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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

1. Situation analysis and health target setting	• Map existing/planned wastewater use areas, practices and produce marketing network. • Assess extent of health risks (water quality, type of crop, exposure of farmer/crop, post-harvest contamination, etc.). • Prioritize health risks interventions through the *hazard analysis and critical control point* (HACCP) approach and set realistic (health-based) targets which can be achieved via one or multiple risk barriers.
2. Identifying and validating risk reduction measures	• Identify suitable risk reduction measures together with sanitation authorities and other concerned stakeholders (farmers, extension officers, traders etc.). • Validate the efficacy, cost-effectiveness and adoptability/reliability of those measures.
3. Implementation of measures	• Develop an implementation plan and compare cost-effectiveness of each planned risk reduction measure. • Implement the most cost-effective measures (e.g. wastewater treatment, reuse regulations, non-treatment options) and support their uptake/sustainability via training, incentives, etc.
4. Operational monitoring	• Develop a monitoring plan i.e. decide on frequency, inspection points and parameters from treatment to farm to point of consumption. • Assess whether the recommended practices/standards are adopted/achieved. • If not, go back to step 2 for alternative options to reduce risks, or • step 3 for alternative options to support implementation.
5. Verification	• Assess to what extent the introduced measures actually achieved the set targets, for farmers and consumers, via surveys and laboratory analysis. • Compare achieved targets with available options for risk reduction and adjust them towards impact optimization under consideration of cost-effectiveness criteria.

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)

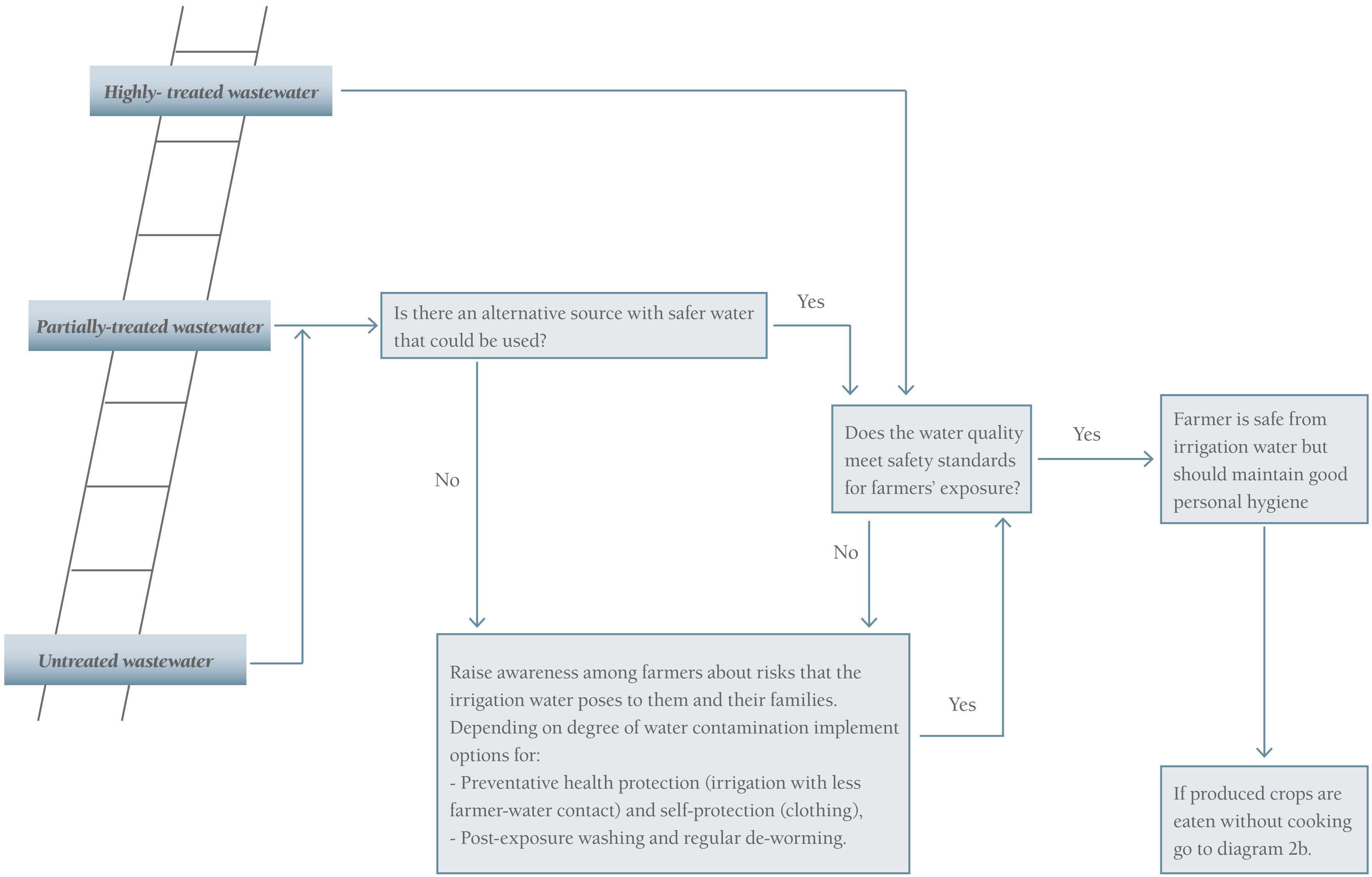
[1] The examples do not imply a necessary progression with increasing economic development. In high-income countries waste stabilization pond systems, for example, can be the most appropriate and economically preferred option for treatment as well. The target should be in any situation to find locally 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.

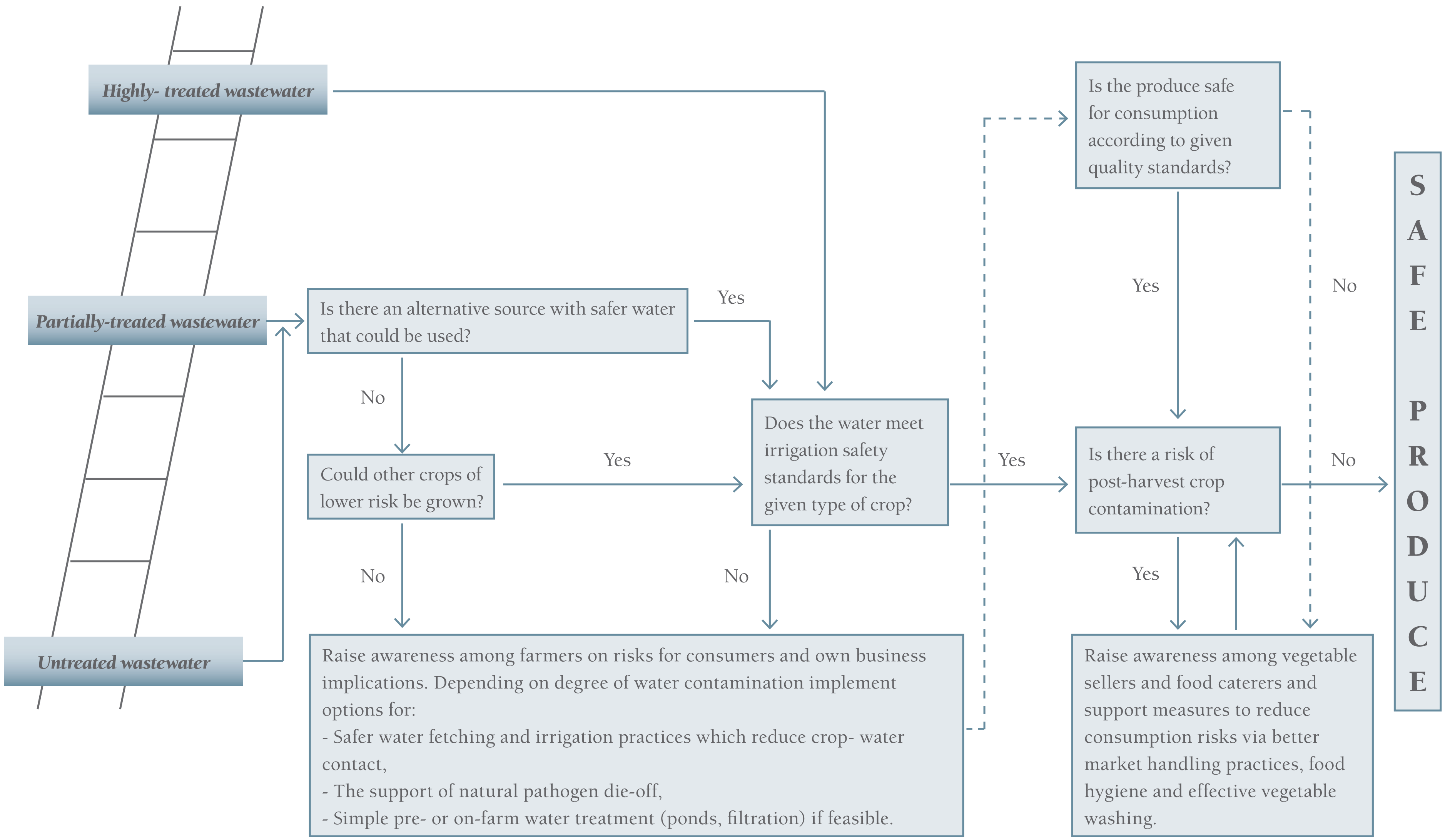
FIGURE 2: Multiple Barrier Decision Support Flow Diagrams

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



FURTHER READING

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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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