to minimize risks and maximize benefits. Management furthermore encompasses up-to-date training of health and surveillance staff and, where appropriate, operators, as well as supporting measures and documentation of all procedures.

Similarities and differences between WSPs and SSPs

The concept of sanitation safety plans builds on the structure of water safety plans, with several similarities, but also with significant differences between the two as summarized in Table 1.

Introducing sanitation safety plans as a new policy tool

The introduction of sanitation safety plans in any given setting aims at providing access to and promoting safe sanitation, managing the safe disposal of waste and protecting communities from associated risks. The main objectives of sanitation safety plans are:

- First, safe use of sanitation facilities, including both technical and behavioural aspects.
- Second, the creation of effective treatment and non-treatment barriers. This includes on the one hand the reduction of exposure along the chain of handling and disposal and, on the other hand, the protection of waste and wastewater from contaminating freshwater sources. Both help reduce microbial risks to human health. In addition, it includes the protection of wastewater from chemical and radioactive contamination, in particular in cases where it is intended for further use in food production.
- Third, the implementation of guideline values and best practice to ensure the safe use of wastewater, excreta and greywater in agriculture and aquaculture.

Table 1. Similarities and differences between Water Safety Plans and Sanitation Safety Plans.

Sanitation Safety Plans	Water Safety Plans
Similarities	
Derived from WHO Guidelines for the safe use of wastewater, excreta and greywater	Derived from the WHO Guidelines for Drinking-water Quality
Incremental risk management approach, HACCP, Stockholm Framework	Incremental risk management approach, HACCP, Stockholm Framework

Essential actions - system assessment - operational monitoring - management	Essential actions - system assessment - operational monitoring - management
Systematic nature, following the sanitation chain	Systematic nature, following the drinking-water supply chain
Differences	
The systematic approach expands to downstream health and environmental effects	The systematic approach remains confined to the drinking-water supply chain
Considers multiple routes of exposure and multiple exposed groups in relation to microbiological and chemical risks	Focuses mainly on drinking water ingestion, considering microbiological, chemical and radiation risks
Usually no clear regulatory framework, with roles and responsibilities fragmented over different sectors and levels	Usually operates in a clear regulatory framework
Diversity in the decision-making process	Uniformity in the decision-making process
Objectives: - reduce the exposure and negative health and environmental impact of wastewater, excreta or greywater disposal and use - prevent wastewater from contaminating fresh water sources and produce	Objectives: - prevent drinking-water from being contaminated
Implementing agency: may vary, national, regional or local authorities, depending on available resources and skills	Implementing agency: water utility, or for small community water supplies: a community association

Scope of the sanitation safety plans

As a tool, sanitation safety plans should be both comprehensive and flexible. They should allow settings in both developing and industrialized countries to be covered and address all types of sanitation systems whether they are organized by large-scale municipal or regional utilities or by communities. As for communities, the concept of the sanitation ladder proposed by the WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation (WHO/UNICEF 2008) may be integrated, in order to allow communities using their position on the sanitation ladder as the starting point to develop an appropriate sanitation safety plan. These plans will particularly serve risk management approaches in settings where wastewater or other waste products from sanitation are used for agriculture or aquaculture, but they will also serve as a useful tool for the safe disposal of end-products. A HACCP-approach for sanitation must be applied equally to existing systems and to new elements being integrated into these.

Wastewater and excreta use in agriculture and beyond

The scope of sanitation safety plans may extend well beyond wastewater and excreta use in agriculture, when considering for instance also solid and chemical waste disposal. Nonetheless, the productive use of waste is an important starting point, bringing into the equation livelihood issues and the economic value of nutrients and water in relation to sanitation, which would be absent otherwise. This perspective of other benefits than health provides added incentives that support the promotion of the sanitation safety plan concept. Safe wastewater and excreta use in agriculture and aquaculture has large potential for the sustainable use of water and improved food security. Using human waste as fertilizer in a safe and structured manner increases agricultural production and sustains the livelihoods of vegetable and fish farmers; it also permits to grow crops close to the consumer, in particular in urban and periurban areas. Wastewater and greywater add to the reliable supplies of water for agriculture in arid climates and are a relatively cheap source of plant nutrients. A comparison of farmers using wastewater and farmers not using wastewater in the same area revealed that the annual income of the former may be 30-50 percent higher (IWMI, 2006). Additionally, improved and secured food production result in increased job opportunities e.g. for traders, vendors and other service suppliers. Using wastewater for irrigation also reduces the need for chemical fertilizers, limiting both costs and health risks for famers. Despite these advantages, there are two major challenges to be encountered in this context. First, there is often a lack of demand for improved sanitation among poorer communities, which is the point of origin for the safe use of wastewater in agriculture, a challenge that has been addressed by promoting demand-inducing sanitation programmes. Secondly, the fragmentation of sanitation responsibilities over a number of governmental agencies needs to be considered when thinking of safe wastewater use in agriculture.

Policy & regulatory framework

In order to use sanitation safety plans as a means to ensure coherently and sustainably safe sanitation, a legal framework for establishing a policy on sanitation safety plans is necessary. Whereas in the case of Water Safety Plans regulatory authorities are responsible for its establishment, the responsible entity for sanitation safety plans needs to be clarified, which should preferably be in line with existing rules and practices, resulting in a number of conceivable options such as: municipalities, communities or wastewater managing organizations, including small-scale private sector operators, or farmer associations. It should be stressed that the use of wastewater in agriculture is practised informally in many regions, but that legalization is required in order to regulate these practices in a health-protective and -promotional manner.

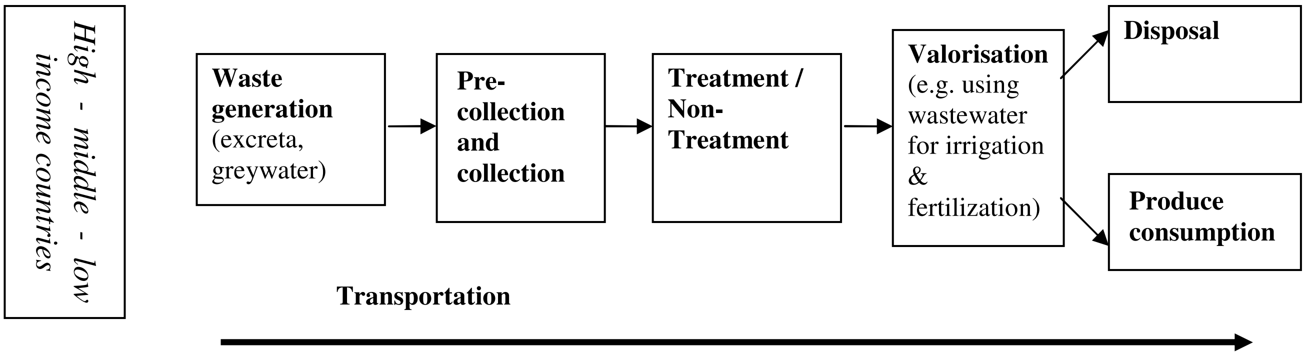
Fostering intersectoral collaboration

Acknowledging that sanitation is a public good, the public sector has to play a role in enabling its organization and regulation. Nonetheless, organizing sanitation is a diverse task that requires the involvement of multiple stakeholders. Possible stakeholders in excreta and greywater use programmes have been listed in the Guidelines (WHO, 2006 – volume 4) including users of sanitation facilities, users of the treated excreta and/or greywater, financial institutions, and research institutions. Links to sectors relevant for sanitation include urban planning, housing, health, education and agriculture. The latter is particularly pertinent for cases where the use of wastewater in agriculture is the focus of sanitation safety plans. It is essential to recognize that the everyday life of a farming community integrates aspects of different sectors such as health, agriculture, construction, trade, sanitation and water naturally. Similarly, the integration of various sectors along the political continuum should reflect the diversity of community members' tasks in order to ensure a participatory and sustainable approach in development in implementation of sanitation safety plans. Local governments or other authorities/groups wishing to develop and implement a sanitation safety plan should involve stakeholders and experts in a comprehensive manner, respecting the needs and the available resources of the setting in question.

Adopting Sanitation safety plans in different settings

Components of wastewater systems & possible pathways - the sanitation chain

Sanitation safety plans should be organized along the sanitation chain, ranging from waste generation, collection, treatment or the implementation of non-treatment options, respectively, valorisation, which refers to the use of wastewater, excreta or greywater for irrigation and fertilization practices, to the disposal of waste products and produce consumption. Furthermore, transportation, which may be piped or non-piped, needs to be seen as a recurring step in the chain, linking one element to the next, requiring equal attention in the risk management approach. In different settings different pathways along the chain may be taken, and there may be more or less steps than those suggested in the flowchart below, which provides a general scheme for orientation; more elaborate flowcharts can be found in the guidance note 'Applying the Guidelines along the sanitation ladder' (Drechsel and Keraita, 2010, in the information kit). This is applicable to different options along the sanitation chain, from basic to advanced, accounting for situations from open defecation or unimproved sanitation facilities with basic manual emptying and use or disposal, to water-based piped systems, with different treatment, reuse or disposal characteristics. This reflects on the concept of the 'sanitation ladder' beyond the technical dimension towards a focus on exposure and critical control points. This is in line with the concept of the guidelines on the safe use of wastewater, excreta and greywater: the different levels of economic development and the available options for the safe use in agriculture are taken into account. Drechsel and Keraita describe the ladder with the high-income countries where wastewater treatment and irrigation generally is a planned process, to the middle-income countries that are trying to move from informal to controlled wastewater use and to the low-income countries often facing a situation of insufficient capacity for wastewater treatment, where wastewater irrigation most often is practiced informally.



Points of exposure in the sanitation chain

The sanitation chain has multiple points of exposure which should be considered when adopting sanitation safety plans in different settings. For every element in the chain there may be several options, mainly determined by the given setting's level of development. Evidently, exposure to certain hazards will be less significant with a higher level of technology and treatment, and consequently lower quantities of microorganisms or chemical constituents, but it is nonetheless required to assess the points of exposure in any system carefully when developing sanitation safety plans, in the spirit of HACCP. Examples of multiple exposure points are presented in the box below.

- Waste generation
    - Dry latrines- improved/unimproved
    - Flush toilets
    - Ecological loop toilets
- Transportation
    - Manually
    - Motorized
    - Sewerage-System
- Pre-collection and collection
    - Buckets
    - Septic tanks
    - Pre-collection sites
- Treatment/ Non-treatment
    - Waste stabilization ponds
    - Constructed wetlands
    - Sedimentation
    - Filtration
    - Coagulation/ Flocculation
    - Disinfection
    - Pathogen-die-off
- Valorisation
    - Irrigation (drip/ spray)
    - Fertilization
    - Fodder for livestock production (duckweed/ fish)
- Disposal
    - Reintegration into aquatic cycle
- Produce consumption
    - Food trade
    - Food preparation
    - Food consumption

Communication

Communication is essential in any health promotion intervention. In the context of sanitation safety there are two aspects to it. Firstly, since cross-sectoral collaboration requires effective communication in order to be carried out efficiently, good communication is required among those designing sanitation safety plans. This will help avoid conflicting messages and increase public trust. Secondly, in order to adopt sanitation safety plans as a policy, communication is necessary for advocacy, in order to create an environment of knowledge that will facilitate decision-making and implementation. It is important to inform and involve the community pro-actively to implement the guidelines in a way that they are acceptable and the public perception of waste use in agriculture is positive. It is essential for the protection of consumer health to maintain good and transparent public relations and to phrase key messages understandable to the audience, considering its educational level. While respecting the diversity of communities when planning a communication approach, it should always reflect the realities of the people in question, including their attitudes, beliefs and lifestyles.

Developing a Manual on Sanitation Safety Plans

A more hands-on approach to the application of the Guidelines is clearly needed. The elements presented in this concept note on sanitation safety plans indicates they are likely to have a value as a complementary policy tool, facilitate guidelines' adoption in different settings and ensure that the combination of guideline values and best practice proposed by the Guidelines are applied in an optimal manner to achieve the incremental impact envisaged. The experiences with the application of the Guidelines in Ghana, Jordan and Senegal also lead to the conclusion that a Manual on Sanitation Safety Plans is desirable in order to put them into practice and make them accessible to a broader target audience (WHO, 2010). The development of a Manual may contribute to an improvement in the global sanitation situation, in a situation where we know the MDG sanitation target is considerably off-track. The Manual will enable governments at different political levels to design a sanitation safety plan which is appropriate to their setting. It will facilitate the use of health-based targets and provide a basis for incremental risk management under the umbrella of sanitation safety plans.

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